The Physical Science Laboratory's First 25 Years (1946 - 1971)

Second Edition

Bumper WAC Rocket

DEDICATION

Raymond Bumgarner (affectionately known as "Raymo") worked for many years on this PSL history project. He almost completed it, but ran out of support, money, and energy before doing so. He left a fairly complete manuscript and a stack of photographs and other graphics that he had planned to use for the figures.

When I became aware that Raymo was terminally ill, I asked him what his other friends and I could do for him in the few short weeks that remained of his life. He asked that we clean up his yard so that his wife Anabelle would not have to deal with the many years of "stuff" accumulated there, which we did before he died. He also asked me to finish the history book, and I promised him that I would. Although this request took a little longer to complete, within one year of Raymo's passing (September of 2001), we had edited his manuscript, incorporated the figures, and produced the pre-publication edition, which chronicles PSL from its inception in 1946 to 1971.

Many PSL employees and alumni edited the pre-publication edition of the book, and their changes and additions have been incorporated to produce this first edition.

We at PSL are very proud of this effort, and I am confident that Raymo would have been as well. I hope that you enjoy this special look back at a very interesting period of PSL's history.

Bernie McCune
September, 2002

COMMENTS ON THE SECOND EDITION

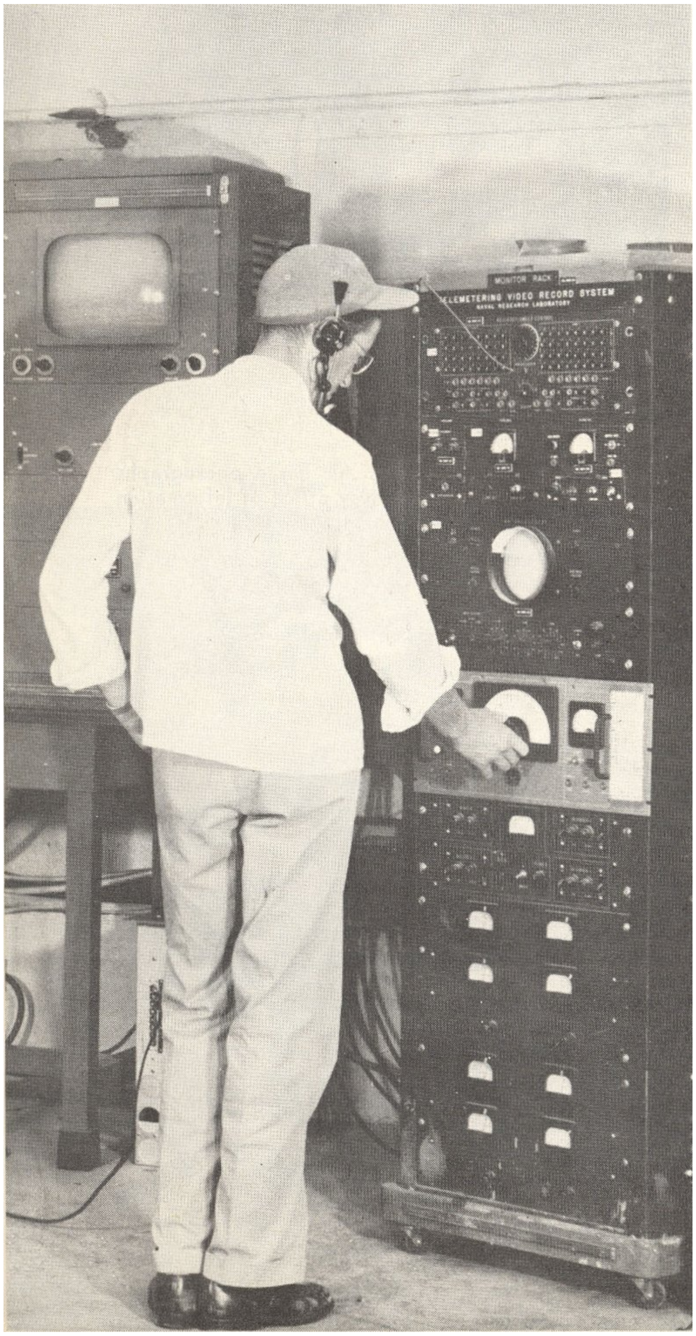
It has been almost nine years since the first edition of The Physical Science Laboratory's First 25 Years (1946-1971) was published (September of 2002). A number of copies were printed at the time (both hard- and soft-cover), but all of these were either sold or given away. Shortly afterward, the writing of Volume 2 of PSL's history (The Physical Science Laboratory's Most Recent Years (1970 – Present), which is currently in draft form) began, and additional ideas, information, and photographs were located in the process. Most of that new material is included in the first chapter of Volume 2; however, because we wanted additional copies of Volume 1 for our own purposes, we decided to enhance it and publish a second edition. Some of the photographs were improved, and a number of pertinent details (e.g., with regard to PSL's WSMR, Navy and SGI co-op programs), personal accounts (from Doty Telles and Dan Nimrod, to name a couple), and photographs were added.

Although "printing" of this second edition will be a digital version to be published on the PSL website, the latest copy there can be printed by anyone wishing to do so. We sincerely hope that you enjoy this new and improved version.

Bernie McCune
Joe Gold
Lorri Roth

March, 2011

AUTHOR'S NOTE



This is not intended to be another dry, "high-tech" report listing the many accomplishments of the Physical Science Laboratory (PSL). Technical aspects of history are included when they are necessary to tell the story of the people, or various small groups of people, who have invested their lives and careers in the Laboratory. This is a collection of stories about the pioneers of PSL—their successes, their failures, and their wanderings. It does not attempt to relate all of the stories, since records tend to become lost and memories fade.

I sincerely hope that each of these pioneers, though perhaps not listed by name in this book, will find some passages that spark proud memories, and that those who have followed in their footsteps will know where their heritage began. They have inherited a workplace that takes great pride in its accomplishments, its will to succeed, and its drive to excel.

Much credit must be given to Harold L. Connell, who conceived the history project, provided encouragement, and obtained funding. I also wish to acknowledge the moral and clerical support provided by Sophora Davis, the technical support by John D. "Dan" Martin as we tried to learn to use a computer for word processing, and the contribution of each of those 96 PSL old-timers whose oral histories were recorded on tape.

Raymond A. Bumgarner
New Mexico State University
September 22, 1992

LIST OF ACRONYMS AND ABBREVIATIONS

ABM	Anti-Ballistic Missile
ABMA	U.S. Army Ballistic Missile Agency
ACS	Attitude Control System
ACU	Automatic Control Unit
AEC	Atomic Energy Commission
AFB	Air Force Base
AFCRC	Air Force Cambridge Research Center
AFCRL	Air Force Cambridge Research Laboratories
AFMTC	Air Force Missile Test Center
AM&F	American Machine and Foundry
AMR	Atlantic Missile Range
ANNA	Army Navy NASA Air Force
APL	Applied Physics Laboratory
ARL	Applied Research Laboratory
ATI	American Television Institute of Technology
BTL	Bell Telephone Labs
BRL	Army Ballistic Research Laboratory
BuOrd	U.S. Navy Bureau of Ordnance
CCID	Continuous Count Integrated Doppler
Comsat	Communication Satellite Corporation
CPC	Card Programmed Calculator
CPCS	Coast Phase Control System
CRR	Churchill Research Range
DAN	Deacon and Nike Sounding Rocket
DOFL	Diamond Ordnance Fuze Laboratories
DODGE	Department of Defense Gravitational Experiment
DOVAP	Doppler Position and Velocity
DSO	Doppler Satellite Office
EM	PSL's Electromagnetics Section
EPUT	Events Per Time Unit
ER	Extended Range
FDL	Flight Determination Laboratory
GAA	Ground-Aided Acquisition
GAS	Get-Away-Special
GBI	Grand Bahama Island
GSFC	Goddard Spaceflight Center
HAFB	Holloman Air Force Base
HDL	Harry Diamond Laboratories
HEAO	High Energy Astronomy Observatory satellite
HT	Homing Terrier
ICBM	Intercontinental Ballistic Missiles

IGY	International Geophysical Year
IMP	Interplanetary Monitoring Platform
IQSY	International Quiet Solar Year
ISIS	International Satellite for Ionosphere Studies
JHU	Johns Hopkins University
JPL	Jet Propulsion Laboratory
LC	Launch Complex
LLS	U.S. Navy's Land-Locked Ship
LOX	Liquid Oxygen
MAR	Multiple Array Radar
MDI	Miss Distance Indicator
MEI	PSL's Missile Electronics Instrumentation Section
MEWTA	Army's Missile Electronic Warfare Test Agency
MGS	PSL's Missile Ground Systems Section
MPI	PSL's Missile Position Instrumentation Section
MR	Medium Range
MRS	PSL's Missile Radiometric Systems Section
NACA	National Advisory Committee on Aeronautics
NACODE	Naval Correlation and Detection
NAG	Naval Astronautics Group
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NMSU	New Mexico State University
NOL	Naval Ordnance Laboratory
NOMTF	U.S. Naval Ordnance Missile Test Facility
NOMTU	U.S. Naval Ordnance Missile Test Unit
NOTS	U.S. Naval Ordnance Test Station
NRL	Naval Research Laboratory
OAO	Orbiting Astronomical Observatory
OGO	Orbiting Geophysical Observatory
ONR	Office of Naval Research
OSO	Orbiting Solar Observatory
PBS	Public Broadcasting Station
PMR	Pacific Missile Range
PPM	Pulse Position Modulation
PSL	Physical Science Laboratory
PWM	Pulse Width Modulation
QA	Quality Assurance
QC	Quality Control
RADINT	Radio Interferometer
RAM	Random Access Memory
R&D	Research & Development
RF	Radio Frequency
RFP	Request for Proposal

SCIGY	Special Committee for the IGY
SGI	PSL's Satellite Ground Instrumentation Section
SLV	Satellite Launch Vehicle
SM	Standard Missile
SMTP	Special Mission Tracking Project
SPARCS	Solar Pointing Aerobee Rocket Control System
SRB	Sounding Rocket Branch
SSD	Single-Station Doppler
STADAN	Spacecraft Tracking and Data Acquisition Network
STRU	Satellite Time Recovery System
SULF	Speedball Uprange Launch Facility
SYNCOM	Synchronous Orbit Communications Satellite
TACO	Technical Appliance Corporation
TACOS	Talos Adaptable Computer System
TAD	Thrust Augmented Delta
TDDS	Transit Doppler Digitizer System
TDRSS	Tracking Data and Relay Satellite System
TDS	Telemetry Data System
TEWDS	Tactical Electronic Warfare Decoy System
TIC	Tactical Intercept Computer
TIROS	Television Infra-Red Observation Satellite
TJR	Talos Junior REAC
TTS	Tartar-Terrier-Standard missile computer system
TV	Test Vehicle
VAB	Vehicle Assembly Building
WSMR	White Sands Missile Range
WSPG	White Sands Proving Ground
WSSA	Signal Corps White Sands Signal Agency
XASR	Experimental Atmospheric Sounding Rocket

CHAPTER 1: THE ORIGIN OF NMSU

The University's roots go back to the days when New Mexico was a U.S. Territory. At that time, Las Cruces was a quiet adobe village with no secondary school (and there were no colleges in the entire Territory). A group of prominent Mesilla Valley residents, including Judges John McFie and Albert Fountain, began campaigning for a combined preparatory school/college so that it would not be necessary for their children to leave the Territory in order to acquire an education.

In 1887, Hiram Hadley, a Quaker educator, arrived in the Mesilla Valley. His 25 years of experience in the founding and administration of various educational institutions enabled him to quickly assume leadership of this campaign. The Las Cruces College opened for classes on September 17, 1888 with an enrollment of 160 elementary, preparatory, and university-level students. Mr. Hadley was appointed President and served as one of the three instructors; Judge McFie became the Chairman of the Board of Trustees. The school was housed in a two-room adobe building located on the south side of Las Cruces.

In 1889, the Territorial Legislature, largely through the efforts of Judges McFie and Fountain, passed the Rodey Act, thus authorizing a land grant agricultural school in the Mesilla Valley, a school of mines in Socorro, and a university in Albuquerque. This was considered a victory by the local residents, because a land-grant college with its attendant federal funding was much more desirable than a university or a school of mines. Las Cruces College then became the New Mexico College of Agriculture and Mechanic Arts. It opened officially on January 21, 1890, prior to the Albuquerque and Socorro institutions. Its enrollment consisted of 17 university-level students and a similar number of preparatory students. Hiram Hadley retained the presidency and John McFie became the first chairman of the new Board of Regents.

Local citizens raised money and purchased approximately 220 acres of desert scrubland (where NMSU is presently located), providing a permanent campus. The first building, aptly named McFie Hall, was erected in 1891 at the center of the present "horseshoe." The first commencement ceremony took place in 1894, with five Bachelor's degrees granted. One of the recipients was Fabian Garcia, who later figured prominently in the development of the New Mexico College of A&M.

Growth for the new College was practically nonexistent in its first decade (due largely to political posturing); however, this changed when Luther Foster became President in 1901. He brought such stability that enrollment soon exceeded 200, the majority of which was still comprised of preparatory students. The Preparatory Division was not dropped until sometime in the 1930s.

Military Science, a required part of the curricula for land-grant colleges, was delayed until the arrival of Colonel Alfred S. Frost in 1902. The R.O.T.C. program soon became a vital part of campus life.

In approximately 1910, the College was lagging behind the universities at Albuquerque and Tucson in both enrollment and funding. No longer the leading educational institution in the southwest, those at the other New Mexico institutions referred to it as the, “Cow College” (this label was hardly accurate, since the majority of students were enrolled in Engineering and Liberal Arts).

World War I and the Great Depression greatly reduced student enrollment, resulting in financial difficulties for the College, as well as for all other New Mexico educational institutions. After the War, Harry L. Kent began a 15-year term as president and, in spite of the odds, gradually increased the enrollment to approximately 800 by 1937.

Dr. George W. Gardiner came to the New Mexico College of A&M in 1934 as the chairman of a one-man Physics Department. His primary task was to teach Physics to Engineering majors (he had received his Ph.D. from Yale in 1929 and had been working as a researcher for the National Bureau of Standards prior to coming to New Mexico; NM A&M provided him with his first teaching experience). By the time World War II started in 1939, the Department had grown to a two-man staff; however, the war curtailed any further growth.

Dean Hugh M. Milton succeeded Mr. Kent in 1937. He, along with students and other faculty, was called to active duty when the U.S. entered World War II. Dean John Branson assumed the position of Acting President, and found that he faced the same financial difficulties as previous administrations. Perhaps the influx of a few hundred students from the Army Specialized Training Corps offset the decrease in enrollment and provided the necessary operating revenue.

New Mexico College of A&M students did their fair share to help win World War II. According to former Registrar Era Rentfrow, more than 120 of them made the Supreme Sacrifice—giving their lives for their country.

In the post-war years, hundreds of veterans took advantage of the “G.I. Bill” and registered at the College. Enrollment peaked at 1,700 in 1947 (Figure 1), where it remained for a few years.

Figure 1. Old Hadley Hall on the New Mexico College of A&M Campus, Mid-1940s

During this time, branches of the College were established in Alamogordo, Carlsbad, Farmington, and Grants. Dr. Roger B. Corbett assumed the presidency in 1955 and set an enrollment goal of 5,000 by 1970. Although some thought the goal unrealistic, it was exceeded by 50% on the main campus alone. In 1958, the College was given the distinction afforded a University, and the Board of Regents renamed it New Mexico State University of Agriculture, Engineering, and Science (the latter part of the name was shortly dropped).

The University's growth has been steady and quite remarkable since 1955 with regards to enrollment, infrastructure, quality of instruction, and breadth of curricula. This growth continued under the direction of Dr. Gerald W. Thomas from 1970 until he retired in 1984 and was succeeded by Dr. James Halligan. In 1986, NMSU's student enrollment was 13,000, it employed approximately 3,000 staff and faculty, and its campus occupied over 6,000 acres.

CHAPTER 2: THE BEGINNING OF A LABORATORY

The Army Lays the Foundation

In 1945, the U.S. Army was searching for a remote, arid piece of land served by a rail line on which to establish a missile testing range. The Tularosa Basin, located 30 miles east of Las Cruces, met these criteria. On July 9, 1945, the White Sands Proving Ground (WSPG) was formally established as a test range, with Lt. Col. Harold R. Turner as its first commander. The Army Ordnance Corps then brought in train loads of captured German V-2 missile parts and the Army Signal Corps brought its Wac Corporal sounding rocket, thus laying the foundation for the creation of the Physical Science Laboratory.

The Wac Corporal was the first rocket to fly over the new proving ground. It was also the first designed from its inception as a U.S. Government-owned atmospheric sounding rocket. The Signal Corps had requested that the Ordnance Corps develop a rocket capable of carrying 25 pounds of meteorological instrumentation to an altitude of 100,000 feet. The result was a scaled-down version of the Army's Corporal missile, which had been conceived by the Jet Propulsion Laboratory (JPL)/California Institute of Technology in 1944. The new rocket was given the name, "Wac" because it was smaller and less powerful than the Corporal missile. It was about 16 feet long and featured an Aerojet liquid-fueled engine, a solid-propellant Aerojet booster, and a Douglas Aircraft Company airframe. Since the Wac was a ballistic (i.e., unguided) rocket, it required a rail or other constraint to maintain its aim along the desired path until it attained enough speed to achieve aerodynamic stability. A three-rail system was selected, and a steel tower roughly 100 feet tall was erected at WSPG to support the rails and to provide working platforms for personnel (Figure 2). The Wac Corporal's maiden flight on September 26, 1945 (seven months before the first V-2 flight at WSPG) was actually a simulation using a Tiny Tim aircraft rocket with a 250-pound lead nose cone. Four of these simulations were fired in two days, followed by a couple of two-stage dummy Wacs. The first full-fledged Wac Corporal, with a Tiny Tim as a booster, was launched on October 11, 1945. It reached an altitude of 43.5 miles, which was approximately twice that expected.

The Wac Corporal probably would have been heavily used as an upper atmosphere probe had not the more powerful V-2 rocket arrived at the same time. As it was, the Wac's chief contribution to sounding rocket technology was to serve as a forerunner of the now-famous Aerobee series, which played a vital role in PSL's history for nearly 40 years. The V-2 firings at WSPG also figured prominently into PSL's story; in fact, they led directly to the entry of the "Cow College" into the rocket business.

The American capture of the V-2 factory (along with the majority of the German rocket scientists) was very unexpected—it was located in an area scheduled for Soviet occupation, but U.S. forces arrived there first. When Lt. Col. Herbert ("Herb") L. Karsch, an American bomb disposal officer, saw the contents of the huge cavern near Nordhausen, he became very excited. U.S. forces had stumbled onto one of Hitler's greatest secrets—the underground Mittelwerk armament plant—and it was completely intact. Lt. Col. Karsch and the troops quickly removed approximately 300

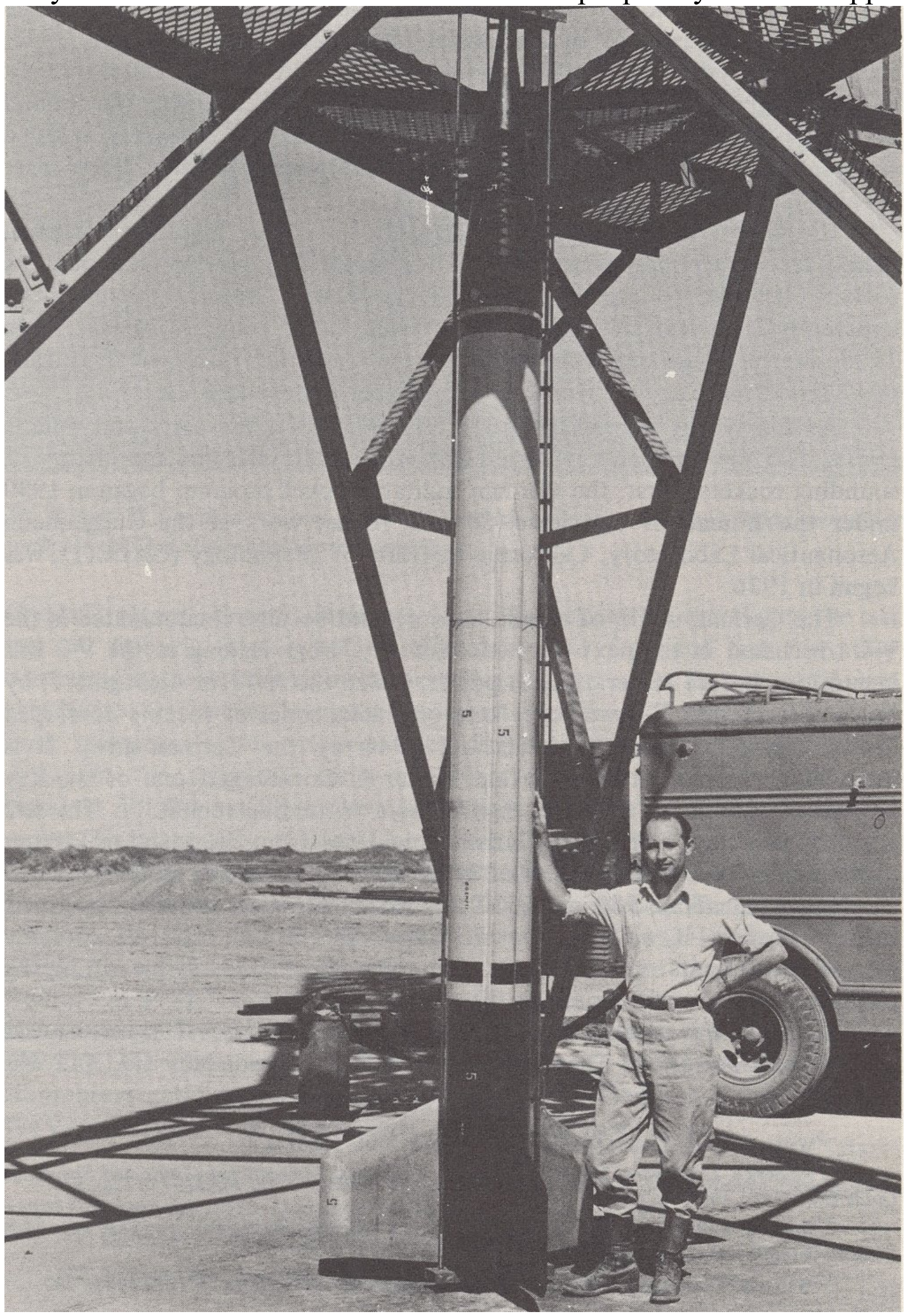


Figure 2. JPL Employee Frank J. Malina with Wac Corporal Rocket at WSPG, 1946

boxcar loads of V-2 parts and equipment. The German scientists (who preferred surrender to the Americans over the Soviets) assisted in this operation. They, along with Lt. Col. Karsch and the hardware, were brought to WSPG at the end of 1945 by the Army Ordnance Department. Lt. Col. Karsch soon became the Technical Director of the new proving ground.

The General Electric Company was hired to sort and assemble the parts into an estimated 100 complete V-2s (there were, however, only enough pieces to assemble two). Many parts were missing or deliberately damaged by the retreating German army, and nearly all were badly corroded from exposure to weather. In fact, when Col. Turner first saw the paraphernalia, he reportedly called it the worst looking bunch of junk he had ever seen!

American industry was enlisted to manufacture the necessary parts. In addition, the one-piece German nose cones (warheads) were scrapped in favor of those with partitions and doors for installation of scientific instruments (these were fabricated by the Naval Gun Factory).

Enter the Navy

In 1945, the U.S. Navy Bureau of Ordnance (BuOrd) began to consider possible peacetime use of rockets for high-altitude research. A group of physicists and engineers at BuOrd's Naval Research Laboratory (NRL) near Washington, D.C. were highly impressed by German rocketry, and were eager to build an American sounding rocket with which to explore the upper atmosphere. This group became the NRL Rocket-Sonde Research Branch on December 17, 1945. Research groups were formed to study the ionosphere, the atmosphere, spectroscopy, and cosmic rays. Their goal was to send 500 pounds of instrumentation to an altitude of 100 miles. Since such a rocket was not yet available (and they were unaware of the captured V-2s), plans were made to design and build one. These plans were temporarily delayed, however, when in January of 1946, the Rocket-Sonde Research Branch learned of the Army's planned V-2 firings. Since there were no Army atmospheric research programs at that time, the NRL was invited, along with the Applied Physics Laboratory of Johns Hopkins University (APL/JHU) and various other organizations, to assemble and fly any instruments they wished (the V-2 could easily carry 2,000 pounds of payload). WSPG's V-2 program was quite possibly the greatest display of inter-service peacetime cooperation yet experienced.

A total of 66 V-2 rockets were assembled and launched at WSPG between April of 1946 and June of 1951. Of these, 15 were instrumented by NRL scientists, nine by APL, 20 by GE (including six "Bumper" shots using a Wac Corporal as a second stage), 10 by the Air Materiel Command, five by the Army Signal Corps, two each by Princeton and Michigan Universities, and one by the Army's Ballistic Research Laboratory (the remaining two were used for ordnance purposes). Fully half of these flights were officially listed as failing to achieve their objectives, even though only 23 rockets did not reach an altitude of 60 miles or greater (Table 1). Because of this and the multitude of problems that plagued the hastily assembled instrument packages, it was a great achievement indeed when both the rocket and the experiment performed according to plan.

Of the six Bumper shots, four experienced major system failures. Bumper shot 5, fired on February 24, 1949, achieved an altitude of 250 miles, establishing a new record. Failures and near-failures notwithstanding, a tremendous amount of knowledge was gained from these firings in the areas of design and handling of rockets, design of instrument payloads, gathering of data, etc., as well as new information about the atmosphere and space.

Table 1. V-2 Launches[1]

Rocket No.	Agency	Date	Burning Time (Seconds)	Altitude (Miles)	Cut-Off By	Remarks
1	WSPG	3-15-46	57.0	--	DESK	STATIC STAND
2	WSPG	4-16-46	19.0	5	Radio	Steering bad from lift
3	WSPG	5-10-46	59.0	70	Integ.	
4	GE	5-29-46	60.2/63.1	70	Integ.	
5	GE	6-13-46	58.5/61.2	73	Integ.	
6	NRL	6-28-46	66.8	67	Burn Out	
7	GE	7-9-46	60.6	83	Time Sw.	
8	GE	7-19-46	28.5	3	Explosion	Explosion at 28.5 seconds
9	APL	7-30-46	68.6	104	Burn Out	
10	PRIN.	8-15-46	18.5	2	Radio	Steering trouble at 13.9 sec
11	MICH	8-22-46	6.5	--	Radio	Steering trouble from lift

[1] Column 1: WSPG = White Sands Proving Ground; GE = General Electric Co.; NRL = Naval Research Laboratory; APL = Applied Physics Laboratory of Johns Hopkins University; PRIN = Princeton University; MICH = University of Michigan; AMC = Air Materiel Command; SC = Signal Corps; BRL = Ballistic Research Laboratory, Aberdeen Proving Grounds.

Rocket No.	Agency	Date	Burning Time (Seconds)	Altitude (Miles)	Cut-Off By	Remarks
12	NRL	10-10-46	67.7	102	Burn Out	High winds at 280 degrees
13	APL	10-24-46	59.8	65	Burn Out	
14	PRIN	11-7-46	31.0	0	Radio	Steering trouble at 2 seconds
15	MICH	11-21-46	62.5	63	Burn Out	
16	NRL	12-5-46	69.0	104	Burn Out	Steering trouble from lift
17	APL	12-17-46	69.6	116	Burn Out	
18	NRL	1-10-47	60.0	72	Burn Out	Roll at 40 seconds
19	GE	1-23-47	59.0	31	Burn Out	Not standard steering system
20	AMC	2-20-47	58.0	68	Burn Out	Steering disturbance at 27 sec.
21	NRL	3-7-47	63.0	100	Burn Out	
22	APL	4-1-47	57.0/60.5	80	Time Sw.	Wind 50 mph at 290 degrees
23	APL	4-8-47	57.0/60.0	64	Time Sw.	
24	GE	4-17-47	66.0	87	Burn Out	Roll at 57.5 seconds
26	NRL	5-15-47	63.5	76	Burn Out	Steering trouble from lift

Rocket No.	Agency	Date	Burning Time (Seconds)	Altitude (Miles)	Cut-Off By	Remarks
29	NRL	7-10-47	32.0	10	Radio	Steering trouble from lift
30	APL	7-29-47	62.5	99	Burn Out	Vane #4 malfunction at 27 sec
27	GE	10-9-47	62.5	97	Time Sw.	Steering problem at 48.4 sec
Special	GE	11-20-47	39.0	13	Fault	Propulsion trouble at 36 sec
28	AMC	12-8-47	61.5	65	Burn Out	
34	NRL	1-22-48	67.0	99	Burn Out	
36	GE	2-6-48	65.8	70	Burn Out	Not standard steering system
39	GE	3-19-48	25.0	3	--	H_2O_2 exhausted
25	SC	4-2-48	69.5	89	Burn Out	
38	NRL	4-19-48	57.0	35	Radio	Steering trouble from 13 sec
BU-1	GE	5-13-48	64.5/67.9	70	Integ.	
35	APL	5-27-48	62.4/65.5	87	Time Sw.	
37	AMC	6-11-48	57.3	39	Fault	Premature valve closure
40	APL	7-26-48	60.8	60	Burn Out	Pulsation starting at 45.2 sec
43	NRL	8-5-48	65.5	104	Burn Out	

Rocket No.	Agency	Date	Burning Time (Seconds)	Altitude (Miles)	Cut-Off By	Remarks
BU-2	GE	8-19-48	33.8	8	Fault	Premature valve closure
33	SC	9-2-48	63.0/65.4	94	Time Sw.	
BU-3	GE	9-30-48	56.5/70.2	93	Radio	
BU-4	GE	11-1-48	28.5	3	Explosion	Tail explosion at 28.5 sec
44	GE	11-18-48	65.5	90	Burn Out	High winds
42	SC	12-9-48	60.6/64.0	67	Time Sw.	Vane 2 to zero at 22 sec
45	NRL	1-28-49	56.5	37	Radio	High winds – low thrust
48	APL	2-17-49	63.5	79	Burn Out	
BU-5	GE	2-24-49	61.0/64.5	63	Integ.	
41	AMC	3-21-49	65.5	80	Burn Out	
50	SC	4-11-49	62.5	53	Time Sw.	Pulsation starting at 43.4 sec
BU-6	GE	4-21-49	48.0	31	Fault	Premature cut-off at 47.5 sec
46	GE	5-5-49	25.6	5	Fault	Premature cut-off at 25.7 sec
47	AMC	6-14-49	67.3	83	Burn Out	

Rocket No.	Agency	Date	Burning Time (Seconds)	Altitude (Miles)	Cut-Off By	Remarks
32	AMC	9-16-49	24.7	3	Explosion	Tail explosion at 10.7 sec
49	NRL	9-29-49	65.5	94	Burn Out	
56	SC	11-18-49	66.4	77	Time Sw.	
31	AMC	12-8-49	65.0	79	Burn Out	
53	NRL	2-17-50	65.0	92	Burn Out	
BU-8	GE	7-24-50	--	--	Integ.	Excessive program
BU-7	GE	7-29-50	--	--	Integ.	Excessive program
51	AMC	8-31-50	64.9	85	Burn Out	
61	BRL	10-26-50	49.7	--	Explosion	OK to 50 sec special program
54	NRL	1-18-51	44.0	1	Burn Out	Lox flow low
57	AMC	3-8-51	18.5	2	Explosion	Tail explosion at 15.5 sec
55	NRL	6-14-51	0	0	Explosion	Separation explosives detonated
52	AMC	6-28-51	22.0	4	Radio	Tail explosion at 8.0 sec

Prior to the end of World War II, BuOrd also began development of an anti-aircraft guided missile for fleet defense. This rather awesome task (code named, "Bumblebee") was assigned to APL (APL had developed the immensely effective proximity fuze for artillery shells during the war[2]).

> According to Hanford ("Handy") Fairchild, "APL got the missile program because they had been so successful with their proximity fuze in WW II. I was on Ie Shima where there were a lot of ack-ack guns banging away at Japanese planes without much success. [In May of 1945], we … noticed they were knocking them down easily, sometimes with the first round. APL's fuze was doing it."

These Navy BuOrd programs gave rise to the Aerobee, Talos/Typhon, and Viking projects that were so prominent in PSL's history. The Navy, after the supply of V-2s was exhausted, provided the bulk of the planning and funding for the United States' sounding rocket programs in the ensuing decade.

PSL's Debut

The primary events that led to PSL's inception in 1946 are listed in chronological order below and with as much pertinent detail as is available.

Early January. Even as the V-2 was being prepared for its first launch at WSPG, its deficiencies as a sounding rocket were already apparent. Foremost among these was the fact that it was too large and powerful for its intended application and (therefore not cost effective for scientific research purposes); secondly, its reliability was questionable. Consequently, after finding no other suitable rocket (the Wac Corporal was too small for extensive use), Dr. James A. Van Allen of APL initiated efforts to have one developed under the auspices of the Bumblebee program. Aerojet Engineering Corporation, builder of the Wac, was asked to submit a proposal for supplying 20 liquid-fueled rockets capable of carrying 150 pounds to 200,000 feet.

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2 Kellogg's Corn Flakes gave PSL a bit of a boost in the beginning. APL won an early Navy contract to support the Aerobee program because of the success of the proximity fuze, a device (about two inches long and two inches in diameter) that resembled an ice cream cone and featured a five-vacuum tube circuit design. PSL was close to WSPG and willing to do APL's "dirty work" on site. Since PSL's "desert rats" could handle working in the Tularosa Basin, it was only necessary for APL to send its engineers out to WSPG for brief periods of time. The Kellogg Corporation actually built these proximity fuzes (and, of course, they also made corn flakes). Many of the APL-furnished tools that PSL used still had Kelloggs' "KLX" marks etched into them.

16 January. The V-2 Upper Atmosphere Research Panel was formed when approximately 50 scientists and engineers from around the U.S. met at the NRL to determine the best usage of the V-2s. Ernst Krause of NRL was the Panel chairman and James Van Allen was one of its members. After the supply of V-2s was exhausted, the Panel changed its name and continued as the guiding force in sounding rocket research for nearly a decade.

Late January. As the Army's Ballistic Research Laboratory (BRL) was building and providing instrumentation for a missile proving facility at White Sands for the upcoming V-2 trials, a number of ballistic motion picture cameras were installed at strategic locations in order to photograph the rocket in flight. After the flight, these films would yield trajectory and attitude information, but only after the rocket image in each of the thousands of frames had been meticulously hand-measured and the readings tabulated as numerical data. This film reading required hundreds of labor hours per launch, prompting BRL to consider the nearby New Mexico College of A&M as a convenient source of inexpensive student labor. PSL files reveal that sometime in late January, Dr. George W. Gardiner (Figure 3) (who headed the Physics Department at the time), received an unexpected letter from Dr. Thomas Johnson, Chief Physicist of BRL headquarters at Aberdeen Proving Ground in Maryland. Although this letter has not been physically located in the files, subsequent events indicate that it probably described the V-2 program's need for student labor. The

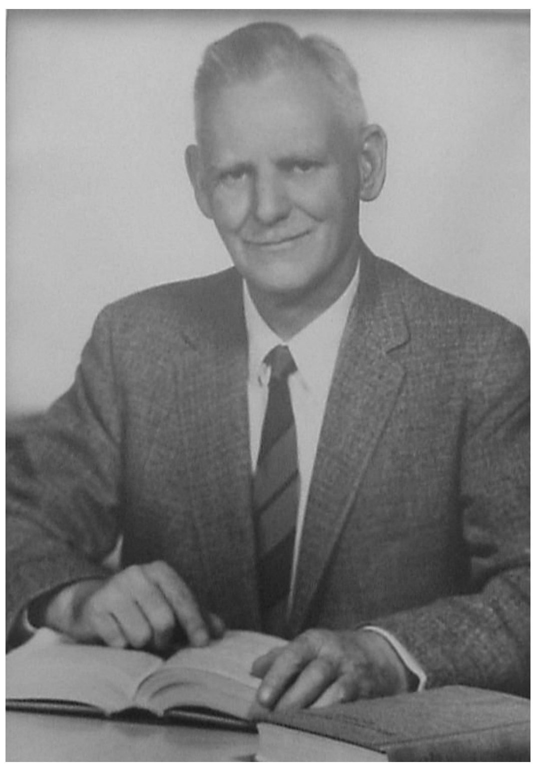

Figure 3. Dr. George W. Gardiner

letter must have also suggested that Dr. Gardiner contact BRL's Col. J. G. Bain at WSPG. On January 26, Col. Bain visited the campus and met with Dr. Gardiner and Acting President John Branson, as revealed in Dr. Gardiner's reply to Dr. Johnson. This reply, dated January 29, requested further details regarding the work to be performed and is the earliest existing official document pertaining to PSL business. Some interesting insights can be extracted from the first paragraph of the letter, which reads, "I was very pleased, as well as surprised, to hear from you and to learn that you are connected with the White Sands project. Please let us know when you are coming out again. We shall be very glad to have you stay with us." This letter reveals that Dr. Johnson, a high official in BRL's V-2 program, was a long-time acquaintance of Dr. Gardiner—the connection that initiated PSL's beginning.[3] Subsequent correspondence undoubtedly included some type of a proposal to BRL. At some point in this time frame, Dr. Gardiner met with Dr. Lewis Delsasso of BRL over a drink at the Amador Hotel bar in Las Cruces. A handshake during that meeting started the process that brought about a contract with BRL and, consequently, the Physical Science Laboratory. The Amador Hotel continued to contribute to the growth of the Laboratory when, later in the year, Professor Harold Brown happened to meet some NRL scientists at the bar who were in town for a V-2 firing (see page 24).

23 March. Dr. Wilbur H. Goss (who had been a Physics instructor under Dr. Gardiner) introduced the College into the Navy's missile programs. Dr. Goss was granted a leave of absence from the College in 1942 to assist in the war effort, and he became involved in the Bumblebee project at APL. Dr. Goss apparently wrote to Dr. Gardiner and to President Hugh Milton on March 23 regarding a possible contract to research the various problems in missile development and/or upper atmosphere physics.

16 April. The first launch of a V-2 at WSPG was attempted on April 16. Unfortunately, the steering mechanism malfunctioned, causing the rocket to veer off course almost immediately. It was necessary to terminate the flight via radio command at T +19 seconds, and the rocket impacted five miles east of the launch complex. APL instrumented this V-2 with a Geiger tube cosmic ray detector that was to be actuated by a g-switch, and insufficient "gs" were attained to turn it on.

Steering problems plagued the V-2 program for two years, affecting a total of 11 flights to varying degrees (Table 1).

30 April. On April 30, PSL's first contract with the Army's BRL (effective May 15, 1946) was signed by the College's Board of Regents. It covered one year of effort for a total of $25,000. The following basic requirements can be extracted from the two-page scope of work:

- ♦ Provide personnel, not to exceed 10 (except during peak loads)
- ♦ Reduce ballistic data from tests of rockets at WSP
- ♦ Provide BRL with reports for determining ballistic characteristics of rockets and/or missiles

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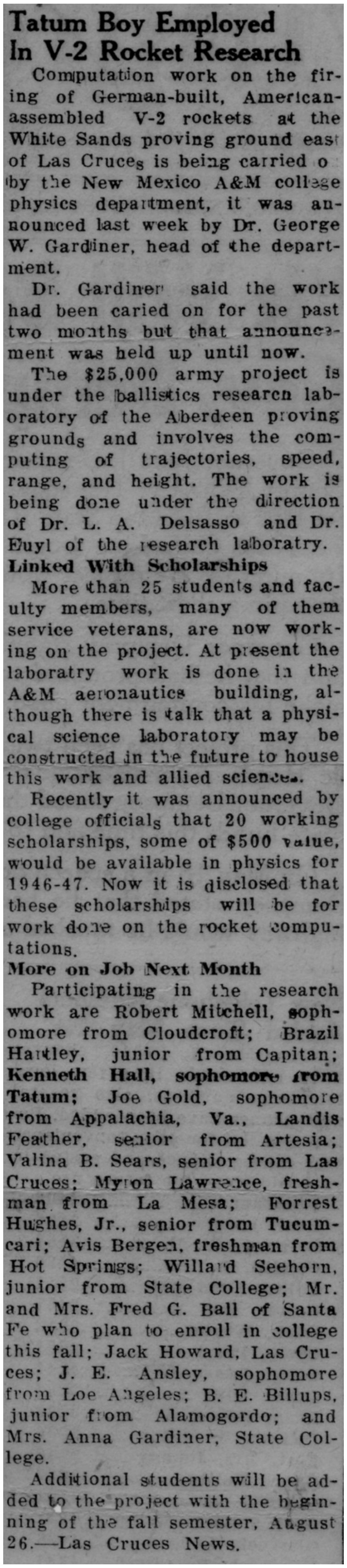
3 Anna Gardiner said that the first query concerning rocket support came from someone at Aberdeen who had been a classmate of Dr. Gardiner's in graduate school at Yale, but she couldn't recall the name. That name is undoubtedly Thomas Johnson.

♦BRL to furnish "computing machines"[4]
♦Develop devices for reduction of data
♦Dr. Lewis Delsasso of Aberdeen Proving Ground to act as the contracting officer's representative for inspection, supervision, and approval of work performed
♦Provide "observers in such numbers, and of such qualifications, as the Government may require"
♦"Computers" to be paid $1.50 per hour; secretary $1.00 per hour

A group of promising Engineering, Mathematics, and Physics students (approximately 12) was hastily assembled to perform the work required to fulfill the BRL contract. Because it was expected for this work to be completed within a year or two, students were told not to expect their jobs to continue (by the early 1950s, however, the number of full time staff had increased to almost 60, and student employees were a permanent component of the Laboratory).

Since it was to involve extensive use of trigonometric functions, mathematics instructor Anna Gardiner (Dr. Gardiner's wife) was chosen as the group's supervisor. Among these students were Valina Bardwell Sears, Fred Ball, Jane Ball, Benjamin Billups, Charles Botkin, Joe Gold, Forrest Hughes, Gail Hungate, Art Maxwell, Robert Mitchell, Alton Jones, Dave Lukens, Ray Chavez, Fred Hinchey, and George Hackler (Figure 4).

Dr. Gardiner had a willingness to take on challenging tasks, and his "can do" attitude profoundly affected his staff. He was an excellent judge of people, and though he had a strong academic background, his practical view of the world from a management and engineering standpoint won him a great deal of respect from his customers and staff.



Tatum Boy Employed In V-2 Rocket Research

Computation work on the firing of German-built, American-assembled V-2 rockets at the White Sands proving ground east of Las Cruces is being carried o by the New Mexico A&M college physics department, it was announced last week by Dr. George W. Gardiner, head of the department.

Dr. Gardiner said the work had been caried on for the past two months but that announcement was held up until now.

The $25,000 army project is under the ballistics researcn laboratory of the Aberdeen proving grounds and involves the computing of trajectories, speed, range, and height. The work is being done under the direction of Dr. L. A. Delsasso and Dr. Euyl of the research laboratry.

Linked With Scholarships

More than 25 students and faculty members, many of them service veterans, are now working on the project. At present the laboratry work is done in the A&M aeronautics building, although there is talk that a physical science laboratory may be constructed in the future to house this work and allied sciences.

Recently it was announced by college officials that 20 working scholarships, some of $500 value, would be available in physics for 1946-47. Now it is disclosed that these scholarships will be for work done on the rocket computations.

More on Job Next Month

Participating in the research work are Robert Mitchell, sophomore from Cloudcroft; Brazil Hartley, junior from Capitan; **Kenneth Hall, sophomore from Tatum;** Joe Gold, sophomore from Appalachia, Va., Landis Feather, senior from Artesia; Valina B. Sears, senior from Las Cruces; Myron Lawrence, freshman from La Mesa; Forrest Hughes, Jr., senior from Tucumcari; Avis Bergen, freshman from Hot Springs; Willard Seehorn, junior from State College; Mr. and Mrs. Fred G. Ball of Santa Fe who plan to enroll in college this fall; Jack Howard, Las Cruces; J. E. Ansley, sophomore from Loe Angeles; B. E. Billups, junior from Alamogordo; and Mrs. Anna Gardiner, State College.

Additional students will be added to the project with the beginning of the fall semester, August 26.—Las Cruces News.

Figure 4. Las Cruces Sun-News 1946 Article, PSL/BRL Contract

[4] These were German mechanical calculators.

Joe Gold told the following story of his recruitment by Dr. Gardiner: "In the spring semester of 1946, I was taking Physics class at New Mexico College of A&M. The head of the Physics Department, Dr. George Washington Gardiner, taught the class. The course must have been an elementary one, because I seem to remember that the book (a thick one with a blue cover) was entitled, Principles of Physics (this also was very likely the title of the course). The class met three days a week with an additional laboratory period. I was enjoying the things I was learning and was appreciative of the fact that Dr. Gardiner was an interesting teacher. One day, about the middle of May, Dr. Gardiner asked if I would stay after class for a few minutes.

"He told me that the German V-2 missiles captured at the end of the war were coming to the newly formed White Sands Proving Ground just east of the Organ Mountains, near Las Cruces (something I already knew). He also told me that he was going to organize a laboratory for the purpose of reducing flight data on these missiles (something I did not know), he would need a few student helpers for the project, and would I be interested? I naturally said, 'Yes.' He said the job would begin with a field trip to the proving ground to watch a V-2 firing and would let me know when."

The original captured German six-place trigonometric tables were used to perform the calculations because they were superior to the four-place American tables. One of Anna Gardiner's early projects involved students in the production of eight-place trigonometric tables, which were then published by PSL.

As explained further in Chapter 3, one errant V-2 flight (in May of 1947) landed in Mexico. This created an international incident and resulted in the shutdown of WSPG until a flight safety solution could be determined. PSL was known for its ability to react quickly to challenging situations such as this. Under the new BRL contract, Keith Guard, a Physics major who worked for Dr. Gardiner as a laboratory assistant, conducted a rocket ballistics study. The study led to the development (by Mr. Guard and Dr. Gardiner) of the "sky screen" device, which enabled WSPG to resume flight operations.

Workspace on the campus was apparently quite scarce at the time, so a room on the second floor of Goddard Hall (which was not being used for summer classes) became the temporary quarters for Mrs. Gardiner's group. There were two small offices on the west side of the room, one of which was undoubtedly used by the group's secretary, Avis (Bergen) Wilson. Mrs. Gardiner said that she believed Mrs. Wilson was the first full-time employee hired under the new contract.

10 May. On May 10, Dr. Wilbur Goss sent a memo to the Director of APL that recommended a "Section T" contract between APL and New Mexico College of A&M and specified the scope thereof.[5] The memo revealed that Dr. Gardiner was visiting APL at the time to discuss a possible contract, and it urged APL to give Dr. Gardiner a tentative answer for the College's Board of Regents.

Dr. Goss's memo recommended a three-year contract starting July 1, 1946 at a cost of $80,000 per year and included a "list of possible introductory problems." This list included some far-ranging items such as celestial navigation and laying out a long-range tracking system at WSPG. These were not included per se in the contract that ensued (see the *26 November* entry below).

10 May. The first successful V-2 flight at WSPG occurred on May 10. Since this flight was a test round flown for Army ordnance purposes, it did not transport a scientific experiment. The news media, including LIFE magazine, had been invited to provide wide coverage for this test. Col. Turner was understandably quite apprehensive about this, since the first attempted launch three weeks earlier had been a failure. However, this flight executed flawlessly, and the rocket reached an altitude of 70 miles (Figure 5 shows the V-2 owned by the New Mexico College of A&M or, as Jed Durrenberger called it, "the V-2 that went to college." This rocket was later donated to the Redstone Arsenal/NASA facilities in Huntsville, Alabama).

Figure 5. V-2 Rocket Owned by the New Mexico College of A&M

This flight provided the College with the first batch of film to be reduced under the new contract —five days before the effective date of May 15 (it is unknown whether or not work actually began prior to this date). The reduction process consisted of looking at a magnified image of each frame of the film and measuring the rocket image's length, aspect angle, and distance from center

5 The "Section T" research contract was designed during World War II to enable the Armed Forces to obtain technical assistance from civilian organizations without limitations that might stifle creativity. This type of contract allowed the Government to issue periodic Task Statements that were very broadly worded, stressing the objective to be achieved rather than the means by which it was to be accomplished.

crosshair. Film was read using fairly simple hand readers that consisted of film spools on the left and right and a magnifying optical unit in the middle. These readings were tabulated by hand, along with the azimuth, elevation, and elapsed time readouts on each frame. Because there were no American-made calculators at the time, all of these figures were entered into a pair of German mechanical calculators that were included in the V-2 shipments. These Brunsviga Double Manual Rotary Calculators were, "two-crank equation solvers" that although fun to use, were quite slow. Not long after PSL began its work in manual data reduction, Frieden developed first an eight- and then a 10-key mechanical calculator, which PSL purchased to replace the German calculators after the procedure was divided into manageable portions for student operators. These groups of students became something of a human computer that input streams of rocket data and produced calculation results that could be formed into flight reports in a short amount of time. Later, in the early part of the 1950s, more sophisticated Frieden and Marchant electromechanical calculators were produced, which PSL purchased for use in its work. Through a process of triangulation of readings from three or more stations, range and altitude parameters were obtained and plotted versus time on large sheets of graph paper. This yielded trajectory curves showing altitude, range, and velocity versus elapsed time from lift-off (Figure 6).

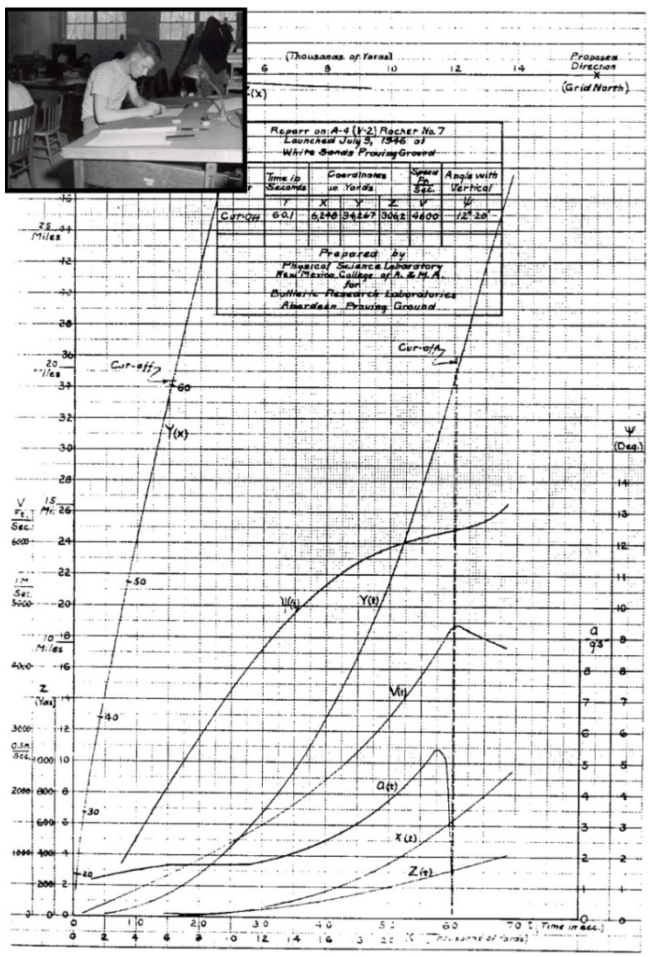


Figure 6. Student Gail Hungate Hand-Plotting V-2 Rocket Flight Trajectory, Spring, 1947

An ongoing competition existed among the students to complete as many computations in a work session as possible. Ray Chavez said, "We had very few breaks during those sessions because Mrs. Gardiner was a pretty conservative lady and expected us all to work hard. We had one 10-minute break in the morning and one in the afternoon, and we were allowed to take only one cookie with our coffee. It was very embarrassing to be caught taking two cookies!" Mr. Chavez went on to say that PSL had a large student turnover in those early hand-calculation days because many of them couldn't do the work and/or maintain the demanding pace.

17 May. BuOrd, through its Bumblebee contract with the APL, responded to Aerojet's proposal (see the *Early January* entry) by ordering 20 sounding rockets—15 for APL and five for NRL. This model, designated Experimental Atmospheric Sounding Rocket (XASR)-1, would allegedly lift 150 pounds to "over 300,000 feet." The NRL named its rockets, "Venus," and Dr. Van Allen coined the name "Aerobee" (a combination of the names "Aerojet" and "Bumblebee") for APL's rockets. Eventually, "Aerobee" was applied to all of the rockets—NRL's as well as APL's—and was retained through several model upgrades throughout the years.

29 May. The second successful V-2, instrumented by GE, also climbed to 70 miles. Anna Gardiner and her group now had two batches of film to process.

Joe Gold, who was one of a small group that attended the launch of the third V-2 to be fired at the WSPG, related the following: “For the viewing of the V-2 flight, we went to an instrumentation site located about 10 miles distant from the launch area, situated on terrain considerably higher, making the launch and flight easily observable. A German Askania Cinetheodolite, which had come over with the V-2s, was located here and would track and record trajectory data on the missile flight (Figure 7). The primary purpose of our trip was to see the instrument in operation and obtain a briefing on its operation.

“The Askania Cinetheodolite was a precision surveying instrument that was able to track in azimuth and elevation with the pointing angles being recorded on film at the rate of four data “points per second. Timing signals [were also recorded] so that all the data collected at other such sites around the range could be reconciled. I thought it was an ingenious piece of equipment. Of course, all labels were in German. The film used was 35 mm, and the optical system recorded pictures of the object being tracked. In the upper corners would be a picture of the azimuth and elevation dials. We were to read the data from the film, and, by use of trigonometric calculations, compute the position of the rocket at each data point, and plot these data in a desirable format. Thus, not only position would be determined, but also velocity and acceleration. Needless to say, this process required that the position of each tracking instrument and the missile launcher be accurately known with great precision. I found later that the Proving Ground was the most accurately surveyed piece of real estate in the country.

“A few days later, the Askania films from this firing were delivered to the College, and we began reading the film and reducing trajectory data. This same small group occupied two or three rooms on the second floor of Goddard Hall, the Engineering Building.”

Figure 7. Askania Cinetheodolite, 1946-1947

Early summer. BRL requested that the College furnish Civil Engineering students for some surveying work on the new Range, including the determination of the precise locations of launchers, camera sites, and other facilities. Mrs. Gardiner said that a number of students responded, including Benjamin Billups, who had just joined her group the previous day.

14 June. By mid-spring of 1946, BuOrd and NRL personnel perceived the need for a Navy field unit at White Sands to facilitate testing of NRL's sounding rockets and Navy missiles developed in support of the Bumblebee program. Consequently, Commander J.A. Coddington and five enlisted Marines were sent there to plan the facilities and to let construction contracts for the cantonment and technical areas. During 1946, over 70 Quonset buildings and a Navy launch complex were erected (Figure 8). Various PSL field groups worked at this launch complex for many years.

Figure 8. WSPG Headquarters and Support Buildings, 1946

Commander Coddington's resourcefulness is illustrated in the following story. Apparently, the Army refused to let Navy personnel use the commuter bus service that it had initiated for employees living in El Paso. Commander Coddington, who lived in El Paso, was determined to ride those buses. So, every morning, he dressed in his regular khaki shirt and pants, added a string tie and a large straw sombrero, and boarded the bus disguised as one of the laborers. After he reached his office, he would remove the hat and tie and put his Navy insignia on. He went through the reverse process each evening.

The United States Naval Ordnance Missile Test Unit (NOMTU) was officially commissioned by the Secretary of the Navy on June 14 (its first commanding officer was Robert McLaughlin). This unit assumed the sizable tasks of preparing and firing various sounding rockets and Navy guided missiles, which continues today. PSL has maintained very close ties with this "Desert Navy" throughout its history. In the early years, PSL worked closely with several U.S. Marine Corps personnel associated with the NOMTU, including Major Pozinski, Capt. Brandenberg, and Sgt. Hoover. The Unit (NOMTU) was upgraded to a Facility (NOMTF) sometime prior to 1950.

30 July. V-2 Rocket 9, the first to be instrumented by APL, set a new altitude record of 104 miles.

21 August. While using the early V-2s as sounding rockets, NRL's Rocket-Sonde Research Branch personnel reasoned that some scientists would need a vehicle larger than the Aerobee (with its 100-lb. payload capability) but smaller than the V-2. On August 21, a contract was granted to the Glenn L. Martin Company to provide 10 rockets capable of carrying 500 pounds of instrumentation to an altitude of 100 miles (a separate contract for the engines went to Reaction Motors, Inc.). This vehicle was originally named, "Neptune" but changed to, "Viking" when NRL discovered that a Navy aircraft called, "Neptune" already existed.

Four additional rockets with an augmented design were later added to the contract. Although the Viking performed quite well and carried many experiments to the upper atmosphere, it proved too costly (both to build and to launch) for extended usage. The Viking program pioneered the gimbaled engine, a very significant contribution to rocket technology.

Eleven of the 14 Viking rockets were fired at the WSPG from 1949 to 1955, one was fired from shipboard in the Pacific Ocean, and the other two were sent to Cape Canaveral, Florida, for use as test vehicles for the Vanguard satellite program in the late 1950s.

PSL's extensive involvement in the Viking launches will be detailed in later chapters.

Early September. Since the classroom used for the ballistic reduction work was needed for the fall semester, Anna Gardiner's group moved to a large room in the east end of the Air Mechanics Building on Vaughn Street.

14 September. Since it appeared that the College's four-month effort supporting WSPG firings would be continuing and expanding, an organizational entity on campus, headed by a single individual who would report directly to the President, was necessary. On September 14, the Board of Regents established a "Laboratory of Applied Sciences" with Dr. Gardiner as its Director. Dr. Gardiner, who was to exercise his duties jointly with those of the head of the Physics Department, guided this newly founded Laboratory based on the following three tenets:

- To assist Federal, State and Local governments in satisfying research and development needs
- To assist in attracting high caliber faculty and students to NMSU
- To provide meaningful employment opportunities to students and their spouses

PSL has always been a place for students to acquire hands-on technical skills, as well as secure gainful employment. In a speech given on March 19, 1964 for the dedication of the then-new Anderson Hall, C. I. ("Rick") Ricketts provided some insight into his and Dr. Gardiner's thoughts when he said, "…The true worth of any structure is measured only by the people it houses. The new laboratory will be furnished throughout with a total of nearly 1,000 man-years of experience, all acquired since late 1946. To this will be added some 500 part-time, young, impatient, curious, and aggressively competent students, both graduate and undergraduate. We look on these students as one of our main justifications for existence. This new structure must be and will be a monument to the keen perception and foresight of the educator and its founding director, George W. Gardiner, who so simply set forth three tenets at the laboratory's inception as follows:

- To contribute, where qualified, to the National and State effort-truly our foremost individual and collective obligation
- To help attract to NMSU an ever better qualified faculty, staff, and student body
- To provide qualified students with gainful part-time, scientific pursuits—the end result— ever better prepared graduates"

PSL employed hundreds of students during its first 25 years who were working and earning money to help them or their spouses through school.

An interesting insight into PSL's pre-1965 working conditions was provided when, in that same speech, Mr. Ricketts said, "As we look forward to our new home and our third decade, we pause but briefly to recall what has gone before—modest beginnings they were space-wise, then annexes, additions, barracks, pre-fab steel buildings, attics, basements, and finally even private homes, which suddenly found themselves within the confines of an exploding campus. May I hasten to add my 'nook and cranny' references here represent no lament—the environment we have seen is the one of our own choosing, and none better exists—anywhere!"

The Laboratory's name was changed to, "Physical Science Laboratory" some time before the end of 1946. Although the files do not disclose the date that this actually occurred, such a change supposedly required an action by the Board of Regents.

Other faculty became joint appointees around this same time or earlier. Among them were professors Melvin Thomas and Harold Brown and instructors Russell Rises and Conny L. Fleissner of the Electrical Engineering Department, and Physics instructor Dr. Albert Burris. A full-time secretary, Phyllis Palmer, was hired before the end of the year.

The Laboratory was given a room in Goddard Hall (the Engineering building) to use as a temporary office. Plans were immediately enacted to erect a laboratory and office building on

Vaughn Street just west of the Air Mechanics Building. Construction was funded by the State and well under way by the end of the year.

18 October. The aforementioned efforts of Dr. Wilbur Goss and Dr. Gardiner (see the *10 May* entry above), which continued through the summer and autumn, resulted in a letter of intent from the Navy's BuOrd. The two-page letter conveyed this message: "We anticipate placing with you a formal contract calling for studies and experimental investigations in connection with ordnance problems, and for the development, construction, and testing of ordnance devices. You may begin work when ready, but when convenient, send us a proposal. Contract amount is estimated to be $240,000. Contract term will be 1 July 1946 through 31 March 1949. Work will be under the technical direction of APL/JHU. Task Statements will be issued from time to time."

An original telegram dated February 18, 1947 from Vice Admiral G. F. Hussey, Jr., BuOrd, Washington, D.C. to the Regents of the New Mexico College of A&M (also addressed to the Inspector of Material Los Angeles "for information") was found in the files. It states, "YOU ARE HEREBY AWARDED CONVERSION OF LETTER OF INTENT NORD 9939 TO DEFINITIVE CONTRACT IN STANDARD BUREAU OF ORDNANCE RESEARCH AND DEVELOPMENT FORM COVERING RESEARCH AND DEVELOPMENT AS ASSIGNED BY TASKS UNDER BUMBLEBEE PROGRAM IN THE AMOUNT OF $240000.00 CHARGEABLE TO APPROPRIATION 1770702 ORDNANCE AND ORDNANCE STORES NAVY 1947 EXPENDITURE ACCOUT 64660. FORMAL CONTRACT FOLLOWS."

The starting date of this contract was made retroactive to July 1, suggesting that some type of work had already begun around that point. There is no written record of the nature of this preliminary work, but since, "reduction of data" was later incorporated into the contract scope (see below), the assumption can be made that telemetry data reduction was provided for APL's first V-2 launch (July 30). It is known that sometime before the end of 1946, Professor Harold Brown, working half-time at PSL, formed the Telemetering Reduction Group to provide reduction of data from telemetry records of various V-2 flights (its first supervisor is believed to have been Fred Ball, who had been a student employee in Mrs. Gardiner's group). The Telemetering Reduction Group was comprised primarily of students, including Alton Emmett Jones and Gilbert ("Gil") Moore (Mr. Jones, who was a student supervisor, was actually responsible for hiring Mr. Moore).

The ground recording system consisted of an oscillograph light source for each channel that actually recorded the signal received from the rocket in flight to wide negative film (rolls) for the original flight record. Then, as many records as necessary were transcribed onto rolls of positive photo paper (Figure 9). PSL had large vats of photo developer solutions that could process these long rolls of film and paper, "fix" them, and dry them.

Figure 9. V-2 Telemetry Data Reduced from Film, 1948

The telemetry reduction was performed strictly by hand, using specially graduated plastic rulers to measure the amount of trace deflection on the strip chart records. These records were usually from 70-100 feet long (Figure 9), and in many cases it was necessary to perform several measurements per inch. The readings (Figure 10) were tabulated by hand, and then converted to engineering units via slide rule or calculator (engineer Robert Sabin was assigned to this reduction effort when he joined PSL in December***)***. The paper records were often quickly taken back out to WSPG for analysis of the recent rocket flight.

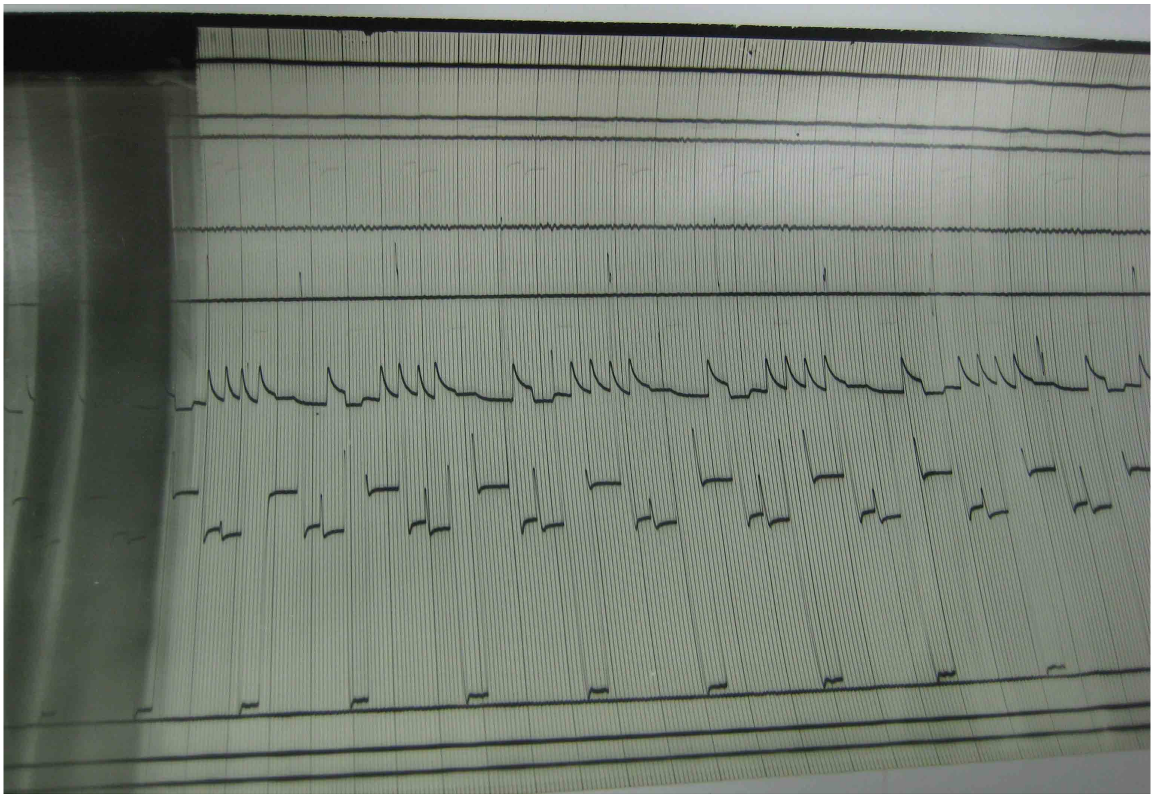


Figure 10. V-2 Telemetry Record with Flight Telemetry Information Shown[6]

The Telemetering Reduction Group was provided space in the basement of Kent Hall, which was a men's dormitory (Figure 11). The basement, which had also been used as an indoor rifle range by the College's Reserve Officers Training Corps, was neither heated nor cooled. It had overhead sewer pipes, leaked water, and was poorly lit and very dirty.

[6] The data on these rolls pertains to V-2 engine parameters (for V-2 flights) and from the scientific instrumentation (cosmic ray telescope) aboard this particular flight and rocket pressure values (for Aerobee flight).

Figure 11. Kent Hall, Circa 1945

26 November. A letter arrived from BuOrd (five weeks after the October 18 letter) establishing the first task of the as-yet-unsigned contract. The scope of Task NMA-1 was slightly more specific than the letter of intent, but was still quite broadly stated as follows: “Research and development work with respect to instrumentation for flight tests of missiles related to Task F (Bumblebee) assigned to the Applied Physics Laboratory of the Johns Hopkins University by the Bureau of Ordnance is to be carried on. This work shall include design, experimental fabrication, operation and field testing of such instruments and auxiliary equipment used in carrying out this work as well as reduction of data obtained from these instruments in flight tests.”

Thus, the Lab’s first call for field support resulted in a second customer (the Army was the first), even though a formal Navy contract did not yet exist. Finally, in February 1947, BuOrd sent a wire converting the letter of intent to a contract and stating, “Formal contract follows.” When (and if) this formal contract was received and duly signed is not known, but funding was provided and work began sometime between July 1 and December 31, 1946.

1 December. As a result of telephone negotiations initiated by Dr. Gardiner in early November, the Army/BRL contract was expanded on December 1 to include the following additional tasks:

- Provide part-time personnel for technical assistance in the maintenance, operation, and development of tracking devices used at WSPG
- Develop films obtained in the tracking of missiles at WSPG
- Increase full-time equivalent personnel from 10 to 15

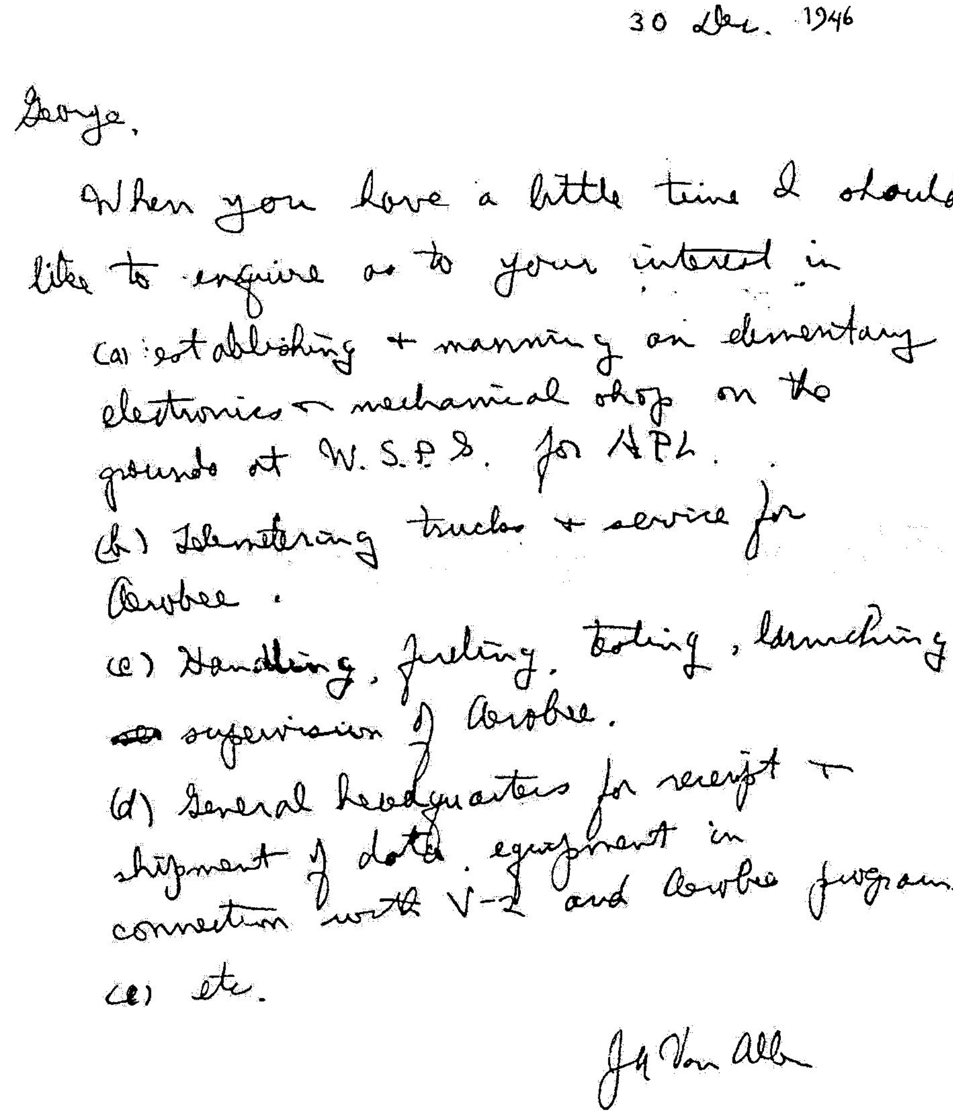
Thus came the second request for field support—after Dr. Gardiner convinced the Army that they needed it. Details are minimal as to when and how these field operation and maintenance efforts actually began, but they developed into efforts involving hundreds of employees and many millions of dollars. Field support (i.e., any work done away from the College campus) has been a PSL mainstay throughout its history.

It is known that the film developing (the second added task) began immediately. Professor Harold Brown quickly set up rudimentary facilities in the Kent Hall basement, sharing space with the Telemetering Reduction group. This "Photo Lab," which was staffed primarily with students under the supervision of Lawrence ("Larry") Gardenhire, began developing V-2 flight films from the Army's Bowen-Knapp and theodolite cameras. There were about a dozen of these cameras, located at various sites scattered over the WSPG. The Photo Lab later assumed the additional task of developing telemetry film records.

PSL now had two customers—BRL/Army Ordnance and APL/Navy Ordnance. Professor Brown told the story of procuring a third customer, the NRL. Professor Brown was at the bar in the old Amador Hotel in Las Cruces when he happened to meet some NRL scientists who were in town for a V-2 firing. He told these scientists that PSL was processing records and reducing data for APL and BRL. The visitors said that they needed the same type of support, and a contract ensued (see Chapter 3).

30 December. As (APL's) Dr. Van Allen was coordinating the support teams necessary for the planned Aerobee program, he began to wonder if the New Mexico College of A&M would be interested in handling the fueling and launching of the Aerobees at WSPG. He then wrote a note to Dr. Gardiner on a plain sheet of paper (Figure 12) to "inquire as to [his] interest in…" providing the following categories of support:

- Set up and operate an electronics and mechanical shop at WSPG for APL Telemetering trucks and service for Aerobee
- Handling, fueling, testing, launching, and supervision of Aerobee
- Act as depot for receipt and shipment of data and equipment in connection with V-2 and Aerobee
- Etc.



30 Dec. 1946

George,

When you have a little time I should like to enquire as to your interest in

(a) establishing + manning an elementary electronics + mechanical shop on the grounds at W.S.P.G. for APL.

(b) Telemetering trucks + service for Aerobee.

(c) Handling, fueling, testing, launching supervision of Aerobee.

(d) General headquarters for receipt + shipment of data, equipment in connection with V-2 and Aerobee program.

(e) etc.

JA Van Allen

Figure 12. A 1940s Request for Proposal Written by APL's Dr. James Van Allen

The proliferation of paperwork that has occurred over 40 years is best illustrated through a comparison of this first "request for proposal" (RFP) to one received in 1986 by PSL from NASA covering an effort of roughly the same magnitude. The NASA RFP totaled 353 pages and undoubtedly took months and many thousands of dollars to prepare. A similar contrast is provided when comparing Dr. Gardiner's 1947 proposal (which consisted of four pages), to PSL's 1986 NASA Balloon Proposal, a four-volume publication weighing over 25 pounds and costing $150,000 to create. The four-page proposal laid out a reasoned response (since, "it is difficult, without knowing the complete requirements of this task, to estimate its costs for a period of one year") to Dr. Van Allen's request. The items included in the rough estimate are shown in Table 2.

Table 2. Items Included in Proposal Cost Estimate

Item	Total
Six New Mexico College of A&M staff, including: Supervisor Technical telemetry person Assembly, fueling, and launch person Machinist Electronic Technician Storekeeper	$28,000
Extra Assistants (for shoots/emergencies)	$ 4,000
Data Reduction Support	$18,000
Equipment	$ 5,600
Installation of Equipment at WSPG	$ 1,700
Travel/Transportation	$ 3,000
Overhead	$ 6,000
Grand Total	**$66,300**

Anna Gardiner told an amusing story about the V-2 firings. Mrs. Gardiner liked to take her newly hired employees out to WSPG for at least one close-up viewing of a rocket launch. They would travel to the viewing area two or three miles east of the launch facility, where the Army briefed them about what to expect. On one occasion, the group included a woman named Mrs. Feather, who listened attentively as Col. Turner told them that, as the rocket climbed, it would give the illusion that it was coming toward them. He said that although the rocket would appear to be directly overhead, such was not the case, and there was nothing to fear. Well, this particular V-2 experienced problems and veered off to the east, directly over the heads of the visitors. They all started scrambling for cover, except Mrs. Feather, who remained calm and unruffled, knowing that the rocket coming toward them was just an illusion (the rocket came to earth a few miles beyond the viewing area).

CHAPTER 3: THE LABORATORY MATURES

1947

The Laboratory matured rapidly in the 18 months spanning mid-1946 to the end of 1947. By this time, it occupied its own building, had grown from approximately 12 part-time to 40 full-time employees, had established field groups at WSPG, and was controlled by its own management (it was not, however, completely independent financially, which is still the case today).

The state-financed PSL building on Vaughn Street was completed and occupied in April of 1947. It was a modest, one-story structure with 3,500 square feet (Figure 13); nevertheless, it must have been a source of considerable pride to its first occupants. The building included inner and outer offices for the Director, two additional offices, stock and storage rooms, and three laboratory rooms. A few months later, an Army dental clinic barracks building was acquired and placed on the south side of the new building. This barracks, which became known as the "BRL Annex,"[7] housed the Ballistic Film Reduction Group (which had already outgrown its quarters in the Air Mechanics building). Mrs. Gardiner said that the large room occupied by the calculator operators was once the dental clinic's waiting room. The Film Development Lab and the Telemetering Reduction Group remained in the basement of Kent Hall.

Figure 13. Front of PSL Building, 1947

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7 These buildings were demolished in 1986 so that a Computer Engineering complex could be constructed.

A complete listing of PSL's staff as of January 1, 1947 has not been located, but it is known that several full-time people were hired during January. Both Figure 14 and Table 3 (which are assumed to have been created that month) provide a fairly accurate count.

Figure 14. PSL Staff, January 1947

Back row, left to right: Lawrence Gardenhire, Victor Fusselman, Conny Fleissner, Ivan Carbine, Dr. Donald Crosno, C.I. Ricketts, Charles Botkin, Harold Brown, Fred Ball. Front row: Robert Sabin, David McFarland, Russell Riese, Dr. George Gardiner, Phyllis Palmer, Melvin Thomas, Dr. Albert Burris (Absent: Albert Antonis, Anna Gardiner, & Hanford Fairchild).

Table 3. Physical Science Laboratory Personnel Employed Under APL/Bumblebee Contract, January of 1947

Name	Position Title	Teaching Position	Portion Time Bumblebee
Antonis, Albert J.	Electronic Tech.	--	Full-time
Botkin, Charles	Jr. Engineer	--	½ (½ Army contract)
Brown, Harold A.	Elect. Engineer	Asst. Prof. EE	¼ (¼ NRL; ½ teaching)
Burris, Albert	Physicist	Assoc. Prof. Physics	½ (½ teaching)
Crosno, C. Donald	Assoc. Engineer	Assoc. Prof. EE	½ (½ teaching)
Fleissner, Conny	Assoc. Engineer	Instructor EE	¾ (¼ teaching)

Name	Position Title	Teaching Position	Portion Time Bumblebee
Gardiner, George W.	Director	Prof. of Physics	½ (½ teaching)
McFarland, David	Machinist	--	Full-time
Palmer, Phyllis J.	Secretary	--	½ (¼ NRL, ¼ Army contract)
Riese, Russell L.	Jr. Engineer	Instructor EE	½ (½ teaching)
Thomas, Melvin A.	Engineer	Prof. EE	1/3 (2/3 teaching)
Fairchild, Hanford	Electronic Tech.	--	Full-time

The V-2 Story Continues

The NRL contract (which was acquired by Professor Brown at the Amador cocktail lounge) must have been effective around January 1, but the exact date is not revealed in the files. The contract requested telemetry field support at WSPG, developing and printing of telemetry records, and reduction of telemetry data (Figure 15) for NRL's ongoing V-2 and upcoming Venus (Aerobee) sounding rockets.

Figure 15. New Mexico College of A&M Students Perform Manual Reduction of V-2 Trajectory Data, 1947 (Joe Gold, Left Center)

The telemetry field support consisted of preparing and installing NRL-designed telemetry transmitters in the rockets and operation and maintenance of NRL's ground stations for recording of telemetered data. Rick Ricketts was hired to supervise the telemetry fieldwork. Others hired were Ivan Carbine, Robert Sabin, and Paul ("Swede") Hill (Figure 16), all recent graduates of the Engineering College.

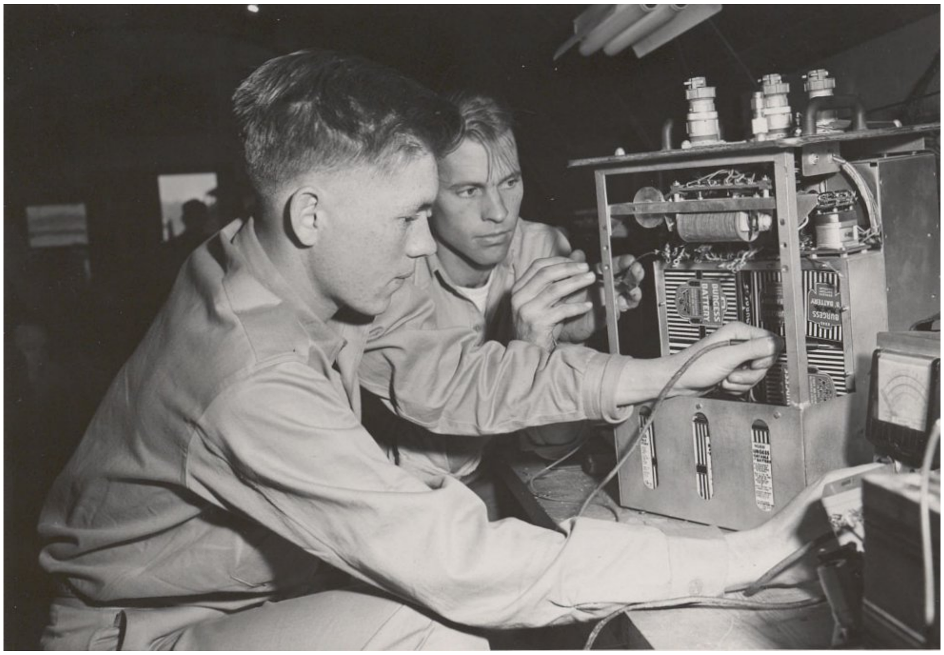

Figure 16. PSL Engineers Robert Sabin and Paul Hill Check Dry-Cell Power Pack to be Flown in a V-2 Rocket, 1947

These four men were the first PSL employees hired to perform work off-campus. Since there were no PSL-owned vehicles in those days, the group car pooled to the main base each day, and then drove a Navy vehicle to their work sites[8]. These sites included a Quonset hut used to prepare telemetry transmitters and the experimenter's instruments and two four-wheeled shop trailers, which each housed a telemetry ground station (Figure 17). The trailers were parked in the desert six miles north of the launch area. Another work site was the launch complex, where Robert Sabin (affectionately known as the, "Transmitter Man") installed transmitters into the rockets (he remained in the blockhouse during pre-launch tests and launches). These men learned on the job, without benefit of formal training (as has been the case with the majority of PSL's new contracts over the years).

The telemetry system used in NRL's V-2s at that time was a Raytheon-built, NRL-designed, 23-channel system with a "sequential" method of encoding. The transmitter used pulse-position-modulation (PPM/AM), a carrier frequency of 1,000 megahertz (called megacycles at that time), and radiated a peak pulse power of 1,000 watts. This output was discovered in later years to be at least 1,000 times more power than necessary because the designers had absolutely no concept of the amount of power necessary to send a signal to earth from an altitude of 100 miles. Putting that much power into a pressurized container resulted in a telemetry transmitter that weighed 90 pounds (as compared to some modern types that weigh as little as a few ounces and transmit a fraction of a watt). Ninety pounds, of course, was of little concern to the V-2 users with that 2000-

8 This vehicle was often an open military jeep, even in mid-winter.

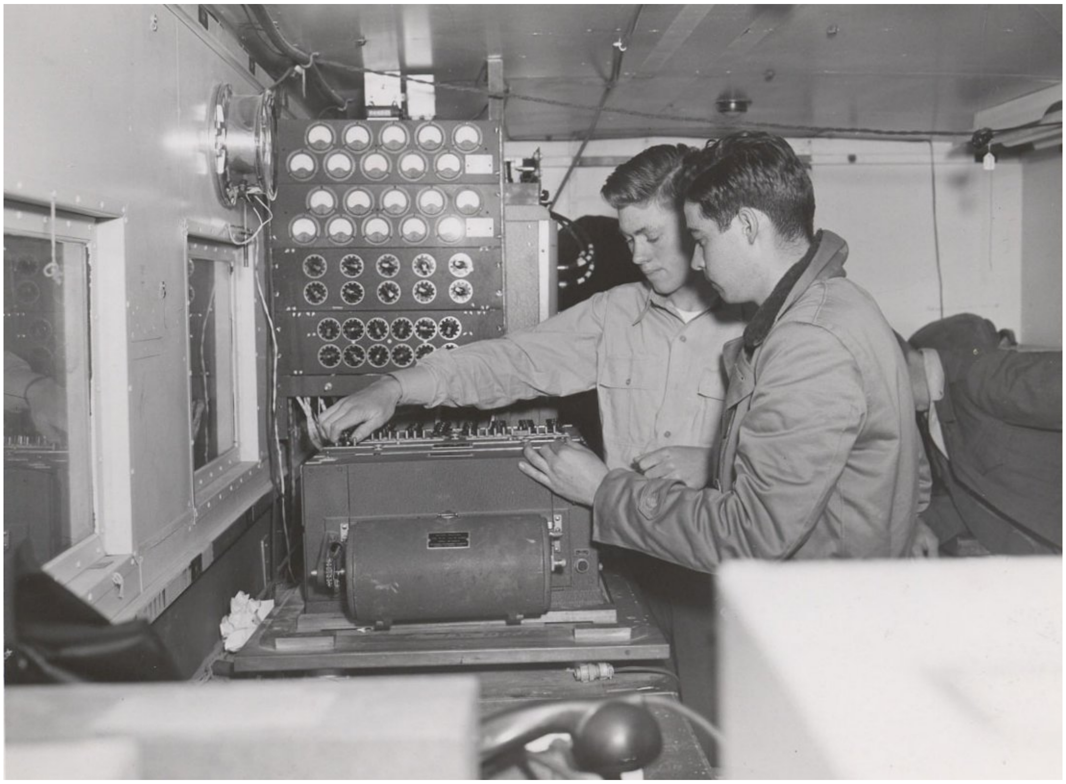

Figure 17. Robert Sabin and Ivan Carbine in PSL's First Telemetering Ground Station, WSPG, Spring 1947

pound payload capacity.[9] After a few months of operating ground stations inside the two trailers, the NRL Telemetering Group was given a permanent building at that location called the "NRL Telemetering House" (Figure 18). Along with the Telemetering House came a new and updated version of the pulse-position telemetry system. It featured 30 channels and a unique recording arrangement employing cathode ray tubes, lenses, and continuously moving strips of 9 1/2-inch wide photographic film. There were two complete and independent ground stations (Sta. "A" and Sta. "B") in the House, each with its own hand- pointed antenna on the roof.

Three people were required to staff a station—a station operator, an assistant operator, and an antenna "tracker." The tracker attempted to keep the antenna (a four-foot aluminum dish) pointed at the rocket throughout its flight by watching a signal-strength meter. A maximum meter reading meant that the antenna was aimed directly at the signal source (i.e., the rocket).

The word "telemeter" is a verb meaning to measure ("meter") from afar ("tele"). A telemetering system, therefore, is a means by which one or several measurements can be read from a distance. A scientist can install measuring instruments in a rocket and read what the instruments are

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9 Raymond Bumgarner, who was involved in V-2 telemetry, recalled climbing 50 feet of ladder on the Gantry crane and hauling that big transmitter up with a rope and pulley in order to install it in the nose section of the rocket.

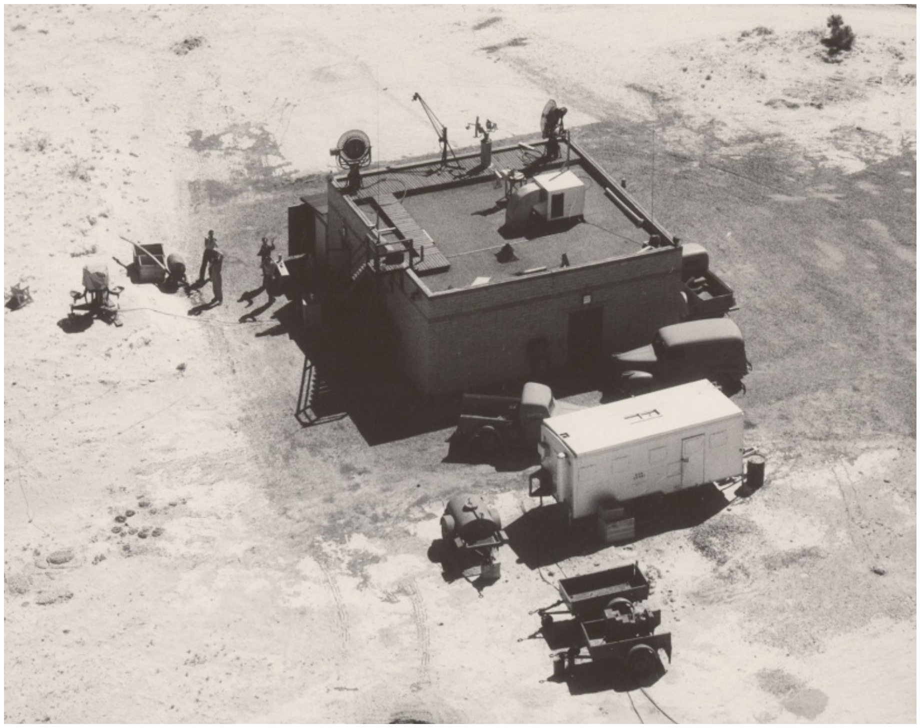

Figure 18. NRL Telemetering House, WSPG, 1947 (later called Parker Station)

sensing throughout the entire flight. Many atmospheric phenomena can be measured, such as temperature, air pressure, radiation particles from space, types of gases present, etc. at all altitudes. These readings, called "data," are sent to the ground via a radio transmitter in the rocket. The ground station equipment receives this radio signal (which can carry dozens of different data channels simultaneously), decodes the data, and records it on a 200-ft. long strip chart.

The instruments that were flown in the V-2s were expendable—that is, they shattered when the spent rocket fell back to earth—but this was not a problem because the experimenter's data had already been recorded. In later years, the Aerobee and other sounding rockets were equipped with a very effective parachute system for soft landing and recovery of the entire payload section.

The Army/BRL contract for V-2 ballistic reduction was renewed effective May 15 for one year, authorizing additional people and dollars to provide ballistic coverage for the Aerobee firings.

Fourteen V-2 rockets were fired in 1947. Four of these experienced propulsion or steering problems, resulting in very low peak altitudes (Table 1). Four V-2s were instrumented by NRL, involving PSL's NRL Telemetering Group. One of these, V-2 29 (launched on July 10), reached a peak altitude of only 10 miles. In September of 1947, a V-2 was launched from the deck of the aircraft carrier U.S.S. Midway in the Atlantic a few hundred miles from Bermuda. Labeled, "Operation Sandy," the test was initiated by Admiral Dan Gallery, who wanted to prove that large missiles could be fired from a ship at sea. He proved his point when the rocket indeed lifted off the ship, but since this was one of the V-2s with steering problems, it lost control and splashed into the ocean a short distance away. The test was not repeated; however, in later years other sounding rockets were fired from ships.

Prior to the shipboard launch, "Operation Pushover" was conducted at WSPG. A fully fueled V-2, erected upon a launch stand, was deliberately dropped over onto steel deck plates to assess the effect of the ensuing explosion and fire. PSL was apparently not directly involved in either one of these tests.

> WSPG was plagued by dust storms, which could be rather erosive to both the landscape and the equipment. General Electric's project manager Leo ("Pappy") White told the story of the serious problems that were resulting from dust getting into delicate V-2 components. When approached for a solution, the German scientists said that they had found condoms to be both effective and inexpensive. Pappy's staff purchased a gross of condoms and sent the bill to the home office for payment. The home office immediately called to find out what was going on down there in that New Mexico desert! After hearing the explanation, they decided to re-label the purchase as "six-inch protective rubber tubing, closed at one end."

"The One That Got Away"

Perhaps the most memorable V-2 flight was the one that landed on a remote hillside in Mexico after sailing over El Paso and Juarez, narrowly avoiding catastrophe and international uproar. In the twilight hours of May 29, the Army prepared to launch the first planned test of the Hermes II project, which was an attempt to use a ramjet vehicle as a second stage atop the V-2. Only a partial load of propellants was required in order to boost the V-2's ramjet to its operating altitude, and it is assumed that steering modifications were made to flatten the trajectory.

This was a secret firing, with no publicity or visitors.

The lift-off occurred at 7:30 p.m. and, to the hundreds of area residents who saw the familiar vapor trail in the rays of the setting sun, the climb appeared normal. However, instead of tilting to the north, the rocket veered southward. Five minutes after launch, it landed in a huge ball of orange flame and smoke 1½ miles south of the Tepeyac Cemetery in Juarez (and only a few hundred yards from a dynamite storage dump). Miraculously, no one was injured, though windows were broken in both Juarez and El Paso. Narcisco Vargas, the cemetery caretaker, who was about 600 yards from the blast, said he was thrown to the ground and dazed for a few moments.

According to Harold Connell, the V-2 actually landed *in* the Tepeyac Cemetery (not 1.5 miles south of it) and related the following story to confirm that. One day in the early 1950s, he was having lunch in the Navy Officer's Mess with a couple of Army officers, who happened to be lawyers from the WSPG Legal Office. They all began talking about the stray V-2 that had landed in the cemetery. The legal officers explained that, since there were no grave registration records for the cemetery, the U.S. Government had no choice but to pay all claims filed for the "disruption of a loved one's grave." In addition, occasional visitors from Mexico's interior visiting a relative at the cemetery were told that, if they filed a similar claim, the generous "Estados Unidos" would pay off like a slot machine. The officers said that these claims were still being filed in the early 1950s, and that if they were all legitimate, the bodies must have been buried "standing up and three deep!"

Colonel Turner told reporters the next day that two mistakes caused the mishap, one mechanical and one human. A faulty gyroscope was assumed to cause the southward tilt[10], and, since the "civilian technician" controlling the radio cutoff switch thought that the rocket was moving straight up, he did not activate it quickly enough.

It was obvious that a serious flaw existed in the process of predicting and controlling rocket impact points. Something had to be done, and quickly. The May 30 edition of the El Paso Herald Post carried this late-breaking item:

"Lieut. Col. Harold R. Turner, commanding officer of the White Sands Proving Grounds, announced this afternoon that scientists at WSPG have started work on a device that will prevent a recurrence of a rocket getting off its course. 'We will have a device that will safeguard the rocket from the human factor of error,' he said. 'When such an accident as last night's wild rocket shoot occurs, it gives us something with which to start working.'"

Colonel Turner was presumably referring to the fact that Dr. Gardiner had already been approached by Wayne Roemersberger, head of the BRL Group at WSPG, to obtain PSL's aid in finding a "quick fix" to the problem of early flight path assessment. Anna Gardiner said that, within an hour after the errant flight, Dr. Gardiner sat down with pencil and paper and drew up the basic design of the "sky screen." The sky screen would be a simple mechanical device through which an ascending rocket could be viewed by an operator; in his view, a pair of wires forming a "V." Simply stated, a rocket that remained between these wires as it ascended would impact within the range boundaries. As mentioned earlier, Keith Guard conducted a ballistics study for Dr. Gardiner on all V-2 rockets fired at WSPG up to that time. From this data he determined the wire positions for the two screens that would be required—one screen west of the launch site to cover the north-south plane, and one screen south of the launcher to cover the east-west plane. PSL

10 Some PSL employees associated with the V-2 shots believed that convincing evidence existed to show that the pitch gyroscope was wired backwards, not faulty. Conclusion unconfirmed.

constructed two frames of angle iron, affixed the wires to them, and probably installed them at WSPG within a few days.

These two sky screens employed fixed wires. Sometime in 1947 (probably late summer), APL/ BuOrd requested that PSL design a sky screen for Aerobee flights, a more sophisticated model with moving wires (described later in this chapter).

In conjunction with providing the sky screens, Mr. Roemersberger of BRL asked PSL to assume operation and maintenance of the cutoff transmitter at WSPG. The Cutoff Group, headed by Ivan Carbine and consisting of Nathan ("Nat") Wagner and others, was organized in order to assume this large task. Three PSL field groups were now working at WSPG, each for a different customer.
.
Socorro's New Mexico School of Mines also became involved in V-2 support at WSPG, requested by BuOrd to devise a means of down-leg separation of the warhead from the vehicle with some type of explosive charges (a function that became known as "blowoff"). The purpose of blowoff was to enhance the recovery of instruments. Several combinations of size and placement of charges were attempted before achieving clean severance; blowoff then became standard practice.

Since the fuel cutoff receiver provided the control link to initiate blowoff, PSL became involved via the cutoff contract mentioned above. Ivan Carbine's group was responsible for pushing the blowoff button at the prescribed time on the downward stage of the flight.

Enter Aerobee

As mentioned previously, Dr. Van Allen of APL had inquired as to whether PSL was interested in fueling, launching, and providing telemetry support for the planned Aerobee sounding rockets. In early January, within a week of receiving this inquiry, Dr. Gardiner drafted a proposal addressing these items. His "very rough estimate" of the costs for one year totaled $66,000. It is interesting to note that neither Dr. Allen's inquiry nor Dr. Gardiner's estimate made any mention of the number of rockets involved.

The various tasks comprising Aerobee support were distributed to the interested parties at a meeting held at APL on January 27. The decision was made for APL to manage the program; USNOMTU to store, fuel, and fire the rockets; and PSL to

- Perform operation and maintenance of telemetry ground stations for APL Aerobee launches at WSPG
- Provide photo processing of telemetry records
- Reduce data from telemetry records

These three areas of support were to be provided in addition to, and concurrent with, V-2 support.

This third request for field support at WSPG resulted in the hiring of more personnel. The Aerobee Telemetering Group was formed under Harold Brown, and Richard Olemacher was hired to lead the field group. The pioneers supporting this effort included A.C. Ebensberger, William Sullivan, Raymond Malloy, Handy Fairchild, and Victor Fusselman. In a letter dated February 20, Dr. Gardiner advised Dr. Van Allen that Mr. Olemacher and Mr. Fairchild would be sent to APL/JHU to receive training on the telemetering system to be used. The men arrived at APL on February 24, where they remained until sometime in April. This is believed to be the first out-of-state assignment for PSL personnel.

Mr. Olemacher's weekly letters to Dr. Gardiner revealed his frustration at discovering that the telemetry system was still in the planning stages[11]. He therefore became involved in the development of the system, particularly of the rocket-borne and ground station antennas. Mr. Olemacher is credited with developing a helical antenna based on work that had been published by Professor J. D. Kraus of Ohio State University. This antenna, which was very successful in receiving telemetry signals at the ground stations, provided circular polarization and a gain of about 10.5 dB over a dipole in free space, at a frequency of 220 megacycles (Mc). These antennas were designed and constructed beginning in 1947 by machinists at PSL, as were various ensuing adaptations that were used into the 1990s (Figure 19).

Figure 19. Helical Beam Antenna for Receiving Telemetry Transmissions from Rockets in Flight, 1959

Through a bit of arm-twisting at APL and some borrowing from PSL's NRL Telemetering Group, Mr. Olemacher managed to accumulate enough equipment to outfit two ground station trailers (Figures 20, 21). These were parked next to NRL's new telemetering "house," with their crew eagerly awaiting launch of the first dummy Aerobee in September.

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[11] Mr. Olemacher also expressed frustration with the weather. In another letter, he said, "I certainly will not be sorry to return to New Mexico. Snow and slush seem to be the only weather available."

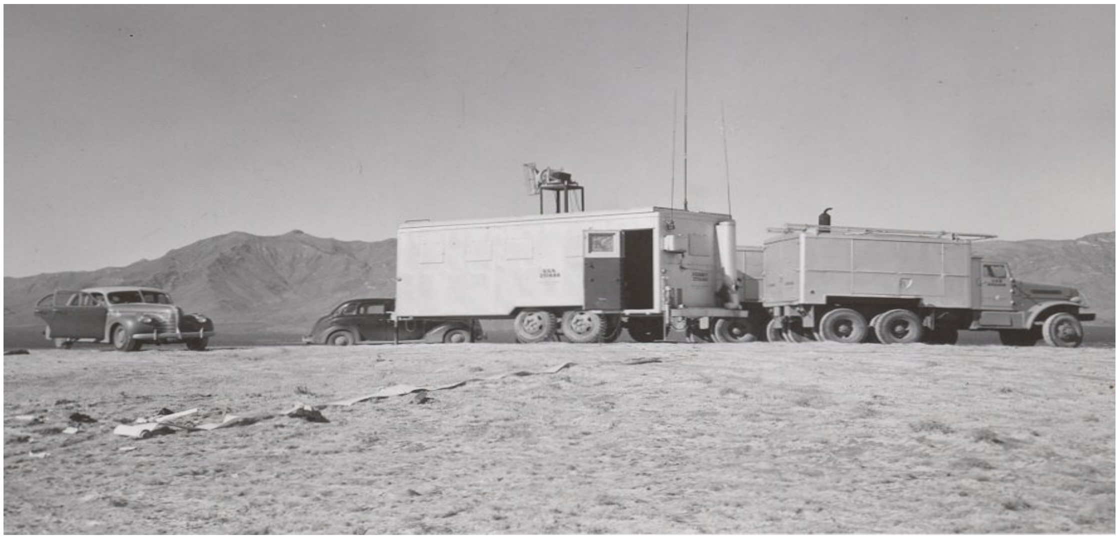

Figure 20. APL Telemetry Van on Range, 1947

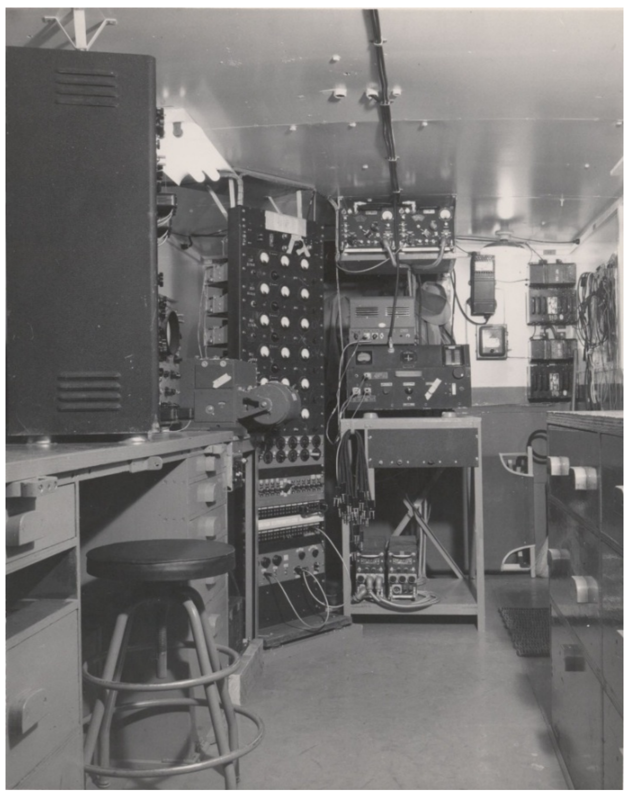

Figure 21. Telemetering Receiving Station in APL Van, 1947

The Bumblebee Research Group was also created for Aerobee support in late 1946 or early 1947. This group was located on campus and headed by Dr. Albert Burris. Included in the group were Conny Fleissner, Charles Botkin, Ivan Carbine, Dr. C. Donald Crosno, David McFarland, and Russell L. Riese. This team was tasked with developing flight hardware and a command receiver for in-flight fuel cut-off.

The cut-off receiver was a major undertaking. The Army was flying one such unit, the ARW-37, in its V-2 rockets, but it was too bulky and heavy for use in the Aerobee. Conny Fleissner led PSL's first attempt to design and build rocket flight hardware, successfully developing a miniature version of the ARW-37. According to the specified design criteria, the receiver was to:

- Operate in conjunction with existing ground transmitter equipment
- Be as small and light-weight as possible
- Be designed such that spurious carriers or signals could not actuate it
- Feature output capable of setting off a blasting cap to sever the fuel line, thus effecting cutoff

Mr. Fleissner, aided by technician Raymond Malloy, was able to reduce the size of the receiver to approximately 6 by 4 by 10 inches and the weight to slightly over seven pounds through use of miniature vacuum tubes and a completely new mechanical design. Like its predecessor, this unit was a frequency-modulated, crystal-controlled super-heterodyne receiver operating on a fixed carrier frequency of 40-58 Mc. A "fail-safe" feature was employed in the cutoff system such that many in-flight failure of either the ground transmitter or the receiver would automatically result in fuel cutoff, regardless of rocket performance. This feature ensured that loss of cutoff control would not cause a rocket to land outside the proving ground and required that the cutoff receiver be extremely reliable.

To this end, the four units fabricated by PSL were subjected to a variety of performance and environmental tests. Fly-over tests were performed at WSPG using B-17 and B-29 aircraft at altitudes of up to 30,000 feet and a range of 40 miles. The units were put on a spin table and tested to 40g. One unit was sent to the Naval Gun Factory in Washington, D.C., where it was placed in an acceleration gun and subjected to 100 g shock. Although the units passed these tests, one of them failed when flown in a dummy Aerobee on October 2, 1947 in an attempt to "prove in" the system.

The flight antenna used for the cutoff receiver consisted of three spring-loaded lengths of aircraft control cable, one of which was stretched from the leading edge of each fin to a Bakelite insulator on the forward end of the tank section. APL adapted this design from one used by NRL for ionosphere experiments aboard V-2 rockets. This antenna produced a good field pattern and was quite effective after Mr. Olemacher and his group modified it. It was used for only a year or two until PSL's Leonard Gough developed the fin notch antenna.

Early in 1947, the Bumblebee Research Group assumed another flight hardware development project—a voltage-controlled audio subcarrier oscillator for use in the APL FM/FM telemetering system. Conny Fleissner, along with Professor Melvin Thomas, worked on this effort concurrently with the cutoff receiver design. A December 13 report describing the circuit does not reveal whether or not PSL actually constructed any of these units or whether the circuit was ever used by APL (it is probable that the task assignment merely called for a design of the circuit). In Harold

Connell's opinion, this circuit was possibly a precursor to the Bendix-manufactured FM-FM modules that used miniature vacuum tubes.

APL built and fired three dummy Aerobees early in the program to "prove in" the launching procedures and equipment and to test booster separation (a secondary objective was to provide PSL with opportunities to practice using the new telemetry ground stations). The mock-ups consisted of standard nose cone, payload, and tail sections attached to a dummy tank section made of 3/8-inch steel boilerplate, thus achieving the weight and the aerodynamics of a fueled Aerobee. Standard boosters were used in all three tests.

The first dummy Aerobee, A1, was tested on September 25, 1947. It carried a simple cosmic ray experiment and a six-channel FM/FM telemetry system operating at 80 Mc with an output of five watts. The telemeter utilized a spike antenna on the nose tip to excite the entire rocket body. No cutoff receiver was used in this test.

A post-flight report written by Wayne Roemersberger of BRL states that the launch was delayed 2.5 hours "due to telemetering difficulties," but doesn't reveal whether the ground stations or the transmitter caused the problem. The PSL ground station crews performed pre-launch checks of the telemetry signal and awaited lift-off for their first attempt to record data from a rocket in flight. Unfortunately, however, the telemetry signal ceased at lift-off, apparently due to failure or inadequacy of its battery power supply.

The test was successful in all other respects—the X-band radar locked onto the booster and tracked it to impact. Although the S-band radar did not detect a signal strong enough for automatic tracking, it followed the dummy all the way. Booster separation was clean, and the dummy rocket coasted up to 13,000 feet, for an approximate total flight time of one minute.

Dummy Aerobee A2, flown on October 2, carried the same instrumentation as did A1, along with a cutoff receiver. Since flight safety had become a primary concern for WSPG, it was now necessary to demonstrate that the Aerobee program included a viable means of bringing down an errant rocket. A flare was mounted on the side of the rocket and wired to the cutoff receiver to provide visual proof that the receiver was responding to commands sent from the ground during flight. Although theoretically sound, the idea failed—the flare did not ignite until impact. Extensive post-flight analyses led to the conclusion that the fault was with the rocket wiring rather than the receiver. The cutoff system test then became the primary objective of the firing of Dummy Aerobee A3.

All other objectives of the A2 firing were achieved, and no telemetry errors were encountered during the flight. One PSL ground station was placed just off of Highway 70 at Organ Pass, a second remained near the NRL Telemetering House (later known as Parker Station), and a third was brought in by APL and operated in the blockhouse. All three stations received strong signals and produced good records; telemetry was therefore considered qualified. Because the full complement of Askania and Mitchell phototheodolites, Bowen-Knapp, and ballistic cameras were employed on this test (as well as on the A3 test), Anna Gardiner's group was also involved.

The flight of Dummy Aerobee A3 proved the old adage that "the third time's the charm." Both the telemetry and the cutoff signal came through beautifully. Telemetry, which was used to monitor the cutoff receiver, indicated that it responded to repeated commands from the ground transmitter throughout the flight. The Army then granted APL clearance to fire a functional Aerobee.

On November 24, 1947, the first launch of an actual Aerobee rocket (A4) was attempted with only partial success. When the rocket suddenly veered off to the northeast, PSL's cutoff receiver sent the signal, and fuel cutoff was accomplished at 35 seconds. Although the cosmic ray experiment did not acquire much data, the flight was of sufficient duration to prove engine performance. The velocity and altitude at 35 seconds were in excess of design predictions, indicating that, with full burn, the Aerobee could achieve an altitude of at least 80 miles with 150 pounds of payload. For the first time, Mr. Olemacher's telemetry ground stations received data from a signal from an altitude of 36 miles, and reliable telemetry information was obtained. Station 2 was placed on a mountain 35 miles north and 27 miles east of the launch area.

This mission presented Harold Brown's Telemetering Reduction Group on campus and Anna Gardiner's Ballistic Reduction Group with their first look at film of an Aerobee in powered flight. No further Aerobee flights were conducted in 1947.

In the autumn of 1947, the U.S. Army Signal Corps began planning the utilization of the Aerobee for research purposes. PSL was asked to provide a cost estimate for reducing telemetry data for Signal Corps Aerobees. Harold Brown responded with a tongue-in-cheek estimate, pointing out that, "only one very short Aerobee record has been reduced to date."

> Handy Fairchild said that there was a Hathaway oscillograph recorder with a pinhole-sized flaw in the cast housing in the telemetry station. This flaw acted as a pinhole camera, and if someone came through the door of the van at the precise moment, his picture would appear on the film when it was developed.

As mentioned earlier, soon after the sky screens for the V-2 were installed, the APL/Navy team asked PSL to provide similar screens for the Aerobee program. Keith Guard, along with David F. Cope, developed a much more sophisticated device that employed moving wires and thus a greatly improved degree of accuracy (Figure 20).

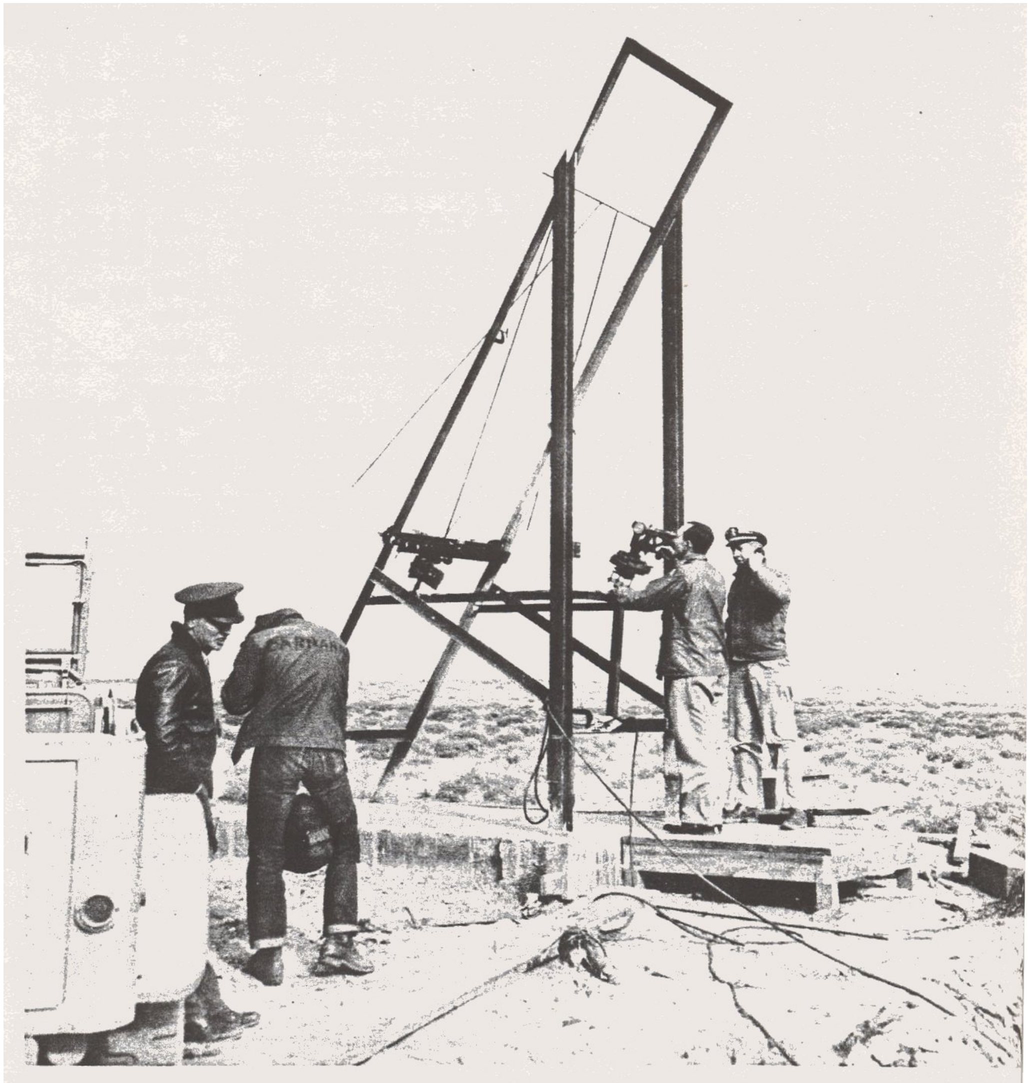

Figure 22. Sky Screen Installed at WSPG for Determining Aerobee Rocket's Trajectory, 1947

The following excerpt from an APL report[12] describes the problem quite well: "A sky screen...is a mechanical aid to human judgment such that an operator can tell whether a missile is following a safe trajectory and can determine the proper moment for actuating fuel cutoff so as to permit maximum altitude commensurate with impact within the boundaries of the range.

"Depending upon the initial program angle, a rocket has at any particular time a space position such that if the fuel supply were terminated it would land at a given point. For different times and different initial angles the rocket will have different positions such that it would just land safely if cut off. Projections of these points onto a vertical plane through the launching site give a number of points which for different times can be approximated by a family of straight lines radiating from a common origin. These time lines furnish safety boundaries such that a rocket crossing one of the

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12 Bumblebee Series Report No. 95, Aerobee High Altitude Sounding Rocket; Design, Construction and Use, L. W. Fraser, APL/JHU, Dec. 1948, p. 35.

boundaries before or at a time represented by the line in question will be classed as unsafe. In practice, the lines are replaced by a moving line such that the position of the line at any instant gives a safety boundary for a rocket viewed through the screen."

PSL engineers and technicians extended Dr. Gardiner's concept. The moving line (referred to previously) became a pair of 1/4-inch by 10-foot steel rods suspended on an angle-iron framework such that the rods were movable by a specially designed motor-driven cam. After completing a ballistic study of all WSPG firings to determine nominal safety parameters, Keith Guard performed the required computations for determining the shape of the cam. The upper pair of rods shown in Figure 20 acted as the support for the lower field-determining rods. The lower rods formed a wide angle at liftoff and, as the rocket rose, the angle closed at a rate governed by the cam. The operator tracked the rocket through the transit eyepiece and, if the rocket image touched the moving rod, he pressed a button to signal mission control that the fuel should be cut off.

David Cope was apparently the Project Engineer. He and Mr. Guard authored a report in January of 1948 detailing the theory and design of sky screens for Aerobee use. Unfortunately, neither a copy of this report nor any V-2 screen documentation has been located.

A Plateau (1948 – 1949)

PSL's personnel roster and level of effort remained fairly constant in 1948-1949 as compared to 1947, experiencing only modest growth until the early 1950s. A copy of the 1948 budget lists 35 full-time employees and eight joint appointees. During this period, approximately 10 full-time employees were added, the size of the PSL building was doubled, two new PSL groups were created, two new customers were welcomed, and the Viking rocket made its debut.

Working space for PSL's on-campus groups more than doubled when a laboratory wing of the same exterior dimensions as the original building was erected just east of it. The 35-foot intervening space was then spanned by a corridor, conference room, and reports office, which gave the entire structure the shape of an, "H." The new wing contained eight lab rooms of various sizes, an apparatus room, and a shipping room (Figure 23). The completion date is not revealed in the records; however, the new wing was in use when Raymond Bumgarner reported for his job interview in August of 1948.

Figure 23. Building the PSL Annex, 1948

The V-2 and Aerobee support efforts initiated in 1946 and 1947 continued through 1948 and 1949. These were telemetry field support, cutoff field support, hardware development, telemetry data reduction, and ballistic film reduction.

There were 28 V-2 launches during this period, 10 of which were instrumented by General Electric; five each by the Naval Research Laboratory, the Signal Corps, and the Air Materiel Command; and three by APL/JHU (Table 1). PSL apparently provided telemetry support for all of these (with the exception of the GE launches) using the NRL PPM/AM telemetry system. An operations logbook created by Raymond Bumgarner in October of 1949 indicates that PSL did support a Signal Corps V-2 on November 17, 1949 and an AMC V-2 on December 8, 1949, as well as others in the subsequent two years.

In 1948, the Signal Corps began using both the V-2 and Aerobee as sounding rockets, and thus became a PSL customer. A contract was issued in the summer requesting telemetry support and for a project to study upper air wind direction and velocity by photographing the dispersion of rocket vapor trails. The U.S. Air Materiel Command also came to PSL for telemetry support sometime during this period. A contract was in place by the end of 1949.

Joe Gold worked on this project, and told the following story: "The Physical Science Laboratory became engaged in a contract to study winds aloft at White Sands using the V-2 vapor trails to indicate wind directions and velocities. I also worked on this project in the data collection phase; others did data reduction. To do this, three widely separated cameras would be used and a series of pictures of the V-2 vapor trail would be made from each site. "Naturally, all three cameras were to have central timing recorded so that the data could be correlated. A crew, [including] Art Maxwell, Gil Moore, and myself, was assigned to operate the camera stationed south of the launch area. The other two [cameras] were to be [stationed] east and west [of the launch area], thus permitting triangulation of the data. One of the firings was to be [held in the] early morning, and, as I remember, in a winter month. Because we needed to be inside the roadblocks in time to set up the camera, check its operation, timing, power and such, we were required to spend the night at the instrumentation site. Sleeping bags were needed; I bought one from an Army Surplus store, a "mummy type" that enclosed all but my face. Unfortunately, it was a summer bag and was not heavy enough. [I spent] a lot of the night in this bag awake, waiting for daylight. We did have cots to put the sleeping bags on, however.

"We received the launch count-down by radio and after launch, when the missile began to form a vapor trail, we started the camera. The upper air wind currents turn a straight vapor trail into odd shapes, and the amount of displacements in the vapor trail would be measured versus time to determine wind velocity. This bit of sleeping in a sleeping bag didn't last long though. In fact, I [don't] think the [entire] project lasted very long."

PSL's contract with the Naval Research Laboratory was expanded in 1948 to include field support for their program that explored the ionosphere using sounding rockets. A group known as the Ionosphere Group was formed—John Pierce was its supervisor, and it included Larry Gardenhire, Herman Ross, Robert Chamberlain, and others. Wesley ("Wes") Joosten and James Masterson joined the group in 1950. Their task was to operate and maintain the data-gathering ionosphere ground stations, which were housed in semi-trailers. Ionospheric parameters were measured by recording and comparing the polarization effects upon two radio signals of differing frequencies transmitted from the rocket while in and above the ionized layers of the atmosphere. NRL employed V-2 and Aerobee rockets for these experiments. The Aerobee (and other types of sounding rockets of later vintage) flew hundreds of these packages until the mid-1980s, when the final Aerobee was flown.

A noteworthy V-2 firing took place in October of 1949—the U.S. Army's second launch of the Hermes II project, in which the use of a ramjet engine as a second stage was attempted. The NRL Telemetering Group, including Raymond Bumgarner, supported this firing and worked throughout the night trying to resolve Radio Frequency (RF) interference problems (these were a common occurrence). When the rocket finally lifted off the next morning, internal explosions at 20 seconds brought it crashing to earth a half mile from the launcher.

A particularly exasperating problem occurred during the course of the early PPM/AM telemetry transmitter flights. Sometimes, when a V-2 reached extreme altitudes, the telemetry unit would stop transmitting shortly before the rocket reached apogee, start again on the descent, and operate normally until impact or blowoff. In other words, the transmitter was altitude-sensitive, indicating that the problem was pressure related. The initial assumption was that the pressurized transmitter container (fondly referred to as the, "Lard Can") was leaking air, causing the high-voltage circuits inside to arc over (additional sealing and bench pressure-testing disproved this theory). After much consternation, PSL and NRL engineers finally discovered that the lid of the Lard Can, a flat aluminum disc 15 inches in diameter, was bulging under pressure. This lid was fitted with a feed-through RF connector that mated with a female connector underneath. The bulging was causing movement such that the center pin was pulling free and losing contact. The problem was resolved by adding a stiffening bar to the lid.

Information concerning Aerobee firings during this time frame is minimal, but it is believed that five were launched in 1948 and six in 1949. Four were APL's, five were Signal Corps', and two were NRL's Venus rockets. Approximately four of the first Aerobees were launched with only the booster active—the second stage was inert. APL Aerobee Flight A5, launched on March 5, 1948, and carrying a 155-pound cosmic ray payload to 374,000 feet (71 miles), is believed to be the first fully successful flight of the new rocket. The other three APL Aerobee firings were also successful. Flight A6 provided the first data concerning the earth's magnetic field above 20 miles[13]. Flight A7 was unique in that it was strictly a high-altitude photography mission and therefore transmitted no telemetry. This flight resulted in a mosaic picture covering the earth's surface from deep in Mexico to central Wyoming. A similar mosaic shot was taken by an earlier V-2 flight in 1947 (Figure 24).

13 The V-2 rocket could not be used to fly a magnetometer experiment because the vehicle contained too many steel components.

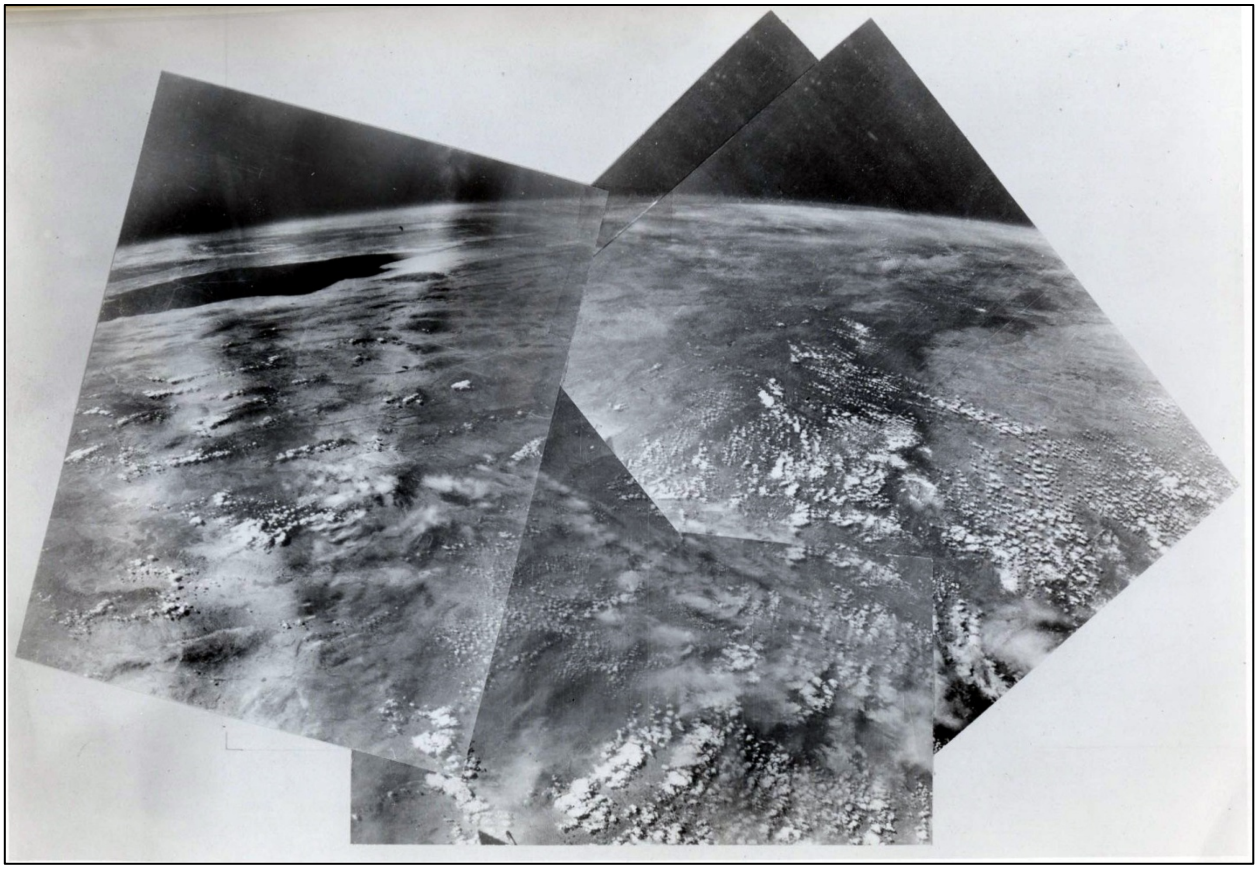

Figure 24. Mosaic Photograph of the Earth's Surface Taken from V-2 No. 21 Over WSPG, 1947

It is possible that PSL was involved in handling the cameras, since this service was provided for numerous Aerobees over many years. Flight A7 was also noteworthy because it was the first to carry a Doppler Position and Velocity (DOVAP) transceiver. This rocket featured a wooden nose cone in which the DOVAP antenna was placed. It was necessary to wrap the outside of the cone with fiberglass and coat the inside with neoprene in order to successfully pass pressure testing.

Handy Fairchild related another interesting experience while he and another PSL employee were installing 16mm aspect cameras into APL Aerobees, two in each nose cone. These were World War II gun cameras and, because they were very unreliable, it was necessary for Mr. Fairchild and his assistant to make frequent last-minute replacements. This sometimes meant halting the countdown, scaling the launcher with the rocket fully fueled, hurriedly removing the dozens of screws securing the nose cone, lifting the cone, and substituting another camera—a tedious and time-consuming operation. Regarding one early Aerobee, Mr. Fairchild said, "We had pulled this cone many times already and it seemed that every time we did, two or three of the screws that secured it would come up missing. This was a bitterly cold day and our hands were getting numb, so [while] trying to rush things, we somehow dropped all the screws we had left. Well, about that time people started yelling frantically for us to come down—that the rocket might ignite prematurely[14]. So we just jammed the nose cone down in place as hard as we could—no screws to hold it—and took off. Well, they fired it, the cone stayed in place, and the pictures from those cameras made LOOK magazine. And this was after the nose section had laid out in the desert for about two weeks with the film in it. Vic Fusselman was the one that figured out from various data where it should be, took a jeep, and drove right up to it."

Antennas in the Forties

As mentioned earlier, the early Aerobee employed an outrigger antenna for the cutoff receiver. While this antenna performed quite well, its configuration presented problems, not the least of which was aerodynamic drag. APL asked PSL to investigate alternate designs, suggesting that a notch radiator be placed in the trailing edge of an Aerobee fin and the investigation of a similar notch as a telemetry antenna for the upcoming 220 MHz frequency band.

Leonard E. Gough started working on the project and, by summer of 1949, had designed and tested a 54.5 MHz notch that proved to be very effective as a cutoff antenna. The notch was molded into a magnesium section that was inserted into the fin at its base (Figure 25). The antenna was the end-tuned type with input impedance of 50 ohms.

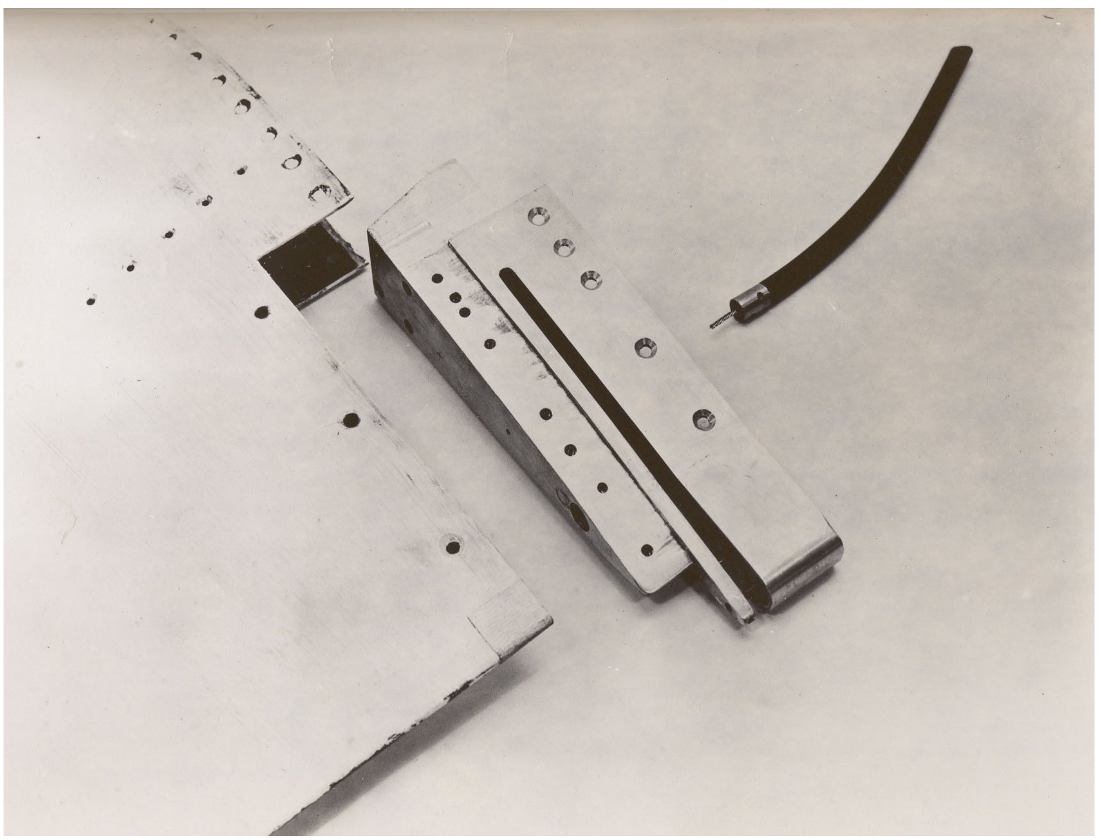

Figure 25. Notch Antenna Insert and Aerobee Fin, 1949

14 The Aerobee had a very limited "holding" time after the helium tank had been pressurized to the required 3,500 psi. This resulted in some dire consequences throughout the Aerobee's history.

When a single notch was installed in Fin 1, there was sufficient radiation except for two deep nulls in the Zero plane. A pair of notches mounted in two of the three Aerobee fins (Figure 26) and phased 120 electrical degrees apart yielded excellent results. A matching section was provided to match the phased notches to the 50-ohm receiver input.

Leonard Gough, along with those employees who helped him on the notch project, were officially designated the Antenna Section in 1948.

Shortly after the development and fabrication of the cutoff notch antenna for use in Aerobee flights, the Section adapted its design for telemetry transmission, as APL had suggested. An unexpected phenomenon occurred with perplexing regularity on early telemetry notch flights, however—signal dropouts would occur for short times at or near a certain altitude.

Figure 26. Notch Pair Installed in Fins

PSL and APL investigators concluded that the notch was experiencing a high-frequency "breakdown." An RF arc would occur across the notch at these low atmospheric pressures, effectively shorting it. PSL, under contract to APL, performed a theoretical and experimental study of the problem and identified a solution. The notch was fitted with machined Teflon filler, which eliminated the breakdown very effectively.

Enter U.S. Air Force

The U.S. Air Force (specifically, the Air Force Cambridge Research Laboratories, Cambridge, Massachusetts) initiated its own sounding rocket program during this period. An Aerobee launch complex was installed at Holloman Air Force Base (HAFB) near WSPG, and PSL was offered a contract for support. In June of 1949, the Air Force became the Laboratory's fourth customer.

One of the first tasks under this new contract was to provide a pair of sky screens for HAFB. David Cope, Keith Guard, and A.C. Keathley designed the third generation of PSL's sky screen, which featured a hydraulically controlled operator's chair for shifting of the viewing position as the rocket climbed. It also featured a more sophisticated mechanism for moving the wires. PSL machinists Phillip ("Phil") Manz and Bob Chamberlain built two screens and installed them at HAFB (the screens were operated by Air Force personnel until 1951 and the advent of the Aerobee HI (Chapter 4).

The Viking's Debut

As mentioned in Chapter 2, NRL ordered 14 Viking rockets from the Glenn L. Martin Company in 1946. The first Viking launch occurred on May 3, 1949, almost three years later.

Numerous design changes were incorporated during production so that none of the 14 rockets were exactly alike. Two major types evolved as a result—the Type 7 and the Type 9. The Type 7 was about 49 feet long, weighed five tons loaded, and was rated to boost 500 pounds to 150 miles. In contrast, the Type 9 was about 42 feet long, considerably larger in diameter, weighed about 7.5 tons, and could carry 1,000 pounds to 150 miles.

PSL was to provide Viking support equivalent to that provided for the V-2 and Aerobee programs. NRL requested the same support elements and expanded the contract accordingly. The NRL telemetry Group (Ricketts, Sabin, Ware, Hughes, Bumgarner, Hill, Savedge, Ross, Kerley, and Mallar) was tasked with preparing and installing telemetry transmitters and recording telemetry data. In conjunction with the Viking program, NRL had repackaged the PPM/AM telemetry transmitter from the Lard Can (Figure 27) to two separate XN2 rectangular boxes. This new version was referred to as the "XN/2" (Figure 28).

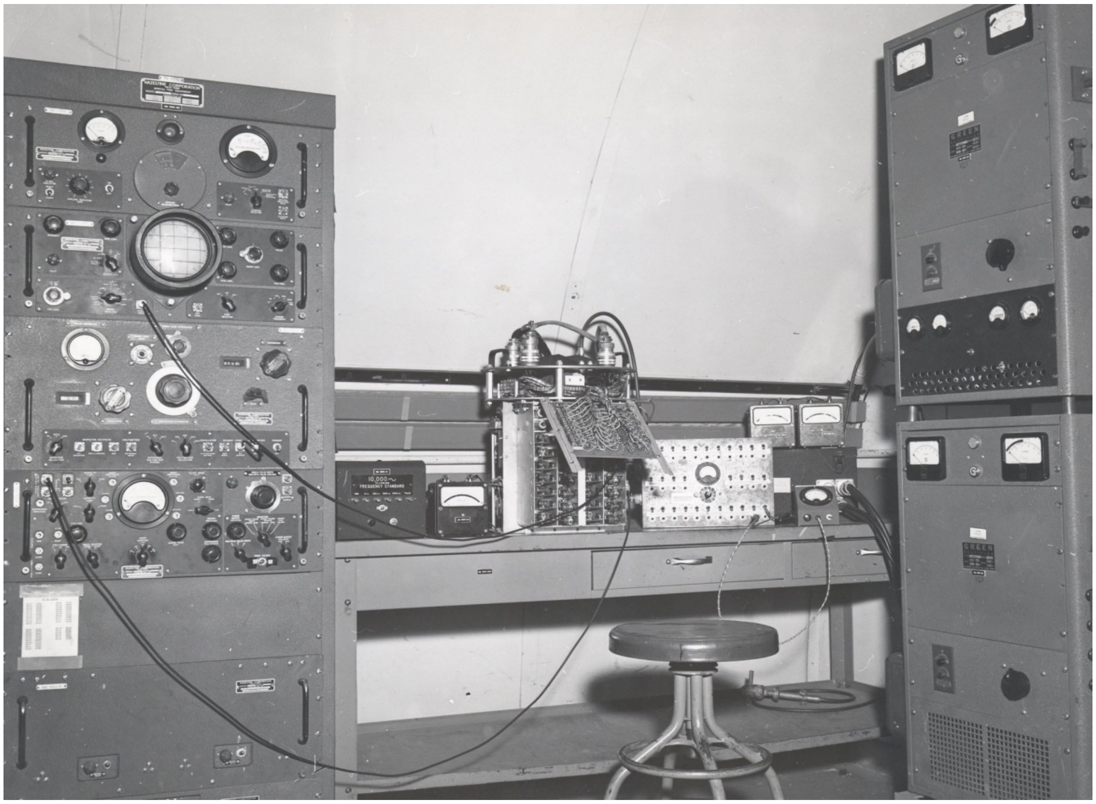

Figure 27. Pre-XN/2 Telemeter (AKA the Lard Can)

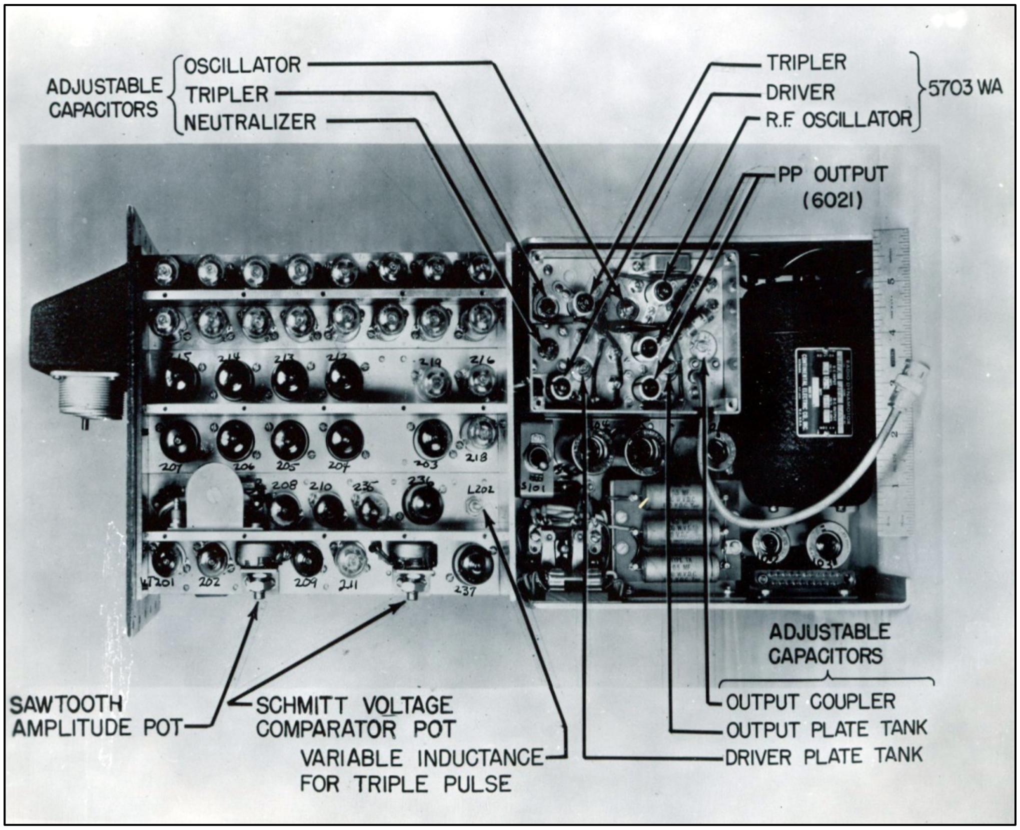

Figure 28. XN/2 Telemeter, 1949

The first launch (Viking 1) was a qualified success. It was fired with a low supply of Liquid Oxygen (LOX) because the LOX vent valves would not close as required. Even so, it was a near-perfect flight, achieving an altitude of 51 miles (and making the Project Manager Milton Rosen very happy).

Viking 2 was launched on September 6, 1949. All went well with the flight until the rocket engine shut down prematurely, achieving an altitude of only 33 miles. Mr. Rosen convinced the people from the Glenn L. Martin Company that the turbines in both rockets had leaked fuel, causing the short burn. Modification of the turbine solved the problem for the remaining Viking flights. LIFE magazine covered the second firing and its pre-launch preparations, and published photographs of the Viking 2 on the launch pad at WSPG and Raymond Bumgarner and John ("Jack") Townsend of NRL installing a telemeter in the nose compartment of the rocket (Figures 29, 30).

Figure 29. Photograph of Viking No. 2 on Launch Pad at WSPG Published in 10/3/49 Issue of LIFE Magazine

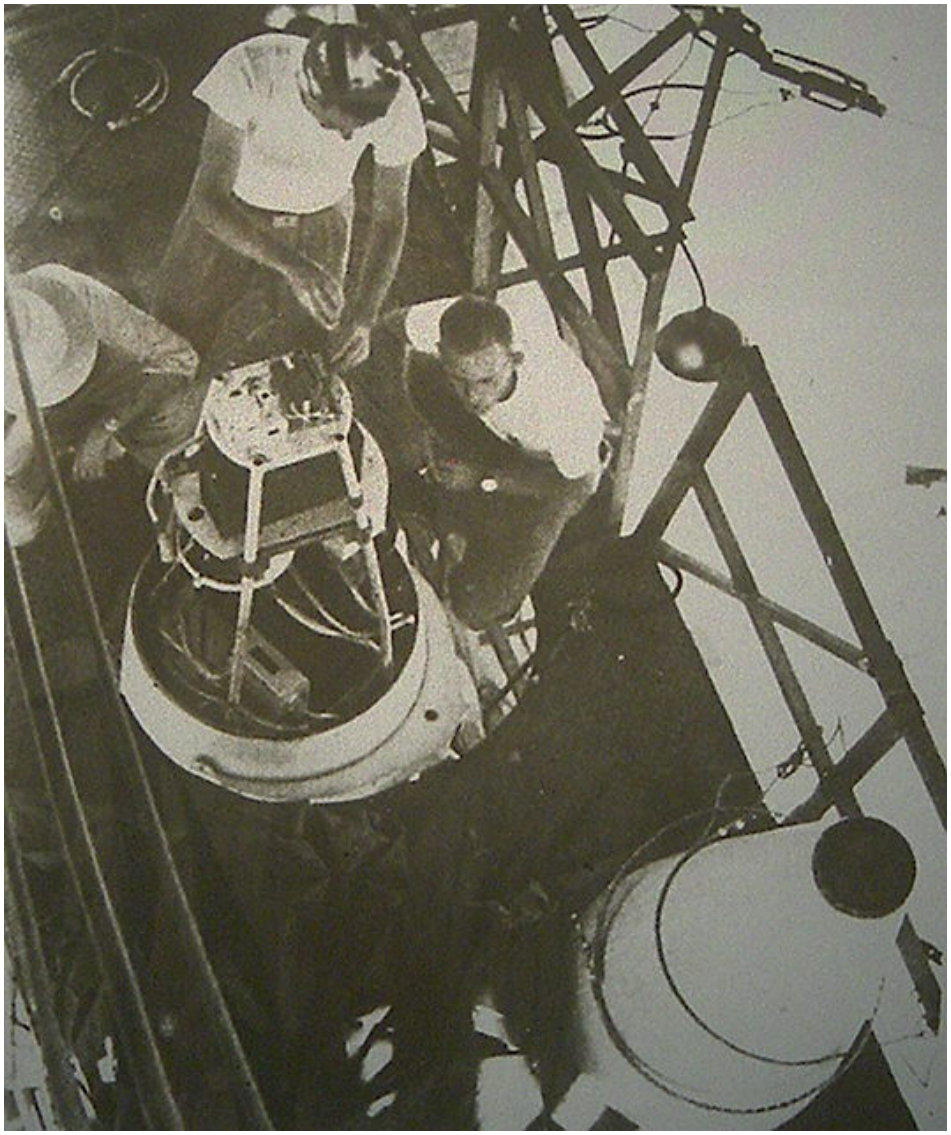

Figure 30. Photograph of Raymond Bumgarner (PSL) and John Townsend (NRL) Installing Telemeter in Nose Compartment of Viking No. 2 Rocket Published in 10/3/40 Issue of LIFE Magazine

Forties Miscellany

PSL's first few years was a unique time in the history of the United States—swords (V-2s) were being made into plowshares (scientific rockets) and there was a large, eager group of ex-GIs ready to return to school. Most of these young men had a vast amount of practical experience (and focus) to mix with their academic training. PSL benefited from both by acquiring its first student and professional employees from this remarkable group of people (PSL's non-military contemporaries profited from their associations with them as well).

A unique situation occurred when some of the United States' top scientists and astronomers assembled at WSPG to fly their experiments aboard these early scientific rockets. "Rubbing shoulders" with these famous people showed its students and staff that PSL's capabilities were often as clever in design as those of the scientists and astronomers. This fostered PSL's willingness to try just about anything. In those early days, no one was really *afraid* to fail, since failure often provided a valuable learning experience.

For example, in 1949, PSL physicists Albert Hatch and Bartel Williams initiated another new effort under the auspices of APL/JHU, laboratory research in gaseous electronics (which continued for many years). The work involved studying the glow discharge phenomenon that resulted from the application of RF power to a pair of electrodes in a gas pressure of one millionth of one atmosphere. Gases used were dry air, helium, or hydrogen, and RF frequencies were applied over a range of 20 to 200 MHz.

Some of this glow discharge study involved ionization breakdown around transmitting antennas and transmission line breakdown at connectors. Bart Williams' study was accepted and published in France's Handbuk Der Physic (the international Physics Handbook).

The phenomenon of ionization breakdown around a rocket-borne antenna was not recognized anywhere until PSL performed these studies. An individual in charge of a classified meeting on the subject held at the Air Force Cambridge Laboratory in Boston told Cecil Post, "You guys really started something with this." Mr. Post added, "Ionization was only part of the problem. Electron multi-pacting develops to an even more severe level in a vacuum. As the vacuum increases, so does the problem, thus shorting out the antenna."

In March of 1949, three Aerobees were launched from the deck of the converted seaplane tender U.S.S. Norton Sound. Since APL wanted to study cosmic rays over the geomagnetic equator, the firings took place in the Pacific Ocean 600 miles west of Peru. PSL supported these flights; however, no details are available.

Another V-2 program note: Bumper 5 reached a new altitude record when the Wac second stage climbed to 250 miles.

> Raymond Bumgarner said that one of the first things he learned when he began working at the "Telemetering House" in 1948 was to listen carefully for a "buzzer" when raising cable-trench covers to check wiring under the floor. That "buzzer" was on the end of a large rattlesnake that frequented those trenches in search of rats! The snake was considered a huge help, since rats were capable of considerable damage—they would gnaw on cable insulation, build nests in equipment racks, chew up valuable papers, and leave droppings everywhere, including desk drawers.

CHAPTER 4: PSL ROCKETS ONWARD AND UPWARD

The 1950s can easily be referred to as "the good old days" or the "boom years" for PSL, as well as for the WSPG. PSL's contract dollar volume increased ten-fold and the staff tripled in number, from over 50 in 1950 to 151 in 1959. The advent of the Space Age, along with the numerous guided missiles to be tested at WSPG, provided the impetus and multiple opportunities for Laboratory expansion. PSL seized upon these opportunities and branched out in many directions, both technologically and geographically.

The following nationally significant events made the headlines in the 1950s: the Korean War; Elvis Presley; the Consumer Society; Senator Joseph McCarthy; the birth of the Interstate Highway System; Harry Truman; the launch of Sputnik followed by the smaller American satellites; Christine Jorgensen; the Soviet invasion of Hungary; Dwight Eisenhower; creation of the National Aeronautics and Space Administration (NASA); the Salk polio vaccine; H bomb tests; recession with lowered inflation; Marilyn Monroe; the bolstering of national defense; Nikita Khrushchev; and Richard Nixon. Embers smoldering in Vietnam, Birmingham, and Little Rock predicted conflagrations in the 1960s.

The phenomena that affected personal lives included a 13% increase in real income; Rock and Roll music; the advent of the shopping center; suburban sprawl; television; and the "Baby Boom."

Two events that profoundly affected PSL's growth were the national commitment to space exploration and the effort to develop guided and ballistic missiles to strengthen U.S. defense. As the decade began, the majority of PSL's contract efforts were directed toward the former, i.e., space probes in the form of sounding rockets (V-2, Aerobee, and Viking). By the end of the decade, the level of PSL's defense-oriented support was almost equal to that of its space effort. The V-2 and Viking had disappeared from the scene, and Army and Navy weapons testing prevailed. As with sounding rockets, PSL provided film and data reduction, hardware development, and various modes of field support for these missile tests.

Exit the V-2

The V-2 rocket's five years at WSPG culminated with the firing of number 52, the 67th in the Project Hermes series, on June 28, 1951[15]--the supply of those hybrids with their mixture of German and American parts was exhausted. PSL provided telemetry, data reduction, and film reduction for the nine WSPG launches attempted in 1950 and 1951; however, only two were successful (three were disabled by internal explosions shortly after liftoff and two suffered excessive program (tilt)). NRL's V-2 55 provided a very spectacular display of fireworks when it exploded and burned on the launch stand (Figure 31). Apparently, the explosion was triggered by

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15 An unknown number of V-2 military flights occurred at various locations, and two Bumpers were launched from the Long Range Proving Ground (now Cape Kennedy) in Florida.

an electrical short that detonated the TNT blowoff charges, separating the warhead precisely at liftoff.

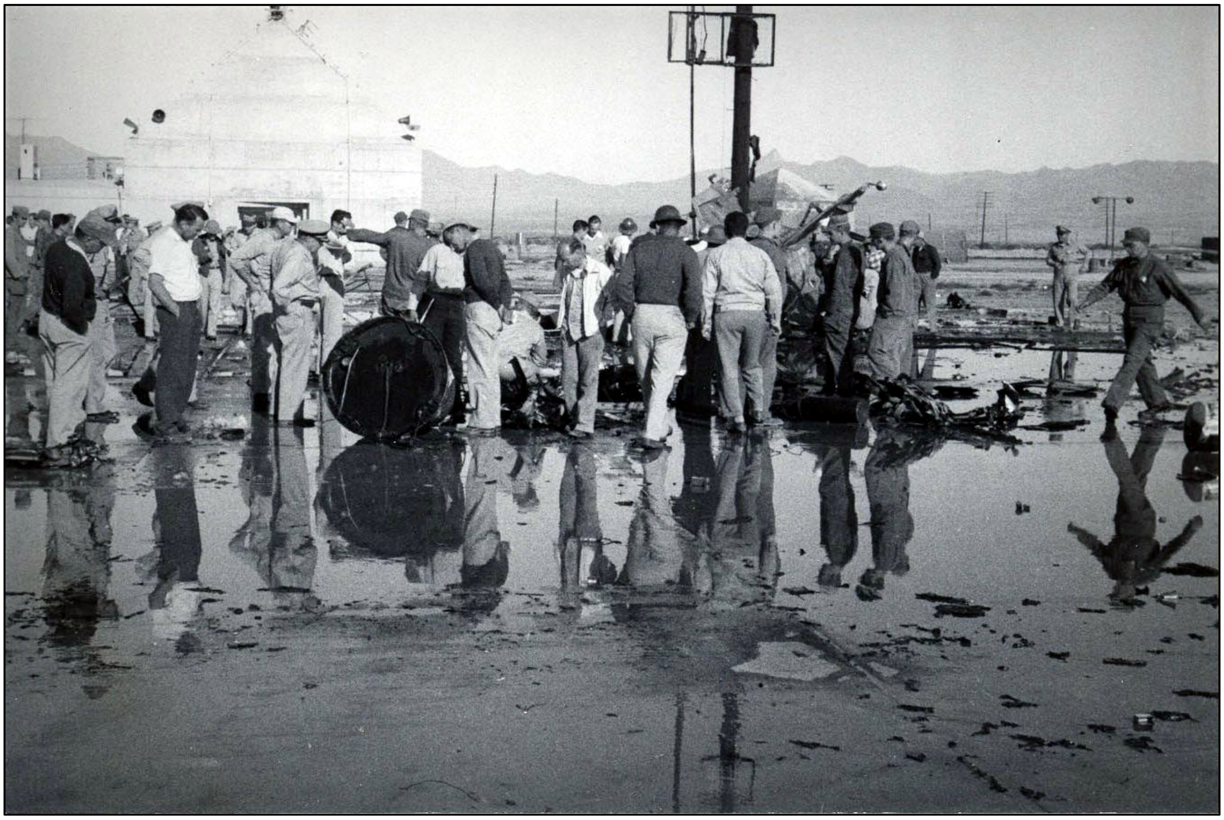

Figure 31. V-2 No. 55 Failure, 1951

Raymond Bumgarner, who was in the blockhouse during this unnerving event, said, "Someone standing at the blockhouse window saw the rocket start to topple sideways and screamed, 'Hit the deck!' Everyone in the room dove for cover under desks, behind equipment racks, etc. After a muffled 'whump,' followed by silence, everyone stood up and crowded at the window to see the fire. Later, we all giggled sheepishly at ourselves for crawling under tables for protection inside those 10-foot-thick reinforced concrete walls."

The Blossom Project (conducted by the Aeromedical Lab of Wright Patterson Air Force Base) used V-2s at WSPG to transport five biological payloads, four monkeys, and one mouse. The first monkey, Albert, was launched into space on June 11, 1948. The mouse was launched August 31, 1950 aboard V-2 51. It was not anesthetized in order that its conscious reaction to changing gravity might be observed (a camera shot film at fixed times). Although the recovery system failed and the mouse did not survive the impact, the film was recovered intact.

Bob Sabin told this story about the V-2 days: "The telemetry transmitting antenna on the V-2 was enclosed in a pressurized, six-inch-diameter radome attached to the trailing edge of one tail fin. In order to preserve aerodynamic balance, a dummy radome was flown on the opposite tail fin. This plastic pressurized space (cylinder) destined to reach outer space was used on one occasion to place six Hershey chocolate bars and two packages of Wrigley's spearmint gum into outer space for the first time in history. Later consumption of these rations that had been exposed to the then-unknown effects of outer space proved benign."

The Dissolution of the Cutoff Group

The Army terminated the PSL cutoff contract in February of 1950 (two years after its inception, making the Cutoff Group the shortest-lived in PSL's history) after an upper-echelon decision that the Range safety function was too critical to be handled by a contractor. It is unknown whether Dr. Gardiner was part of that decision, but many at PSL were of the opinion that performing the cutoff function put the College in a precarious position, considering the fact that human error could result in catastrophic loss of life and property (since at least two large rockets had already landed outside of Range boundaries).

There is no indication that the Army was dissatisfied with PSL's performance on the contract—in face, the Army later hired Nat Wagner, who was in charge of the PSL Cutoff Group at the time. He later became the Director of Range Safety for WSPG, a position he held for many years. Mr. Wagner deserves much of the credit for WSPG/WSMR's sterling safety record.

The final report for the contract, written by Ivan Carbine and David Cope, indicates that the Cutoff Group had supported the firing of 24 rockets in the preceding 12 months, including V-2, Aerobee, Viking, Corporal E, Bumper, and Wac rockets.

Exit The Viking

Viking, another program carried over from the 1940s, continued until 1955. Although 14 rockets were built per NRL's original order, the Viking was deemed too expensive for extended use as a sounding rocket after 10 or 12 launches. Thus, the program came to a halt after the 14 rockets were used. Though the Viking encountered a number of setbacks in its short existence, it contributed much to American rocket technology and demonstrated that the U.S. could improve upon the Germans' design.

Twelve Vikings were fired—11 at WSPG and one from the deck of the U.S.S. Norton Sound. In 1956, Vikings 13 and 14 were diverted to Cape Canaveral, Florida to serve as test vehicles for NRL's upcoming Vanguard program (Table 4).

Table 4. Viking Launches

Viking No.	Launch Date	Altitude (miles)	Static Firings	Remarks
1	3 May 49	50	2	Leak in steam turbine
2	6 Sep 49	32	1	Leak in steam turbine
3	9 Feb 50	50	2	Veered west, fuel cut off by radio
4	11 May 50	105	1	Shipboard launch
5	21 Nov 50	108	2	First good land launch
6	11 Dec 50	40	1	Rocket tumbled near burnout; fins crumpled
7	7 Aug 51	136	1	Altitude record
8	6 Jun 52	4	1	Broke loose on static
9	15 Dec 52	135	3	First successful larger airframe
10	7 May 54	136	2	Rebuilt after motor exploded on first try
11	24 May 54	158	1	Photos of earth; record altitude for Vikings
12	4 Feb 55	144	2	Good flight
13	8 Dec 56	126.5	Unknown	Flown at Cape Canaveral as Vanguard TV-0
14	1 May 57	121	Unknown	Flown as Vanguard TV-1

Because the Viking required static testing, each rocket firing involved double (and at times, triple) effort on the part of all concerned compared to that of other rockets. A few days prior to the scheduled launch date, the vehicle was erected on the firing stand and bolted solidly into place. The instrumentation and telemetry were then installed, along with their flight batteries—the static tests were to be run on "internal power" for all electronic components. During a 12- or 14-hour countdown, numerous "turn-ons" were the rule to check the operation of various elements, and the propellants were pumped in. The engine was then ignited and forced to strain against its moorings for 50 seconds, protesting with a deafening roar and forcing tremendous clouds of steam from the water-cooled concrete pit below. Meanwhile, the telemetry channels recorded the engine's performance parameters, indicating to Mr. Rosen and Glenn L. Martin Company representatives if this rocket was acceptable for launching in a few days. No Viking would leave the ground until it had passed the static test perfectly (except for one, which is described later). Five of the WSPG firings required two static tests each, and Viking 9 required three.

Support for these 14 missions involved every PSL group (with the possible exception of the APL Telemetry Group). PPM/AM telemeters, aspect cameras, and X-ray densitometer cassettes were installed (by Raymond Bumgarner and Gil Moore) into each rocket, and the Telemetry House recorded telemetry from each one. On-campus groups provided the usual telemetry record film developing and telemetry data and ballistic film reduction. The PSL Cutoff Group installed cutoff receivers in the first three (prior to termination of the cutoff contract). The cutoff receiver was used to extinguish Viking 3 after it began to drift to the west toward Las Cruces early in its flight. It crashed west of the mountains, on the Jornada del Muerto, the large desert plain between the Rio Grande Valley and the San Andres mountains.

> Gil Moore told the following story at Daniel G. ("Dan") Mazur's expense: "I would go out to WSPG and process telemetry film records at Parker Station after each test. We were using Eastman Kodak film, and all of a sudden, Eastman changed the anti-halation backing on the film to something sensitive to red light and didn't tell us, so we got black streaks from our red safelight. Mazur claimed I goofed and put the film in the hypo bath first. It took a long time to find out what happened, [but] Mazur [then] apologized."

The shipboard launch of Viking 4 was a truly remarkable accomplishment because not only was it the first vehicle in the series to achieve the expected altitude, the payload it carried was heavier than those of the other Vikings. PSL's Rick Ricketts and Henry ("Hal") Ware, along with Dan Mazur of NRL, installed two telemetry ground stations in the blockhouse on the Norton Sound's deck and provided telemetry coverage. Although they were blamed when the first firing attempt on May 7, 1950 was aborted (the telemetry transmitter in the rocket failed to activate), it was later proved that the defect was with the connecting cables rather than with the telemeter. The resulting two-hour delay allowed moisture to condense in the rocket and short out certain vital monitoring circuits in the guidance system, "scrubbing" the launch for the day.

After solving various vehicle system problems that ensued in the next three days, Viking 4 lifted off the deck on May 11. Mr. Rosen's book, <u>The Viking Rocket Story</u>, provides a charmingly entertaining first-hand account of these events and of King Neptune's vengeance upon the "pollywogs" (a group to which Hal Ware belonged) the day after the firing.

The purpose of this "Operation Reach" mission was to fly NRL's specially designed cosmic ray telescope above the area where the earth's geographic and magnetic equators intersect. This one-month cruise of the South Pacific (with stops at Hawaii and Christmas Island) must have been a most memorable trip for all aboard.

Another Viking flight that attracted an unusual amount of attention was number 8, otherwise known as, "the Viking that got away." The fact that Viking 8 was the first with the new larger airframe was at the root of its demise and destruction. The older Vikings had been restrained during static firings via four threaded blocks—one in each fin—that were bolted to the stand, requiring the fins to be stronger and heavier than necessary otherwise. The Glenn L. Martin Company designers decided that the new, larger diameter vehicle could rest on its base rather than on the fins, thus saving considerable weight. They therefore designed the body frame to be supported at four points. It was further decided that it was only necessary to bolt down two of these points for the static firings.

There are conflicting accounts as to exactly how Viking 8 stripped its moorings, but it was apparently a combination of overzealous efforts to reduce vehicle weight and an unfortunate accident. Its thrust was abnormal in that surges apparently took place in the engine's burning and overloaded the airframe—the restraining blocks broke loose and remained bolted to the stand. The cause of the surges is unclear, but one theory held that the pulsing in oxygen pressure was caused by an electrical short that intermittently opened and closed the liquid oxygen vent valve. Successive Vikings were restrained with tie-downs on the engine mount, but WSPG and Viking 8 hold the world's altitude record (four miles) for a static firing.

Raymond Bumgarner installed and operated the telemetry transmitter during Viking firings. The fin-mounted transmitting antenna was located too close to the ground and the steel firing stand to provide the Telemetry House usable signal strength during static firings. To alleviate this problem, a substitute antenna was used that was mounted on a six-foot portable stand and set on the pad several yards away from the rocket. Approximately 75 feet of coaxial cable extended from this antenna across the pad, up the side of the rocket, and through an open access port to the transmitter. Such was the case with Viking 8.

Raymond Bumgarner described the liftoff of Viking 8 during static firing as follows, "After a moment or two of stunned disbelief, we shouted over the intercom to the House that the rocket had taken off. We ran to the window to see if our antenna was anywhere in sight on the pad. It was not, but the 40-pound stand was there, toppled on its side. The antenna in its six-inch radome had been ripped loose by the pull of the cable. We could visualize that antenna dangling at the end of that 75 feet of cable as the rocket climbed, and how it would surely be vaporized by the exhaust flame. Was the House getting the signal? We ran back to the intercom; yes, they were. Wonderful!

"A look later at the developed telemetry records showed that the signal had been normal to X+15.3 seconds, then became weaker and intermittent until it ceased at 61 seconds (impact). The antenna and the broken cable were found not far from the launcher—the cable must have held together until 15.3 seconds. How did the signal persist to 61 seconds with no antenna? The broken end of a piece of RG-8 coaxial cable apparently is quite a decent radiator at 1,025 MHz—perhaps that 4,000 watts of transmitter power was of some benefit after all."

The Viking story is incomplete without a brief look at 10. Although its flight on May 7, 1954, was very routine, such was not the case the day of its first launch attempt (June 30, 1953, a year earlier). As the countdown reached zero on this day, a violent explosion in the tail section left the rocket ablaze, but still standing. The liquid oxygen plumbing was damaged such that the tank's contents quickly spilled into the pit. Although the alcohol was leaking at a much slower rate, it was enough to sustain the fire at the base of the rocket. After the fire was finally extinguished, the alcohol continued to leak, creating a partial vacuum in the tank. Efforts to open the vents from the blockhouse control panel (Figure 32) to relieve the vacuum were unsuccessful. After a while, the aluminum skin of the rocket, which was also the wall of the tank, began to dimple inward in a beautiful geometric pattern. A new fear developed in the blockhouse—if the tank continued to dimple, it was likely to collapse. If that happened, the heavy nose section would lean to one side, topple the rocket, and cause it to explode, losing both rocket and payload.

Figure 32. Viking Blockhouse

The NOMTF's Viking Project Officer, Lieutenant Joe Pitts, offered a solution—he would use a .30-caliber carbine to put a bullet hole in the tank skin, thus relieving the pressure. After some debate among project officials, Lt. Pitts was given the required authorization. His aim was true; Raymond Bumgarner distinctly recalled watching through the blockhouse window as those dimples slowly flattened, making the skin perfectly smooth again.

Viking 10 was dismantled and rebuilt and, after patching the bullet hole, was flown successfully. The bullet, found inside the tank by Glenn L. Martin Company technicians, was mounted on a wooden plaque and presented to Lt. Pitts. The following words were inscribed on the plaque: "To Lieutenant Joe Pitts, USN, the only man who ever shot a rocket." Viking 10 was the first to be launched from the Navy's complex; previous launches took place at the Army blockhouse, pit, and gantry tower. In 1954, the NOMTF constructed its own gantry and flame pit.

Number 11 achieved the highest altitude of all the Vikings—158 miles—and, because Gil Moore, Stewart Bean, and Gordon Hawley had installed K-25 aerial cameras on it, it provided some breathtaking photographs of earth.

> Mr. Bean said, "Gordon Hawley was the man who worked with me—big tall guy from San Jon, New Mexico. He was a Physicist, and so the two of us worked together. He supplied the Physics technology, I supplied the photo technology, and we did it. We put those cameras on Aerobees, Vikings, and V-2s. Then we got better cameras. [As a] matter of fact, then from that, from the 16mm cameras APL...this was back in '54 I guess, or '55 or '56—somewhere in there—took on the task of flying a camera that took 4x5-inch negatives. We put it on board the Vikings and the V-2s and they flew it and took pictures during the flight. That was the first picture we ever had of the smog over L.A.—one of the pictures showed that. One of the pictures out over the Gulf showed a developing storm. It wasn't a hurricane, but you could see the circular pattern that you see every day when you look at the...weather pictures...on TV where you have these circular patterns—but that was the first time that anybody had actually seen it."

Talos Comes Aboard

The national effort in the early 1950s to develop an arsenal of missiles brought a considerable number of newly designed weapons to WSPG for testing. PSL eventually became involved in all of these programs, some on a large scale that continued for decades. One of these was the Talos and its various successors, a family of anti-aircraft missiles generated by the Navy's Bumblebee contract with APL/JHU.

Built by the Bendix Aviation Corporation plant in Mishawaka, Indiana, the Talos was powered by a ramjet engine, weighed 3,000 pounds, and measured 20 feet long and 30 inches in diameter. It rose to supersonic flight speed via a solid-fuel booster, and then rode a radar beam toward its target until its internal homing system took control. The Talos was sometimes referred to as "a flying stovepipe" since it looked like a cylinder open at each end and had rather small fins (Figure 33). WSPG's first Talos was fired on July 10, 1951 from a temporary launcher beside the Army blockhouse (since the NOMTF's launch complex was still under construction). Hundreds of these missiles would be flown from the Navy complex over a span of over 20 years.

Figure 33. Test Flight of the Navy's Talos Anti-Aircraft Missile, WSPG, 1950s

To simulate shipboard launching conditions to the maximum extent possible, the NOMTF constructed a special facility for the Talos called "the Desert Ship Land-Locked Ship (LLS)-1." A combination blockhouse and "deckhouse" was erected to house the firing controls and instrumentation. This structure remains in use today (Figure 34).

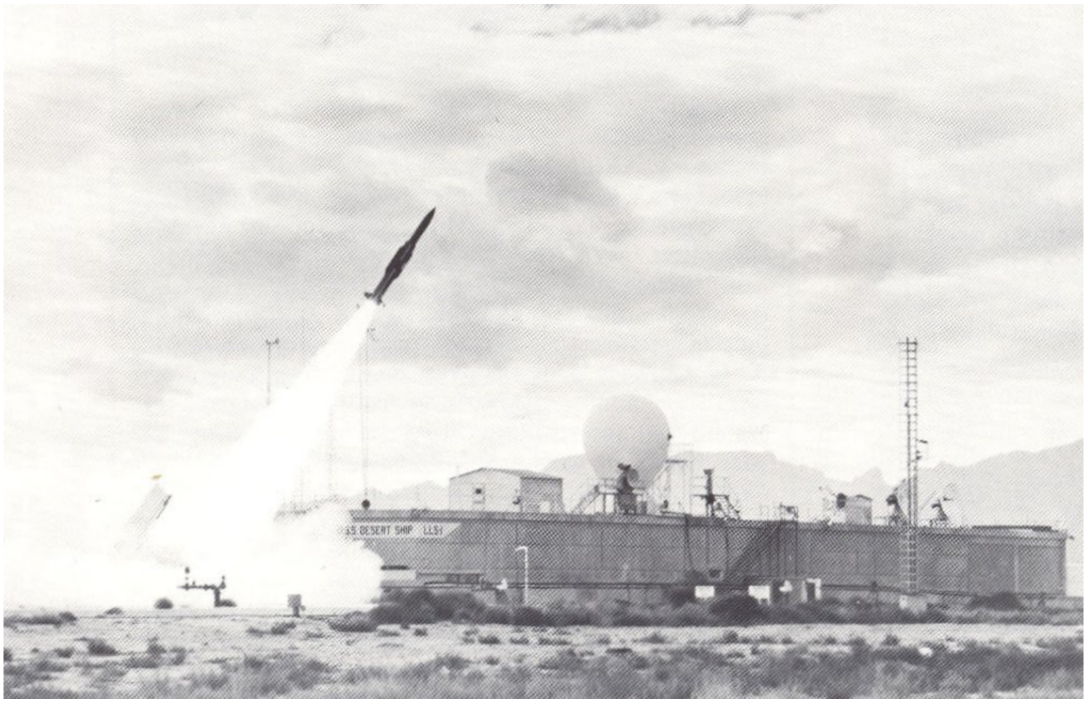

Figure 34. U.S. Navy's Land-Locked Ship (LLS-1), AKA "The Desert Ship," WSPG

In 1951, PSL's contract with APL was expanded to include field support for Talos. PSL was to

- Operate and maintain two telemetry ground stations
- Check out the proximity fuze and monitor its performance during flights
- Install and operate cameras on the radar dish antennas
- Operate and maintain the Talos computer
- Generate certain documentation relative to each firing

Each of these five categories resulted in a new PSL group. These groups and their leads were as follows:

- Talos Telemetry Group (Robert Sabin)
- Talos Fuze Group (Melcor ("Colonel") Marquez[16])
- Talos Radar Instrumentation Group (Charles Combs)
- Talos Computer Services (James Masterson)
- Talos Documentation (George Hackler)

These groups were eventually combined into the Missile Ground Systems Section (James Masterson was its Chief). Participation in this long-term missile development program put PSL employees on the forefront of missile guidance computer applications.

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16 This group was formed later when the Naval Ordnance Laboratory (NOL) took over DOFL operations.

Talos launches employed two modified SCR 584 radar sets, one for guidance and one for target tracking. As the tracking beam followed the target drone, the missile would climb along the guidance beam at a slightly higher elevation angle. As the Talos neared the drone aircraft, a device called a "computer" would close the angle between the two beams, guiding the missile toward its target. This first computer, which was a simple cam-servomechanism, was an integral part of the radar.

Various analog computers and peripherals followed during the 1950s. The first computer used in the Desert Ship, circa 1953, was called the Talos Junior REAC (TJR). It consisted of 14 operational amplifiers with associated servomechanism interfaces that enabled programmed guidance computations. In 1955, after a lengthy development phase at APL, the Talos Adaptable Computer System (TACOS) was brought on board, installed by PSL personnel, and used very effectively until 1969. In addition to operation and maintenance of the computer, the Talos Computer Services Group was responsible for training Navy servicemen in its use. In 1957, the system was enhanced by the inclusion of the Launcher Order and Capture Computer, which enabled control of both the Talos Mark 5 and Mark 6 launchers. In the late 1950s, PSL was asked to design and fabricate a computer for the ground-aided-acquisition version of Talos. This resulted in the GAA computer, a TACOS adjunct that was brought online in 1959. Sperry Gyroscope, Inc. was contracted by BuOrd to develop a computer for sea-going use, resulting in a prototype model called the EX-7 Talos computer. PSL helped Sperry and NOMTF set up and evaluate this system at WSPG. Use of the EX-7 for tactical and training firings made the TACOS available for additional Research & Development (R&D) programming.[17]

It is assumed that the Talos Telemetry Group was an extension of the APL Aerobee Telemetering Group formed in 1947 under the APL/BuOrd contract. For Talos operations, APL brought a semi-trailer containing an FM/FM telemetry ground station to WSPG and set it beside the Talos hangar in the Navy main post area. PSL operated and maintained this station for pre-firing tests and flights. The trailer was named the, "Red Wagon" because it was painted bright red (it retained this name even after it was painted a silver color to make it cooler in the desert heat) (Figures 35, 36). At various times during the 1950s, the Red Wagon crew included Robert Sabin, Hugh Gardner, Edward Daneliak, Charles Stransky, Robert Ecklund, Donald ("Don") Peterson, and others. This group operated a second telemetry ground station in the Desert Ship.

17

The aforementioned computers were all of the analog type; the much more accurate and versatile digital computer did not arrive until the mid-1960s.

A. F. (“Al”) Bowers told this story about Hugh Gardner: “We had a relay rack in the Red Wagon that contained an Events Per Unit Time (EPUT) meter that we used to measure the frequencies on the telemetry channels. This EPUT had a bug in it—it would stop working now and then. When this happened, Huey would run over and give the rack a good hard kick in a certain spot and the EPUT would come on again. EPUTs and Coke machines have a lot in common!”

Figure 35. Exterior of the Red Wagon

Figure 36. Interior of the Red Wagon

The Talos Fuze Group was headed initially by Colonel Marquez and later by Phillip ("Phil") White. Others in the group included Harold Connell, David Barnett, John Maure, and Richard Peterson. The Group's principal duties were to furnish, test, and install the fuze and the safety & arming device in the Talos missile, along with various explosives. The Talos fuze and safety & arming device were initially developed by DOFL. The Talos Fuze Group was formed when the Naval Ordnance Laboratory (NOL) decided to take over its own fuze work. The group also operated a telemetry station associated with the fuze.

The primary duty of the Talos Radar Instrumentation Group was camera installation and operation. This group, initially headed by Charles Combs, included G.E. ("Jerry") Garing, Carmen Marrujo, James Perdue, and Phil White (Mr. Garing succeeded Mr. Combs at some point during the 1950s). Movie cameras with high-powered lenses were used for boresight photography on the four radars at the Army Talos Defense unit and on the two radars at the Desert Ship. In addition, two closed circuit television systems were operated and maintained for the Navy, with one camera each on the target radar and the guidance radar. According to Mr. White, the group also mounted ruggedized camera pods on the missiles and the drones in order to capture motion pictures of the intercept. The PSL Rocket Section developed these camera packages for Talos. The missile-borne pod was bolted to the tip of the tail fin and recovered from the wreckage after impact (Figure 37). Another function of the group was to build, operate, and maintain the equipment that supplied timing signals to all of the range stations that supported Talos firings.

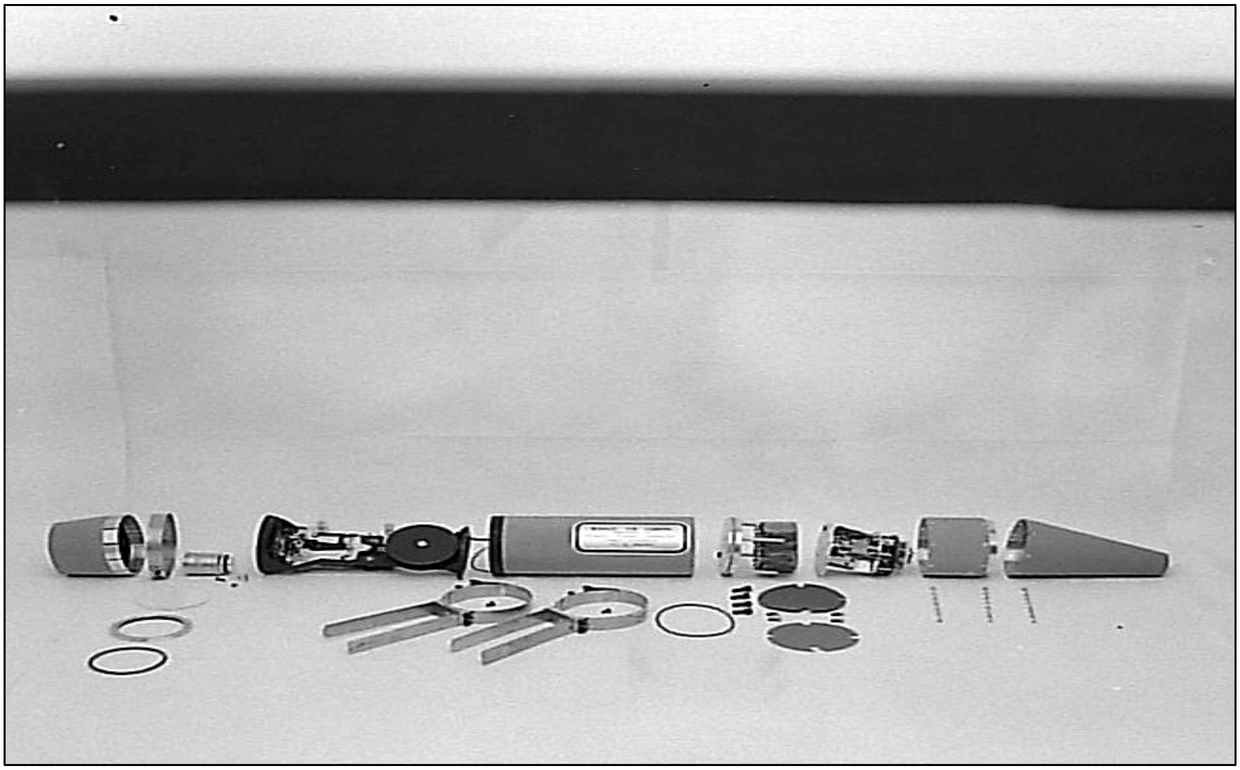

Figure 37. Exploded View of the Talos Fin Camera, WSPG, Mid-1950s

The Talos Documentation "group" consisted only of George Hackler. His job, which was to coordinate missile system test data, involved preparing system test proposals, coordinating the reduction of data by PSL/campus, and preparing test and periodic status reports. Mr. Hackler remained in this position for two years and was succeeded in 1953 by Robert ("Red") Smith (who had been associated with the program as a student employee).

The Talos firing rate peaked in 1957, with a total of 71 missions (a total of 294 of these rockets left the ground in the 1950s). Talos's successor, the Typhon, underwent a couple of test firings in 1958, but was not fired again until 1961 (this will be addressed in Chapter 5). These missiles were very instrumental in PSL's early growth and history.

Red Smith was aboard the Navy's first missile cruiser, the U.S.S. Galveston, for a series of Talos test firings. His workspace, which was a small cubicle two or three levels above deck, had no ventilation. Red said, "One day I was in there trying to work, sitting there cussing and moaning about the heat and the whole situation, when I [became] aware of someone standing behind me. I looked around and saw the ship's Captain. He asked what my problem was and I told him. Well, the next day…a sailor [came] with a torch and cut a hole in the bulkhead to give me some air. So, I'm probably the only civilian to ever have a porthole cut for him in a U.S. Navy ship."

What's In a Name?

The terms "group" and "section" had been applied interchangeably until the mid-1950s, after which usage of these terms evolved until each carried its own distinct meaning—a group was a part of a section and a section could contain any number of groups. This specification persisted into the 1990s.

Organization charts were not part of Dr. Gardiner's modus operandi (in fact, there is no evidence that such a chart existed for the Laboratory until well after his retirement). In the same manner, Rick Ricketts (Dr. Gardiner's successor) kept paperwork to an absolute minimum (which at times created confusion among his subordinates and irritated his superiors). Memorandums from the Director were very rarely seen around PSL until Harry Posner was appointed to that position in 1966.

Harold Connell said that there were approximately 12 groups in the early 1950s—several at WSPG and the remainder on campus. Each group had a supervisor (who was also part of the technical team), and each was assigned to a particular contract. It was Dr. Gardiner's practice to hold a meeting every Saturday morning with all of the group supervisors. These were somewhat informal meetings, and each supervisor reported his contract's status and accomplishments and problems encountered during the previous week (both technical and political). They would also present solutions, both actual and proposed. All of these supervisors, who were technical people possessing a great deal of experience, were encouraged to share their potential solutions in the event that someone required additional help in a time of difficulty. Many times a solution was either initiated or improved upon during one of these meetings, and sometimes the principle participants were asked to hold a separate meeting. There was what appeared to be a great deal of mutual respect among the members of this group, which definitely helped the interchange.

At any rate, “groups” came to be termed “sections” by 1955; for example, the NRL Telemetering Group was known as the Telemetry Section (the Antenna Section was an exception to this—it had apparently been called a section from the time of its inception in 1948).

Pat Throneberry provided some insights into Dr. Gardiner’s character: “Right after I started at PSL, this strange man started coming around where we were working and looking over everybody’s shoulder, which made me very nervous. So I went in to Leon Hart and said, ‘I wish you’d get that funny little man out of here—he makes me nervous!’ Leon said, ‘Oh no, what did you say to him?’ ‘Nothing.’ ‘Good thing—that’s Dr. Gardiner, the Director!’” Pat continued, “Dr. Gardiner was a very fine gentleman—very concerned about the welfare of his employees. One night I was working very late, and he [planned to] stay until I finished. I was on the last page when I made an error, and when I tried to erase it, I rubbed a hole in the paper. I went in and told him I’d have to do a page over, so he may as well go on home. He refused—he stayed and escorted me home. That’s the kind of man he was.”

As mentioned in Chapter 1, the New Mexico College of Agriculture and Mechanic Arts was renamed, “New Mexico State University of Agriculture, Engineering, and Science” in 1958. The benefits to PSL as a result of this new designation are difficult to identify, but it can be assumed that the word, “University” on PSL’s letterhead commanded more respect from both actual and potential customers. Benefits notwithstanding, PSL was required to purchase new stationery and identification cards, change the signs on its vehicles, and notify all customers and suppliers of its new name and address (no doubt a costly undertaking).

Another change occurred in 1958 that did prove beneficial for PSL. In the summer of 1958, the U.S. Congress passed the National Aeronautics and Space Act, which directed that the United States' space activities “should be devoted to peaceful purposes for the benefit of all mankind” and that these activities should be directed by a civilian agency (with the exception of weapons development). When NASA was formed in October of 1958, NRL’s sounding rocket group (the Rocket Sonde Branch) and Vanguard Group transferred, en-masse and virtually intact, to NASA and became the nucleus of the Goddard Spaceflight Center (GSFC). These two groups, with whom PSL had been associated for 10 to 12 years, continued with the same programs and contractors, effecting little more than a mere change of name. Through these connections, then, PSL was already recognized as a member of the support team when NASA was founded. To this day, NASA remains one of the Laboratory’s largest customers (PSL also retained NRL as a customer after the change).

Another change occurred in 1958 when, on May 1, the Army changed the name of its proving ground to, “White Sands Missile Range” (WSMR).

The Annex

Prior to 1951, PSL's Photo Lab and Telemetering Reduction Section had been sharing space in the basement of Kent Hall. It became apparent early in the year that both groups would require more area in order to accommodate the increased workload imposed by the expanding missile program. Since no room for expansion was available in the Kent Hall basement, the decision was made to move the Photo Lab to a new building. An annex to the PSL building was built south of the east wing, and was made large enough to accommodate both the Photo Lab and Anna Gardiner's ballistic reduction facilities, which had been housed in a barracks building (Figures 38, 39).

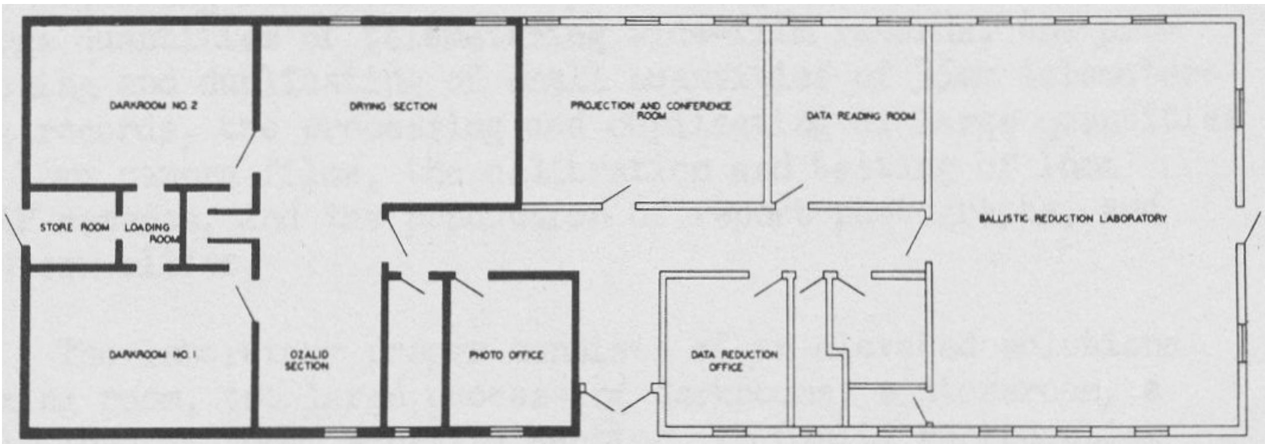

Figure 38. PSL Building Annex Floor Plan, 1951

Figure 39. PSL Building Annex, South View, 1953

Although the annex did not provide the Photo Lab with increased floor space, its improved design enabled the addition of new capabilities. A solutions mixing room was constructed on the roof of the annex directly over the darkrooms to employ gravity flow of photographic solutions. This eliminated the need for costly circulation pumps, which were difficult to maintain.

The College provided funding for construction of the annex, and the BuOrd/APL contract absorbed the costs of the special facilities required for photo processing and ballistic reduction.

PSL's Building Occupation in the 1940s and 1950s

As discussed in Chapter 2, PSL initially consisted of the Ballistic Reduction group, which was housed in a classroom on the second floor of Goddard Hall. Two offices on the west side that adjoined the classroom were used for administrative purposes. In 1946, over 70 Quonset huts were erected at WSPG; by 1947, PSL occupied one of these huts and two four-wheeled shop trailers.

In the fall, the Ballistic Reduction group moved to the east end of the Air Mechanics building on Vaughn Street. PSL continued to occupy temporary office space in Goddard Hall. The Telemetry Reduction group was formed and located in the basement of Kent Hall, which was a men's dormitory at the time. It had been an indoor rifle range for the ROTC and its exposed overhead pipes leaked water. A Photo Lab was established there to process V-2 flight films taken by the numerous cameras located at WSPG (this laboratory later processed telemetry film records).

Late in 1946, construction of a new PSL building began on Vaughn Street just west of the Air Mechanics building (it was completed in April of 1947). By the summer of 1947, an old dental clinic barracks building was moved to the south end of the new building and called the "BRL Annex." In 1947, the Telemetry House (Parker Station) was built, and PSL began work at that location as well. In 1948 (sometime before August), an addition to the building on Vaughn Street was completed, giving it the final "H" shape.

In the early 1950s, in response to rapid growth at WSPG, PSL moved into the Red Wagon and Desert Ship Facilities in order to provide support to the U.S. Navy. In 1951, the Photo Lab was moved from Kent Hall to the main PSL building on Vaughn Street. As stated earlier, a batch chemical mixing facility was located in a small room on the roof so that the required chemicals could be mixed in large quantities and gravity-fed to the lab below. In 1953, PSL's antenna range was constructed for testing of early antennas. The PSL garage, which was south of the main building across the arroyo, was accessed via a footbridge. There were three homes located on what is now PSL's parking area that were used for housing and eventually as data reduction and storage facilities. Administrative offices occupied some of the barracks buildings that were located north of the present building (across Stewart Street) as PSL grew out of its original building in the late 1950s and early 1960s.

When the College built the new library in 1954, the top floor was unoccupied. PSL, always in need of space, moved its Ballistic Reduction Group from the Air Mechanics Building to that facility (the new IBM 650 computer was installed there). In 1955 at WSPG, the Navy building N-103 was constructed and PSL occupied offices there. In 1956, a PSL Army support group moved into Hangar Building 1678.

PSL—A 1953 Snapshot

An article in the March 1953 New Mexico Aggie (the Alumni and Ex-Students Association publication) showcased PSL on page four. "The director of PSL is Canadian-born, Dr. George W. Gardiner, who joined the A&M faculty 21 years ago. When he was given the job of establishing and organizing PSL, the big obstacle was lack of personnel and facilities. But with the cooperation of college authorities, he has been able to build PSL from its beginning in 1946 to its present stage of 79 staff members with an operating space of 12,000 square feet and 11 buildings in and around campus. In addition, 48 part-time personnel and 140 students are employed by the laboratory. Of the 79 staff members, 27 are engaged in work at White Sands Proving Ground; the remaining 52 work on campus. Three large phases of the Laboratory's operations that require the participation of student employees are the photographic, ballistic, and telemetering reduction sections. Ballistic Reduction, headed by Mrs. A.H. Gardiner, conducts work in computing the position, speed, and related data for various missiles launched at White Sands Proving Ground. Raw data for this ballistic work is recorded on film by ground-based camera instrumentation. At present, there are 70 students from almost every department of A&M and 40 part-time employees engaged in this work which requires much patience and ability to apply mathematics to the solution of rocket trajectories. Student wives comprise the bulk of part-time workers. Thirteen juniors and seniors from Las Cruces Union High School and Gadsden Union High of Anthony are being trained to be computers to enable them to work part-time when they enter A&M. The Ballistic Section, since its beginning in May of 1946, has employed approximately 400 students, many of whom have entered related fields after graduation.

"Professor Harold A. Brown is in charge of the photographic and telemetering reduction section, which now employs 45 students and has employed about 175 students since 1946. Their job is the processing of data radioed back from the missile to the ground while the missile is in flight. The group also determines missile aspect – its orientation, by installing cameras in the missile and reducing data from the resultant films.

"Co-supervisors of the research and development section of the laboratory on campus are Dr. Ralph Dressel and Mr. James Arnold. These and other physicists are studying problems in high frequency discharge, hydrocarbon combustion work, radio antenna characteristics, and others that cannot be mentioned because of their security classification. Of the fifteen staff members working on these projects, six teach classes in physics in addition to research work. Students also work here as laboratory technicians.

"At White Sands Proving Ground, Mr. Rick Ricketts heads a group of engineers, physicists, and technicians engaged in the installation of electronic equipment in rockets and missiles and the operation of various types of ground-based equipment. Outstanding among these projects are telemetering operations, ionospheric studies, and high altitude photography."

The Army's Arsenal

As discussed earlier, PSL became part of both the Navy's and the Army's guided missile development programs in 1951. The Army had also used the proximity fuze very effectively in World War II and wished to employ this and other fuzing systems in its various missiles. The National Bureau of Standards (NBS) gained control of the Army's fuze development, largely through the efforts of employee Harry Diamond who, according to Army archives, is credited with inventing the proximity fuze. Both Army and Navy fuzing was performed initially by NBS and DOFL. PSL acquired a contract with NBS in 1951, and the NBS Fuze Group was formed (Hal Ware was its first supervisor). Members of that Group over the next few years included Vernon ("Bud") Monjar, Colonel Marquez, Harold Connell, David Paul, Edward McDowell, James Boyd, William Shaffer, Tony Pizana, Arthur Thompson, John Rice, Logan Ritchey, Asa T. ("Ted") Hoy, and Billy D. Bridwell.

Additional contracts were acquired in the late 1950s with the Army Chemical Warfare Center at Edgewood Arsenal, Maryland for the evaluation of chemical bomblet warheads and later with the Biological Warfare Center at Ft. Dietrich (also in Maryland) for the evaluation of biological bomblet warheads.

In its early years, the NBS Fuze Group's primary mission was to perform preflight electronic checks on the fuze units at WSPG, install them on Corporal (Figure 40) and Honest John (Figure 41) test vehicles, and evaluate their performance via post-flight analysis of telemetry records. For post-flight analysis, the Group operated and maintained two portable telemetry ground stations (housed in four-wheel trailers), where FM/FM telemeters were prepared and installed in the missiles.

Figure 40. Corporal Missile, Early 1950s

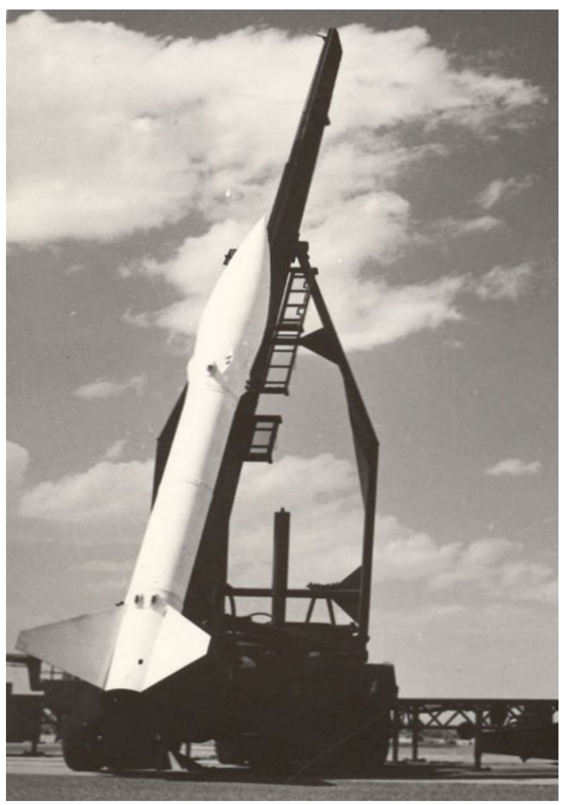

Figure 41. Army's Honest John Missile, Early 1950s

These portable ground stations were usually located far up-range on WSPG. According to Harold Connell, "Operations at WSPG were much more primitive (and much more relaxed) in the fifties. The Corporal project scheduled flights into the 30-, 50-, and 70-mile area of the Range, corresponding roughly to the Lake Lucero salt flats; just west of Tularosa; and the area west of Oscura, NM, and south of the Oscura mountains. PSL would move its telemetry stations (in short, four-wheel director trailers), along with trailer-mounted generators, into these areas for one to two weeks at a time. This was a real safari. We would draw a number of four-wheel-drive vehicles (3/4- and 2 1/2-ton trucks) initially from the Navy's (and later from the Army's) motor pool and move up Highway 54 and onto the Range in convoy. Everyone would camp on the Range near the telemetry trailers for a week at a time while the stations were set up and calibrated, then wait for the missile to be launched. When the roads were wet, they were a sea of mud, and we often had to daisy chain the vehicles together to get through the worst mud holes. When the roads were dry, they were usually so rough that it was impossible to drive over about 20 mph, making each trip a daylong venture. If we had to stay more than four or five days, we would move into the [only] motel in Tularosa for one night to clean up and get a decent meal.

"Telemetry trailers were generally located a safe distance from the impact area and on high ground, but a secondary instrumentation system was added right in the impact area. Some way was needed to measure the height of burst triggered by the fuze. There were spotting charges on the missile warhead that were both visible and audible. At first, a sound ranging system was devised and deployed about the impact area. This did not work out very well, so eight surplus gunsight cameras were deployed at the corners and center of each side of a ½-mile by 1-mile rectangle—the impact area. There were targets in the field of view of each camera that were accurately surveyed, and Gilbert devised a data reduction process to determine the height of the spotting charge bursts. Now, the Corporal was quite accurate in azimuth but lousy in range, and as it happened, it never landed within this rectangle. Next, we added four more cameras pointing north from the north end and south from the south end. During the life of this program, we caught one image of the spotting charge. Because transportation was so difficult, and knowing the azimuth accuracy of the Corporal, the camera crew would move a few hundred yards to one side and wait for the launch. Later, on a weekend, I 'borrowed' a grader that was left parked in the area, cut a road around the rectangle, and improved the existing road. People working on these projects included Jim Boyd, Art Thompson, David Paul, Bill Shaffer, John Rice, Greg Allman, and Ernest Jiminez."

DOFL handled the warheads on the Corporal, Sergeant, Honest John, Little John, and LaCrosse missiles. Ft. Bliss soldiers launched the Corporal from a point near Oro Grande (where the Nike-Zeus complex was later constructed). According to Teodolo ("Ted") Arellano, the field conditions were terrible—the mating took place in the desert, sometimes in a large tent because of sandstorms. Mr. Arellano said, "When the warhead was attached, we taped the openings on the vehicle. One time after the vehicle was in the vertical position, Ernest Jiminez and I were up on the cherry picker at the top of the vehicle where the probe and spotting charges were located. The GIs could see us actively swatting at something up on top. When they got us down, we told them that flying ants were swarming up there, apparently attracted by the duct tape that we used. We were given a bottle of bug spray, which we applied—45 minutes later the Corporal was launched."

The NBS Fuze Group also performed another uprange function—recovery. After each flight, one of the telemetry station crews would make an expedition to the impact site and retrieve bits and pieces of the shattered rocket. If telemetry had indicated a rocket malfunction during flight, the crew would screen the dirt from the impact crater to recover as many pieces as possible. The Army would then send out a bulldozer to fill the hole.

Several interesting mishaps occurred during the Corporal program. Harold Connell was at the Army blockhouse for the 100^{th} (and final) R&D Corporal firing. The Corporal was considered a mature and reliable system by this time, and a large celebration was to be held after this firing. The missile ascended normally, but for some reason it turned 90 degrees and headed east. In those days, everyone working at WSPG had access to the Range net (i.e., the WSPG communications and timing network), and many would go outside and watch whenever a missile was fired. A two-story Quonset hut was located approximately 10 miles east of the blockhouse that housed a number of Nike project personnel. Mr. Connell was later speaking with a GI who had emerged from this building to watch the launch. Although the GI saw that the missile was directly overhead, he wasn't concerned because, as anyone who has ever watched a vertically launched missile will attest, they *always* appear to be in this position. This missile, however, kept getting larger, remaining overhead until the GI finally decided that it was aimed at him. He started running, but the missile impacted and knocked him down. The resulting crater was no more than 25 feet from the Nike building. Although it shattered all of the windows, nobody was injured. Needless to say, no celebration took place that day.

Mr. Connell described another occasion as follows: "We had a tactical firing of the Corporal by a battery of troops from Ft. Bliss. They were bivouacked in the desert north of the Oro Grande road and east of the Oro Grande gate with the launcher set up about 1½ miles north of the bivouac area. This missile rose just a few hundred feet, rotated 180 degrees, and came roaring back south on a downward path toward what looked like the bivouac area. Gil Moore was manning the tracking antenna, a helix with an [approximate] four-foot diameter frame covered with a screen wire for a ground plane. The missile came roaring by our telemetry trailer like a run-away locomotive, but Gil tracked it all the way into the ground, crouching down behind the ground plane like it was somehow going to protect him. We all thought for sure that we were going to find troops splattered all over the landscape, but the impact was well south of the bivouac area."

At least two other Corporal missiles went astray—one landed near the intersection of Highway 70 and the WSMR access road, and the other landed south of the "C" station.

The NBS Fuze Group also became involved in some countermeasures activities. Three different types of electronic fuzing systems and various pressure-sensing fuzing systems were evaluated with respect to their vulnerability to then-current electronic countermeasures equipment. PSL produced a documentary film describing the fuze test operations.

Other missiles supported later in the 1950s were Lacrosse, Little John, Sergeant, Redstone, and Cobra (Figure 42). Some of these rockets were tested at the Army's Yuma Test Station near Yuma, Arizona, requiring NBS Fuze Group personnel to travel there occasionally to support firings.

Figure 42. Redstone, Lacrosse, and Little John Missiles, Early 1950s

By 1954, the Army's fuze program had been transferred from NBS to a newly established organization called the Diamond Ordnance Fuze Laboratories (DOFL, pronounced, "Dah-full), which then continued as PSL's customer. At approximately the turn of the decade, the fuze project was physically relocated from the NBS complex in Washington, D.C. to a new location in Gaithersburg, Maryland, and the organization was renamed Harry Diamond Laboratories (HDL).[18] This contract continued into the 21st century.

In 1956, PSL's NBS/DOFL Fuze Group became involved in another aspect of missile warhead testing, the testing of certain chemical type warheads that were being developed by the U.S. Army Chemical Corps. The Group's function was to receive, test, and install explosive elements in the warhead, perform post-flight inspection of each of the impacted munitions, plot their location, and prepare a report. These warheads were flown on Corporal, Honest John, Little John, and Sergeant missiles.

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18 Ted Arellano claimed that DOFL stood for, "Department Of Frustrated Lovers"; Charlie Marshburn, an HDL Technical Monitor, liked to call HDL the, "Hot Diggity Laboratories."

> Harold Connell said, "We had a special project going one time where we needed a detonator in a hurry. So, two of the guys (Bob Yarbrough and Bob Ammons) were very carefully sawing a smoke grenade canister open to take the detonator out. Ted Hoy, [who was] quite the cut-up, slipped up behind them and dropped a large aluminum bulkhead cover—scared 'em out of their wits! They really chewed him out good."

The Group moved to a new hangar (Building 1678) for the Redstone program. There was a basement area in this building and a large hydraulic elevator platform in the middle of the hangar floor upon which the missile could be supported vertically and raised or lowered. The elevator platform consisted of steel tread plate. According to Harold Connell, "A number of the personnel in the building (PSL, civil servants, and military) would go down under the elevator at lunch time to play poker, and sometimes the lunch hour would become extended. A spit-and-polish colonel by the name of Colonel Napper (affectionately known as 'Snapper Napper') was in charge of the ARMTE at the time...His office [was] on the second floor of this building, across from the PSL quarters. One noon, Ted Hoy strode out of our laboratory [carrying] a large, round, steel plate with the intention of dropping it on the elevator platform while the poker crew was underneath. Just as he was about to drop the plate, he noticed Col. Snapper on the second floor balcony watching him. He had decided it would be better not to drop the plate until Col. Snapper motioned for him to go ahead—[which] he did. The crew below came boiling up the stairs like ants out of an anthill, spotted Ted and were ready to kill, but then [they] noticed Col. Snapper laughing his head off on the balcony. They turned and went back down the stairs."

System Study Section

Another contract involving the Army's missile development was signed in 1954 with the Signal Corps White Sands Signal Agency (WSSA). Assigned to Ivan Carbine, it requested the study of electronic countermeasures in two phases:

(1) A general study of electronic countermeasures against electronic systems
(2) The study of the effects of countermeasures against specific missile systems.

The general study was a broad consideration of all signals and devices that might potentially have an effect on electronic equipment. It included the theoretical treatment of the interference phenomena, as well as a survey of available equipment and techniques. The Hawk (Figure 43) and Lacrosse systems were assigned to PSL for the second phase of the study. These studies continued for the remainder of the 1950s.

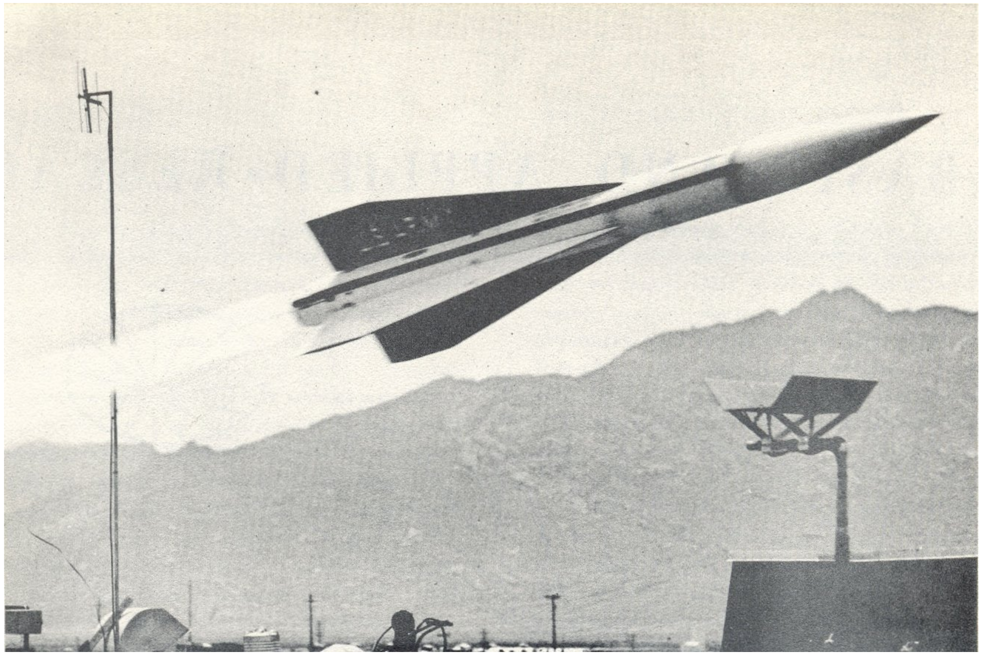

Figure 43. Hawk Missile, Mid-1950s

Gil Moore indicated that all senior scientists who worked at PSL throughout the 1950s, including James (“Jim”) Arnold, were always looking for research projects in order to involve Laboratory and College staff, faculty, and students in practical research activities. He remembers Jim as being instrumental in starting PSL's Countermeasures Group. This study, which was most likely an outgrowth of Jim Arnold's early efforts (probably 1950-52 before he departed the Lab), resulted in an area of specialty for PSL, which remains at its core of expertise today.

POGO

Another PSL section was established when Roy Larson of APL notified Gil Moore that the Talos required a target capable of reaching altitudes much greater than 40,000 feet. The Rocket Section (headed by Mr. Moore) was created in the fall of 1953 to support this effort.

Drone aircraft, which had been used as targets since the inception of the Talos testing program, were the most realistic targets available. The Talos, however, was so proficient at knocking them down that a drone shortage was developing (and replacements were very costly). This prompted APL and the Navy to search for a less expensive target. Another problem with the drones was their altitude limitations (and APL wanted a target capable of reaching 100,000 feet).

Mr. Moore knew of a project in which Deacon rockets were used to deploy parachutes carrying meteorological instruments to altitudes up to 100,000 feet, and PSL was given permission to attempt to adapt this system to produce a suitable target. The result was the POGO, a six-inch diameter, solid-fueled rocket that delivered a radar-reflective target composed of a parachute coated with metallic silver. The parachute could be deployed at pre-selected altitudes ranging from 40,000 to 100,000 feet. The cost of the POGO was significantly less than that of a high-performance drone aircraft, and it could reach the desired altitude in significantly less time.

Stewart Bean described the POGO development as follows: "...[Our group] conceived the idea for a target and worked this out with the customer, who happened to be APL at the time (they needed a target for a rocket they were testing). So we worked out their desires for a target—we had mechanical engineers who actually designed the airframe, designed the tail fins, designed the timers that went inside, built them in our own machine shop, screwed them together, and found out they fit. Then, we took them to WSPG...put them in the launcher, and fired the things and created a target for APL, who wanted to run a rocket test or a radar test against it. Very interesting! One of the exciting [things] about working for PSL is that we got to live through all parts of the task, including the data reduction by Ray Chavez. Later on, he reduced the data and came up with the final report—a trajectory report and a performance report for the rocket that fired against our target."

> Gil Moore was well known for creating parodies of the ©POGO comic strip—he drew humorous caricatures of PSL and Government personnel based on the characters from the strip as they might appear during Viking and Talos flight operations (see the following foldout).

Finding the right parachute to use for the target presented a few problems. A standard nylon personnel parachute large enough to be seen by the radars at long ranges was too bulky to fit inside the rocket. Silk material solved this problem, and one U.S. company, Gentex, was located that still manufactured silk parachutes. However, because silk contains natural oil that resists adherence, it would not absorb the silver coating evenly. After a long and tedious search, a process was developed whereby the silver would adhere uniformly. Other difficulties were encountered and solved via trial and error. For example, a spherical parachute shape was found to be much less "noisy" than the typical convoluted shape, and the radar return was much improved by coating the canopy in a checkerboard pattern as opposed to applying a solid coating. This was a two-year development effort (Figure 44).

Figure 44. Robert Ammons with the PSL-Developed 24-Ft. Parachute Target[19]

In the early days of POGO rocket design, drawings were required to enable PSL's Machine Shop (or other external shops) to build the rockets. As a result, a very competent woman named Corine Clementine ("Clem") Jellison (who later married a PSL staff member with the last name of Mozer) started the Drafting Department. George Baker said that, "[Clem] was one of most professional people that I worked with in…my career at PSL. She established the Drafting Section, she made professional drawings…the majority of the engineers at PSL in those days had no experience or background—they only had book learning. This prevented them from being able to communicate with the working world of shops and fabricators. Drawings are a communications device; a good drawing allows a person to communicate with anyone in the world regardless of language. They provide a permanent, historical record that can be modified, approved, and controlled. Clem didn't get her training here at PSL. I do not know where she learned it, but she was very good. With POGO, we started with a basic concept and, as changes were made, she generated the drawings that would go to our Machine Shop or to outside vendors. Not only did she [fabricate] make the drawing, she put all of the specifications on it, which is a tremendous job (especially since a lot of our engineers did not have a clue how to do that), and all the notes, which made it a stand-alone document. The drawing would go to Engineering for final approval, then on to Fabrication, and a copy would go to Quality Control so that the fabricated item could be checked against it for compliance.

"These drawings were the main factor in this whole process—without them, we couldn't function —[and] Clem kept them up to date. Whenever there was a change or revision, she would change the master drawing, put a revision letter on it, and reissue new drawings to all the proper people. She maintained these historical drawings and records. All this work went on in the 1950s and beyond."

Much of the early Quality Control for POGO resulted from the many failures that occurred due to non-standard fabrication, integration, and flight processes. Once fabrication and assembly

[19] A 36-foot parachute was also developed.

processes were controlled and field operations became less subjective, failures declined. Of course, a formal, controlled system, whereby drawings could only be changed via an Engineering Change Order, was integral to this program. Leon ("Tate") Tatreault was the first inspector in the Quality Control office, and George Baker replaced him less than a year later after graduating from college (Mr. Baker had worked in the Machine Shop as a student prior to that time). Dr. Gardiner decided that the Quality Control function was necessary to ensure a greater possibility of successfully flying POGO targets.

In order to fulfill the varying altitude requirements of different missile tests, two types of targets, POGO HI and POGO LO, were developed. The name POGO HI was given to the rocket/parachute combination described above; it was used whenever a target was to be placed above the aircraft ceiling of 42,000 feet (Figure 45). The POGO LO system was used for operations below that altitude, where a parachute was merely dropped from an aircraft.

A project to control the height of the POGO began when George Conrad attached a thrust-reducing ring below the nozzle. There were problems with this, so Robert ("Bob") Ammons designed a series of nose cone balls that varied in size in relation to the requirements for the height of the target parachute. The field crew could screw any one of these tips onto the nose cone, depending upon height requirements. Mr. Ammons' design proved to be the one that worked best in the field since they did, in a calibrated way, control height while maintaining flight stability.

The need subsequently arose for a target for heat-seeking missiles, i.e., a source of infrared energy rather than a radar reflector. This was accomplished simply by using a pair of infrared emitting flares as the stabilizing weight on a non-silvered parachute—HI or LO, as desired.

POGO's fame as an inexpensive but effective tool spread quickly, and by 1958 it was being used as a target by aircraft-seeking missiles such as Talos, Nike-Ajax, Nike-Hercules, Sparrow, and Sidewinder. POGO HI underwent considerable revision and improvement all throughout the 1950s, resulting in the development of several versions. One of these, which employed a 24-foot parachute, was placed in production in 1957 for use at WSPG, HAFB, two test ranges in California, and at sea. Hundreds were fired at WSPG over many years.

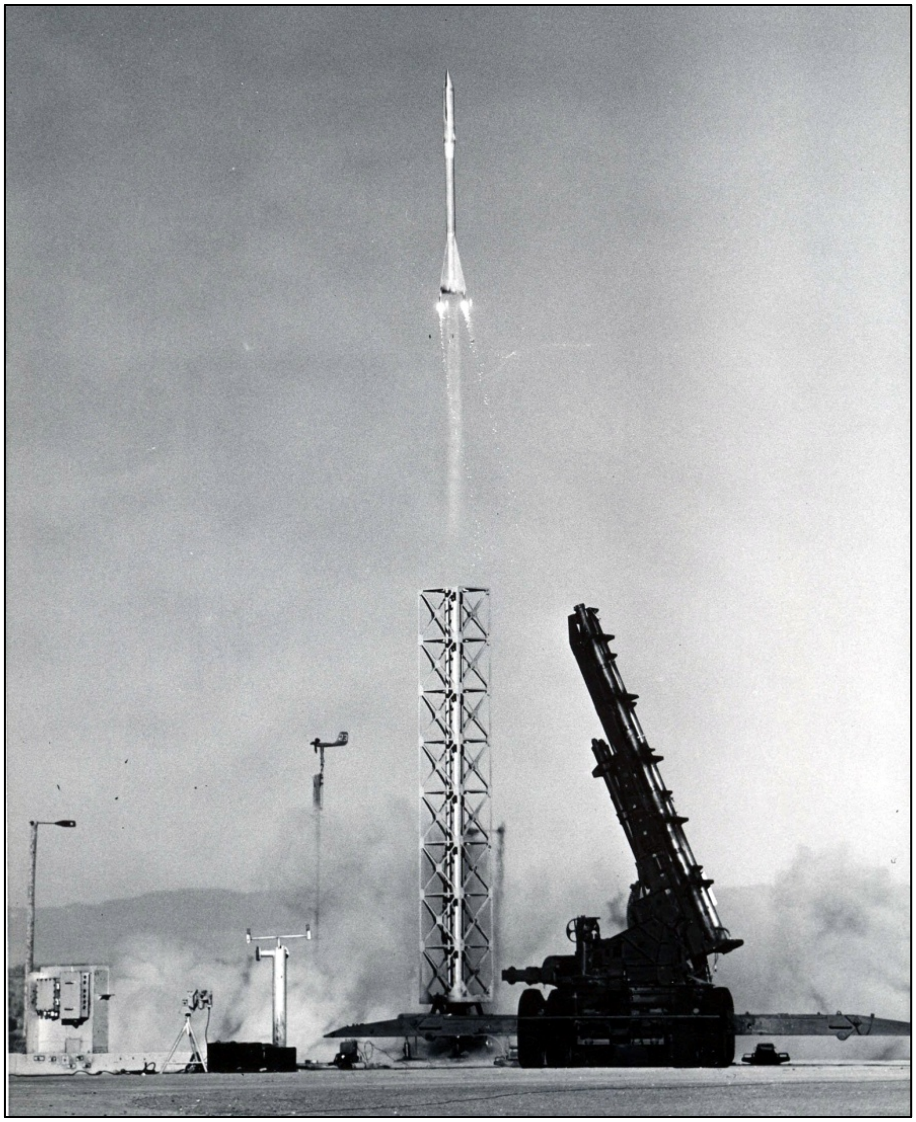

Figure 45. PSL's POGO HI Target Rocket

The first two POGO flights failed because the parachutes ejected considerably later than the time of the trajectory peak. The improper ejection time resulted from misinformation regarding the thrust characteristics of the Deacon motor. The third flight was a dummy (i.e., with no parachute) fired in order to establish the trajectory. This was accomplished, and subsequent deployments occurred at or near peak altitude.

To simulate larger aircraft, a version of the POGO HI was developed in 1958, using a 36-foot parachute capable of carrying four infrared flares (Figure 46). It was necessary to expand the diameter of the rocket nose in order to accommodate the larger parachute.

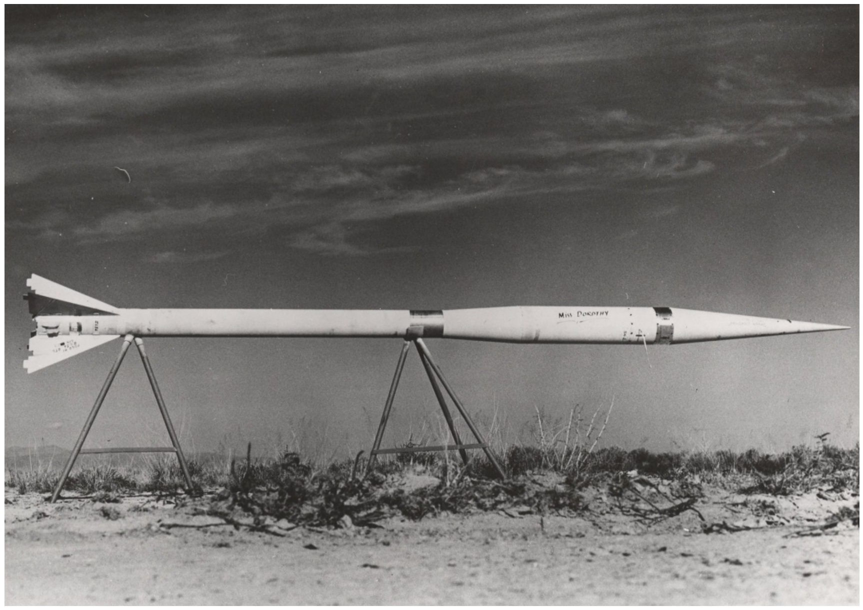

Figure 46. Modified POGO Rocket with Enlarged Nose Section, 1958

PSL parachute targets supported an Air Force missile called the Falcon. Stewart Bean said, "That didn't last too long, because the Falcon people—we did a good job, they did some testing—but pretty soon, the Falcon competitors got ahold of it. I don't remember if that was the Sidewinder, or who it was, and they began to say, 'Bring out the Falcons! We're being attacked by parachutes!' So then Falcon said, 'No more parachutes—you guys go home.' That ended our work with the Falcon people."

In 1959, a major improvement was made to the aircraft simulation technique. A radar transponder, developed primarily by Robert Sabin, was hung on the parachute, emulating a high-speed target. Development of an electronic system that would automatically register the missile's point of closest approach to the target was also begun.

In addition to developing the POGO, PSL's Rocket Section provided launch services, which meant that they fired the missile from various WSPG locations. Hundreds of missile tests were supported in this manner.

The Rocket Section and the Machine Shop designed and fabricated a portable launcher that was mounted on a flatbed trailer. The tower portion was hinged so that it could be placed in the horizontal position to facilitate insertion of the rocket (Figure 47).

Figure 47. Logan Ritchey and Jerry Cooper Loading HIBALL Rocket in Launcher

In a typical operation, the missile project would specify the distance and altitude of an imaginary "box," or cubicle of space, into which the target parachute was to be placed at a certain time. The POGO launch crew would hitch a four-wheel-drive truck to the launch trailer and haul it up-range to the vicinity of the "box" (this was usually done without the benefit of roads for part of the trip). The direction and velocity of the upper winds would then be measured and the precise point from which to launch the POGO calculated, and the ejected parachute would (hopefully) drift into the "box" as it fell toward earth. The POGO crew, led by Norris Hannum, became quite proficient at this. After the test, the group would mount a recovery expedition to attempt to locate and retrieve the downed parachute, which might be reused if it was in good condition.

Stewart Bean and Norris Hannum had taken a vehicle up-range one day to search for a parachute that had been shot full of holes, supposedly by a Nike-Hercules missile. The Nike people wanted very much to recover this particular parachute. Following is an excerpt from an interview with Stewart and Norris.

NH: ------ We broke down! Remember how we broke down?

SB: Let's talk about something else!

Interviewer: No, let's talk about that...sounds interesting.

NH: Well, our vehicle broke down, and the sun was fast slipping away.

SB: Hold on—let's don't just make it our fault. Let's point out that the battery was low, and we went out there with a clear understanding that you never let that engine turn off because if you did, you'd better have somebody else around to push-start you. And then—OK, go ahead.

NH: Well, it wasn't too bad—we had a recovery plane overhead, and he knew we were having problems and we thought, "Well, it won't be too long—we'll have some recovery people come out and take care of us, help us in." But they never did show up for one reason or another. I finally told Stewart, "We'd better take a reading on one of those mountains over there and start walking in." Which we did, and before we got over to the highway we'd gone through all kinds of brambles and tornillo bushes and arroyos, but we made it over there.

SB: We broke down by Twin Peaks...and we got to the highway about mile marker 190 or somewhere in there. So we were out in the middle of the desert—just nothing but desert—and this was before it was the desert it is now, when it was all salt.

NH: Yeah! We came up on one of those weather balloons, remember?

SB: You bet I remember!

NH: And I cut that thing up in pieces, and [Stewart] said, "What are you doing?" I said, "I'm getting my blanket for the night—we may be out here a long time." So, Stewart cut himself a piece off too. That was one of the fun times.

SB: That was a fun time. But we let that thing die and that was bad.

NH: Then we stood on the highway hitchhiking. We didn't care whether the bus went to Alamogordo or to [Las] Cruces, just so we could get out of that—it was beginning to get cool. Who was it [who] came by and picked us up?

SB: Whoever else was working—Gilbert, wasn't it?

The POGO also distinguished PSL's missile-launching crew as the first at WSPG to actually hit the Navy blockhouse with a rocket. The crew had placed its portable launcher near the Aerobee tower and pushed the "Fire" button. Upon ignition, the rocket motor casing ruptured. The crippled POGO veered, struck the Aerobee tower, tumbled end-over-end through the air, and hit the blockhouse, still spewing flame from its burning propellant. It then fell to the ground, knocked over a camera tripod, and came to rest so that its exhaust smoke was blowing through cable ports into the blockhouse firing room. Gil Moore said, "I had been outside taking pictures, so I was trying to get into the blockhouse, and all the guys inside were trying to get out." Fortunately, this caused no injuries.

George Conrad recalled another POGO-HI launch in which, after a nominal flight, the vehicle impacted the earth approximately 25 feet south of the launcher. Some thought the vehicle should be renamed the, "Boomerang."

Mr. Conrad also recalled using the lawn area on the north side of the old PSL building as a site to conduct POGO-HI parachute ejection tests. The test articles were within a few feet of Dr. Gardiner's office window, and some potent explosive cartridges were used. He said, "Dr. Gardiner never complained, maybe because he was shell-shocked!"

Miscellaneous Rocket Section Memories

The Office of Naval Research (ONR), in cooperation with the U.S. Weather Bureau, decided to take advantage of the sounding rocket's demonstrated ability to return photographs of cloud formations and storms as viewed from above the earth. Such images could potentially revolutionize the science of weather forecasting. In 1957, PSL was awarded a contract to develop an instrument/camera package, join it to a rocket fired to an altitude of 75 miles, and recover the package from the ocean's surface—a project called "HUGO"[20]. Bob Ammons, Norris Hannum, Charles Mozer, and Phil Manz were among those who contributed to this effort.

Rocket Section personnel designed and constructed a payload package to fit the Cajun, a solid-fueled sounding rocket similar in size to the POGO. The package contained two movie cameras, a free-running radio transmitter, a radar beacon, a timer to control functions during flight, and a recovery parachute. The Cajun and payload were then joined to a Nike booster, which resulted in a two-stage vehicle capable of reaching the desired 75-mile altitude. The plan was to fire the

[20] Although it is assumed that this acronym is a combination of the words "hurricane" and "POGO," George Conrad said, with tongue in cheek, that it stood for "Highly Unusual Geophysical Operation."

HUGO from Wallops Island, Virginia when large-scale weather disturbances (such as hurricanes) occurred within 500 miles of the island (Figure 48).

The payload separated from the rocket body on the ascent, at which time the cameras began photographing the terrain and clouds below. The pod was designed to float after parachuting into the sea, and to emit a locator signal until a ship or aircraft with direction-finding equipment

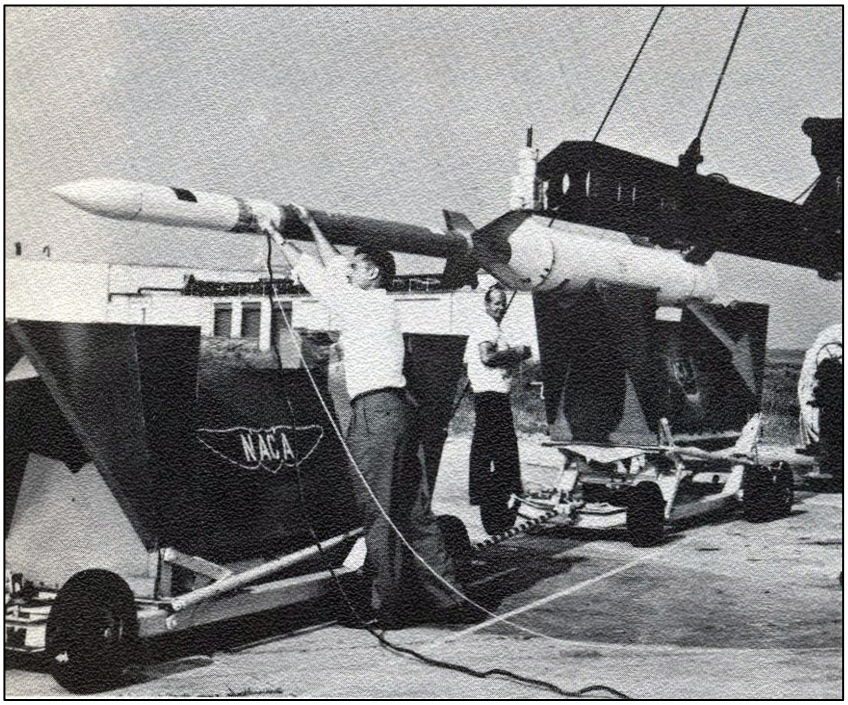

Figure 48. PSL Crew Prepares HUGO Photographic Rocket for Weather Study Firing at Wallops Island, VA

could locate it. Theoretically, this was a good idea, and the pod floated properly when test-dropped into Caballo Lake and the Salton Sea; however, it sank when test-fired over the ocean (Phil Manz piloted a leased airplane for the Caballo Lake drop tests). Norris Hannum said that, when the time came for a HUGO proof firing, the crew decided to travel to Cape Canaveral, Florida, for a "dry run" over the Atlantic Ocean. During routine preparations two or three days prior to the scheduled flight, the group heard the news that Hurricane Gracie was headed toward the Cape. In Mr. Hannum's own words, "Everybody got quite excited, and we decided to go for broke. We put one of our men out on the Navy ship (he got quite seasick while he was out there, with 15- to 20-foot waves). Anyway, we corked one off. We had told the radar people how fast this missile would accelerate, but they lost it completely...We had some beacons on there for signals, but they were never picked up. We thought…that was the end of it because Gracie started moving out. So we broke everything down and we were getting ready to come back to New Mexico when...we got a report that Gracie had turned around and was heading back for Cape Canaveral. So, we put everything back together again, got the launcher out there and all sighted in —this time we had our own people at the radar stations. We got our volunteer to go out again on the ship, even though he was so sick the first time, but we didn't find this one either. We corked it off and it came down to splash. We looked for several days, but we never did find it. We still don't know what happened to it—it just didn't float like it was supposed to." Since the problem was never solved, the project ended quickly.

PSL entered into a contract with the University of Chicago to support TORO, a program that was similar to HUGO. The purpose of TORO was to photograph tornadoes. "Tornado Alley" in Oklahoma was selected for the test site, resulting in a trip to Ft. Sill by Norris Hannum, Bob Ammons, Roy ("Pete") Markle, Emmett ("Toke") Rogers, George Baker, and possibly others in the summer of 1959. Several weeks of waiting, however, ended in frustration—no tornadoes developed in the area.

Norris Hannum related the following story: "…We didn't have any tornadoes at Ft. Sill at the time we were there. We had only a certain length of time for firing and if we didn't fire within that length of time, then we'd have to come back the next year. The amusing thing was we were pretty...well loaded—we had about three pickups, we were pulling trailers. We had all our gear with us, and we pulled into [a service station in] Lawton just outside of Ft. Sill...The owner came out and looked at our decals on the side of the pickups and said, 'What are you boys doing here from New Mexico?' I said, 'Well, we're here to take some high altitude photographs of some of your tornadoes.' So he turns and yells, 'Hey, Fred, come out here and look at these nuts from New Mexico!' Then to me he said, 'When a tornado comes around, we all head for the cellar. Have you ever been in a tornado before?' I said, 'No.' 'Well, it'll only take one time to make you a believer!'

"We were well protected—we had a launch site out on the range and we had a slit trench there that we were supposed to dive into if the tornado came in pretty close. We also learned from some of the natives that you can drown in that slit trench, because along with that tornado comes a drenching rain."

In November of 1959, PSL received a contract to instrument and fire Arcas rockets to measure the Ozone concentration in the atmosphere. Gil Moore implemented the project, called, "Ozonosonde" (instrumentation was provided by the NMSU Physics Department). Robert Sabin developed a miniature telemeter to be used in these packages. The Arcas, a product of Atlantic Research Corporation, was a small solid-fueled rocket, approximately six inches in diameter and eight feet long, capable of carrying 12 pounds to a 40-mile altitude. It used a simple tube for a launcher, making it very portable. Since no Arcas firings occurred in 1959, this rocket will be discussed in Chapter 5.

Early Ballooning at PSL

After World War II, polyethylene material was used to construct high altitude helium balloons (i.e., balloons reaching altitudes greater than 30 kilometers (100,000 feet) that were flown by the

U.S. Air Force and Navy. The NRL used these huge balloons in its famous Skyhook program (the balloons were often mistaken for UFOs before the program was declassified). The purpose of the majority of these balloon flights was to conduct scientific research, but some were used to develop military systems. Although sounding rockets were also used during this time for upper atmospheric research, balloons proved to be less expensive and less complicated in some cases (expenditures for balloon flights can be 10—20 percent of those for rocket flights, and a small fraction of those for satellite flights).

The testing of military missiles often required the use of targets (PSL used balloons or parachutes placed at high altitudes) in order to measure their accuracy. In 1953, the Rocket Section was created in order to develop various modes of delivering these targets. In the early 1950s, rockets and small polyethylene balloons were used to carry the targets to high altitude; in the late 1950s, PSL implemented a program of radar targets, flying inflatable Mylar balloons underneath the polyethylene balloons for use as aluminized target spheres (Figure 49). These Mylar target balloons were also flown on rockets (e.g., HIGHBALL and SPEEDBALL) and ejected at the maximum rocket flight altitude.

Figure 49. Balloon Radar Target

During this time, the U.S. Air Force was launching high altitude balloons for scientific and military purposes from various U.S. locations, as well as from their headquarters at HAFB near Alamogordo. PSL had an ongoing contract with the Air Force Geophysics Laboratory at Hanscom Air Force Base to support its sounding rocket program. PSL's Missile Electronics Instrumentation

(MEI) Section (headed by Raymond Bumgarner) managed the sounding rocket program and, under this contract, periodically supported portions of the Air Force balloon program.

All Aboard for IGY

The International Geophysical Year (IGY) was a worldwide scientific effort designed to gather data about the earth and its atmosphere. All available measuring devices were used, including sounding rockets and the first earth satellites. All nations were urged to participate, each gathering data to share with the others.

The IGY was an 18-month period spanning July 1, 1957 to December 31, 1958. Preparations began in 1951 when the International Council of Scientific Unions decided to hold a Third International Polar Year (the name was changed to IGY one year later). In 1953, the United States' IGY effort began when the National Academy of Sciences established a committee to oversee the program and the National Science Foundation provided the funding. The sounding rocket, having proved its worth, was viewed as the primary tool for fulfilling IGY objectives. At the same time, hopes were high for the U.S. to put a satellite into orbit before the Soviets could do so (the Soviets won the race with Sputnik in 1957). By the end of the IGY, hundreds of sounding rockets had been launched (210 by the U.S. alone), and both Soviet and American satellites were in orbit.

Management of the IGY sounding rocket program was primarily NRL's responsibility, since it had been a leader in developing and using rockets for scientific exploration. NRL rocket pioneers Homer Newell and Jack Townsend headed the Special Committee for the IGY (SCIGY), formed as a technical advisory group for IGY sounding rockets. Approximately six other agencies, as sounding rocket users, were represented in this committee.

The SCIGY selected the following launch sites for the U.S. rockets: Ft. Churchill (Manitoba, Canada); WSPG; the Arctic and the Antarctic oceans (for shipboard. firings); San Nicolas Island (off of California); Guam; and Danger Island (Pacific Ocean). Ft. Churchill, a Canadian Army post, was selected when the SCIGY asked the Canadian government to provide a suitable location for extensive examination of the Aurora Borealis, or "Northern Lights," and Canada invited the U.S. to construct an Aerobee launch complex there. The Army Corps of Engineers built the facility[21]. Nearly half of the IGY rockets were fired from this facility and included Nike-Cajuns, Nike-Deacons, Loki-Darts, and Aerobees.

By this time, PSL had supported hundreds of sounding rocket missions for NRL and other agencies, and had become well established as a team member. SCIGY therefore asked the Laboratory to send people to various launch sites around the world in order to provide the same services as they had for sounding rockets at WSPG—namely, antenna production, complete

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21 Because it was constructed specifically to conduct research on a special atmospheric phenomenon, the Ft. Churchill range is often referred to as "the auroral site."

telemetry field services, ionosphere ground station support, DOVAP, photographic processing, rocket wiring, and telemetry data reduction.

In addition to the actual IGY firings, PSL was asked to support a large number of "pre-IGY" sounding rocket firings at Ft. Churchill and a special NRL task force at Cape Canaveral, Florida, whose mission was to set up a crash program (called Vanguard) to develop a satellite launch vehicle. The final two Viking rockets (V13 and V14) were diverted from WSPG to the Cape in 1956. They were launched there as test vehicles to debug and prove in the new Vanguard launch complex.

As a result, in the autumn of 1956, PSL's NRL Telemetering Section expanded northeast to Ft. Churchill and southeast to Florida. Since the WSPG firing schedule was to continue unabated, a telemetry crew was required to remain there as well (in other words, it was necessary to staff three rocket launch sites simultaneously and continuously for at least two years). The Section grew to triple its former size with new hires and transfers from within PSL.

American Television Institute of Technology

For several years in the 1950s, Dr. Gardiner traveled to Chicago and interviewed a select group of American Television Institute of Technology (ATI) graduates, offering them positions at PSL. James Perdue, the supervisor of the DOFL group in 1954, was a former ATI instructor. As such, he was interested in a strong representation of ATI graduates at PSL, especially in his group.

Engineers recruited from the ATI in the 1950s included David Barnett, Edward Daneliak, Robert Davis, Robert Ecklund, Raymond Gonzales, Lloyd Griffin, Henry Hoffmann, Martin Metzer, Bud Monjar, Tom Noda, Arthur ("Pete") Reeves, Don Peterson, Robert ("Bob") Wagner, Gerald Lucas, Takashi Yamatani, and Charles Rice. Mr. Wagner was in the initial group of those offered positions in 1954 (Dr. Gardiner informally interviewed him in his downtown Chicago hotel room). If Mr. Wagner had come to work for PSL immediately, he would have been assigned to the DOFL group; as it was, he worked in Raymond Bumgarner's group, which he said he enjoyed very much.

The Ft. Churchill Story

Preparations for telemetering rockets at Ft. Churchill began about three years prior to the official start of the IGY. Karl Medrow, an instrumentation engineer in NRL's Rocket Sonde Branch, was given overall instrumentation responsibility for the Ft. Churchill program. In the summer of 1954, Mr. Medrow and Raymond Bumgarner began detailed planning for procuring and installing telemetry ground stations, antennas, etc. NRL had developed an Aerobee-sized version of their PPM/AM transmitter and had a number of them built commercially. The transmitter, referred to as the "DKT-7," featured 15 data channels and operated in the 225-Mc band. Its physical dimensions were approximately that of a twelve-inch cube. Two complete PPM ground stations would be necessary for semi-permanent installation at Ft. Churchill. PSL offered to design and build these, but NRL chose to adhere to the old design (with a few minor changes) and have them built commercially (Elsin Electronics Corporation of Brooklyn, New York was awarded the contract).

Mr. Bumgarner's group then performed the testing and debugging of the stations (Bob Wagner, a new engineer, made several trips to NRL in Washington in the process). Each station was then installed in a shop trailer and shipped to Ft. Churchill. The trailers and contents became known as Stations "S" and "T," and remained in use there for many years.

Since the Port of Churchill (situated a few miles from the Army post) is a major shipping point for Canada's grain exports, it is served by a railhead of the Canadian National Railway. This railhead is the reason that it was possible to build a rocket complex in the area—there were no automobile roads connecting Churchill to the interior (Figures 50, 51).

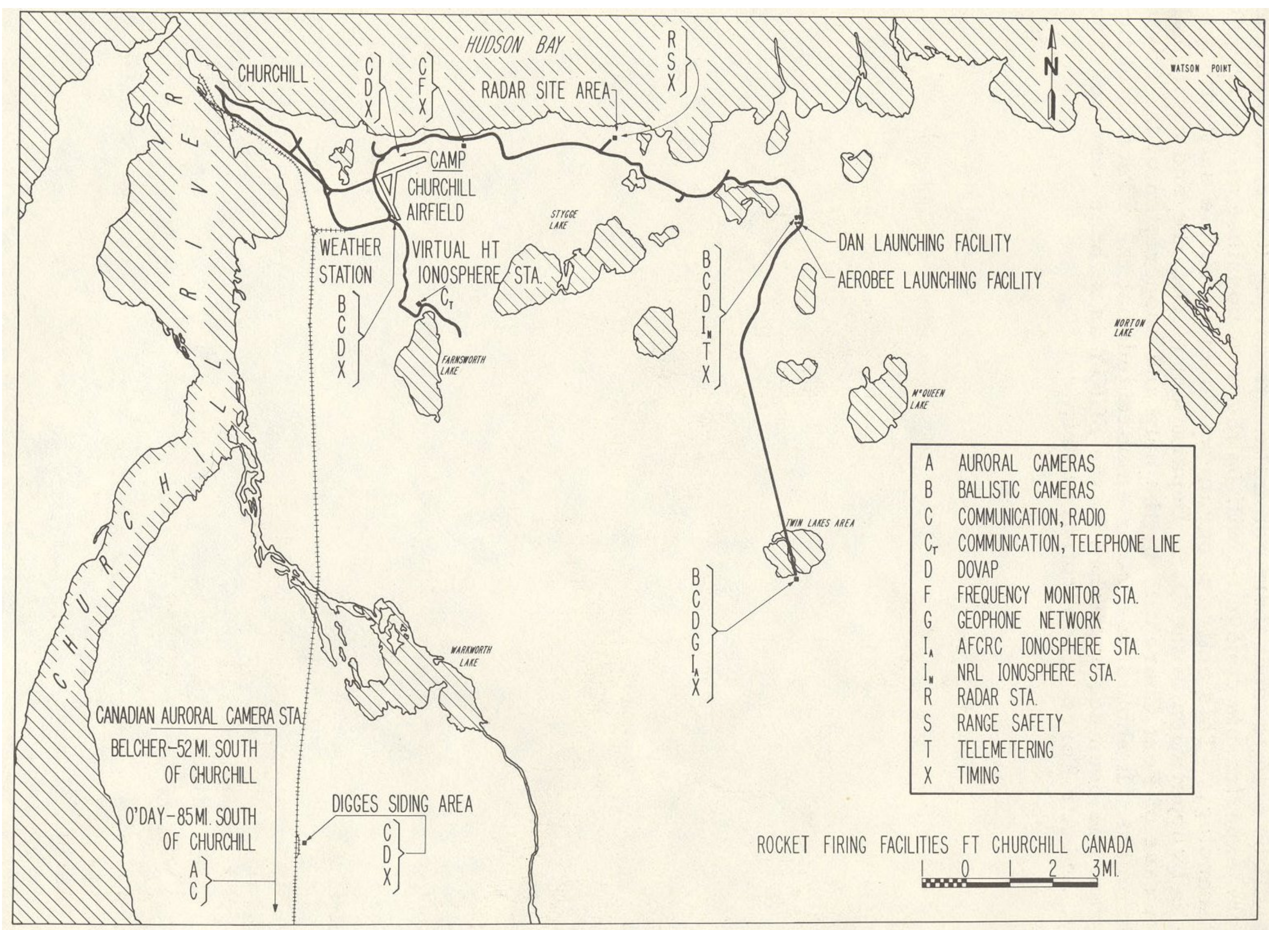

Figure 50. Map of Ft. Churchill Area, Showing Location of Launch Facilities, 1958

Two ground station operators, two assistant operators, two antenna trackers, and one transmitter operator were required to staff the operation. Those selected were Bob Wagner, John Cross, Jerry Cooper, William ("Bill") Mallar, Ray Young, Ted Arellano, and Eugene Lee. Mr. Lee was a member of the Ionosphere Group, which would be supporting ionosphere payloads with its own ground station (he would assist the Telemetry group between those firings). Since this was the first time that most of them had traveled to a foreign country (except for periodic trips to Juarez, Mexico), the group faced some unique challenges. These included the required series of vaccinations for both the Ft. Churchill and Vanguard crews (which made Jerry Cooper ill for a few days), uncertainty regarding how and when their living expenses would be paid (New Mexico's per diem policy was vague at best), and simply getting to Ft. Churchill in those days prior to the jet age.

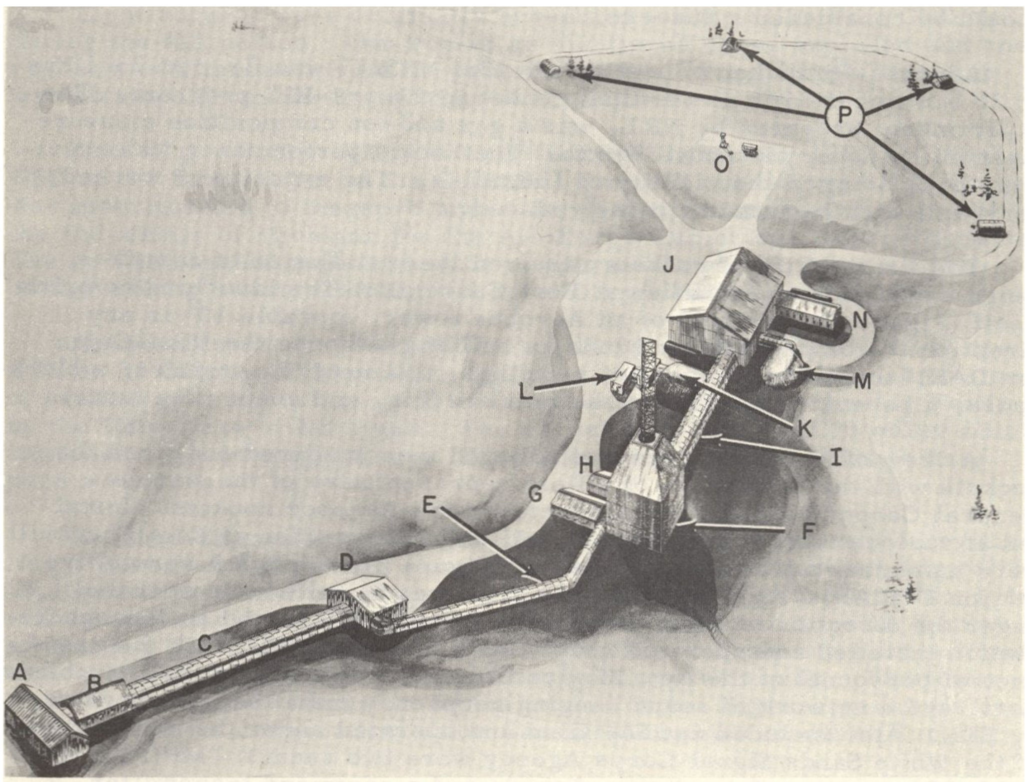

Figure 2 - Aerobee and Nike-Cajun (or DAN) Launching Complex

LEGEND:

A - Nike-Cajun receiving building
B - Nike-Cajun preparation building
C - Nike-Cajun tunnel
D - Nike-Cajun launcher
E - Nike-Cajun to Aerobee tunnel
F - Aerobee launcher
G - Aerobee heater and water building
H - Aerobee propellants building
I - Aerobee tunnel
J - Aerobee preparation building
K - Blockhouse
L - Telemetering trailers
M - Helium building
N - Generator building
O - DOVAP and Ballistic Camera site
P - Magazines

Figure 51. Aerobee and Nike-Cajun Launch Complexes, Ft. Churchill, 1956

The group left Las Cruces on September 13, 1956 (with the exception of Bill Mallar, who was averse to flying and had departed by train earlier). After two or three plane changes enroute, they arrived in Winnipeg, the staging area for Ft. Churchill. After enduring a customs inspection, they were transported by military vehicle to a hotel, where they stayed until the next bi-weekly flight to Ft. Churchill. Mr. Arellano said, "When I left El Paso, the temperature was 102 degrees; when I got off the plane in Winnipeg, it was ten below zero." Their next conveyance was a somewhat dilapidated-looking DC-3, a two-engine, 14-passenger craft with a crew of three—pilot, copilot, and one stewardess—and no heat in the cabin. After approximately four hours and a refueling stop in The Pas, they landed on the military airstrip on Ft. Churchill. It was September 18, five days after leaving Las Cruces.

Raymond Bumgarner paid his only visit to Ft. Churchill a month later, after a quick trip to Cape Canaveral, Florida. He arrived on October 13 (after spending approximately 48 hours in transit). By that time, Mr. Wagner and crew had parked and prepared the two trailers and inspected the equipment.

Not long after, the first sounding rocket was fired at Ft. Churchill—a Deacon and Nike (DAN) launched successfully by the Air Force Cambridge Research Laboratories (AFCRL) on October 20, 1956 (the DAN was a solid-fueled Deacon rocket, six inches by nine feet, mated to a Nike solid-fuel booster that could lift 60 pounds to a 60-mile altitude). Three launchers for this type of vehicle were installed as part of the complex. AFCRL had developed a very small adaptation of NRL's PPM/AM telemeter that employed only two channels and could be recorded by PSL's ground stations. Bob Wagner and John Cross were responsible for most of the design and fabrication of this unit. AFCRL also launched the first Aerobee rocket successfully three days later (Figure 52).

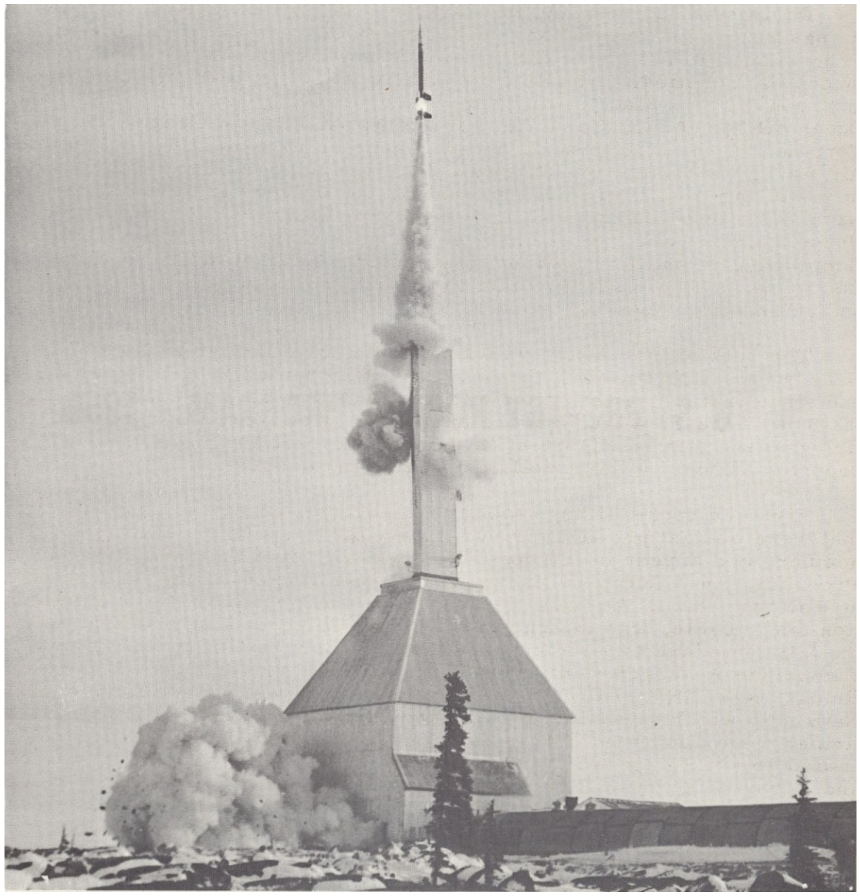

Figure 52. Aerobee HI Rocket Launched at Ft. Churchill, 1956[22]

The NRL's attempt to fly an Aerobee, however, was anything but successful. The problems began with the initial pre-flight check on Aerobee HI NRL-45—a crack in a body weld, a couple of misfires (due to human error), a telemetry transmitter failure at X-2 minutes, heavy cloud cover, and a blockhouse power failure. Finally, while holding the count in the early morning hours of November 5 (to wait for an aurora to appear), an enormous blast rocked the blockhouse, from the direction of the launcher. Then there was silence—no sound of the rocket leaving the tower—indicating that perhaps the booster had exploded. After a few minutes, the doors to the tunnel that led to the tower were opened. Although the tunnel was filled with smoke and fumes, there was no evidence of a fire (the tower deluge system was apparently functioning very well).

When it was safe to approach the tower, the Aerobee remained in place but with the upper portion of its tank section a jumble of twisted sheet metal. The helium tank had ruptured, with its 3500 pounds of pressure. Raymond Bumgarner entered the following in his notes the next day: "Aerobee 45 still in tower. Missile body and booster covered with oxidizer stains (red fuming nitric acid), as well as tower members around and below it. Nose cone and structure jammed at angle between rails about six feet up from rest of rocket, crumpled and bent. Holes in tower

[22] The smoke cloud is from the solid-propellant booster.

enclosure walls where shrapnel went through. Dolly rail bent out of line at point of explosion. Tail cone just ahead of fins slightly accordioned by downward force."

The accident bent the tower rail, which was taken to the railroad yard in Churchill and straightened. The mess was cleaned up, the rail was replaced, and firings resumed within one week. Four Aerobees were flown successfully until November 25, when the facility was temporarily closed to await the next scheduled series of firings. All PSL personnel returned to Las Cruces during this time.

Bob Wagner recalled an interesting problem encountered on the return trip with the Winnipeg Airport's U.S. Customs Department. "We were hand-carrying the telemetry records from the Aerobee flights at Churchill, which were on photographic film and to be processed at PSL. The film contained data from the experiments on board the rockets and was, of course, extremely valuable; all would be for naught if the film was lost or exposed to light. The Customs people were insisting on opening the film cans to see what we were trying to 'smuggle' into the country. We insisted that the cans could be opened only in a photographic darkroom. No such facilities were available at or near the Winnipeg airport. After much discussion, we finally convinced them we were legitimate and were allowed to board our flight to Chicago with the film. On later expeditions to Churchill, we were prepared for Customs with official papers to allow our film to go through."

Numerous PSL employees made many trips to Ft. Churchill through the remainder of the 1950s and into the 1960s (see Chapter 5). Ninety-five sounding rockets were launched during the actual IGY, followed by a series of "post-IGY" firings. Bob Wagner's crew, which arrived in November of 1959, remained for five months.

Keith Hennigh and Dolores ("Doty") Telles traveled to Ft. Churchill when the IGY started in 1957 and calculated the wind measurements necessary for aiming the Aerobee launcher. It was absolutely essential that all rockets land east of the launch site (in the Hudson Bay) and not on land.

The Ionosphere Group, headed by Wes Joosten, supported numerous ionosphere payload launches in Ft. Churchill, staffing two NRL ground stations. A crew of Naval officers and enlisted men from NOMTF prepared the rockets. Numerous instrumentation facilities, including five DOVAP stations, ballistic cameras, two radars, timing, plotting boards, sound ranging geophones, etc. were installed at sites throughout the military reservation.

In 1956, PSL acquired a contract from the National Science Foundation to produce a series of thirteen 30-minute documentary films to inform the general public about the meaning and significance of the IGY and to attract young students into scientific careers (each film addressed a separate geophysical science discipline). Dr. Russell Sherburne managed the effort[23], aided by the film unit of the Lowell Educational Foundation of Boston, Massachusetts (this is the precursor to the Boston's Public Broadcasting Station (PBS) WGBH, which produced the NOVA series). Professor Joseph Forsyth of the New Mexico College of A&M English Department wrote the scripts.

Two new Aerobee rockets were developed during the IGY, the Spaerobee and the Aerobee Junior. The former (also called the Aerobee 300) was a two-stage vehicle with a Sparrow missile atop a standard Aerobee 150, developed by NRL in order to take a 50-pound package to a 300-mile altitude. The Spaerobee's initial flight took place on October 25, 1958 at Ft. Churchill, scarcely within the IGY time frame. The rocket, which was instrumented by AFCRL, reached an altitude of 260 miles.

Aerojet built 20 Aerobee Junior (also called the Aerobee 100) rockets with the expectation that a customer would buy them. The NRL purchased some of these, firing the first at WSPG in February of 1958. NASA and AFCRL purchased the remainder, firing the last one in 1961 (this was the only failure in the entire lot).

The Vanguard Story

Project Vanguard was organized when, in July of 1955, orders were issued to design and build a vehicle with orbital capability to launch one or more scientific satellites during the IGY.

President Eisenhower decreed that the hardware used to launch the United States' first satellite must be civilian- rather than military-developed. At that time, the NRL/Glenn L. Martin Company Viking was the United States' largest non-military rocket, proven with seven successful launches. Viking, therefore, would be modified and used as the first of a three-stage Vanguard Satellite Launch Vehicle (SLV) (Figure 53). The U.S. Army Ballistic Missile Agency/Jet Propulsion Laboratory (ABMA/JPL) team, directed by Werner von Braun, was ready to orbit its Jupiter/Explorer package in 1956 but was prevented from doing so by the White House, which did not want attention diverted from Project Vanguard. On October 4, 1957, the Soviets unexpectedly announced that they had placed a satellite (Sputnik I) in orbit. Political interests, then, rather than lack of technology, prevented the U.S. from being first in space.

The Soviets proceeded to launch Sputnik II on November 3. President Eisenhower set political concerns aside and authorized the ABMA/JPL to proceed with its launch attempt in December. On December 6, 1957, the Vanguard TV-3 lifted from its firing stand, rose a few feet, and exploded. The Army was enlisted to attempt recovery from this fiasco. Explorer I (which weighed 31 pounds), was successfully placed into orbit on January 31, 1958, with very little pre-launch publicity and fanfare, putting the U.S. back into the race.

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[23] In 1953, Dr. Sherburne and Jim Arnold had served as moderators on a program called, "Frontier to Space." This program, which aired live on the newly created El Paso television station KROD on Sunday afternoons, undoubtedly provided the basis for the IGY educational series.

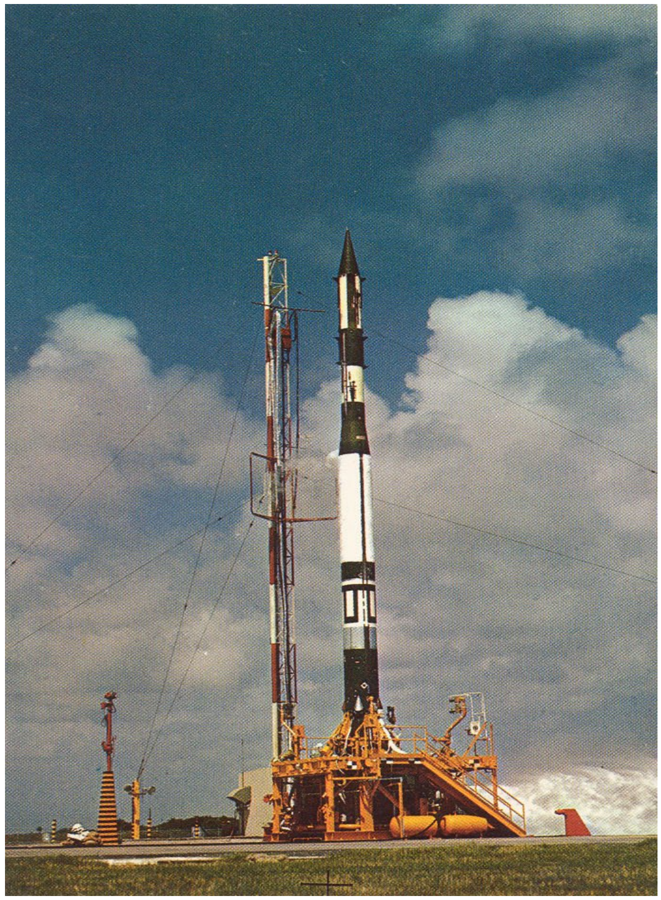

Figure 53. Vanguard Rocket

Two successive attempts to launch both the Vanguard and Explorer satellites failed (on February 3 and March 5). Finally, at 7:15 a.m. on March 17, 1958 (just two weeks after its second launch endeavor), the Vanguard was sent spinning around the earth at a height of over 100 miles, its transmitter working perfectly.

The March 17, 1978 edition of Spaceport News (Kennedy Space Center's newsletter) featured an article commemorating the 20th anniversary of Vanguard I. In summarizing the project, the article stated, "Project Vanguard people had, in record time—two years, six months, and eight days—developed from scratch a complete, high performance, three-stage launch vehicle, a highly accurate worldwide satellite tracking system, and an adequate launching facility and range instrumentation. And, specifically, they had accomplished their mission, which was to place one satellite in orbit during the International Geophysical Year" (the Vanguard launch team is shown in Figure 54).

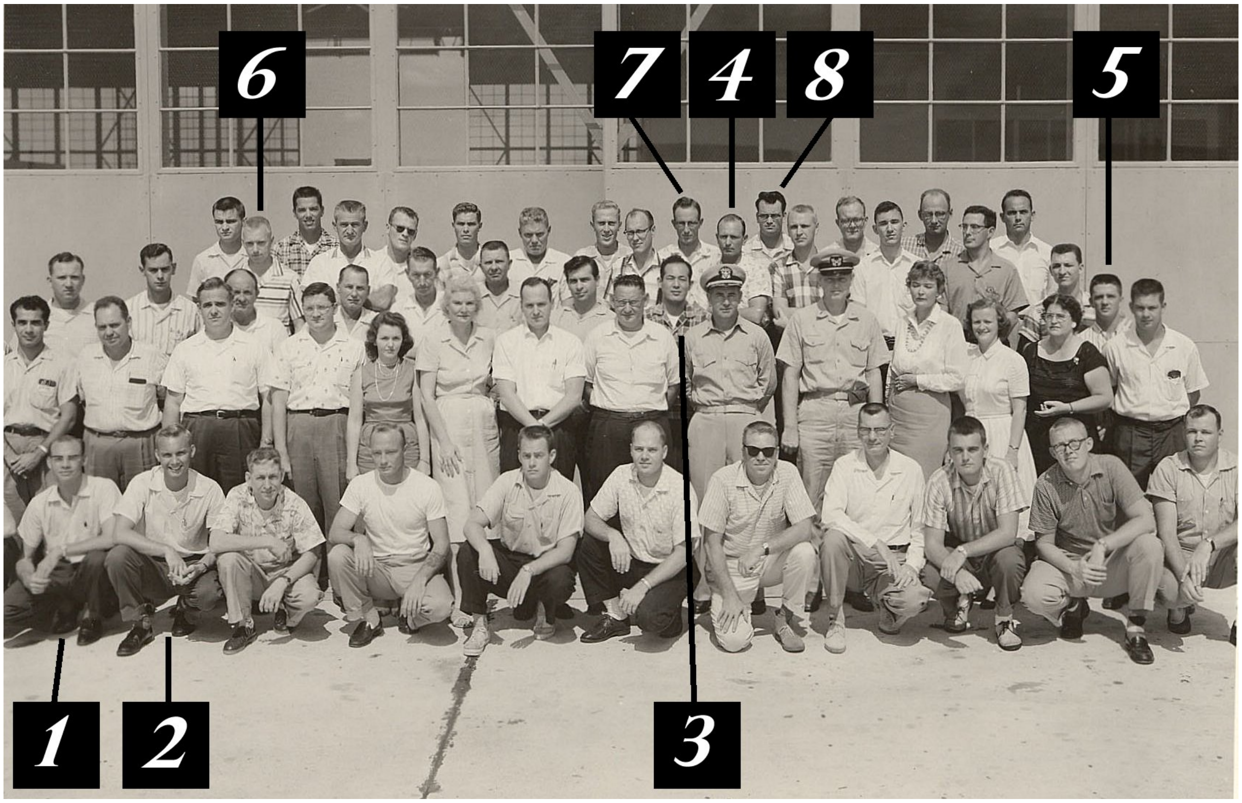

Figure 54. Vanguard Launch Team, NASA & Contractor Personnel [24]

Although Vanguard I was not the world's first satellite, it was the first to use solar power for its electronics. Sputnik I was battery-powered and its signal lasted only three weeks; Vanguard I far exceeded its predicted life span by transmitting until May of 1964—a period of six years (in fact, as more spacecraft crowded into orbit, its signals eventually became a nuisance).

As mentioned earlier, the NRL employees who were placed in management positions on the Vanguard project requested that PSL provide telemetry support at the Cape Canaveral launch site. This coincided with the request for PSL to provide telemetry support at Ft. Churchill (mid-1956). Although establishing crews to provide this support simultaneously at two remote locations presented some logistical problems (due to no previous experience doing so), PSL handled it successfully. Dan Mazur said that PSL operated three PPM/AM and two Pulse Width Modulation (PWM)/FM ground stations, which required 9-12 employees.

At this point, Mr. Ricketts suggested establishing a Lab-wide "instrumentation pool." This was a group of PSL employees with applicable experience that could be asked to travel on TDY to one of these sites to assist with peak workloads or to relieve someone who needed a respite in Las Cruces. Dr. Gardiner approved the idea, and it was implemented. Mr. Ricketts drew up a list of experienced personnel that were willing to travel (the list contained approximately 30 names).

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[24] 1 = W. F. Brininstool; 2 = R. J. Young; 3 = T. T. Noda; 4 = J. H. Davis; 5 = J. B. Cooper; 6 = R. B. Ratliff; 7 = R. A. Bumgarner; 8 = L. D. Williams.

The initial group selected from the instrumentation pool for a trip to Florida included Rick himself, Tom Noda, Orville Pace, James Cole, Robert Sabin, Bud Monjar, Logan Ritchey, Ernest Jiminez, and D'Wayne Sartin, a co-op student. Other co-ops that supported operations at Cape Canaveral included Gary Linsey, Bill Wood, Bob Jansen, and Mike Hankamer. Departing on August 27, 1956, the mission of this "advance party" was to install the five telemetry ground stations. Raymond Bumgarner, Theodore Thompson, Roger Ratliff, Valentin Orona, and Jerry Cooper arrived in late September, before Vanguard operations actually began. Mr. Ratliff was sent to handle the radar beacon flight units, after a late-hour request from NRL for this additional support. Mr. Bumgarner remained for two weeks, after which time he moved on to Ft. Churchill for two months.

Lodging was scarce and expensive in the Cape Canaveral area in those days. Mr. Ricketts solved the problem for himself and the crew by purchasing a new, three-bedroom house on Merritt Island. He furnished it with 9-10 single beds and kitchen appliances and collected $3 per night from each "tenant." It was a lucrative arrangement for all concerned, since, at approximately $10/day, commercial room rates (without kitchen privileges) were equal to PSL's per diem rate.

The PSL crew quickly encountered some of the problems inherent in building a launch complex in a "jungle." Three of the five telemetry ground stations were first installed in vans, which were parked on a hardened pad located amid that jungle several hundred feet from the blockhouse. It was necessary to run cables to each station through palmetto and other growth so thick that it was almost impassable on foot. The crew members dug trenches and laid these cables in the midst of rain, clouds of mosquitoes, enormous rattlesnakes, leeches, and salt spray from the ocean. For years afterward, technicians in the group spoke of how amazing it was to see Chief Engineer Ricketts operating a gasoline-powered trenching machine in that location.[25]

One PPM/AM station was installed in a small building erected specifically for that purpose. The other station was set up in Hangar "S," an aircraft hangar that had been donated for Vanguard project office and workspace. PSL's Antenna Section and Machine Shop manufactured the receiving antennas for all of these stations. Each was a large helical array (known as a tri-helix), consisting of three eight-turn helical elements mounted on a hexagonal-shaped ground plane (PSL had previously built a few of these for use at WSPG). Motor-driven, remote-controlled mounts for these antennas were purchased. The PSL field group spent several weeks assembling the antennas and mounts, having them painted with special corrosion-resistant paint, and installing them at the various sites (Figure 55).

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[25] Cape Canaveral was part of Patrick Air Force Base, which had a base maintenance contract with Pan American Airways; consequently, ditch-digging was supposed to be accomplished by Pan American employees. However, because labor disputes were frequent, one of Pan American's many unions (for electricians, painters, carpenters, and plumbers) was often on strike when Project Vanguard work was required, resulting in a great deal of "do it yourself."

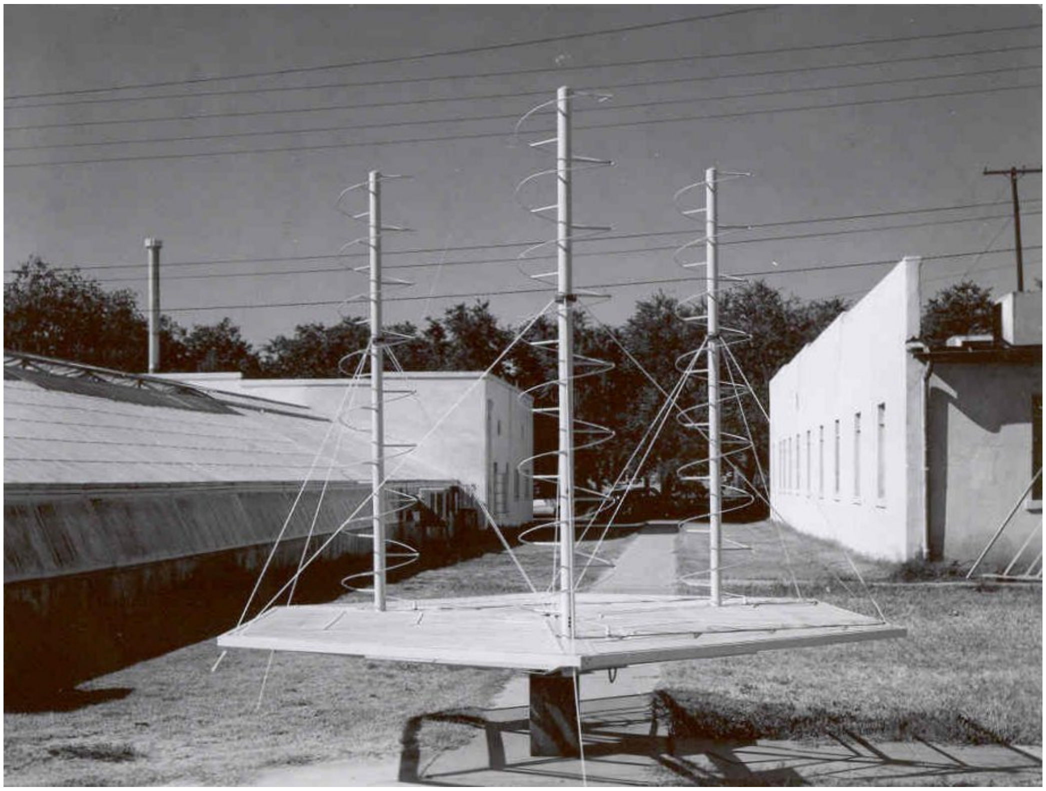

Figure 55. PSL-Built Tri-Helix Receiving Antenna for Vanguard Telemetry Station, 1958

The first rocket launched for Project Vanguard was the Viking 13 (newly designated as Test Vehicle (TV)-0). The firing occurred while Raymond Bumgarner was in Ft. Churchill in November of 1956. The launch was apparently successful, although no records of the event have been located. Afterwards, most of the PSL group returned to New Mexico for a reunion with their families and a change of climate (several of them would later become members of a permanent field group in Florida, where they would buy homes and raise their children).

The TV-0 flight apparently demonstrated the requirement for down-range coverage, and PSL was asked to staff a PPM/AM ground station on Grand Bahama Island (GBI) for subsequent launches (GBI was the primary down-range instrumentation site for the Atlantic Missile Range (AMR)). This resulted in installation of more equipment racks and another tri-helix antenna, assigned to Mr. Wagner, Mr. Noda, and Mr. Cole in January and February of 1957.

TV-1 (Viking 14) was flown successfully on May 1, 1957. The launch team was comprised of Rick Ricketts, Raymo Bumgarner, Bob Wagner, James Cole, Roger Ratliff, Mr. Howell, Ray Young, Bill Mallar, Jerry Cooper, Theodore Thompson, and Orville Pace, along with new hires Leon Miller and William ("Bill") Dodson, a student. Robert Sabin, Tom Noda, John Cross, Valentin Orona, and Don Brown assisted with the preparations but left prior to the launch. Dr. Gardiner traveled by train to attend three days of TV-1 testing (this is the only time he is known to have visited a PSL field site other than WSPG). Once again, the PSL crew returned to Las Cruces four days after the firing except for Mr. Cole, Mr. Young, Mr. Thompson, and probably Mr. Ratliff.

TV-2, Vanguard's first brand-new test vehicle, arrived at Cape Canaveral in late July. Raymond Bumgarner, Orville Pace, Ted Arellano, and Bob Abbott drove to Florida in two PSL vehicles; Tom Noda and new hire Fred Lemon brought their families in personal vehicles. Preparations began immediately for the static firing, scheduled for August 10; however, it was delayed by a succession of launch vehicle problems (for example, TV-2 arrived at Cape Canaveral from the factory without its roll-control system). Static testing, which was attempted a total of nine times, was finally successful on October 10. In the interim, there was a great deal of travel to and from New Mexico, since most of the crew had been away for two or three months. Mr. Bumgarner flew home, drove his family to the Cape, and moved into the new home he had purchased in the village of Merritt Island.

> Ted Arellano and his wife Dellia used to invite the Cape Canaveral co-ops over to their house for enchiladas on a regular basis. He said that the first time they did this, Dellia had to call her mother back in Las Cruces in order to get the recipe.

Amidst the difficulties with TV-2, Sputnik I was launched on Friday, October 4 (although the crew didn't become aware of this until the next day). Alton Jones and other NRL personnel went to the hangar that day and devised a means of receiving Sputnik's signal. Needless to say, TV-2 preparations received little attention on Monday, October 7, since the priority was to attempt to decipher any data that Sputnik might be transmitting (the signal turned out to be a simple pulsed carrier with no apparent intelligence). When mixed with a beat frequency oscillator, the "beeps" were audible and the Doppler effect could be heard as the satellite passed overhead—the very first signal from an orbiting object.[26]

Despite numerous pre-flight problems, TV-2 fulfilled its flight objectives on October 23, 1957. Entries in Raymond Bumgarner's flight journal describe some of the difficulties encountered, including a malfunctioning plotter board and regulator and DOVAP and beacon interference.

Preparations became intense, with only six weeks remaining before TV-3's scheduled (and much anticipated) launch date of December 4. Immediately after the Soviets launched Sputnik II (on November 3), the Vanguard Project Director had received orders from President Eisenhower to launch "a baseball in December and a basketball in March." PSL notes indicate that the NRL and PSL crews worked many nights in November, including Thanksgiving Day. The first firing attempt on December 4 was canceled due to winds and various rocket problems. As mentioned earlier, TV-3's second firing attempt failed on December 6 (perhaps the explosion on the launch pad was at least partially due to the effects of this compressed schedule on personnel). "Veterans"

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[26] APL scientists, who were also recording those beeps, consequently invented the Transit navigational satellite system. They also quickly realized that satellite signals could be used to precisely determine the shape of the earth (see, "The Origin of SGI" in this chapter).

Raymond Bumgarner, James Cole, Valentin Orona, Ray Young, Jerry Cooper, Theodore Thompson, Orville Pace, Don Brown, Roger Ratliff, and Ted Arellano supported the TV-2 launch, along with new hires Ed Mayfield, Don Peterson, and Joe Otero. Mr. Arellano and Mr. Mayfield returned to WSPG and, in response to a request from Alton Jones of NRL for additional assistance, Tom Noda, Ernest Jiminez, Eugene Lee, James Davis, and Rick Ricketts arrived to support the TV-3 launch.

After the TV-3 launch, PSL was advised that its satellite support would be required through mid-1958 (at least), with 15 people required for each launch. TV-4 testing began immediately, but the majority of the field group traveled to Las Cruces in the interim. Mr. Ricketts remained as supervisor, and Raymond Bumgarner spent January and February at WSPG.

As mentioned earlier, TV-4 placed the Vanguard satellite (the "baseball") into orbit on March 17, 1958. This was a small softball size satellite.

TV-5 was then prepared to launch the "basketball," a 20-inch diameter satellite named Vanguard II. It roared off on April 28 and all went well until, when the time came for third stage ignition, nothing happened. The Vanguard II ended up on the ocean floor.

The next Vanguard rocket was given a new name, "Satellite Launch Vehicle" (SLV). SLV-1 was launched successfully May 27, 1958. PSL notes regarding this firing are very sparse, but it appears that the Vanguard II satellite was successfully placed into orbit.

The SLV-2 launch on June 25 was a failure—its second stage burned erratically for eight seconds, then was shut down by the automatic cutoff system. The first attempt to launch SLV-3 on August 16 also failed when automatic cutoff occurred at ignition. On September 26, a second launch was attempted. SLV-3 lifted off, but a second-stage malfunction resulted in mission termination. Raymond Davis, on loan from the APL Telemetry Section, received his Florida swamp initiation on this mission.

The forming of NASA in October of 1958 created questions about the future of PSL's involvement in Project Vanguard. NASA was officially chartered on October 1, and the Vanguard group, comprised of 150 people, transferred from NRL to NASA on November 16. In April of 1959, PSL was informed that Dan Mazur would head NASA's Satellite Applications Systems Division. In May, it was decided that the Florida Vanguard Project would be part of Mr. Mazur's division and that PSL's services would be required to support it.

In 1959, four more SLV launches were attempted, with one success that placed the Vanguard III satellite into orbit. Project Vanguard came to an end and was replaced by the Delta program, under which the NASA and contractor teams remained throughout the 1960s (see Chapter 5).

The Big Blast

It was challenging, interesting, unusual, and unlike any project PSL had attempted before; in fact, it was quite far-fetched. But, in early 1951, the Laboratory was seeking to acquire more research contracts (in order to provide more work on campus) and was ready to attempt almost anything, including simulating the blast effects of an atomic bomb.

On January 15, 1951, the Sandia Corporation in Albuquerque (under the sponsorship of the Atomic Energy Commission (AEC)) issued a purchase order to PSL covering a one-year period. The purchase order called for an investigation of all possible means of producing a blast wave in the air with the approximate pressure-versus-time characteristics of the blast from an atomic bomb at a distance of one mile from ground zero. The AEC wanted this type of system in order to test the effects of an atomic blast on structures. The spatial extension of the wave was to be such that it covered a frontal area 10 feet high by 35 feet wide, and the depth was to be reasonably uniform for a distance of 10 feet. The positive pressure duration was to be on the order of 100 milliseconds. PSL's AEC Group, headed by James Arnold and including C.W. ("Bill") Williston, J.F. Arndt, R.E. James, Harold Connell, Richard ("Dick") Barron, Phil Manz, Robert Chamberlin, J.W. Field, Lee Kimmons, and W.F.C. Smith, performed this investigation. The project continued for two years (a one-year extension was granted in January of 1952).

According to Gil Moore, Jim Arnold, who had served as a Navy underwater demolition frogman in the war, possessed extensive training and experience for this project. Gil was still in charge of the Telemetry Reduction Group, but became Jim's apprentice in order to learn the finer points of explosives handling.

Mr. Moore said, “Jim Arnold and Bartell Williams were both looking for interesting research projects for PSL to get involved with. Bartell was working on flame combustion studies—how flames were formed, the flame front, and so on. Both of these fellows were gentlemen and were senior scientists at the Lab (though Jim was not that much older than I was). Jim was in charge of the Blast [Wave] project, and he was teaching me about the use of explosives in a way that strictly emphasized safety. He was the only one in the Lab that really understood them. Jim was very 'fussy' about handling explosives, and he did not let me do anything with them without him being right there [to show] me how. He insisted on doing the primacord setup on the blast tubes himself. He would carry a radio to the site (while I remained away), and he would tell me exactly what he was doing during the detailed process of preparing the tubes for the test so that, if anything bad happened, we would know what might have [caused] the mistake. He let me do some shooting on my own with quarter pound blocks of TNT. I would put the blasting cap in, light the fuse, and get away. The first time I did it, we backed off about 100 yards, but I quickly learned that it was too close because the blast, ‘darn near knocked me off my feet'. Fortunately, there was only the raw explosive with no shell to fragment. I had a ‘Q’ clearance for the AEC project; that and the explosives experience gave me an entry into another small, interesting project that followed with a 'mad' scientist at Sandia [National Laboratories].

“Jim told me about a interesting 'light bomb' that Harold Edgerton had developed, and there was a scientist at Sandia who was interested in 'illuminating' the blast stages of high explosives with a very bright and intense light source. I don’t remember his name, but he really looked [like] and acted the part of a mad scientist. I talked to Mr. Edgerton on the phone, replicated the device, and then worked with our Sandia contact to try to help him get some results. This device was quite simple—it was a small glass funnel with some primacord knotted at one end dropped through the narrow end of the funnel and C3 powdered explosive filling the rest of the funnel (the primacord blocked the escape of the explosive powder through the narrow end). Warm wax was deposited on the top rim of the funnel, and a domed glass cover with a small glass tube in the top of it was mated to the funnel rim when the wax was flowing and then allowed to bond to the funnel as the wax cooled. A rubber tube was placed on the glass tube and Argon gas was flowed through the inside of the funnel and the explosive. I would set off the primacord, which would create a shock wave in the Argon. When it collapsed to neutral, it “would fire off a tremendously bright flash (500,000 candlepower or very large anyway), but a very, very brief one. Standard film emulsions of that period would not be able to react to the short flash, so results were disappointing on this project. One of the early shots was set off behind the Manzano Mountains at night, and the bright flash bounced off the Naranja Mountains behind the Manzanos and lit up the sky (it could be easily seen in Albuquerque). Everyone in Albuquerque knew what was in the bunkers in the Manzanos, so the Kirtland switchboard was flooded with calls expressing concern over the nuclear warhead stockpile there all 'going off."’ Mr. Moore speculated that these little light bombs might be very useful today—UAVs could drop them at night in areas of interest and image the entire region with more modern electronic imaging systems that might be able to capture the very bright, very short, light pulse.

The first year's effort consisted of studies or actual trials using the following blast techniques:

- Line charges
- Arrays of charges
- Directed waves from reflectors, etc.
- Slow-burning fuels
- Shaped charges
- Compressed air

Since the compressed air blast technique appeared to be the most promising, the second year's effort concentrated on developing and testing this concept. A small blast test facility had been constructed in the desert east of the campus at the beginning of the project. This facility was used to determine that the sudden release of compressed air from an end of a large, elongated tank produced the desired 100-millisecond blast duration. Release of the air was accomplished by bursting (via primacord) an aluminum diaphragm in the end of the tank.

The facility was then improved for larger scale tests. The conclusion was reached that a large blast wave front could be produced by the use of multiple tanks with simultaneous release. Nine tanks 15 feet in length were fabricated by the PSL Machine Shop using 20-inch diameter steel pipe, with welded ends of steel plate and an eight-inch hole in one end for the diaphragm. The tanks were mounted in three horizontal rows of three tanks each, supported by a massive framework of steel beams anchored in concrete piers (Figure 56 shows the structure, diaphragms, and primacord). The structural design provided for shifting the position (or alignment) of each tank to allow aiming the nine blasts into a converging, parallel, or diverging pattern. A concrete ramp was added in front of the structure to minimize dust and provide a mounting base for pressure gauges.

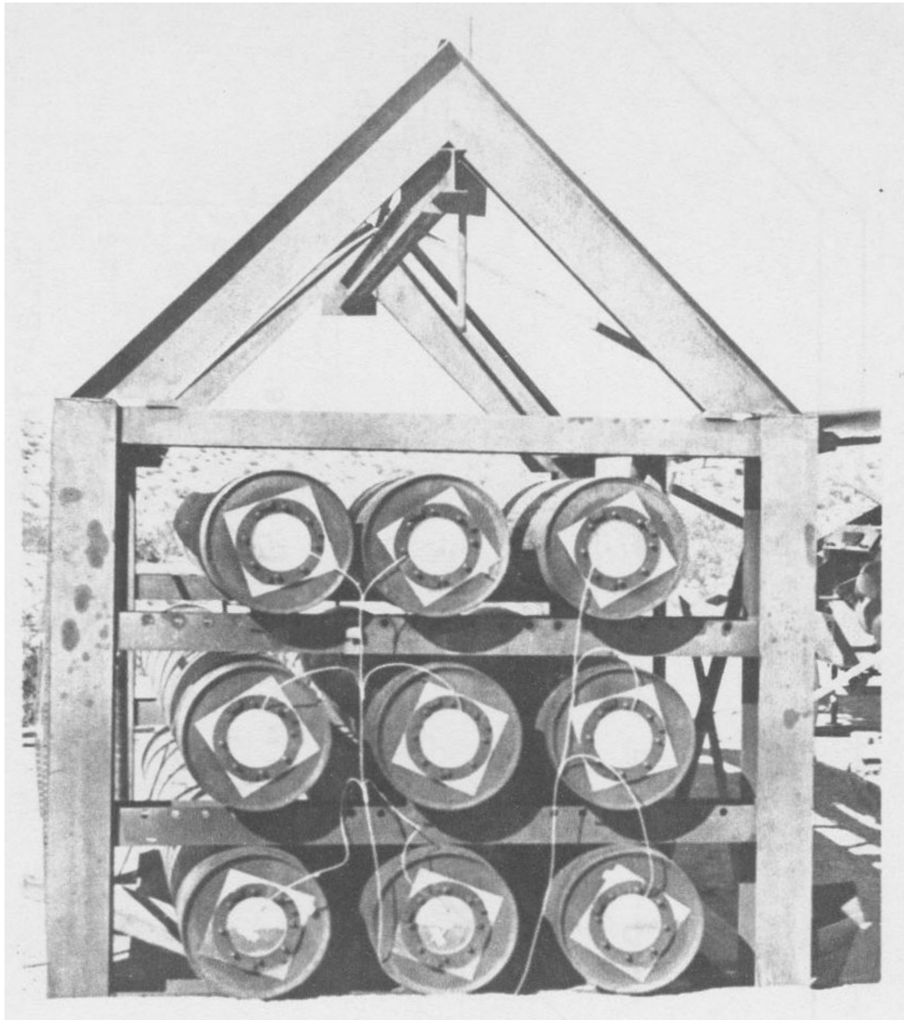

Figure 56. Blast Wave Generator with Air Tanks, Support Framework, Diaphragms, and Primacord, 1952

Hundreds of "shots" were accomplished with this equipment in an effort to reproduce the desired pressure versus time gradient. Although various pressures up to 150 psi were tested and the number and alignment of tanks varied, the desired result was never achieved.

Nozzles were then added to the tank outlets to provide more blast directivity, but this resulted in unwanted pressure wave oscillations (the reason for this was never determined). PSL's conclusion was stated in Jim Arnold's final project report to Sandia Corporation: "There are reasons to suspect that the desired blast cannot be reproduced in free space without the expenditures of an excessive amount of energy."

Dick Barron described the immense energy in that blast of air as follows: "That compressed air was really very scary. We didn't realize what we were dealing with until Dr. Gardiner came out one time to see what we were doing. To give a little idea of how much blast there was, we took a sheet of old armor plate like they used in aircraft—roughly 3/8 or a little thicker steel—and just propped it up out there well away from the pad, just to see if the blast would knock it down. Well, we were totally unprepared for what happened. It flipped that piece flat like we expected, but then [the sheet] took off through the air. It cleared that huge arroyo that used to be out there, came down and bounded along, spinning on the edge...it was two or three tenths of a mile to where it hit the ground; from there it continued 8/10 of a mile down there (we measured it with a Jeep). Then, it turned a little bit and took another course, and went another 3/10 of a mile on up there. We couldn't believe it! We had been planning to set up our cameras for the next shot at about where that piece of steel was, but after that experience, we sure didn't do it.

"Another thing—by the time you pumped that up, [there was] a relative humidity of 100% inside the tank. When that stream of air would come out of there, it was expanding so rapidly that even in the dry summer we had that year, we could see it because it would be full of frost. Any wires that were left hanging there [had] ice all over them and…still had ice…five minutes later."

The power discharged by those air blasts was further demonstrated when the pressure was initially set at 140 psi. Shot 456 caused severe stress on the steel framework supporting the tanks—the vertical 10-inch I-beams were bent back and several of the cross-bracing segments had buckled. In addition, the rear concrete piers moved in the ground (Figure 57). Heavier bracing was added, enabling the blast generators to withstand shots at 150 psi.

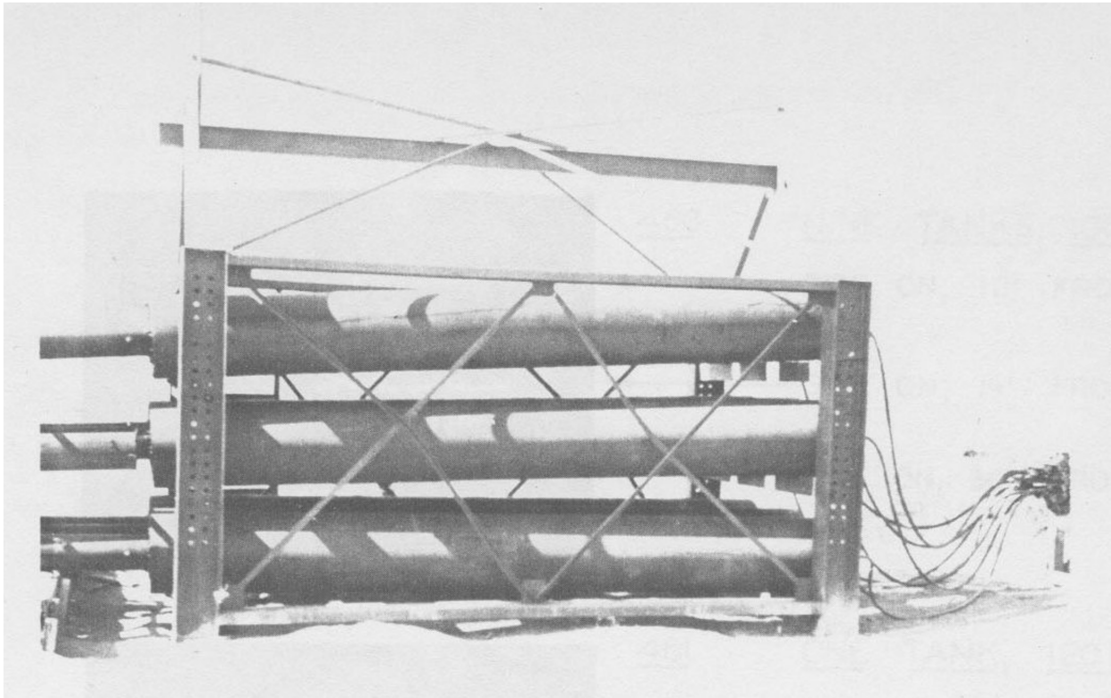

Figure 57. Structural Damage to Blast Generator

Antennas and More Antennas

As mentioned in Chapter 3, Leonard Gough (under the APL contract) developed the telemetry and cutoff notch antennas for the Aerobee rocket, which resulted in the creation of PSL's Antenna Section. The Section rapidly became engaged in design, development, and production of both airborne and ground-based antennas for national space and defense efforts, concentrating primarily on telemetry antennas in the 1940s and 1950s.

The first official Antenna Section Chief was Dr. Ralph Dressel, who served in that capacity from 1950—1955. At that time, Dr. Richard Duncan assumed leadership of the newly renamed Electromagnetics Section and initiated research into the theory of linear antennas and associated problems dealing with mutual coupling, current distributions, impedance, etc.[27] By 1957, the Section consisted of Dr. Duncan, Herbert Haas, Cecil Post, Harold Smith, and Tate Tatreault. Student personnel included Dennis Henry and Henry Weinschel, who later became permanent staff members.

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27 During the period in which he was Chief of the Electromagnetics Section, Dr. Duncan independently researched and wrote, <u>Exact Mathematical Solution of the Characteristics of the Dipole Antenna</u>. The mathematics that he used to achieve this solution can be applied to many other sophisticated problems. The research conducted by Dr. Duncan has provided PSL with a great deal of visibility among those in the aerospace electromagnetics industry.

By the end of the decade, the level of activity had increased significantly, especially in the development of practical VHF, UHF, and microwave antennas, and in research concerning ionization and electron multi-paction breakdown of antennas in a vacuum and near-vacuum.

In the mid-1950s, Staff Engineer Herbert Haas was asked to develop a telemetry antenna for NRL's Vanguard Project, a VHF antenna with minimum aerodynamic drag for use on the first stage of the satellite launch vehicle (notch antennas were not suitable for this particular airframe). As a result, Mr. Haas invented a very capable and effective antenna known as the "Quadraloop" (Figure 58). These antennas, which are omni-directional, resonant-tuned, multi-band units with a frequency range up to S-band, have since been flown on a wide variety of rocket vehicles, and are still widely used today. Mr. Haas was granted a U.S. patent jointly with Section Chief Dr. Ralph Dressel.

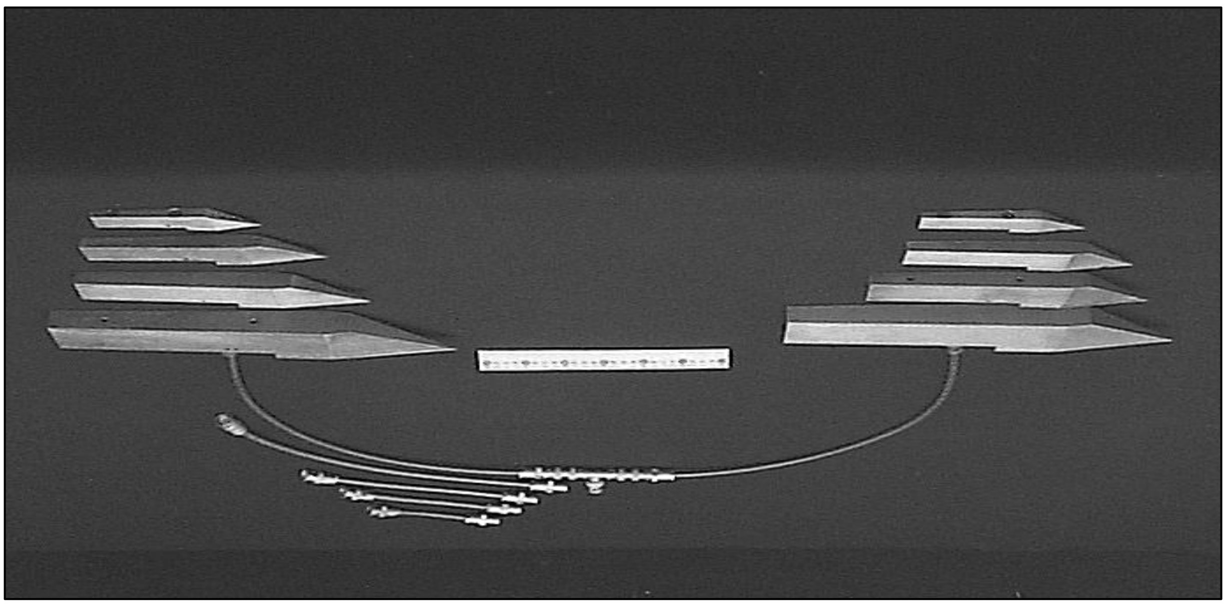

Figure 58. Quadraloop Antenna for Mounting on Skin of Rocket Vehicles, Late 1950s

The first Quadraloops were manufactured by the Glenn L. Martin Company (builders of the Vanguard first-stage vehicle) for use as telemetry transmitting antennas in the 220 Mc band. This stage carried two telemeters—one PWM/FM unit and one PPM/AM unit (the same type used on the Viking rockets at WSPG). The PPM/AM system experienced antenna voltage breakdown, causing considerable loss of vital data on certain Vanguard flights (particularly TV-4). PSL researchers determined that:

- A pulsed RF signal is much more conducive to breakdown than is a continuous wave
- Breakdown worsens as spacing between the RF pulses narrows
- Lowering the output of the 40-watt transmitter to 10 watts greatly reduces the breakdown; lowering it to four watts essentially eliminates the problem

Further benefit resulted from widening the spacing between the three-pulse synchronizing group and the first data pulse on the PPM transmitter. Vanguard SLV-3 was launched with the four-watt transmitter, and no data were lost during the Stage 1 flight.

The Quadraloop's breakdown characteristics were further enhanced so that higher transmitter power could be used. Reliable results were achieved by addition of a Teflon cuff surrounding the sides of the external notch; transmitter power could be increased by 40% with no data loss.

In 1953, PSL's antenna research capabilities were greatly enhanced when the Laboratory's first experimental Antenna Measurement Range was constructed. It was located just west of the present NMSU golf course (a new, modern range was erected further east in 1962, as will be seen in Chapter 5). The range was used initially to conduct measurements on X-band radar for APL/JHU; it was later used to test a variety of antennas, including Quadraloops, notch antennas, helical arrays, etc. The installation consisted of three structures—two small wooden buildings supported on towers and a third small building mounted on skids (Figure 59).

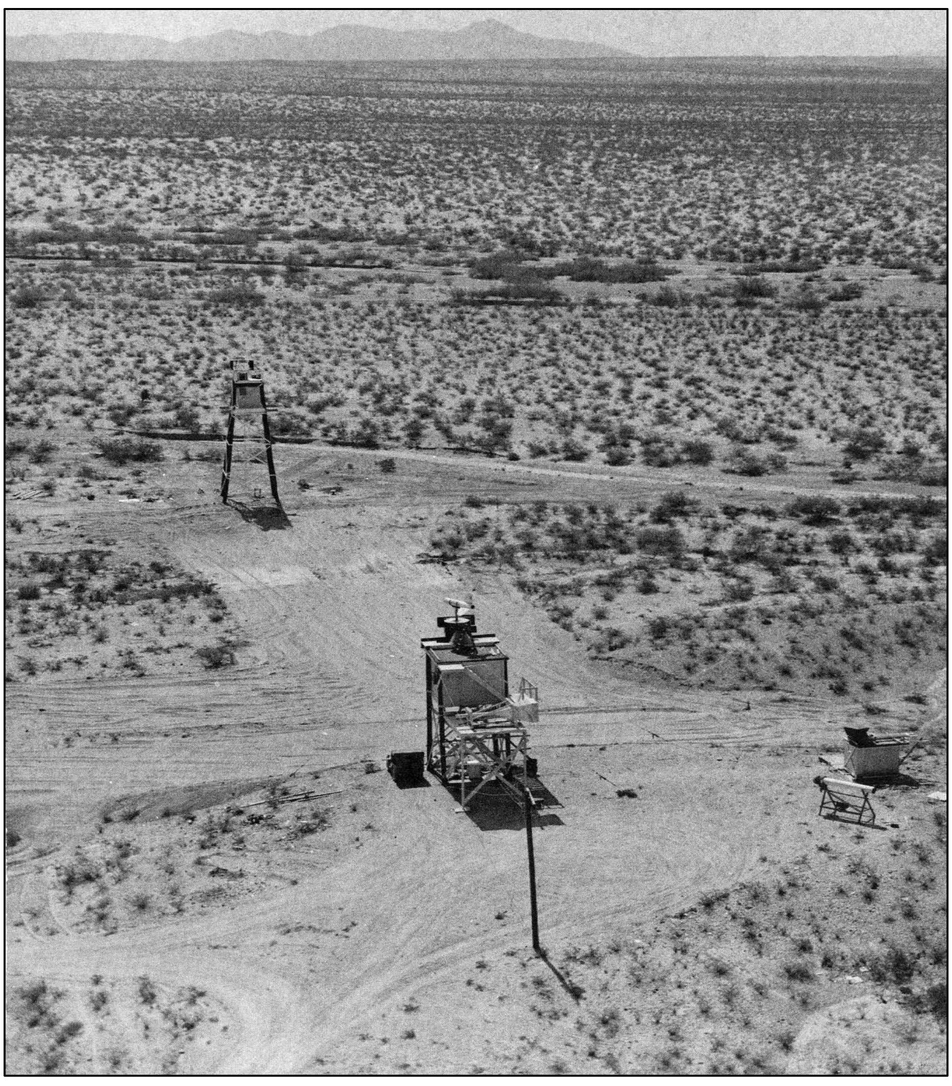

Figure 59. Aerial View of Antenna Range from north, 1955 [28]

The North Tower (which was located on the north bank of the Tortugas arroyo) housed instruments for recording antenna radiation patterns. A rocket vehicle mounted on a rotating mechanism (an old SCR-584 radar mount) above the roof of this building was used to determine exactly how much signal would be transmitted in all directions from a rocket-borne antenna. This was accomplished by rotating the entire rocket 360 degrees in azimuth, and roll adjustments were manually made while a fixed receiving station monitored and recorded the signal strength. This fixed receiving setup was located in the North Tower, which can be seen in the foreground in Figure 57. The South Tower housed the transmitters which were usually General Radio “unit oscillators” and this tower was 346 feet south of the North Tower (background of photo). PSL-constructed, full-sized mock-ups (rather than genuine rockets) were usually employed for obtaining the measurements. Scale models were used for pattern tests in cases where the rocket or spacecraft was too large and cumbersome to handle in this manner. The West Instrument Building (located at the right-hand side of Figure 59) supported a small rotator for model and small antenna pattern measurements. This structure could be easily moved to provide various propagation path lengths. The rotator was controlled remotely from the central tower. Close-up views of the three buildings are provided in Figures 60 and 61.

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[28] The North Tower in the foreground, the South Tower (transmitters) is in the background, and the Rocket Vehicle is mounted on the rotator.

Figure 60. PSL's Early Antenna Range Central Instrument Building (left) and West Instrument Building[29]

[29]The small model rotor on roof with model missile is in position for antenna pattern tests.

Figure 61. Antenna Range South Tower[30]

In 1956, John Mengel and Dan Mazur of NRL asked Dr. Duncan for PSL to design, construct, and install a network of fixed antennas for tracking satellites at sites all over the world. PSL's system, called "Minitrack," was anything but small—each array, consisting of horizontal aluminum girders, measured approximately 25 X 50 ft. (Figure 62). Eight of these arrays were arranged at each of 14 sites such that they constituted an interferometer system capable of determining the azimuth and elevation of a transmitting satellite at any given time. Each station also employed five ambiguity antennas that, in like manner, required precise positioning.

[30] Forty three feet to the top platform; transmitter and instrument Room at 32-foot level.

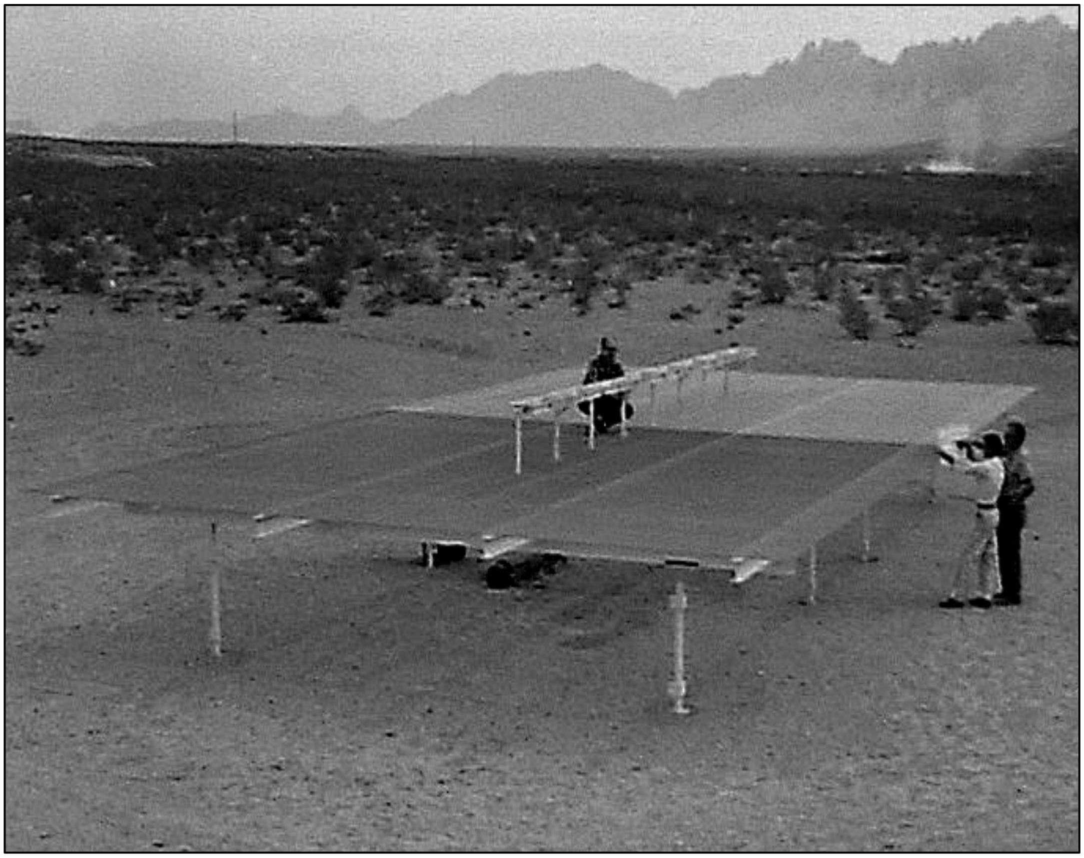

Figure 62. Minitrack Antenna Array Located East of Campus, 1959 [31]

The Minitrack antenna was designed by Wes Joosten, Cecil Post, and Louis ("Lou") Snow. Dr. Duncan was involved in the design as well, providing guidance for the mathematical calculation of the very sophisticated feed system used on this antenna. PSL built a prototype antenna, which was positioned in the desert east of the campus for testing to obtain its power distribution pattern. Since the prototype was too large and heavy to mount on the antenna range rotator, it was necessary to move the signal source around and over the fixed antenna. This was accomplished via a rented airplane (piloted by Phil Manz), into which a transmitter had been installed. Lou Snow said, "We had to do a lot of waiting to get a day and hour when winds were not a problem. The tests proved satisfactory, and Mr. Mengel and NRL were quite happy with the outcome."

PSL performed the original Minitrack design at the request of NRL's Dan Mazur. When Mr. Mazur moved to NASA shortly after the antenna was created, the contract was transferred to that agency. PSL retained this contract with NASA for over 25 years. Cecil Post represented NASA at a bidder's conference in Washington, D.C., after which NASA contracted with the Technical Appliance Corporation (TACO) of New York to produce the antennas. Mr. Post and others conducted in-plant acceptance testing of the production models.

[31]Bronson Woods is on the antenna; Eddie Shannon (front) and Lou Snow are on the ground.

After 112 of these massive aluminum structures were installed around the world (eight per site), one PSL engineer and two technicians would visit each site every two years to tune the antennas and refurbish the RF cables and connectors. Lou Snow said that they would alternate servicing sites in the Americas with all others. He also said that the soil was unstable enough at some sites that the antennas would shift position, requiring that they be surveyed again (it was necessary that all eight ground planes be within 1/4 inch of the same level). The 14 locations were:

- Fairbanks, Alaska
- Woomera, Australia
- Goldstone, California
- Antofagasta, Chile
- Santiago, Chile
- Quito, Ecuador
- Winkfield, England
- Ft. Myers, Florida
- Tananarive, Madagascar
- Blossom Point, Maryland
- East Grand Forks, Minnesota
- St. John's, Newfoundland
- Lima, Peru
- Johannesburg, South Africa

After the Minitrack had been in operation for several years, NASA discovered that adequate tracking could be accomplished with fewer stations and closed those at Antofagasta, East Grand Forks, Lima, and Blossom Point. PSL continued to calibrate the antennas until the late 1970s, after which time that function was turned over to the station operators.

According to Lou Snow, the Tananarive station, along with its antennas, was dynamited during a Communist takeover. The Quito station, located on a mountain top at an elevation of 11,000 feet, experienced problems with the llamas that were kept there to "mow" the grass. Apparently the llamas would rub their backs on the antennas and nibble on the RF cables, necessitating numerous repairs (Figure 63).

In addition to the three engineers mentioned earlier, personnel involved in the Minitrack contract at various times were Herbert Haas, Dr. Richard Duncan, Phil Manz, Mike Sanchez, Dennis Henry, Alexander Waterman, Eddie Shannon, Albert Anglikowski, David Paul, Roy Krinitz, Gus Johnson, Joe Diehl, William Cooper, Robert Littau, Bobby Stout, Oscar Lytton, John Litton, Bronson Woods, and Robert Lanphere, among others. Jerry Smith and Paul Vercher were among the numerous students.

Figure 63. Llama at Worldwide Minitrack Antenna Site (Quito, Ecuador)

The Minitrack stations are no longer in use, replaced by modern and sophisticated tracking systems such as the Tracking Data and Relay Satellite System (TDRSS) used by the NASA Johnson Space Center at WSMR. A Minitrack antenna is currently on display at the Space History Museum in Alamogordo, New Mexico.

PSL's contract with the Air Force Cambridge Research Center (AFCRC) in January of 1956 specified development of Quadraloop and notch antennas for the Aerobee HI and a radical new concept for a small-diameter rocket antenna. The latter resulted in the split-missile antenna, a system wherein the fore and aft portions of the rocket body (separated by an insulating disc) act as the radiating elements of a dipole antenna (Figure 64). It is possible to pass circuit leads through the insulating disc without affecting its operation. This antenna proved to be quite effective and was provided to the Air Force and to the majority of other users of the Cajun and Nike-Cajun sounding rockets. Richard Duncan, Herbert Haas, Handy Fairchild, Phil Manz, and Ramon Maruffo were involved with this project.

Figure 64. PSL-Developed Split-Missile Antenna

PSL procured another state-of-the-art development project, the slotted cylinder antenna, for the Sandia Corporation in 1956. AFCRC was also interested in slot antennas, sponsoring development of a three-slot array to be incorporated into Aerobee nose cones. A nose-tip antenna (a quarter-wave stub) was also developed for the Aerobee under the Air Force contract.

A patent was granted in 1959 to James Arnold, Ralph Dressel, and Herbert Haas for a microwave antenna feed. This was a rear feed for paraboloid reflectors (often referred to as “dishes”) designed especially to produce a circularly symmetrical pencil beam with low side lobes (Figure 65).

Data Processing Way Back When —

The distinction between the terms, “data processing” and “data reduction” can perhaps best be understood by viewing the reduction of data as one step in the processing of that data. For example, “processing” might include the playback of magnetic tape records to produce oscillograph strip charts. The data are “reduced” when second-by-second displacements of the lines on this strip chart are tabulated on paper as columns of numbers. As a second example, the “processing” of missile data would include the developing and copying of the film that recorded the missile image, “reducing” the data by translating the parameters of the missile image to numbers on paper, and analyzing the data.

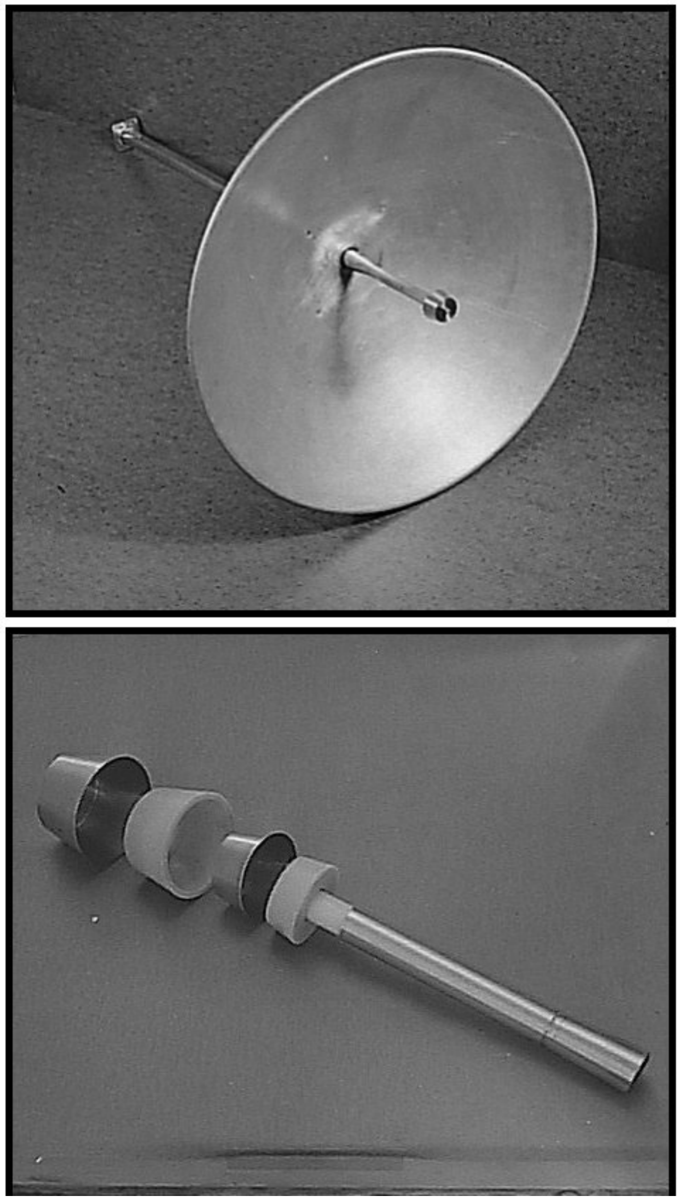

Figure 65. PSL-Developed Microwave Antenna Feed, 1959 (Feed Installed in Top Photo)

As mentioned earlier, PSL became involved in ballistic data reduction under Anna Gardiner and telemetry data reduction under Harold Brown, which continued through the 1950s. At the end of the decade, Mrs. Gardiner's group was referred to as the Ballistic Reduction Section. Keith Hennigh supervised the other group, referred to as the Telemetry Processing Section. By 1959, both sections were providing substantially more than just data reduction services, as described below; the combined effort was aptly referred to as data processing.

Ballistic Reduction

PSL considerably expanded its data processing capabilities in the 1950s, a decade of sweeping automation. Anna Gardiner's Ballistic Reduction Section acquired a significantly larger working area, as well as a computer.

The Section's new and larger workspace came about when, in 1954, the College erected a new library building, Branson Hall. Since the top floor of the three-story building was not to be utilized for a few years, PSL was permitted to use this 10,000 square feet of empty space. Political and fiscal details regarding permission for this are unknown, but PSL provided partitions and finishing touches, and Mrs. Gardiner's group moved from the PSL annex to the library, occupying several rooms. The Telemetry Reduction Section's tape playback station was also moved to the new location.

Bob Skaggs, who was a student employee in Anna Gardiner's Ballistic Reduction Section from June of 1954 to August of 1958, said, "I worked first in the [Air Mechanics] building for about a year, and then we got the top floor of the library. I worked there for the next three years while taking a full load in ME. I started out at about 50 cents/hour before I even entered college as a freshman, and when I finished in August of 1958, I believe I was one of the highest paid undergraduate students on campus."

Mr. Skaggs said that approximately midway into his third year, his group began reducing data by placing punched cards in a deck and running it through the IBM card program calculator time after time. Walter Haas was one of the programmers.

After the computer, an IBM "Type 650 Magnetic Drum Data Processing Machine," was delivered in August of 1957 (Figure 66), the quantity and complexity of data managed by the group increased dramatically. According to Mrs. Gardiner, another machine actually preceded the 650. "Before we got the IBM 650, we had a Card Programmed Calculator (CPC) (also by IBM) which consisted of a bookkeeping machine, an electronic unit, and several mechanical memories. You may remember seeing it at one of the Christmas parties—those mechanical memory units clanked beautifully and the bookkeeping part printed out carols and Santas for all." Ray Chavez noted that, "the CPC was a tube- and relay-based unit that, though probably ten times faster than the hand calculations, had to be monitored closely during processing. Several times the tubes went out or the relay contacts malfunctioned, and the whole run was no good."

Programs for the IBM 650 were written by Section personnel to perform all but one of the computations used in the film reduction. Numerous programs were written for special data computations for the Army at WSPG and for other PSL sections and College divisions. For example, 68,000 cards containing 1896-1957 weather data for New Mexico were punched and verified for the Agronomy Department. An extensive statistical study of southwest sheep marketing conditions was also performed.

Optical comparators capable of five-micron (five millionths of a meter) accuracy were used for the majority of the film reading (Figure 67). Also in use were a Zeiss stereo comparator, and two comparators for measuring ballistic camera plates at one-micron precision. Two comparators were equipped to transfer digitized output to IBM cards. Other equipment included three keypunches and a front projection telereader, verifier, copier, and sorter.

Figure 66. IBM 650 Computer

Despite this high degree of automation, a great deal of the work was still performed manually. Desk calculators were used for computation along with the computer, and manual measurements were taken from oscillograph records to obtain a plot of the radar beam position vs. time for reduction of radar data for Talos flights. In conjunction with this, films from boresight cameras on the radar dish were read to obtain the deviation of the missile from the radar beam. Another manual operation was the DOVAP film reading performed by the WSPG sub-section, which involved counting the number of waveform cycles photographed on film and used to determine the velocity of the missile.

The automation of ballistic reduction resulted in one negative consequence for PSL—WSPG acquired its own automatic film measuring and computing equipment, which meant that the Askania cinetheodolite data were all reduced at WSPG by Civil Service personnel. However, in a short time the firing load had increased such that this equipment required 24-hour operation, and PSL staffed the night shifts.

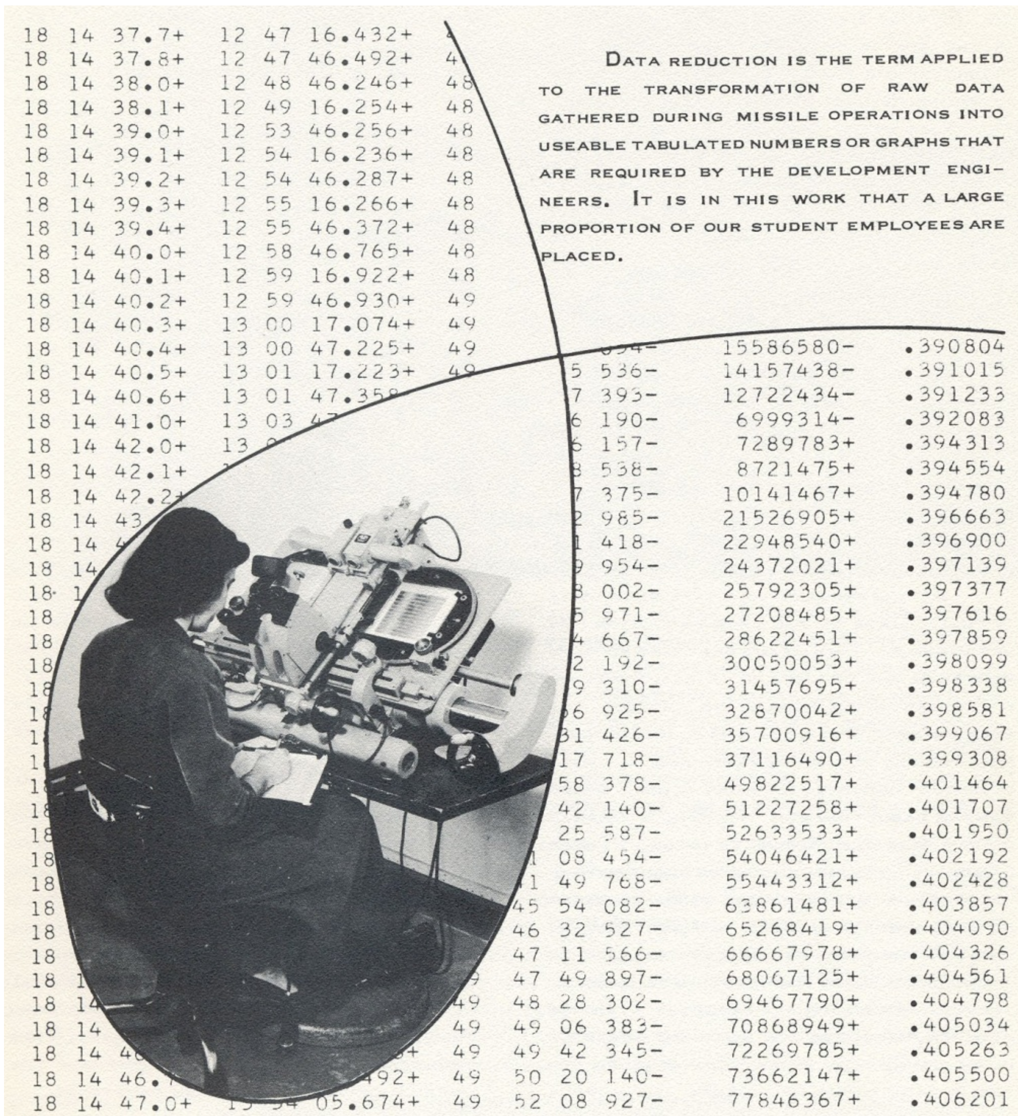

Figure 67. PSL Technician Uses Optical Comparator to Read Missile Flight Film, 1957

The growth of missile testing programs at WSPG resulted in vast amounts of work for the Ballistic Reduction Section, some of it unlike any done previously. The Section performed the data reduction for all types of instrumentation used to study the performance of a missile (including fixed cameras), and produced a preliminary data and miss-distance report for each flight. As implied in the name, fixed cameras were placed in a carefully oriented, fixed position on the ground. The missile passed through the camera's field of view while successive exposures were made at timed intervals. Stationary targets, accurately surveyed in the field, were seen in each frame and supplied the basis for determining the azimuth and elevation of the missile at any given time. These data were used from all available stations to determine the most probable position of the missile and to obtain and publish in report form velocity components, acceleration, yaw, pitch, and roll. Over 1,000 of these reports were produced in Fiscal Year 1957-1958 (the first year that the computer was in use); 2,000 were produced the following year.

Apparently, shortly after PSL developed and began to provide engineering support for the worldwide Minitrack system (toward the end of the 1950s), the Data Reduction Section won a NASA GSFC contract to provide data reduction support for the Minitrack stations. Ray Chavez said, “This was a big, ongoing contract that involved taking exposed plates of star fields with images of satellite streaks in them and precisely calculating the satellite and antenna positions. This work also included the NASA worldwide dish antenna systems that followed the Minitrack [system]. We were soon using optical instruments that were accurate to one micron, and they were some of the most precise devices at that time.”

Barbara Post (Cecil Post's wife) and Patsy Tombaugh came to work part-time for Mrs. Gardiner in the summer of 1951. In September of 1952, Barbara became a full-time staff member. Mrs. Tombaugh was offered a full-time position, but decided to remain part-time, which she did for about five years. Mrs. Post became the supervisor of the ladies that hand-plotted the film data (Figure 68). She worked for about ten years in this capacity, but was forced to retire due to poor health.

Figure 68. Reports Group, Early 1950s

According to Cecil Post, the hand-plotted graphs that these women produced were incredibly well done. He said that the plotted points were so close on the graph that from a few feet away the lines looked continuous.

Mr. Post spoke of how, as Barbara's health declined, he would use the outdoor staircase to carry her to the top floor of the library to work, since there was no elevator to that floor. Then, every day after work, he would carry her back down again.

Tsuyuko (Sue) Yanaga joined the Ballistic Reduction Section in April of 1957. When asked to describe her job, Ms. Yanaga said, "I started as a film reader, back when everything was done by hand with pencil and paper. The only machines we had were mechanical adding machines. Today (1984), we are in the machine age—we went to the Telecordex and then to the Sendex, which puts the data directly onto tape. My job...remained very much the same over the years—only the equipment...changed. In those days, we were reading film from three kinds of cameras: the fixed, the ballistic, and the tracking types. The ballistic plates were phased out about 1976.

"…A few of the people I was working with [were] Mrs. Gardiner, her secretary Frances McClernon, my supervisor Ruth Smith, and Naomi Crum (now Sayles), who wasn't in our section but worked in the same building—the top floor of the library. And there was Mrs. Wurgler, whose husband was a minister; and I remember a Basil Brazil, George Hackler, and Carroll Hall…"

Sue Yanaga related a couple of problems that she encountered when she first started work. She had been told by her doctor to stop her farming duties, and thus considered herself very lucky to find a job. She wrote a letter to her sister in California to tell her of her good fortune, then went looking for a mail drop. Concluding that the padlocked steel barrel with a slot in the top was for mail, she dropped her letter in. Ms. Yanaga wrote to her sister regularly, putting each letter into this barrel, but became worried when her sister wasn't answering. One day she received a letter that said, "Why did you stop writing to me? Are you mad at me?" Upon investigation, Ms. Yanaga discovered that this barrel (which was located directly underneath the coat rack) was a depository for classified waste that was taken out daily and burned. One morning as she was hanging her coat, her keys fell out of the pocket and dropped through the slot into the (locked) barrel. Ms. Yanaga said, "Mrs. Gardiner kept the key, and I was scared to death to go and ask her to open it up. So one of the other girls went and asked her for me, and Mrs. Gardiner was very nice about it. But it seems I [just] kept dropping those keys in there, until she lost patience with me and declared I would have to start hanging my coat somewhere else."

Ballistic cameras were used in the process of calibrating the tracking accuracy of the various Minitrack antennas located around the world. The film plates from these cameras were brought to the campus and reduced by the Ballistic Reduction Section. Others who worked in this section in the 1950s included Mary Lou Kearns, Maudie Densmore, Roberta Westhafer, Hazel Cramer, Ann Spence, Maxine De Moulin, Irene Cates, Walter Allen, Leonard Ward, Ray Chavez, Paul Engle, Keith Guard, and Emily Good.

Walter Allen said, "Mrs. Gardiner would come out to White Sands once or twice a month on our swing shift—we had no daytime operations in those days—and visit and talk with us. She was a grand lady. We had a strange setup [because] Leonard Ward, my immediate supervisor, was under Mrs. Gardiner in Data Processing, but Leonard was also in charge of the Film Processing Lab, which was under Dr. Gardiner. So, he had two bosses [who] didn't always see eye to eye as to how things ought to be done. This would cause problems sometimes."

Telemetry Reduction

The purpose of telemetry reduction is to translate raw telemetry data from rocket flights into useful form. In contrast to ballistic reduction, where photographic images on film are used, the Telemetry Processing Section used strips of film or photo paper often up to 200 ft. in length. The telemetered data included scientific payload, as well as missile performance information. By the time the 1950s ended, the Section was divided into three groups according to the following functions: (1) manual data reduction, (2) tape playback station, and (3) computing.

Like the Ballistic Reduction Section, the Telemetry Processing Section was affected by WSMR's data processing mechanization. In time, however, numerous special tests were identified that were not amenable to automatic reduction schemes—data from these tests could be only be reduced by hand. Manual reduction continued for many years, therefore, as a necessary adjunct to the Army's computers.

PSL also provided manual reduction support to other agencies that utilized the WSMR. Students and their wives performed almost all of this work in the basement of Kent Hall. John Byers said, "We had 25 mechanical calculators clanking, and 50 people. It was very crowded, noisy, and dingy. Keith Hennigh decided to have the students paint the room, including [the] overhead pipes, and [he] let them choose the color. So some kids came up with black, some vivid pink, and some green—really livened the place up." Mr. Byers continued, "We were constantly busy—had more work than we could handle. [We] put in a lot of overtime."

> Various people who worked in that area have mentioned that when Kent Hall became a women's dormitory, girls would sneak out through the PSL workspace in the basement, which was a violation of the curfew rule. PSL personnel neglected to report this to College officials.

The tape playback station was assembled in 1954 when space became available in the library building. Its purpose was to convert magnetic tapes of FM/FM telemetry data to oscillographic records. It was possible to produce multiple copies of these records, as many as the manual reduction group needed. The tape playback station consisted of a complete FM/FM telemetry ground station, with the addition of an innovative unit called the Simplified Automatic Data Plotter (SADAP). The SADAP was an APL-designed oscillograph recorder that automatically incorporated the calibration curves of rocket-borne measuring instruments into the reduction procedure. It accomplished this by tracing a grid onto the oscillograph record that acted as a built-in calibrated scale for that particular rocket parameter, enabling the data to be read directly from the strip chart without the use of a hand-held calibrated ruler (which greatly decreased the time required to reduce a telemetry record (Figure 69)).

Figure 69. Gaertner Fixed Camera Film Reader with Telecordex Processor, Late 1950s

In response to an APL request, a satellite tracking capability was added to the tape playback station in June of 1958, after the Sputnik and Vanguard I were launched into orbit. Robert Sabin and Wes Joosten assembled and installed the necessary equipment. Tracking was accomplished by recording the Doppler frequency shift of the satellite transmitter as the satellite passed over or near the station. This required an extremely sensitive receiver, high-gain antenna, and reference frequency oscillator with a stability of one cycle in a billion over a 30-minute period (Figure 70). It was necessary to position the antenna manually for maximum signal. Don Peterson said, “We got orbital parameters through the Smithsonian. The only time we could receive it was early morning, so I'd go up and manually point this antenna in the right direction.”

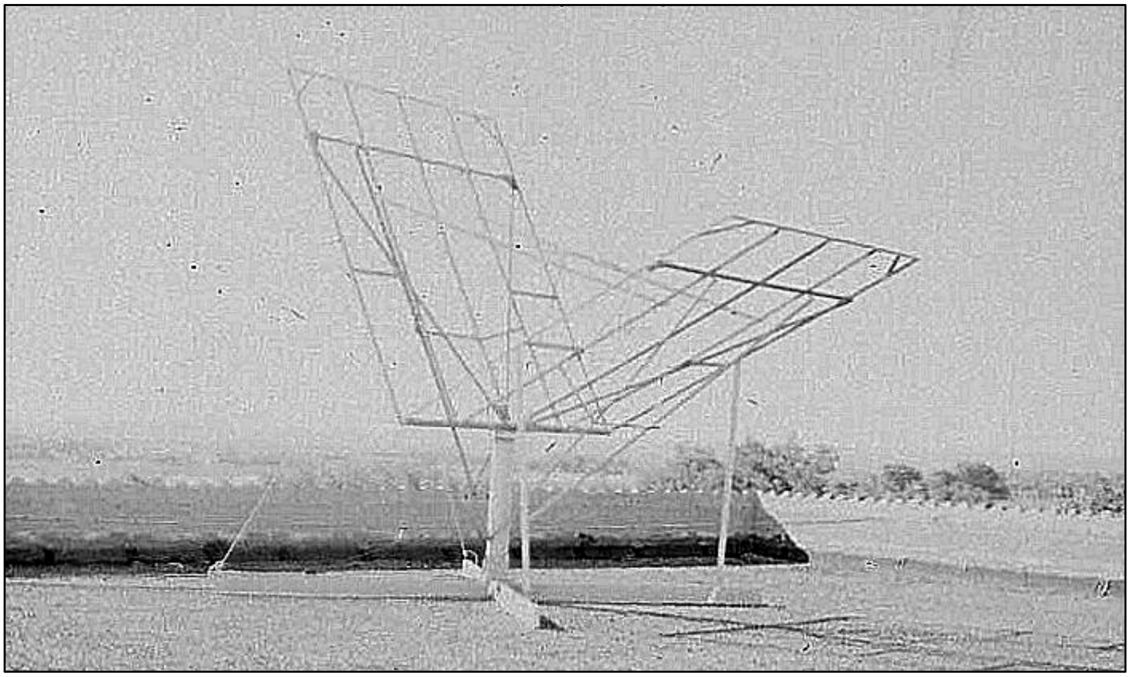

Figure 70. Doppler Satellite Tracking Antenna, 1958

The end product of the tape playback station was a magnetic tape of the shift frequency. Extracted data were input to the computer to obtain the actual satellite orbit parameters. These data, along with figures from a similar station operated by the University of Texas at Austin, were used to triangulate the orbit and thus improve accuracy.

The acquisition of the IBM 650 computer resulted in the creation of the Computing Group. The Telemetry Processing Section used the 650 primarily for computations in connection with wind weighting, which consisted of measuring launch-area wind velocities at various altitudes just prior to firing a rocket. These velocities, obtained by Theodolite observation of small balloons released at the launch site, were telephoned to a keypunch operator at PSL, who input them into the 650. The computer would then calculate the degree of tilt necessary in the launcher to counteract the effect of winds on the impact point, which was telephoned back to the launch site.

Doty Telles recalled, "I was hired as a mathematician [in 1953] with the responsibility of telemetry reduction, and I did some aspect camera reduction and missile flight simulation. We did some wind theory analysis…at White Sands, primarily on the Aerobee rockets... We would measure the lower surface winds with Theodolites, then…take those and run them through some mathematical equations and predict where the missile was going to impact. Sometimes we'd go out around midnight—normally the firing was around dawn. It was exciting to see missile firings, especially when you're young…[and] when you're right there watching..."

"PSL was scattered throughout the campus. We were in three locations—Kent Hall basement, the top of the library, and another building on campus. PSL purchased an IBM 650 computer and some of us in Kent Hall started programming it. IBM came in and gave us some training, which I took. The only language available was Machine Language—you had to code (tell the computer) everything—exactly how you wanted to do things. There were no nice operating systems to handle your input, output, error checking—you had to do it all yourself. And we didn't have a nice mnemonic language—it was all numbers. We went ahead and programmed the computer to calculate missile trajectories, which made missile flight simulation very fast. In 1959, I became a programmer/analyst. I did systems analysis and design and applications programming for the IBM 650."

PSL entered the wind-weighting business in 1956 when an Aerobee from WSPG landed near Hatch, convincing the Navy that action was necessary in order to keep rockets inside Range boundaries. Don Anderson was the first supervisor of this effort, followed by Keith Hennigh when Mr. Anderson left PSL.

Telemetry Processing Section employees personally performed the wind measurements themselves—at WSMR, Ft. Churchill, and Wallops Island. Charles Gardenhire said that he traveled to Wallops Island about once a month from 1959-1962. As mentioned in *The Ft. Churchill Story*, Mr. Hennigh and Ms. Telles traveled to that location during the IGY. At WSMR, Mr. Hennigh and others were supporting PSL Rocket Section POGO firings for various anti-aircraft missiles. He told of a unique experience during one of these firings. "Our most fascinating and fatiguing day—we were trying to get a target up for an armed Nike Herc. It was March, and the dirt flew in the wind—the wind kept shifting. We tried all day to get that target up in that windstorm. [We] finally ended up east of the Navy blockhouse—the Nike launch site was the Army blockhouse. At sunset, the wind stopped, so we counted down on the POGO and...*misfire*! Frank Atmore ran out to the rocket over the screams of the Range Safety Officer and fixed it. We launched the POGO, but just then lost radio contact with the range, so we couldn't tell if we had a parachute or not—they couldn't tell us whether they had a target or not. But the Herc took off, and flew...then the warhead detonated and made the most beautiful smoke ring you ever saw, way up-range. And there, right in the center of that ring, was our parachute."

Those comprising this section in the 1950s included Gil Moore (who became the Section Chief), Keith Hennigh (who succeeded Mr. Moore), Fern Russel (the Section's secretary), Doty Telles, Frank Atmore, Rod Thomas, Charles Gardenhire, Dan Martin, Don Peterson, Allie Snodgrass, Elsie Anderson, John Byers, Jasper Robinson, Jerry Cooper, Paula Hines, Charles Hibler, Kathy Ward, Josie Maldonado, Jon Ottesen, James Sims, Nash Garcia, Stuart Tracy, Clay Thomason, and Larry Higgins, among others.

Keith Hennigh and Doty Telles were working in the Telemetry Processing Section at the same time—he was a full-time employee and she was a student. Mr. Hennigh became Section Chief after Gil Moore left to head the Rocket Section, and Ms. Telles graduated from NMSU, with plans to seek a position teaching Mathematics. Mr. Hennigh, who recognized her numerous abilities, encouraged Ms. Telles to remain at the PSL and apply her Mathematics background to the challenging area of data reduction. Mr. Hennigh made her an offer "she couldn't refuse," and with his support, Ms. Telles (following in the footsteps of PSL's first female manager, Anna Gardiner) became Chief of the Data Analysis Section in 1969.

The missile programs supported by the Telemetry Processing Section in the 1950s included Talos (the most heavily supported), Lacrosse, Nike-Ajax, Nike-Hercules, Corporal, Plumbob, POGO, Redstone, Sergeant, Honest John, Aerobee, Arcon, Viking, and V-2. The Section was also involved in reduction for electronic countermeasure tests, infrared detection measurements, and flight simulation computations. In 1958, efforts began to improve the wind theory measurement procedures.

In 1955, Gil Moore and Keith Hennigh installed WSMR's first color film processing machine in the NOMTF's new building, N-103.

Aerobee: The Reliable, Versatile Rocket

Although the V-2 and Viking rockets faded away in the 1950s, the Aerobee became very popular with experimenters because of its reliability, capability, and the fact that it was relatively inexpensive. Approximately 50 Aerobees of all varieties were launched during this decade; PSL supported all but a few of these firings in some manner.

As with the majority of complex hardware systems, modifications and improvements began on the Aerobee vehicle practically before the paint was dry on the first production run. After launching approximately 40 of the original design, an extended model called the "Aerobee HI" was developed for upper air research. Aerojet had approached both the Navy and the Air Force in 1952 with the idea of enlarging the Aerobee's propellant tanks to make it more powerful and with the capability of lifting 150 pounds to 150 miles (Figure 69).

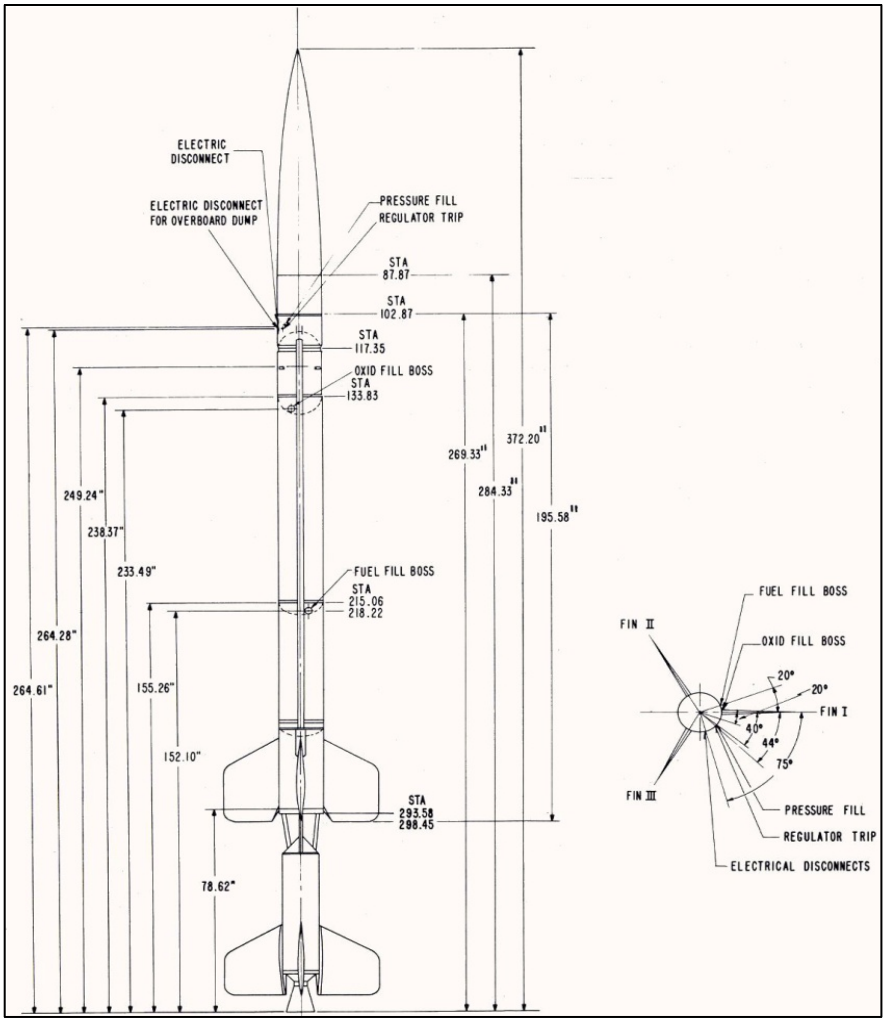

Figure 71. Drawing of the Aerobee HI Sounding Rocket

This resulted in two slightly different Aerobee HIs—the Air Force version and the Navy/NRL version. The Air Force was the first to purchase and launch its version—with a heavy payload of 215 pounds, it was fired on April 21, 1955 123 miles over Holloman Air Development Center near Alamogordo. PSL's Telemetry Section provided support for the launch—it installed a DKT-7 telemeter (the Telemetry House crew recorded data). Raymond Bumgarner said that the House, located approximately 30 miles from the launch site, was unable to acquire the telemetry signal until approximately two seconds after liftoff, as the rocket cleared the horizon. In August of the same year, NRL attempted to launch its Aerobee HI at WSPG; however, the engine failed to ignite.The various rockets in the Aerobee series that were used in the 1950s are described in Table 5.[32]

[32] Condensed from "NASA Sounding Rockets, 1958-1968" by William R. Corliss. NASA SP-4401.

Table 5. Aerobee Series Rockets

Rocket	Overall Length in Ft. (Including Booster)	Nominal Peak Altitude (Miles)	Nominal Payload (Pounds)	Remarks
Aerobee 100 (Aerobee Junior)	25	100	40	20 Fired 1947-1961
Aerobee 150 (Aerobee HI)	29	170	150	"Standard" Aerobee, First Used at WSPG in 1954
Aerobee 150A	29	170	150	Aerobee 150 With Four Fins (Rather Than Three)
Aerobee 300 (Spaerobee)	33	300	50	Aerobee 150 Plus Sparrow Third-Stage; NRL Funded Development; First Used in 1958

Many modifications were made to the Aerobee vehicle throughout the 1950s, the majority of which were minor. The Aerobee Junior and the Spaerobee were added during the IGY. The Aerobee 350 and 170 (described in Chapter 5) were added after 1960.

In January of 1950, two cosmic ray experiments were launched by Aerobees that were fired from the U.S.S. Norton Sound in the Gulf of Alaska. It is believed that PSL supported these, but details are not available.

The first man-made objects to escape earth's gravity were steel pellets fired from an Aerobee by a shaped charge in 1957. The pellets are currently in orbit around the sun.

The Aerobee program brought a development project of considerable magnitude to the Telemetry Section. In 1958, NRL asked PSL to assume the task of miniaturizing the PPM/AM telemetry transmitter (DKT-7). Although it appeared a formidable task, Bob Wagner assumed the position of Project Engineer, with Charles Y. Johnson as NRL's Technical Monitor. In 1959, Mr. Johnson specified the fabrication of 12 miniature units (Figure 72), along with the additional task of developing a new and better voltage calibrator using relays rather than motor-driven micro-switches. Gerald R. ("Roy") Sanders assumed the position of Project Engineer for this new task.

Since both of these projects were completed in the 1960s, more details will be provided in Chapter 5.

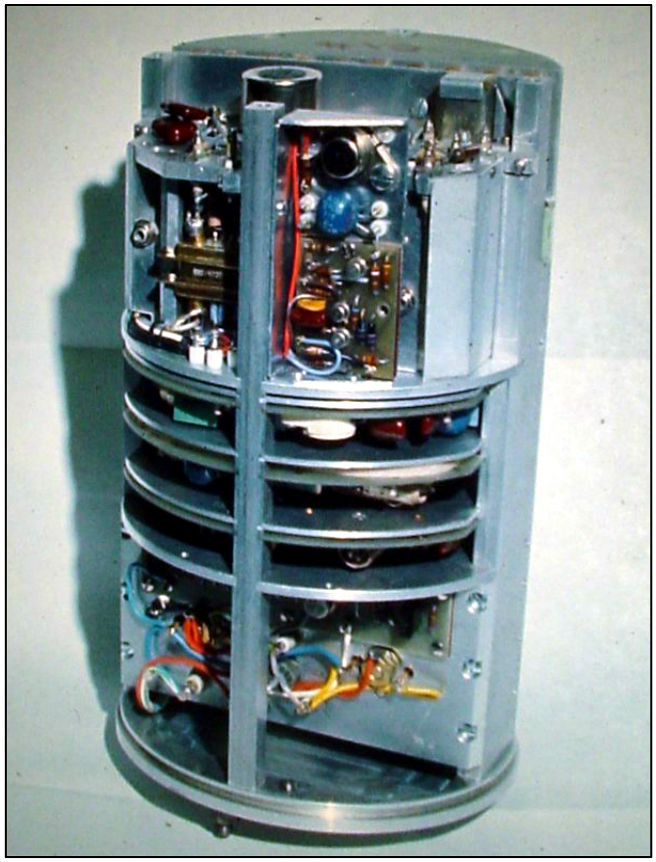

Figure 72. Miniaturized DKT-7/XN-4 Telemetry System

Aerobee HI's advent at HAFB resulted in the obsolescence of the sky screens that PSL had built for Aerobee 100 firings there. The ± 50 additional miles of altitude would obviously require more stringent criteria to assure impact within the Range boundaries, which involved either modifying the existing screens or building new ones. Discussions with Air Force personnel revealed various mechanical deficiencies with the original models, including

- Flexing of the framework and moving arm, allowing the moving arm to oscillate during use
- Difficulty in operating the chair-moving mechanism
- Inadequacy of the lubrication system
- Erratic operation of the cam drive control circuit

Because of these deficiencies, the decision was made for PSL to design, construct, and install new sky screens applicable to both Aerobee models (Figure 73). This assignment was given to James Arnold, James Arndt, and Stewart Bean in 1950. Mr. Bean performed the calculations for determining the shape of the cams for driving the moving arm. Three interchangeable cams were required, one each for Aerobee 100, 150, and 150 without booster.[33] Two of these new screens were built and installed in 1951—one south and one east of the Aerobee tower. There is no record of the length of time that these screens remained in service.

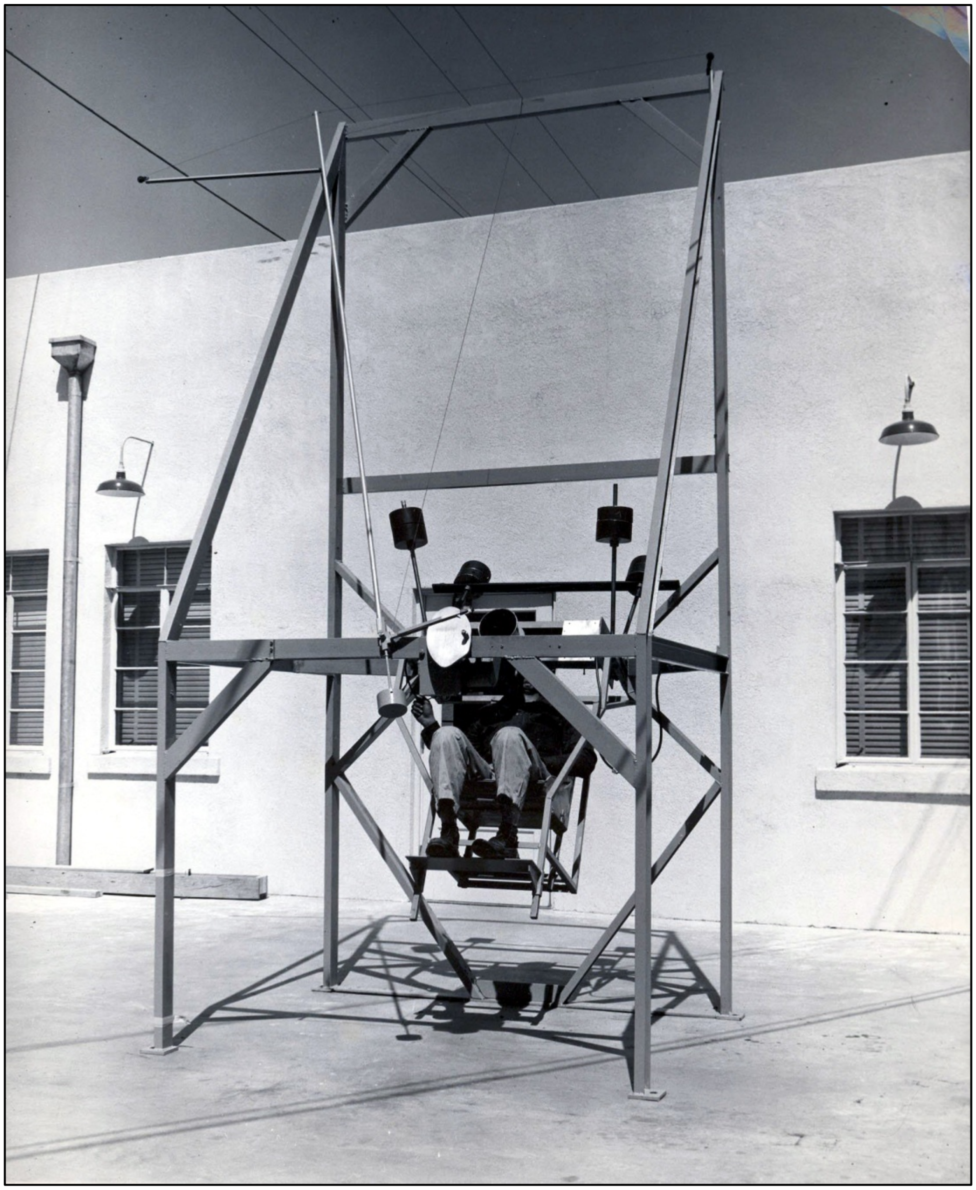

Figure 73. HAFB Sky Screen

Cecil Post described a telemetry problem that Air Force Cambridge personnel were experiencing with HAFB Aerobee firings. Apparently, since 1958 (for two years), they had been using non-traditional telemetry at 400 Mc with a slot antenna designed by a contractor other than PSL, and, during each flight, were losing the telemetry signal at an approximate altitude of 30 miles. The signal would then reappear at 12,000 feet as the rocket was descending, resulting in no data. PSL

33 Records of non-boosted Aerobee firings have not been located.

was finally called for consultation, at which time Mr. Post suggested that the telemetry antenna was experiencing breakdown. The engineer responsible for designing the antenna was skeptical, but Mr. Post tested a recovered antenna and discovered that electron multipacting was indeed occurring, as he had suspected. He told John Downing of AFCRC that he could make a small modification of the antenna that would only slightly reduce its efficiency. He suggested that reducing the power to 75 watts or less would result in data loss for about 15 seconds as the rocket passed through an area approximately 30 miles above the surface, but that the problem would disappear after that. Mr. Downing's engineers strongly disagreed—their recommendation was to upgrade the power to 150 watts. Mr. Downing went out to the rocket himself 15 minutes before launch and clipped off a tuner, as Mr. Post had suggested. A week later, PSL was asked to bid on a new antenna. This unit was flown with reduced power, and data was received for the first time in two years.

Off to Wallops

In 1959, the newly created NASA was preparing to assume its role as manager of the United States' scientific space research activities. NASA established the Beltsville Space Center in some empty government buildings near Beltsville, Maryland (just north of Washington, DC). The Sounding Rocket Branch (SRB), consisting of NRL transferees, was moved there, and Karl R. Medrow was appointed Branch Head. Mr. Medrow was responsible for four sections, the chiefs for which came from similar positions at NRL. In May of 1959, the Beltsville Space Center was renamed Goddard Space Flight Center, and its main offices were moved to Greenbelt, Maryland, which is a few miles southeast of Beltsville (the SRB remained in Beltsville).

The SRB was tasked with providing rocket vehicles for various experimenters—it would not conduct experiments on its own. NASA would screen proposals for rocket experiments and select the most worthwhile. It would furnish a suitable rocket from its own supply, launch from the location requested by the experimenter, and finance range and telemetry support for that rocket.

It is important to note that Wallops Station became a part of NASA. Located on Virginia's Atlantic coast, it was a National Advisory Committee on Aeronautics (NACA) research facility and had occasionally been used to launch various rocket vehicles since 1945. NASA absorbed NACA in 1958, along with the Langley, Ames, and Lewis research centers. Wallops Station was considered by GSFC as conveniently located (only 150 miles away), and it had its own airport (as opposed to WSMR, which was over 2,000 miles away and 40 miles from its nearest airport). Wallops Station also utilized the Atlantic Ocean as an impact area of almost unlimited dimensions (a distinct advantage since there were no Range boundary concerns). It would, however, be necessary to use WSMR if land recovery of the experiment was required (which is frequently the case). The SRB immediately began building an Aerobee launcher and blockhouse at Wallops Station, as well as launchers for smaller rockets (Figure 74).

Mr. Medrow's group included Edward E. Bissell who, as Chief of SRB's Instrumentation Section, became the Technical Director of PSL's telemetry support contract. Mr. Medrow and Mr. Bissell made it known that they wanted PSL to provide telemetry support for the Wallops Station firings and for NASA sounding rockets fired at WSMR. Once again, therefore, satisfied NRL customers wanted to retain PSL's services when they initiated new programs with NASA.

Figure 74. Aerobee Launch at Wallops Station, 1960

The NRL Telemetering Section prepared to place yet another field group at a site on the East Coast.

Mr. Bissell acquired three PPM/AM telemetry ground stations for use at Wallops Station and requested that PSL install and operate them. One station would be permanently located in the blockhouse building, and the other two would be placed in semi-trailers for mobile use. PSL purchased and equipped a 40-foot trailer in order to house one of the stations. This project was assigned to Fred Lemon and James Cole early in 1959, and the van was ready to be transported from WSMR to Wallops by the end of November. With only two weeks remaining before the first scheduled firing, James Cole, Valentin Orona, and Carmen Marrujo arrived at Wallops in early November and began installation of the ground stations (Raymond Bumgarner, Fred Lemon, and Orville Pace arrived on December 4). One week later, the three ground stations had been installed, checked out, and were ready for use. PSL's frenzied efforts were rewarded by a month's slippage in the firing schedule. The support crew returned to Las Cruces—although they didn't see the results of their labor until the following year, they did make it home in time for Christmas.

The Telemetry Section was now supporting four launch sites—Wallops Station, WSMR, Ft. Churchill, and Cape Canaveral—making PSL a Nation-wide organization. Wallops Station operations were also supported by PSL's Ionosphere, Antenna, and Telemetry Data Reduction sections, but the starting dates for this other support are unknown.

The Origin of SGI

As described earlier, PSL entered the satellite tracking business in 1958 at the request of APL/JHU, and Robert Sabin and Wes Joosten installed a Doppler tracking station in the library building. After studying the Sputnik's signals, APL scientists developed methods to predict when it would pass over a particular point and determine its precise position relative to the tracking station (Figure 75). They also found that reversing the process enabled the receiving station's geographical position to be identified. APL sold this concept to the Navy as a navigational tool

Figure 75. APL Scientists (left to right) W.H. Guier, F.T. McClure, and G.C. Weiffenbach[34]

for ships at sea, and it became the basis for the Navy's navigational satellite system. Support of this system resulted in the creation of PSL's Satellite Ground Instrumentation (SGI) section, one of the Laboratory's largest and longest-lived. Since the majority of the SGI Section's growth occurred in the 1960s, it will be discussed in Chapter 5.

SGI was formally established as a Section in late 1958. Al Bowers was its first Chief and APL its customer. Mr. Bowers had worked under Robert Sabin during the setup and operation of the station in the library building, where they first tracked Sputnik (and later Explorer and Vanguard) satellite signals. Staff members Don Peterson, Robert Ecklund, and Robert Yarbrough worked under Mr. Bowers, and Hugh Gardner joined the group later. A few students were employed in 1959, including Earl Downing, Bill Fleming, and Don De Moulin.

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[34] Drs. Guier and Weiffenbach developed the first successful method of tracking satellites using the Doppler shift; Dr. McClure invented the Doppler method of navigation.

By December of 1958, APL had installed tracking stations at Austin, Texas and APL in Bethesda, Maryland. In early 1959, additional stations were required and, with PSL's help, APL assembled two from commercial equipment and installed them into mobile vans for PSL operation. Hugh Gardner and Robert Ecklund spent several months at Bethesda assembling these stations. Mr. Gardner, Earl Downing, and Mr. Ecklund then transported one of the vans to Argentia, Newfoundland, and prepared it for the planned 1960 launch of the first in a series of navigational satellites.

> Earl Downing told this story of solving an interference problem: "We had an interesting problem at the campus satellite station one time...interference on our satellite frequency… was hurting the quality of our data. This happened every day for some time, so we set out to try to locate the source of this signal. We took a direction-finder antenna and got a triangulation on this signal, using a Las Cruces city map. We marked it as being a certain street, drove to the area with our antenna, and discovered it was coming from a pawnshop. We asked the owner if he had any electronic equipment running, and he said, "No." He nevertheless agreed to turn off all the power to the building for a moment, and when he did, the [interfering] signal went away. We finally tracked it down to his burglar alarm (it was one that emitted a signal to detect intruders). We never had any more interference after that, so I guess he took care of it."

1950s Miscellany

The PSL Co-op Program

The 1950s marked the arrival of an extremely useful entity called the "co-op." In 1952, the Army approached the New Mexico College of A&M administration with regards to establishing a co-operative student work/study program similar to those in effect at several other colleges and universities around the United States. The Army proposed enrolling 400 Engineering, Physics, Mathematics, and/or Accounting students in the program to fill 200 positions at WSPG. Each student would work at WSPG for six months per year, earning enough money to cover his/her education expenses for the remainder of the year (thus alternating between work and study). In this way (and if summer sessions were utilized), a degree could be obtained in five years and 24 to 30 months of invaluable hands-on experience accumulated. The administration approved the idea, and the Co-operative Education Program became official in March of 1952. Earl Downing was among that first group of WSPG co-op students.

PSL became interested in using co-ops for some of its contracts, implementing its own small-scale program in 1955 or 1956. This happened when the Army requested (in 1956) that PSL assume the nighttime operation of the range timing stations at WSPG. Al Bowers supervised the contract, which was in effect for two years (he accepted this position so that he could take graduate courses during the day). Dale Beach was among that first contingent of PSL co-ops.

Two to five students and a supervisor were placed at each of two remote stations, "Uncle Two" and "Uncle Three," and two or three people worked in the Timing Laboratory in the Base technical area. The purpose of these stations was to generate very precise timing signals for input to the vast network of instrumentation stations distributed along the 100-mile-long Range—cameras, radars, telemetry stations, etc.—so that the entire Range operated from the same time standard during missile firings. Civil Service personnel operated the timing network during the daytime hours.

Raymond Bumgarner distinctly remembered two early co-op students, D'Wayne Sartin (who was the first co-op employee with whom Mr. Bumgarner worked) and Bill Dodson. Mr. Sartin was part of the NRL Telemetry Section crew that traveled to Florida in August of 1956 to provide telemetry support for the Vanguard project. Mr. Dodson, another co-op from the Vanguard days, became a PSL Section Chief in later years. These two young men, along with almost all of PSL's co-op employees, were highly motivated, dedicated, and very productive.

PSL's co-op program, which employed only a few students through the 1950s, grew at least ten-fold in the 1960s, when the Laboratory became heavily involved in the previously mentioned satellite-tracking network. Hundreds of these top-notch Engineering, Mathematics, and Physics students were utilized at stations worldwide, as well as at WSPG. Volumes could be written on their adventures, tribulations, and accomplishments as they tracked satellites on a Pacific island, pulled cable in the desert sun, or staffed a recorder station in the Florida swamps or the frozen Arctic. PSL is justifiably proud of its co-operative education program—through it, thousands of students have gained invaluable field experience as they earned their way through college.

Other PSL Student Programs

From its inception, PSL's students have been an integral part of its organization. Students were employed primarily for data reduction support in the early years, but Dr. Gardiner also hired their wives as secretaries in order to help them finance their college education. The question, "Are you a co-op or not?" would often arise, but since PSL's charter was to hire students in a variety of positions (including security guards in the 1950s and janitors in the 1960s), a distinction was not usually made between students who participated in the co-op program and those who did not. In general, however, co-ops supported technical projects at the Laboratory on campus, WSPG, or various sites throughout the world. Many of these students continued with PSL as full-time staff after graduation. One thing is very clear—PSL hired a large number of students in the first 25 years of its existence. The money they earned greatly helped most of these students (who might not have had the opportunity otherwise) to complete their degrees and graduate from the New Mexico College of A&M (and later NMSU).

In a letter to Dr. Corbett dated April 17, 1959, Dr. Gardiner provided the following details of student employment from July 1, 1957 to June 30, 1958:

- Students working for degrees in A&S (94), Agriculture & Home Econ (18), Engineering (158), Teacher Education (1), Graduate (11) totaled 282, with total earnings of $253,924.00
- In addition, 41 student wives were employed by PSL that year, with total earnings of $70,950.00

The report included a complete list of these student employees. Some of the names include Dale Beach, Blaine and John Byers, David Gose, Dennis Henry, Calvin Hoggard, Jon Ottesen, Shirley Thomas, Jessy Vaughn, Horace ("Clay") Watkin, Jr., and Henry Weinschell. Almost every one of these students went on to become staff members at PSL.

A Search for Natural Satellites of the Earth

In the early 1950s, College faculty member Dr. Clyde W. Tombaugh became a PSL joint appointee. In 1953 he initiated a systematic search for small, natural earth satellites. The project had a threefold purpose:

- To ascertain whether or not the earth had any small, natural satellites
- To chart the orbits of any such satellites so that their positions would be known at any given time
- To develop equipment and techniques for optical tracking of any future man-made satellites

Dr. Tombaugh knew that these objects would be too small to view with the unaided eye and would move through a large telescope's field of view too quickly to be seen or recorded on film. Therefore, a small telescope driven at angular rates to match those of the possible satellites was employed with the expectation of increasing the exposure time to several seconds.

The required angular tracking rate would depend upon the distance of the object from the earth. Consequently, the space to be examined was divided into approximately 200 concentric zones, each of which required a different rate. To cover all sectors of a zone, many types of procedures were created in order to utilize the earth's shadow and the various tracking rates. The search was initiated at Lowell Observatory (in Flagstaff, Arizona) in December of 1953, and, in order to cover the equatorial plane nearer the earth, a station was established at Quito, Ecuador in mid-1956. In 1957, a visual search was undertaken at two locations—on campus and at Presidio, Texas—using the human eye (which is much more sensitive than photographic emulsion).

The search was concluded at the end of 1958. No satellites were discovered, although a few faint (but unconfirmed) "suspects" were seen. Some of these were apparently tiny asteroids passing close to the earth in their elliptical orbits around the sun. Bradford A. Smith of the Astronomy Department and Dr. Russell Sherburne, a PSL/Physics Department joint appointee, assisted Dr. Tombaugh with this project.

Ionosphere Studies

Beginning in the 1940s and continuing through the 1950s, the NRL conducted investigations of the ionosphere using radio signals transmitted from rockets. The rocket firings occurred at two locations—WSPG and Ft. Churchill in Canada.

For these investigations, two signals were transmitted simultaneously while a rocket remained in the ionized region of the atmosphere. One of these served as the reference signal and was high enough in frequency that it was unaffected by the ionosphere; the other signal's frequency was low enough that it was decelerated by the ionosphere. The ground station received and recorded these two signals, or frequencies. Analysis of the recorded information revealed several ionosphere parameters: (1) index of refraction, (2) electron density, (3) strength of the earth's magnetic field, (4) high ion density, and (5) collision frequency between free electrons and neutral molecules.
Two ground stations installed in trailers were maintained and operated by the PSL Ionosphere Group (Figure 76). Wes Joosten and Eugene Lee, the two Group engineers throughout the major part of the 1950s, continually designed improvements to the station equipment in order to enhance the accuracy and reliability of the recorded data. In 1957, Robert Sabin was involved in development work initiated on a Doppler receiving system for tracking rockets.

Figure 76. Ionospheric Station, WSPG

The "Rockoon"

A rockoon is a rocket/balloon combination in which a small sounding rocket (such as the Deacon) is boosted to a point above the denser atmosphere by suspending it nose-up from a large, helium-filled balloon. When it attains a sufficient altitude, the rocket is ignited via radio control and it shoots up through the balloon. No launcher is necessary, and rockets fired in this manner achieve greater altitudes than do those fired from the ground. Figure 77 shows a Navy rockoon immediately following a shipboard launch.

Although the rockoon concept is believed to have originated with Naval officers aboard the U.S.S. Norton Sound in 1949, James Van Allen and his group from the University of Iowa were the first to actually use them. They fired several in the fall of 1952 from a Coast Guard cutter near

Greenland in a successful attempt to detect high-altitude radiation near the earth's magnetic poles. Mr. Van Allen discovered much more radiation than expected, providing the first clue that radiation might be trapped by the earth's magnetic field. Ten rockoons were fired from a U.S. Navy ship in July of 1956 off the coast near San Diego, California. These were Deacon rockets that carried solar ultraviolet and X-ray detectors that NRL hoped to launch during a solar flare. It was necessary to fire several of these rockets when no flares were present because the balloons were about to drift out of radio range; however, at least one was launched successfully during a solar flare.

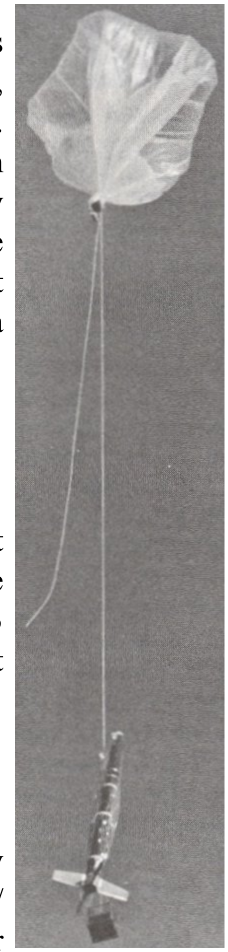

Figure 77. Navy Rockoon, 1956

In 1957, a U.S. Air Force/University of Maryland team, in an effort called Project Farside, fired six rockoons near Eniwetok Atoll in the Pacific Ocean. Altitudes close to 4,000 miles were attained, using a four-stage solid-fueled rocket hanging from a 3 3/4 million cubic foot balloon. It is believed that PSL provided some level of support for these rockoon programs, but details are lacking.

Energy Research

In the 1950s, the use of solar energy to heat homes or buildings was considered by most to be an interesting innovation without practical merit. Dr. Albert Burris, a PSL/Physics joint appointee, undertook experiments to examine the feasibility of solar heating of homes in the area. This research was greatly facilitated by two developments:

- Revere Copper and Brass Company's development of a sheet-metal strip known as "tube-in-strip" that unlocked the possibility of circulating and heating water
- An agreement with Dr. Jack Soules of the Physics Department allowing installation of an experimental solar heating system in his new home as it was being constructed

PSL would be allowed to collect data on the system for five years and make minor changes if necessary.

Three banks of flat plate collectors were integrated into the flat roof of the house (Figure 78). The solar-heated water was stored in a 2500-gallon underground tank. A closed loop circulated heated water from the tank to a heat exchanger in a regular warm-air duct system. Thermocouples were placed at pertinent points and in the soil around the tank. The system was completed in January of 1958. At the end of that heating season, it was determined that about half of the heat requirement had been supplied by the solar system (without the benefit of storage tank or water line insulation).

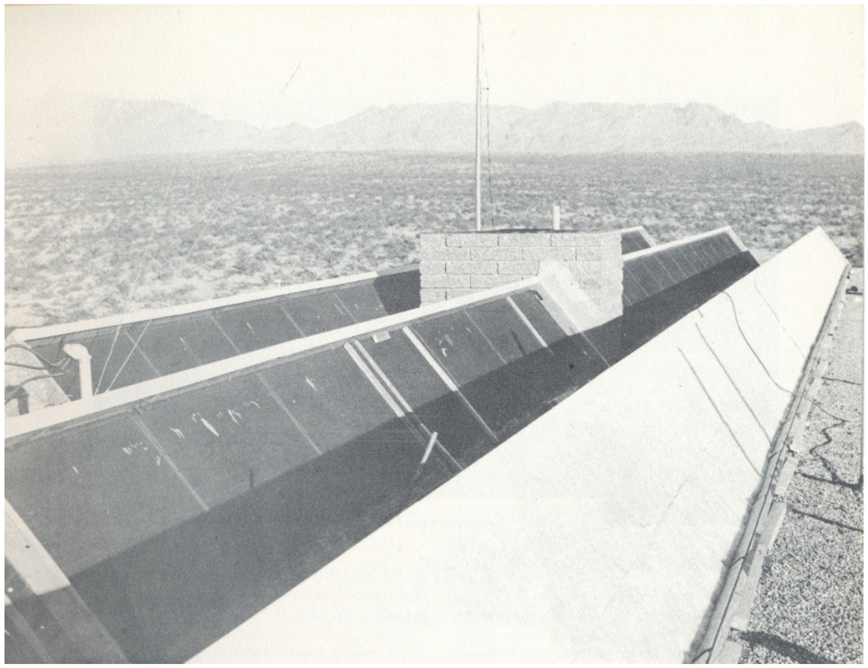

Figure 78. Solar Collectors on Roof of Jack Soules' Home, 1958

Gaseous Electronics

The term "gaseous electronics" applies to all phenomena involving the ionization of atoms and molecules. Research in this field, begun in 1949 by H. B. Williams and Albert Hatch, continued through the 1950s under a contract with APL/JHU. During this decade the work progressed in two distinct directions:

- Continued study of the cause of glow discharge onset, commonly referred to as "breakdown"
- Studies of glow discharge properties after breakdown occurs

Of significance to the scientific community was the creation, under certain conditions, of a potential well for positive ions, trapping them in a region in space. This made it possible to contain gases with temperatures of millions of degrees in an apparatus (bell jar) without damaging the container's walls (Figure 79). Thus, an excellent laboratory tool was provided for thermonuclear research and for astronomers to simulate the conditions on the sun and other stars.

Figure 79. Testing an Antenna in a Bell Jar

Two other highly theoretical studies sponsored by APL were microwave current distributions and ferrite and waveguide studies, performed at PSL by Dr. Ralph Dressel. Papers describing the results of these investigations were presented in 1958 to the American Association for the Advancement of Science.

An X-ray spectrometer was built at PSL to support Dr. Jack Soules' studies to examine the properties of artificial organic crystals. This work began in 1958.

Electronic Development Group

The Electronic Development "Group" consisted solely of Robert Sabin, who had a proclivity for working alone and for devising state-of-the-art electronic systems to satisfy special requirements.

In 1957, while Mr. Sabin was in charge of Talos telemetry support at WSMR, APL announced a requirement for a target device that could be deployed from a parachute and would emit a Doppler radar return, thus emulating a high-speed aircraft. Mr. Sabin left his field post and relocated to campus to undertake this development problem. He said that this was PSL's first attempt at solid-state circuit design, and it was successful—the design was completed in 1959. The target, a microwave phase-locked system, was used for WSMR missile testing through 1963. The Naval Air Systems Command applied for (and received) a patent for the simulated target.

In 1959, Mr. Sabin completed development on NASA's SSD tracker for sounding rockets.

Various other circuit design projects in those early days focused on providing special devices suited to the severe environmental conditions encountered during small sounding rocket flights. One of these projects involved modification of a radar beacon, which is an electronic device flown in a rocket, missile, or any vehicle so small that it will not reflect enough of a tracking radar's signal to enable the radar to follow its movement. The beacon receives, amplifies, and re-transmits the radar signal with power sufficient for the tracking radar to follow it. In this case, the modification involved using a portion of the beacon's transmitted signal to send data from various rocket instruments to the ground, as a telemetry system normally does. This system, which made it possible to obtain the data without the additional weight of a telemetry transmitter, was used on the early experimental flights of the POGO rockets.

In 1959, PSL's Rocket Section developed a miniature telemetry unit flown in small rockets for measuring the concentration of ozone in the atmosphere.

Electronics Shop

Shop support is a critical component of any research and development organization. By the time PSL had been in existence for three years, it had established its own Electronic Fabrication Shop, Photo Lab, and Machine Shop. Initiated in 1947 as a single-employee operation, the Electronics Shop grew into a first-class, state-of-the-art production and testing facility.

Although it is difficult to determine precisely when the Electronics Shop was formally named, this probably occurred in 1949 or 1950. In 1947, Conny Fleissner began the design and construction of electronics in the "Radio Shack," a non-descript, two-room building near Goddard Hall. It had once housed the College's radio station, KOB, but was vacated after Dean Ralph Goddard was accidentally electrocuted there and the station sold in the 1930s. Some enterprising students of Professor Harold Brown had erected a neon sign that read, "Brown Hall" on this building. Mr. Fleissner was assisted by technicians Richard Matthias and Handy Fairchild, who each supervised the Shop in the mid-1950s (by this time, it was housed in the PSL building on Vaughn Street). K. F. ("Jim") Manz became the Shop supervisor in 1957.

Apparently, after the PSL Rocket Section was established as a supplier of missile targets, the majority of the Electronics Shop's work consisted of constructing electronic components to be flown in the POGO target rockets. The primary items supplied were timers and programmers for control of the sequence of events such as nose cone separation and parachute deployment. The Shop also developed the "Mytymouse" transmitter in support of the Rocket Section's HUGO project, which was used to recover payloads from the sea. Printed circuitry was employed for this transmitter, which was probably PSL's earliest use of this technique (Figure 80).

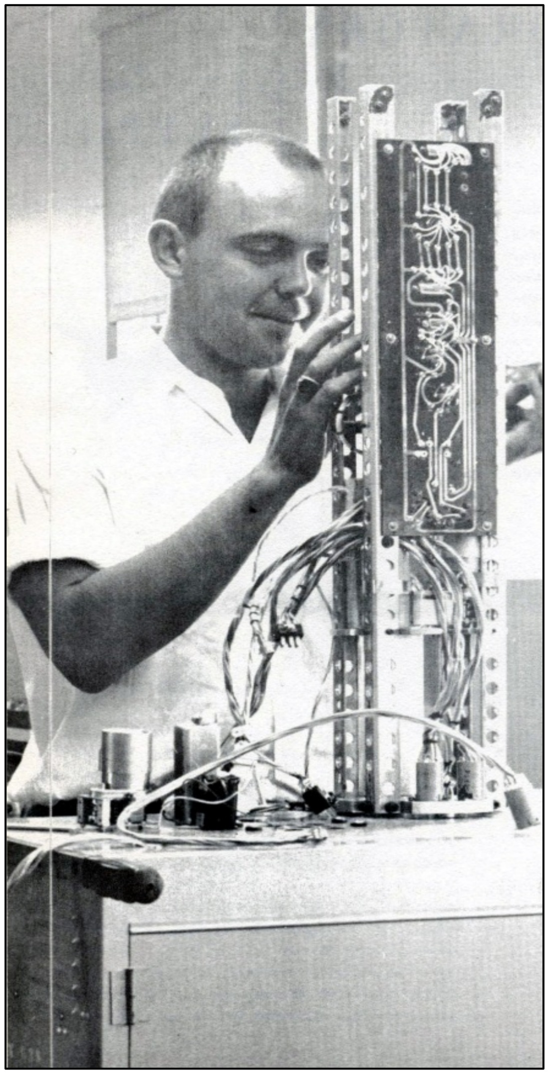

Figure 80. Charles Mozer Prepares a Mytymouse Transmitter for Flight in a HUGO Rocket

The Shop provided support to other departments on campus, including coil winding and assembling various types of cables.

Quality Control

In 1956, Dr. Gardiner expressed concern about the quality of some of the flight hardware that the Laboratory was producing. As a result, a Quality Control (QC) facility was created, and Tate Tatreault was PSL's first Inspector. The purpose of QC is to assure the highest quality of workmanship and conformity to standards in all phases of development and production of hardware, particularly flight hardware. Like the Electronics Shop, the QC department performed the bulk of its work on POGO rockets during the 1950s. George Baker succeeded Mr. Tatreault in 1957. In a 1958 report, Mr. Baker wrote of numerous trips taken around the country to inspect, at the source, various rocket components being manufactured for PSL's use (a total of 115 POGO rockets were checked in a one-year period). For example, Mr. Baker and Stewart Bean traveled many times to American Machine and Foundry (AM&F) in Buffalo, New York, to perform inspections as 100 POGO rockets were being built for the U.S. Navy. Clem Mozer drafted the original drawings, which AM&F revised for manufacturing purposes. Mr. Baker inspected the work as AM&F built the rockets, resulting in an excellent product. The Army at WSMR subsequently contracted directly with AM&F for rocket production, and PSL offered to help with inspections. The Army declined the offer and consequently encountered problems with the rockets that AM&F built for them (PSL was called in after-the-fact to try and correct the problems).

George Baker said that one of his first jobs as a Quality Control inspector was to travel to the Thiokol Chemical Company in Elkton, Maryland, to inspect some rocket engines. PSL had been purchasing Deacon engines from this supplier, and the engines were coming apart when fired. Since Thiokol's machine shop was incapable of building the metal parts to specification, defective threads resulted, causing the engine casings to separate. PSL purchased certified thread gauges and, at the request of Dr. Gardiner, Mr. Baker flew to Washington, D.C., got a room at the Harrington Hotel, took the train to Elkton, and inspected the rocket engine parts. He said that he had never inspected rocket engines before, but he had the gauges, Dr. Gardiner's confidence, the added confidence of youth, and was reasonably intelligent; thus, he was able to accomplish his task. The company corrected the defect, saving PSL a great deal of time and embarrassment.

On one of his later trips, Mr. Baker visited the Thiokol plant in Elkton, then went on to Buffalo to AM&F. He was in Buffalo several days later when he heard a radio announcement that the Thiokol plant had exploded. Although pieces of the building were blown everywhere, nobody was killed.

Machine Shop

As mentioned earlier, Dr. Gardiner hired David McFarland as the Laboratory's first Machinist in 1947. Since PSL had not acquired any machining tools by this time, it was necessary for Mr. McFarland to use the Shop in the Engineering College in order to accomplish his work. Two additional machinists, Robert Chamberlain and Phil Manz, were hired in July of 1948. By that time, the Shop (Figure 81) had acquired three lathes, two milling machines, two surface grinders, welding equipment, and miscellaneous smaller tools (Mr. Manz described it as, "a pretty decent little shop"). At the beginning of the 1950s, Mr. McFarland had left PSL, Mr. Chamberlain was in charge of the Shop, and a third machinist, Ramon Maruffo, had been hired. In 1952 or 1953, Mr. Chamberlain accepted an offer from Boeing in Seattle. Mr. Manz, who remained in charge of the Shop until he retired in 1979, succeeded him.

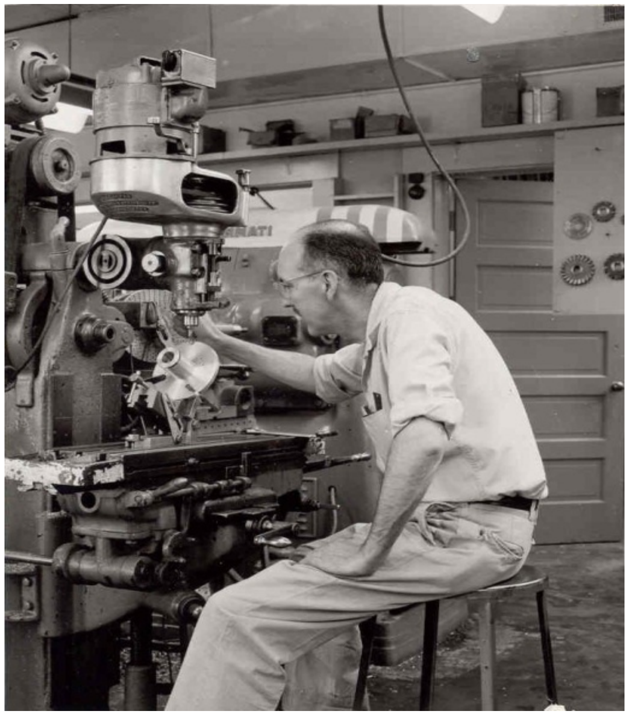

Figure 81. Machine Shop

One of the earliest major tasks performed by Shop personnel was machining the notch antenna prototypes for the Aerobee and Aerobee HI rockets. After the notch design was proved in, the Shop machine-finished the casting, Teflon filler, and tuning slug for each notch. Mr. Manz and Mr. Chamberlain assembled the two sky screens mentioned previously for Aerobee use at Holloman.

As with the other PSL shops, the bulk of PSL's machining work in the 1950s was done in support of the POGO target program. Machine work was required in the prototyping and production of various rocket body components and some parts of the instrumentation. Requirements of high thermoresistivity, erosion, and corrosion properties resulted in extensive use of Inconel, stainless steel, and Monel metals, requiring the acquisition of special tools.

The Machine Shop fabricated 13 large antenna arrays for NRL's Vanguard telemetering ground stations (these were the three-element helical arrays with hexagonal ground plane referred to in T*he Vanguard Story* earlier in this chapter*)*. Plating and anodizing capabilities were added in the 1950s; later in that decade, a new 14 ½-inch tool room lathe and vertical milling machine were purchased.

Administration

Many of PSL's administrative functions were handled by just a few people until the mid-1950s. One of the first full-time administrative staff hired (in the fall of 1946) was a secretary, Phyllis Palmer. She supported Dr. Gardiner (PSL's director) and the Ballistic Reduction Group (headed by Anna Gardiner), and performed technical administrative tasks.

Ray Chavez said that, in the early years (before it became so large), PSL was characterized by a family-like atmosphere. Picnics at that time were small potluck affairs held each year on July 4 at White Sands National Monument. Mr. Chavez related the following story about Donnie, the Gardiner's well-loved pet (Figure 82). "One year, just before the [date of the] picnic, Donnie had disappeared, leaving Dr. Gardiner almost inconsolable. Well, someone at PSL found him, but everyone kept this fact (and the dog) hidden until he arrived with Donnie at the picnic. When Dr. Gardiner saw Donnie, he was so happy that he grabbed him and rolled and frolicked in the sand like a little boy."

Figure 82. Dr. Gardiner and Mrs. Gibson with Donnie at PSL Picnic, Late 1940s

By 1952, PSL was occupying the building on Vaughn Street. Its administrative staff had expanded to include Mr. Bright (Purchasing), Betty Stevenson (Administrative Assistant), Marie Nemesh (Mr. Bright's secretary), and Edward ("Eddie") Brittle, who performed the Security, Reports, and Personnel functions. The Personnel function was basically just a screening process, because the various groups interviewed and hired their own employees. Most of the other administrative functions, such as property, payroll, and supply, were informally run in those early days.

Eddie Brittle said that Mr. Bright, the head of Purchasing, made a large number of long-distance phone calls. The very primitive phone failed on a frequent basis, and it sometimes took an entire day to get it repaired.

As head of Security, Mr. Brittle was responsible for burning "security trash" in PSL's incinerator. He liked to dress nicely for work, and he said it was funny to see him out there, burning trash, dressed like he was going to a funeral or a wedding. Another of Eddie's responsibilities was inventory, and he said that problems arose in those early years because, "Items would come in the back door, whoever ordered them would come get them, and I never knew they were in-house until I received the invoice."

By 1955, the Reports Office was printing all of PSL's reports and the Photo Lab had moved to the main building on Vaughn Street. Offset machines were purchased and an Ozalid machine was obtained for production of reports for special rocket shots. There were 7-8 administrative employees by this time, including Sherry Lenard, a Reports Typist, and a couple of others in the Reports secretarial pool. The Security Office had moved to the third floor of the new library, which was completed in 1954.

By the late 1950s, the Laboratory became so large and diversified that a vast amount of paperwork was necessary to keep track of employees, equipment, materials, contracts, funds, travel, technical achievements, etc. In fact, the end product of many contracts was paperwork in the form of reports. The administrative staff had increased to 25-30, and to make more space in the main building for shop and laboratories, PSL's administrative offices were moved to a wooden barracks building on Stewart Street. They remained there until Anderson Hall was completed in 1965. The Photo Lab, Ozalid machine, and copy equipment were moved to the BRL Annex. In 1958, the following standard administrative entities could be found at PSL, as with any other defense contractor:

- Reports and Reproduction Office, under Eddie Brittle
- Security Office, under Mr. Brittle
- Purchasing and Property, under Allen Sayles
- Payroll and Accounting Office, under Leon Hart
- Motor Pool, under Bill Don Naul

The Motor Pool, or Garage, was located south of the PSL building between Stewart Street and an arroyo (Figure 83). The Snack Bar was located in the main PSL building on Vaughn Street (Figure 84).

Figure 83. Ford Lineup, 1956

Figure 84. PSL Snack Bar, 1956

1950s Miscellany

1951

- Dr. Gardiner's budget estimate on Task NMA-1 of the APL contract shows a field crew of six and 18 "shoots"
- April 6—Deacon Round 11 launched
- List of customers dated June 20: Nord, ONR, Army, Signal Corps, AFCRC, AEX, AER, IRL, Harvard

1952

- Holloman and WSPG integrated; Army in control overall
- Flight Determination Laboratory (FDL) created at WSPG
- NRL Telemetering Group included Bumgarner, Bunyea, Savedge, Mallar, Kerley, Farrell, and Masterson
- September 3—Aerobee 11 fired, expected 49 miles; achieved 61 miles

1953

- April 21—Work started on Telemetering House addition
- October—Telemetry House addition completed; now called Parker Station
- 19 November—First Nike-Deacon fired at Wallops by NACA to test model aircraft at high mach numbers
- 16 December—First trials w/two telemeters in one rocket, 223 and 227 Mc; results OK

1954

- New dial phone service put in use on WSPG
- Pete Welch, Ivan Carbine, Dick Barron, and student Luther ("Jack") Fussell worked on radar reflection coefficients for various types of terrain
- Portion of the PSL Annex being used as laboratory classroom for undergraduate Physics students
- March—Third PPM ground station installed at Parker Station
- March—Silvercel batteries for flight power came into use
- July—PSL staff roster totaled 87
- October 5—First NRL Aerobee HI; Parker Station crew: P. Hill, R. Wagner, W. Mallar, A. Jones, C. Ricketts, E. Savedge, K. Medrow (NRL), R. Yarbrough, R. Sabin, M. Marquez, and P. White

1955

- Construction began on Gardiner Hall, the new Physics and Mathematics building; funded partially with PSL overhead money
- April 8—First Nike-Deacon used as a sounding rocket
- April 21—First Aerobee HI at HADC; carried 215 lbs. to 123 miles; Parker Station recorded telemetry
- The overhead rate on PSL's contracts was 20.2%; contract billings totaled $1.8 million
- November—Dr. Gardiner attended initial meeting of "Resource Committee" established by President Corbett to plan growth for the next 15 years

<u>1956</u>

- PSL began awarding research grants to undergraduate Physics students
- Gardiner Hall completed; PSL provided 1/3 of the cost
- July 6—First Nike-Cajun to be used as sounding rocket fired at Wallops

<u>1957</u>

- Dr. Gardiner resigned as head of the Physics Department to devote all of his time to PSL

<u>1958</u>

- PSL provided $200,000 to build the Research Center building
- Dr. Gardiner founded the Research Center and was appointed as its first Director, a position he held concurrently with that of PSL Director (he held both positions until his retirement)
- March 17—J. Townsend of NRL asked PSL to develop a single-station Doppler Velocity And Position (DOVAP) system for tracking sounding rockets
- August—Wes Joosten and Robert Sabin began design of single-station DOVAP tracker system referred to as SSD
- October 11—Pioneer moon probe launched at Cape Canaveral; PSL Vanguard crew provided support with a Minitrack station and telemetry stations
- October 12—NRL fired eight Asp rockets from Puka Puka Island during total solar eclipse
- October entry in Raymond Bumgarner's log: "Dr. Gardiner and Regents trying to impose 7% fee on all off-campus contracts. NRL and NASA not buying it."

<u>1959</u>

- The Research Center building was completed
- NASA's J. Mengel and J. Townsend offered PSL's Rick Ricketts a high NASA position; Mr. Ricketts refused

CHAPTER 5: THE SURGING SIXTIES

The 1960s was a decade of profound internal change for PSL and phenomenal growth in its scope of endeavor. These changes were:

- PSL's founder retired
- The new PSL building was constructed
- The directorship changed several times
- A major management structure reorganization occurred
- Competitive bidding became more common, putting an end to some sole source contracts
- PSL was swept along with the rapid expansion of the national space and defense programs

National happenings with significance to many included the Vietnam War, the "Pill," the assassination of John F. Kennedy, the Apollo lunar landings, the Civil Rights Movement, and Lyndon Johnson's "Great Society," among others. The following made headlines: Cassius Clay, Twiggy, Malcolm X, Bobby Kennedy, the "Six Day War," the Beatles, Eugene McCarthy, Mao Tse Tung, the Twist, and the first human heart transplant. Perhaps the phenomenon that struck closest to home in New Mexico, far away from the riots in Watts and Detroit, was the advent of drug experimentation among youth, with its accompanying rebellion against "The Establishment."

The retirement in 1961 of PSL's founder and first Director, Dr. George W. Gardiner, triggered a series of management changes, including three changes in directorship before the end of the decade.

Dr. Gardiner is credited with numerous major contributions to NMSU and PSL. He established and became the first head of the New Mexico College of A&M's Physics Department in 1934. In 1946, he almost single-handedly organized a group of faculty and students into the entity known as PSL. He guided PSL's growth throughout the 1950s, was instrumental in acquiring funding for NMSU's first doctoral program, conceived and brought to realization PSL's student co-operative education program, founded the Research Center in 1958, secured funding for the Physics (Gardiner Hall) and Research Center buildings, and initiated the PSL Scholarship program for qualifying students. He was a man of great character and stature; few commanded more respect from the University administration, faculty, students, and PSL staff.

Anna Gardiner retired along with her husband in 1961. Mrs. Gardiner's contributions to the area of data processing during her 15-year career at PSL were significant. She pioneered the development of methods and procedures for reducing rocket ballistic data, a task unprecedented in the United States. From its inception, the quality of the work produced by Mrs. Gardiner's group drew high praise from both American and German scientists at WSMR and from the Army rocketeers. She was esteemed and respected by those who worked closely with her and admired by those with whom she had casual contact. She fostered the hiring of women in several of the technical areas at the Lab especially in the data handling fields.

Failing health, including a heart attack in June 1961, was the primary reason for Dr. Gardiner's retirement. He and Mrs. Gardiner moved to New York City's Central Park, where they lived until he passed away on April 26, 1965. The George W. Gardiner Memorial Fund was established the following month.

Mr. C.I. Ricketts succeeded Dr. Gardiner as PSL's Director. Mr. Ricketts started working at the Laboratory in 1947 and served as Assistant Director for two years. He remained as Director until 1966, when philosophical differences with the University administration caused him to seek and assume a subordinate position.

> Gil Moore shared some insight into this change of command. After Dr. Gardiner's retirement, NMSU first suggested that Mr. Moore and Mr. Ricketts share the directorship—each would be in charge of different PSL technical and business functions. When Mr. Moore determined that he would not be given full responsibility for and budgetary control of those functions for which he would be in charge, he firmly declined the offer. Shortly after that, he left the Laboratory altogether.

Harry A. Posner of Bell Telephone Labs was appointed as Mr. Ricketts' successor, but resigned after two years after accepting a position at Redstone Arsenal in Huntsville, Alabama. Harold R. Lawrence, who came from the Jet Propulsion Laboratories in Pasadena, accepted the directorship in August of 1968. He enjoyed the longest tenure of any Director, exceeding Dr. Gardiner's by a few months. He resigned in 1983.

Because PSL was primarily an engineering organization infused with Dr. Gardiner's attitude that all work was achievable, it was difficult to manage at times. The technical groups' top priorities were generally making things work and pleasing the customer rather than appealing to the sensibilities of upper management. Because most groups knew very well which tasks they needed to accomplish and their limits, the majority of projects were completed within budget and schedule, resulting in satisfied customers. PSL's first three directors encouraged this view (or at least tolerated it); however, Dr. Lawrence's management approach was entirely different. Some of PSL's employees considered him to be aloof; most considered him dictatorial. For the first few years his activities did not disrupt PSL's "can-do" attitude, but most section chiefs (in particular) complained of not being able to perform their duties in an efficient manner. For example, edicts were issued that made simple interchange with other PSL entities (like the Contracts Office) very difficult. Dr. Lawrence's lack of knowledge concerning certain sensitive relationships between PSL and the federal government created sometimes temporary and often long-term conflicts with some of PSL's best customers. This insensitivity to the section chiefs' needs and general unwillingness to offer support to middle managers led directly to an ongoing internal conflict that lasted throughout the 1970s.

From PSL's inception until the mid 1960s, many of its contracts were not formally bid, and PSL would generally offer to return all unspent money to the government. By the 1960s, the standard practice was, rather than reduce spending, to steadily increase the contract value regardless of the need for it, and competitive bidding became the means of operation. During those times, if PSL did not spend all of the contract money, it was directed to purchase ongoing support instrumentation with the extra funds. Some groups fared well in this mode and acquired state-of-the-art equipment; however, depending upon the nature of the work, that equipment was not always necessary.

The First Major Restructure

A significant reorganization of the PSL management structure took place amid the many changes in directorship. Under Dr. Gardiner and Mr. Ricketts, the Laboratory was comprised of up to 14 sections, each headed by a Supervisor who reported to the Director. This meant that there were only two levels of management within PSL, which many believed to be a very efficient structure. Neither Dr. Gardiner nor Mr. Ricketts was very interested in formal organizational charts; however, an old chart located in Mr. Ricketts' files from the early 1960s did show a simple structure that was seemingly drawn up to help delineate group budgets (Figure 85).

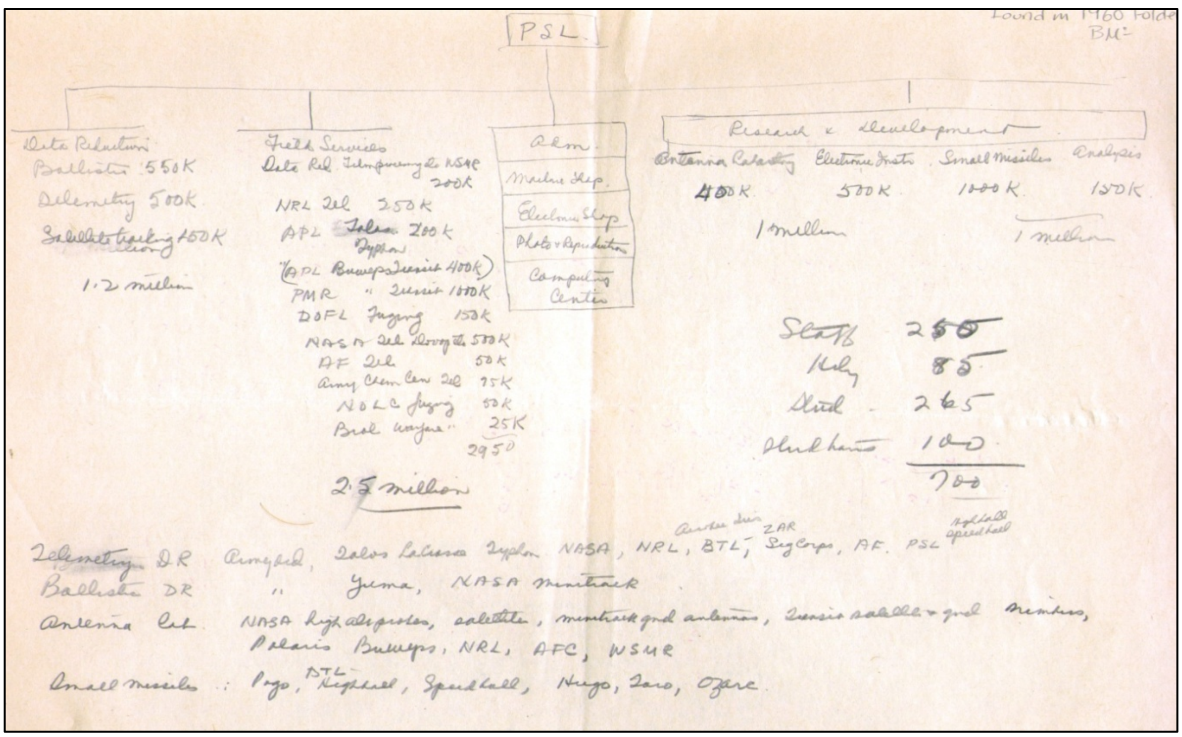

Figure 85. PSL Structure, Early 1960s

Mr. Posner, however, wanted to reduce the number of staff reporting to him, so in June of 1966 PSL's sections were rearranged into three divisions (each with its own Division Chief) and PSL's administrative functions were formalized (Figure 86). In subsequent years, the majority of Section Chiefs expressed the opinion that this new structure diminished the level of communication between sections as PSL grew.

Four new PSL sections were created in the 1960s, all in the Data Processing Division. The Applied Analysis Section, with Keith Guard as Chief, was established in 1960 and initially comprised of David Mott, Jon Ottesen, and Bill McCool. Their initial tasks included rocket impact predictions, wind weighting studies pertaining to unguided rockets, and analysis of various data reduction methods. The group was performing highly sophisticated analyses by the end of

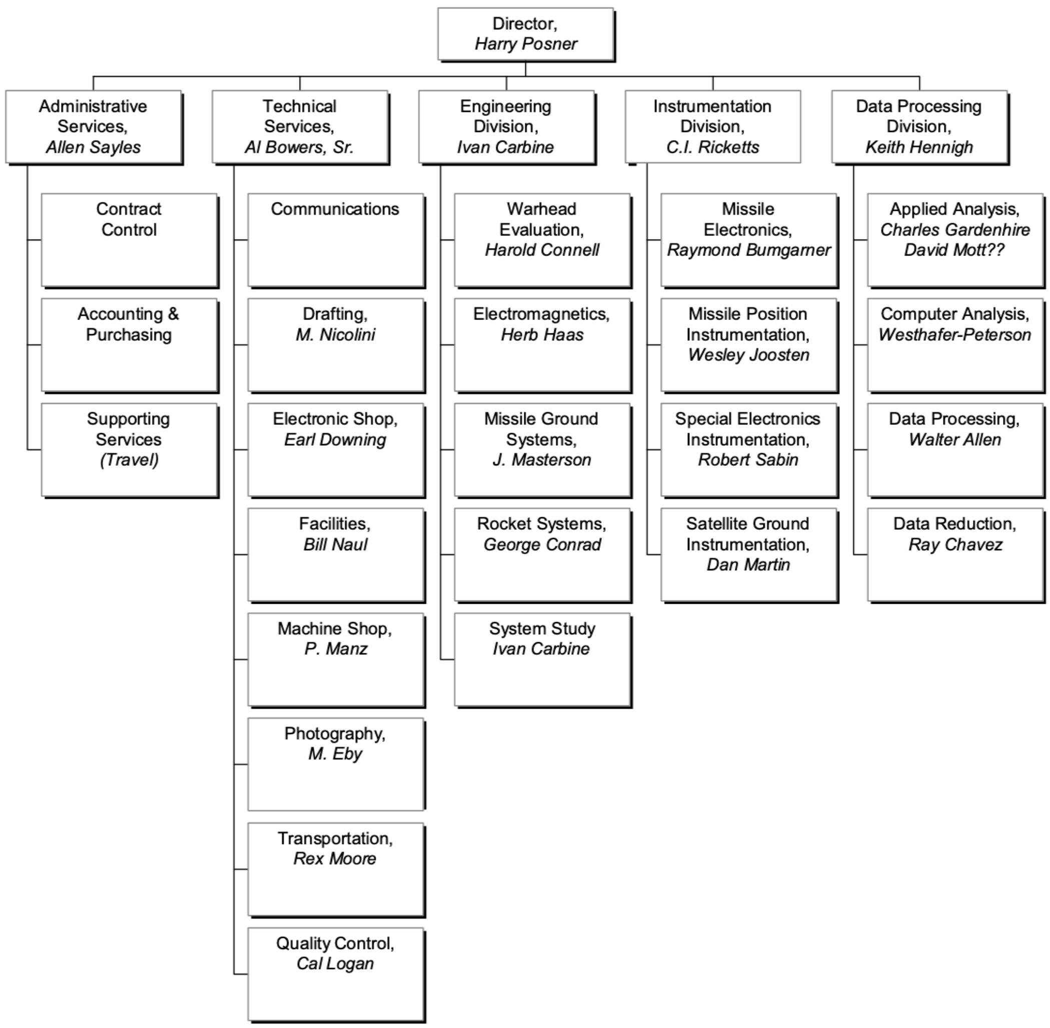

Figure 86. PSL Organization Chart, 1966

by the end of the decade, such as gravity gradient stability problems for earth satellites and analysis of spacecraft re-entry data and rotational problems on the Delta launch vehicle.

When Anna Gardiner retired in 1961, the Ballistic and Telemetry Reduction sections were combined and called the Data Reduction Section. Ray Chavez was placed in charge of this group, which continued to provide the same types of support as it had prior to the reorganization. The Data Reduction Section was housed in the Kent Hall basement and the Jones House.
Rick Ricketts (former PSL Director) headed the Instrumentation Division, and Ivan Carbine and Keith Hennigh headed the Engineering and Data Processing divisions, respectively. The following year the Administrative Services Division was added, headed by Allen Sayles. By this time, some

sections had been renamed, as can be seen in Figure 77, The DOFL Group, Antenna Section, and Talos Group became the Warhead Evaluation Group, Electromagnetics Section (EM), and Missile Ground Systems (MGS) Section, respectively. NRL Telemetry became the Missile Electronic Instrumentation (MEI) Section, and the Ionosphere Group became the Missile Position Instrumentation (MPI) Section, even though these two entities were working only with sounding rockets and spacecraft, not with war missiles.

In 1969, director Harold Lawrence reorganized the Laboratory again (Figure 87). All administrative functions were organized into the Administrative & Technical Services Division

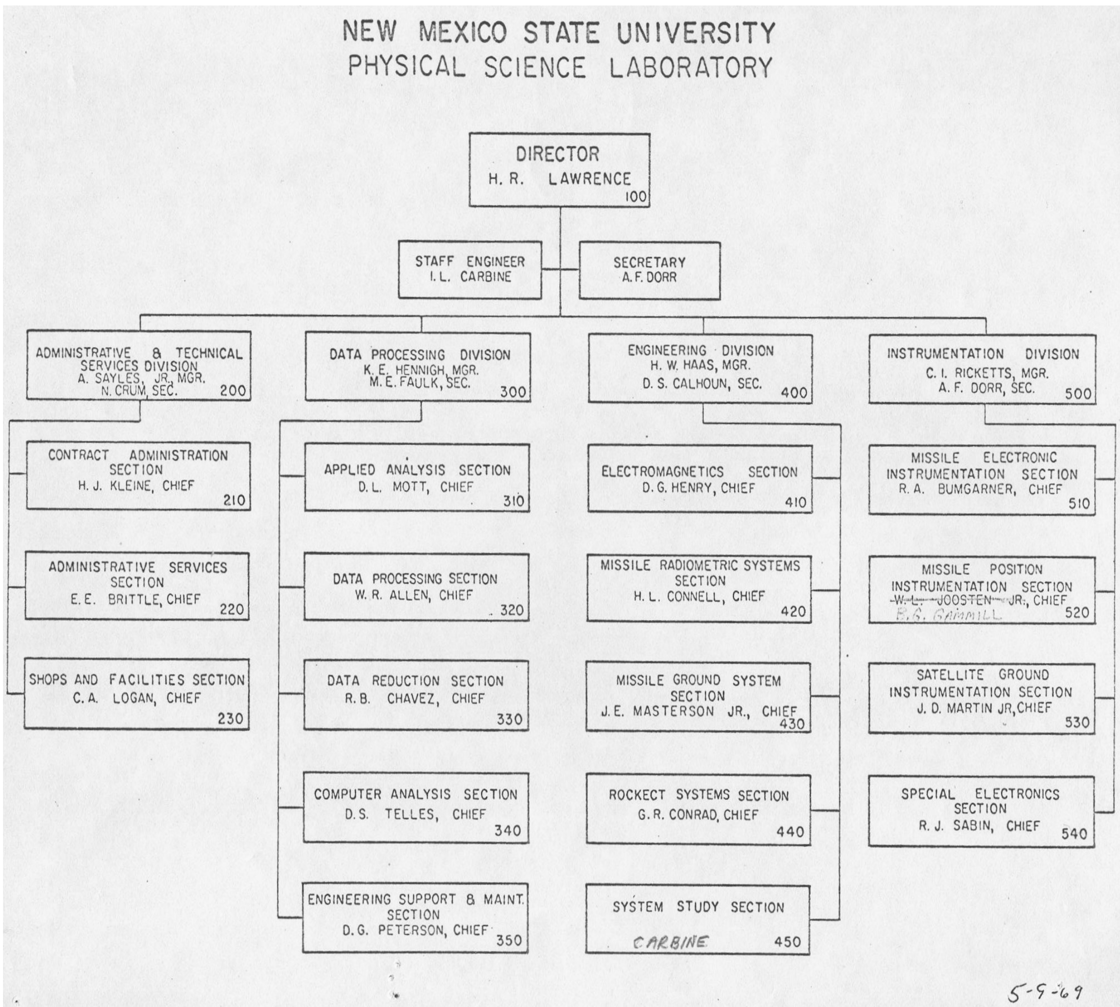

Figure 87. PSL Organization Chart, 1969

under Allen Sayles. This Division was comprised of the Contract Administration (H. Kleine); Administrative Services, including Personnel, Travel, Security, Communications, & Reproduction (E. Brittle); and Shops & Facilities (C. Logan) sections. It is interesting to note that, although PSL has been reorganized many times since, its administrative functions have basically remained the same.

As part of the reorganization, two additional sections were created in the Data Processing Division utilizing employees whose functions had become specialized—the Engineering Support and Maintenance Section and the Computer Analysis Section. Initially, Don Peterson and David Mott were the respective Section Chiefs, but Dr. Mott stepped down after six months and Doty Telles assumed his position.

Don Peterson had already distinguished himself by designing and building a tape deck for the Burroughs 220 computer, to be used for processing telemetry magnetic tapes from WSMR (no 220-compatible deck had been found on the market). Don said that, although he and Bob Abbot worked many extra hours on this project for about six months, it paid off— the tape unit worked so well that they built two more. Modification to the computer, which Don handled as well, was also necessary to accommodate the unit. Since all of the technical sections were doing both engineering- and instrumentation-related work, the division in which to place them was not obvious. It is believed that the resulting placements were dictated by politics rather than by logic. This was not the case with the Data Processing Division—since some sections were doing only data processing, the choice was apparent. However, in the latter 1960s, considerable engineering design work was being accomplished by various people in the Data Processing Division, as seen in the preceding paragraph and later in this chapter.

A New Building

By 1960, PSL's functions were housed in twelve different locations on the NMSU campus, including the Kent Hall basement, barracks buildings, the library, the PSL building on Vaughn Street, and two former private homes (the Jones and Sherburne houses, which had been encompassed by the expanding campus). Efficiency, employee morale, and public awareness were raised considerably when the spacious new PSL building (Clinton P. Anderson Hall) was completed in the spring of 1965 (a new Machine Shop south of the main construction site had been built in 1964). The new building provided 100,000 square feet of working space for all of PSL's on-campus groups (and there was a mad scramble for window offices!). Three houses occupied by PSL were demolished in order to accommodate a parking lot (Figure 88).

Figure 88. House Demolished to Accommodate PSL's West Parking Lot[35]

The PSL building contains some architectural features that were considered quite unique at the time. A feature strongly desired by PSL management was the freedom to alter the floor plan or the location of partitions in order to cope with ever-changing workloads among the various groups occupying the space. They needed the flexibility to move walls, doors, lighting fixtures, power and communication cables, air conditioning ducts, etc. with minimum expense and disruption, which meant that no load-bearing partitions could be used within the 300 x 100-foot span of each of the three floors. Using pre-stressed concrete "double-tee" beams as floor/ceiling joists satisfied these requirements (this was among the first uses of these beams in NMSU's campus construction). Each floor's 300-foot expanse was therefore divided only by several steel support columns, the centrally located elevator shaft, and stairwells and rest rooms at each end. A suspended ceiling of 2' x 4' acoustic panels spanning the entire floor provided room overhead for utilities and enabled complete flexibility in partition placement or movement. The partition walls were fabricated of two-foot-wide interlocking modules using "sandwich" construction (where two panels made of one-inch gypsum board were separated by one-inch spacers). The spacers provided for sound insulation and routing of wiring. Al Bowers, the PSL engineer who devoted two years to supervising the building's construction, said that he discovered this system on the market while conducting a thorough study (Figures 89-91).

The Electronics Shop, the Rocket Section's offices, and the Drafting Group moved from the Rocket Building (the metal building in the present compound) to the new building on June 21, 1965.

35 Espina Street and Student Housing can be seen on the right-hand side and top left-hand side of the figure, respectively. Dona Ana Community College is now located in the empty field that can be seen in the upper right of the picture.


Figure 89. Excavation for PSL Building, 1963 looking to the NW (notice barracks)


Figure 90. The “Shell” Nears Completion, 1964

Figure 91. Clinton P. Anderson Hall, 1966

Wes Joosten and Raymond Bumgarner (supervisors of the MPI and MEI sections, respectively) moved their offices and laboratories to the new building as well, bringing along some of the engineering and fabrication work that PSL was doing at WSMR. These moves provided improved access to supporting Shop facilities and administrative services and improved interaction between sections.

The new building provided plenty of office space for PSL's administrative staff. The Personnel, Security, and Travel functions were all handled in a central location (Travel's workload peaked in the 1965-1970 time frame because of the SGI co-ops' support of the TRANET contract). Professional security guards were hired (and uniforms ordered), and a more sophisticated badge system was implemented.

A little-known fact is that this new PSL building was not financed through state appropriation. At a cost of $1.2 million, it was built with a portion of a $40 million NMSU bond issue. PSL's share of this issue was then removed from the Laboratory's overhead monies.

Director Ricketts, a staunch Republican, objected strongly when he heard, near the time of the building's completion, that it was to be named for U.S. Senator Clinton P. Anderson, who was a Democrat. Mr. Ricketts contended that, since Mr. Anderson had played virtually no role in helping PSL to acquire the building, it should be named for PSL's founder, Dr. Gardiner. Although the majority of the PSL staff agreed, the building was named Clinton P. Anderson Hall.

Shortly after occupation of the new building, a portrait of Dr. Gardiner was hung in the lobby. In August, as plans began for a formal dedication ceremony, NMSU's Vice President for Research Richard Duncan was ordered to have Mr. Ricketts remove the portrait. Mr. Ricketts grudgingly complied, placing the portrait in the PSL vault "until this blows over."[36]

The official dedication of Anderson Hall, along with an open house, was held on Saturday, October 23, 1965, with Senator Anderson in attendance. An informal open house for PSL employees and their families took place the following day.

The advent of the new building fostered various other minor disagreements between Mr. Ricketts and the NMSU Administration, one of which concerned the janitorial services for the building. Mr. Ricketts (presumably in adherence with PSL's policy to provide employment for students wherever feasible) hired a number of students as part-time janitors. This agitated the "powers" in Hadley Hall, as evidenced by a terse memo from Vice President Duncan in July 1965 asking, "Why are you hiring janitors in PSL vs. using PPD [Physical Plant Department] services?" A second memo was sent in September that read, "You haven't answered me re janitors." It is unknown whether there were subsequent exchanges or if Mr. Ricketts merely ignored the memos—in any event, PSL continued to use student janitors for many years.

The PSL Janitors—A Spirited Group

The PSL Janitors evolved into a spirit group in 1967, a time when the NMSU Aggies had lost much of their credibility as a regional athletic power (the basketball team in particular had fallen from prominence). This, along with the war in Vietnam, the draft, and the counterculture, resulted in a University community with little interest in the Aggies. The fraternities had abdicated any leadership role they had in focusing student spirit at that time, and there was no core.

The PSL Janitors, most of them non-engineering students, worked diligently to clean the laboratory every night, of course. But, as sports fans, they were concerned about the general apathy and low morale of the student body in regard to the turnaround that the Aggies were beginning to make under Lou Henson in 1967. So, they began making large pep rally signs to hang at the games, sometimes borrowing ladders to display them up high. These banners were hung between the light poles at Memorial Stadium, and high on the walls at the Las Cruces High School gymnasium (and later at the Pan American Center). Typically the signs reflected cryptic "janitor humor," displaying such messages as "PSL Janitors Say Go Aggies—Wax the Miners," "…Mop Up the Lobos," or, "Buff the Buffs" (Figure 92).

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36 The portrait currently hangs in PSL's lobby.

Figure 92. Carl DeRosa and Tim Clifford Hang a Banner for the West Texas State Buffalos Football Game, October, 1967

Steve Owen, the first president of the PSL Janitors, said that, since some of the Janitors were members of the band or ROTC, they occasionally took banners to out of town games. Once, a banner was shipped to Purdue University to hang in the Aggie locker room, and then-coach Lou Henson commented on the positive effect it had on the team. When the Aggies went to the NCAA basketball regionals at Weber State, the Janitors took a sign to hang in the rafters. Sam Lacey was quoted in the newspaper as saying, “Man, do they have PSL Janitors here too?”

The PSL Janitors’ primary goal was to involve the students again in Aggie athletics. They not only inspired the team and stirred up the crowd at games, but they put the giant sign on the flood-control dam spillway (located above the NMSU golf course) for the NCAA golf tournament (Figure 93).

Figure 93. Original Layout of the "Welcome NCAA Golf Tourney" Message on the Flood-Control Dam Spillway, Spring, 1968

The Janitors also built the giant Aggie (designed by Charlie LeMire) for football and basketball games (Figures 94 and 95). This mascot was taken to many out of town games, and at one Lobo game, the head was stolen from the transport and hung from the UNM bell tower. It was returned by officials, but a second head had already been built.

Figure 94. Giant Aggie at the NMSU President's Residence, February, 1968

Figure 95. Back of Giant Aggie at the Pan American Center, 1968 (With Janitors' Names)

In addition to creating and transporting banners, the PSL Janitors entered floats and Homecoming Queen candidates for the 1967-1968 and 1968-1969 academic years and participated in the Spring Carnival. They were featured in the 1968 and 1969 editions of the Swastika and won an Organization Page Award for their 1969 pages. They won the Aggie Spirit Trophy in 1967 and a special Outstanding Spirit trophy for the 1967-1968 academic year (Figure 96).

Figure 96. The PSL Janitors, 1968[37]

A Second Decade of Growth

PSL's expansion in the 1960s continued as it had in the 1950s. Its staff again tripled in size, totaling 900 in 1969 (450 staff and 450 students). Contract income during this period grew from $3.2 to $7.4 million. This growth, however, peaked in 1969-1970; an industry-wide period of reduction followed that extended into the 1970s.

The level of effort for the Army, Navy, and NASA increased uniformly throughout the 1960s, with a dip in fiscal year 1965 (Figure 97). Considering the fact that Bell Telephone Labs (BTL) and a portion of Navy contracts fall into the area of defense, the relative levels of funding for PSL's

[37] Row 1 (Left to Right): David Hemingway, Steve Owen, Richard Lopez, Jim Miller; Row 2: Tim Clifford, Carl DeRosa, Bob Richardson, Malcom Hardin, Jamie Lee; Row 3: Wain Johnson, Joe Bailey, Ed Gilliland, Jim Hawman, Neil Loomis.

three main areas of emphasis—sounding rockets, defense, and space—remained virtually unchanged during the decade.

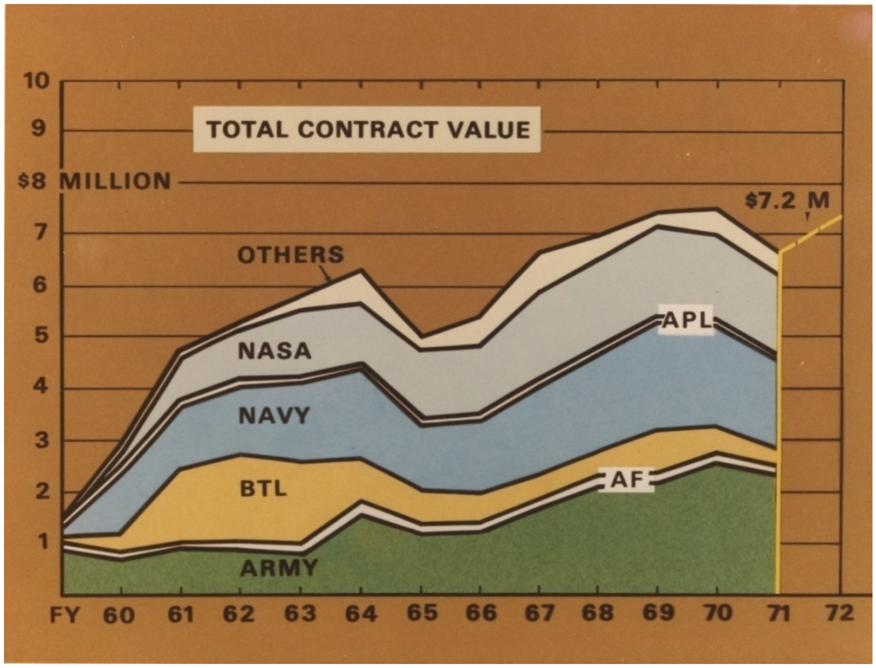

Figure 97. Total Contract Funding for Fiscal Years 1960 - 1971

PSL's customer list also increased significantly in the 1960s, from approximately 15 in 1959 to 41 in 1969 (Appendix A).

The Laboratory's activities during this decade continued to expand to foreign shores. Rocket, missile, and satellite launches were supported in many new locations, including Argentina, Australia, New Zealand, Antarctica, Greece, Dutch Guiana, India, Italy, Pakistan, South Africa, Germany, Spain, Portugal, the Philippines, Japan, Iran, Ethiopia, Norway, Sweden, Brazil, Greenland, Canada, aboard ship off South America, Kwajalein and Johnston Islands in the Pacific, and other islands too numerous to list. PSL also supported launches at new U.S. work sites, including China Lake NOTS, Pt. Mugu and Vandenberg Air Force Base (AFB) in California; Anchorage, Alaska; Seattle, Washington; Yuma Proving Ground in Arizona; the Jemez Mountains near Cuba, New Mexico; Blanding and Green River, Utah; Hilo, Hawaii; Boulder, Colorado; Pasadena, California; among others. In addition, portable satellite tracking stations were exchanged among dozens of locations all over the country.

PSL continued to staff the remote sites established in the 1950s at Wallops Island, Virginia; Cape Canaveral, Florida; and Ft. Churchill, Canada, throughout the 1960s. Wallops and the Cape became permanent PSL field stations, with many PSL employees purchasing homes and becoming legal residents of those communities (this was also the case at Vandenberg AFB, California, when PSL began operating a ground station there in 1964). These stations supported hundreds of launches, ranging from the tiny Arcas to the massive Saturn V. Under contract with NASA, they provided telemetry and Doppler station support, while PSL/campus furnished flight antennas and provided data processing support. A 1968 NASA report reveals that, in the preceding ten years, NASA launched 1,154 sounding rockets (this total does not include the multitude of spacecraft launches (actual and attempted) that occurred in the same period).

Although the number of sounding rocket and missile programs varied (see Appendix B for a list of rocket and missile programs supported by PSL), the need for data processing and other types of support that PSL provided at WSMR continued to increase until 1969, after which it leveled off.

An important upgrade to PSL's test facilities occurred in the early 1960s when it modernized and relocated its ten-year-old antenna range (Figure 98 shows the range under construction, and Figures 99-101 show it after completion). A proposal dated January 25, 1960 indicated that this effort would cost approximately $135,860.00. Site preparation, survey, utility installation, structures, instrumentation, phone system, air conditioning, RF absorbing material, and labor expenses were detailed in the proposal. Land "in sections 23 and 26" had been formally requested in 1957 by NMSU's Physical Plant Department from the federal government. By the time the above proposal was completed, the land was in the final stages of approval for permanent withdrawal.

Figure 98. Antenna Range under Construction

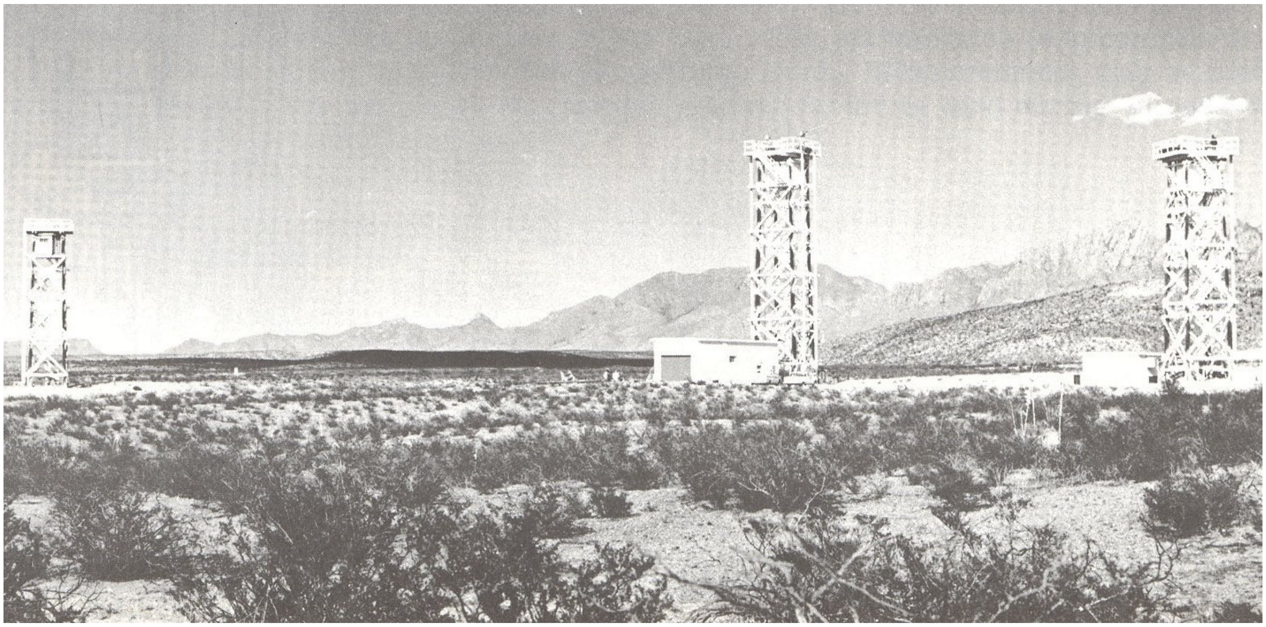

Figure 99. Completed Antenna Range

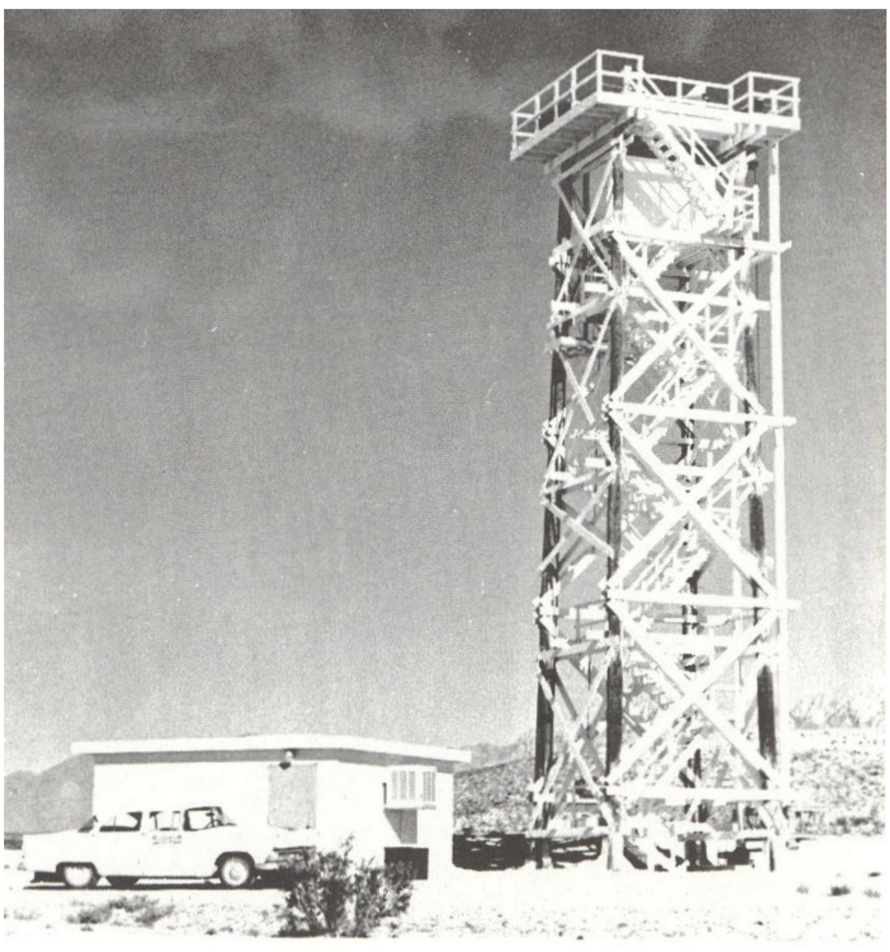

Figure 100. Close-up View of Tower on the Completed Antenna Range

Figure 101. Close-up View of "A" Mountain Section of the Completed Antenna Range

Like its predecessor, this facility was primarily used to measure PSL-developed antenna radiation patterns. Located at the foot of Tortugas Mountain (i.e., "A Mountain"), it consisted of four transmission paths of up to 3,000 feet and a variable-length model range of up to 100 feet. Three 85-foot towers provided 150- and 350-foot paths. This range greatly reduced the elapsed time between design concept and finished antenna. Flight antennas for rockets of all sizes and sophisticated spacecraft were provided, as well as many antennas for ground installations.

In the 1960s, as America's space and missile programs multiplied and the instrumentation industry began to transition from analog to digital technology, PSL was able to expand from operation and maintenance into design and development. New contracts with NASA and other agencies were acquired for design and fabrication of digital hardware for satellite tracking, telemetry (both flight- and ground-based), data processing, missile guidance, and other applications.

Rapid advances in the computer industry made it necessary for PSL's Data Processing Division to upgrade its mainframe computer several times during the 1960s in the attempt to match its equipment with ever-changing customer requirements.

Administration

As mentioned earlier, PSL's administrative staff grew from approximately 4-5 in 1952 to 25-30 in the late 1950s, which required moving from the PSL building on Vaughn Street to a barracks building located on Stewart Street. The functions they performed included accounting, personnel, security, reproduction, report production, switchboard, travel, purchasing, and property. A secretarial pool was established to provide the extensive typing support required for documenting tasks and handling correspondence. Automation of the administrative functions began in the early 1960s with the advent of the computer, which was a challenge for the staff. An official Personnel Office was established in 1963 under Stuart Tracy.

After moving into Anderson Hall in 1965, director Harry Posner reorganized PSL, thus formalizing its administrative functions for the first time. The switchboard (Figure 102) was located in the basement and the mailroom was behind the switchboard.

Figure 102. Birtie Douglas Operating the Switchboard, Late 1960s

Birtie Douglas came to PSL in 1966, working for Frances Gillis as a switchboard operator. She and Dorothy Hampton operated the Switchboard, Snack Bar, and Teletype machine and helped Malita Ruffner in the Mail Room (which was located behind the Switchboard). Ms. Douglas said, "Dorothy helped [me to] sort the mail, run the postage machine, and make the mail runs three times a day. We made the mail runs with our high-heeled shoes and dresses (no miniskirts back then)...No wonder my feet hurt today! We weren't allowed to wear pants (slacks) until later on...we were a busy pair for sure. All [incoming and outgoing] telephone calls went through the PSL switchboard. We also helped Frances with the telephone bills and sent all the [outgoing] TWX messages, including [those sent] overseas.

"I [also] started the Snack Bar (Figure 103). We made the coffee and cleaned up the kitchen area each day… at the time, payment was made by 'putting your money in the cup.' The money kept disappearing, so they hired someone to manage the Snack Bar. Those were fun days and we knew everyone personally, their extension and their room number."

Ms. Douglas also related the following about her Teletype experiences: "Dan Martin used international Teletype a lot. We'd get page after page from him (I did a lot of work for him and Wes Joosten), and we'd have to decipher his writing and type it on that Teletype. I'd stay up way into the night typing their messages (and I wasn't a typist!). I learned, though, and evidently the messages got through well enough to decipher, because they got their work done."

Figure 103. Jerry Noe at the Snack Bar, late 1960s

The Personnel, Travel, and Security functions were all handled in one large room (Figure 104), with two adjoining offices—one for Mr. Tracy and the other for the security guards. By the late 1960s, PSL employed 900 people, half of whom were students. PSL accepted and screened its own applications at the time, and those that PSL was interested in were sent over to NMSU personnel. This sometimes created a great deal of work for those in the Personnel Office.

Figure 104. Secretaries Louise Vernagelli (Haley), Security; LaVerne Wood (Griffiths), Personnel; and Cheryl Murray, Travel, Posing for "Cigar Shot," 1968

LaVerne (Wood) Griffiths, who started working for Verla Daugherty in the Personnel Office in 1968, said that PSL received over 300 applications in response to its first advertisement for Technician trainees. She and the others in the Personnel Office screened all 300 (and only 10 of the applicants were hired). She said, "That was quite a job, reading all of those applications." Ms. Griffiths also spoke of the long hours that she and others worked processing salary increases: "Talk about staying up late at night, that's what we did one July—we were short-handed with so many employees, and we stayed up until midnight some nights getting the salary increases done."

Sounding Rockets

The following sections provide greater detail about PSL's sounding rocket, defense, and space endeavors.

Overview

As research satellite technology matured in the 1960s, many in the aerospace community were predicting that satellites would replace sounding rockets, rendering them obsolete. In fact, at the end of the decade, Raymond Bumgarner was advised by PSL management to get out of the sounding rocket field for this very reason. In reality, these prognosticators were overlooking the fact that rocket-borne instruments provide the only means of obtaining a vertical profile of the atmosphere/stratosphere up to several hundred miles at any selected location and time. Other advantages of the sounding rocket include lower cost, greater access, and quick recovery of payloads. Sounding rockets, though fewer in number, have persisted and are being launched with sufficient regularity to keep PSL's support personnel employed into the present century.

Rocket-borne telescopes viewing the universe from above the earth's atmosphere provided scientists with some very intriguing discoveries in the 1960s. Three new Astronomy branches—ultraviolet, X-ray, and gamma ray—are attributed to sounding rockets.

On March 13, 1969, detectors aboard an NRL Aerobee flown at WSMR revealed the first evidence that a celestial object emits X-rays in bursts, or pulsations. The detectors were focused on the Crab Nebula, near whose center a "pulsar"[38] had been located by a ground observatory just two months prior. The rocket experimenter, NRL scientist Gilbert Fritz, found that these X-ray pulses occurred at the same rate as the visible ones— approximately 30 times per second—but were 200 times more powerful and 500 times more potent than the total energy radiating from the sun. These findings were verified one month later on a successive Aerobee flight, instrumented by Professor Hale Bradt of the Massachusetts Institute of Technology.

38 A pulsar is a star that emits visible light and radio frequency pulses.

A NASA Aerobee launched June 13, 1969 from Natal, Brazil, detected an X-ray star only 16 km (10 miles) in diameter with a weight identical to that of the sun. University of California scientists conducting the experiment said that this object might be the first direct evidence of a neutron star, and that this was the first time the size of an X-ray source from deep space could be determined. PSL/MEI's L.D. ("Doug") Williams supervised telemetry coverage for this historic event.

Rocket research in the decade also provided:

- Characterization of the earth's upper atmosphere
- Initial recognition and definition of Geocorona
- The majority of ionospheric chemistry intelligence
- Evidence of the existence of electrical currents in the ionosphere
- The majority of significant space astronomy results in the 1960s

In 1959, NASA/GSFC's Sounding Rocket Branch launched 16 rockets; in 1964, the number increased to 152. Meanwhile, the Air Force and Navy continued their own scientific rocket firings in considerable numbers and at various sites, primarily WSMR and Ft. Churchill. GSFC, NOMTF, and other agencies (including the Air Force) sponsored approximately 1200, 300, and 200 major sounding rocket launches in the 1960s, respectively (in fact, NASA's Wallops Island facility launched nine rockets on July 29, 1968, alone). The combined firing rate for all agencies gradually increased, peaked in 1968, and then began to decline.

The most popular rocket in the 1960s was the Nike-Apache (Figure 105). Thiokol introduced this rocket in 1961 at the request of the PSL Rocket Section, who was in the market for a more powerful vehicle for the POGO target program. The Nike-Apache was a two-stage, solid-fueled vehicle very similar to the Nike-Cajun, but its use of a different propellant and a phenolic lining in the steel exhaust nozzle provided it with 30% greater thrust. Approximately 400 of these

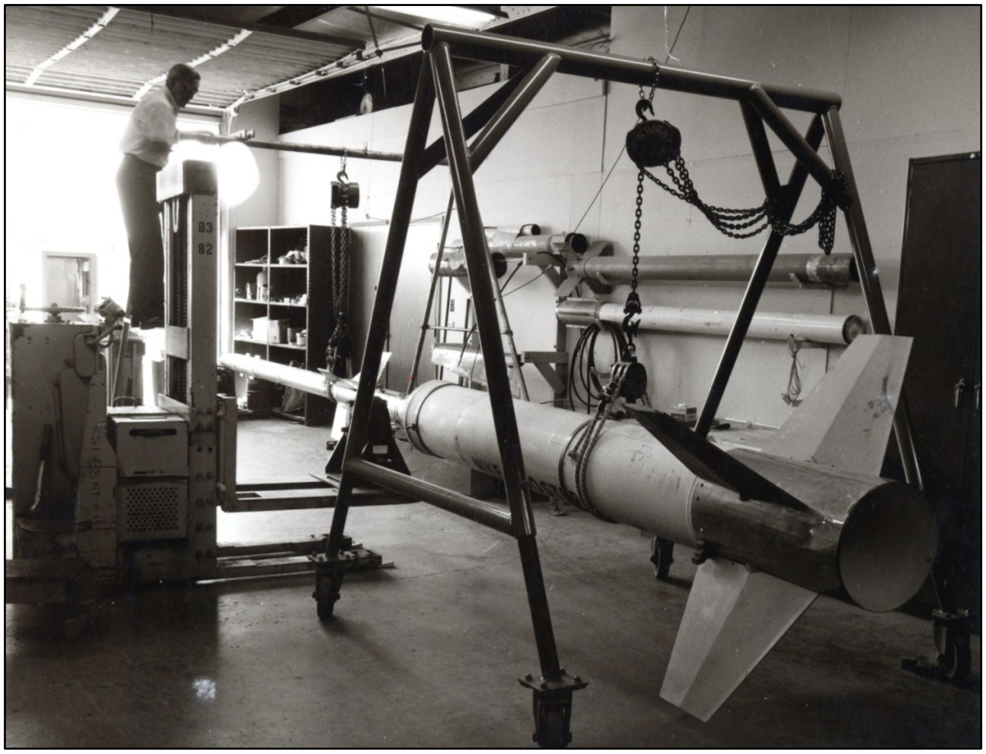

Figure 105. Integration of Nike-Apache Rocket

simple, reliable vehicles were used as sounding rockets during the decade. In 1960, the Aerobee 150 was redesigned using four tail fins instead of three and renamed Aerobee 150A. In that same year, the 150A was paired with a Nike booster, resulting in the Aerobee 170. Other new additions to the variety of rockets in this decade were the IRIS (1960), Argo D-8 Journeyman (1960), British Skylark (1961), Black Brant (1961), Astrobee 1500 (1962), Aerobee 350 (1964), and Nike-Tomahawk (1965). The Argo D-8 was comprised of military hardware—a modified Sergeant, two Lances, and an X-248—capable of lifting 150 pounds to 1,000 miles.

Over 400 of the above-mentioned 1,200 NASA firings were Nike-Apaches, 350 were Nike-Cajuns, and about 250 were rockets from the Aerobee series. Wallops Station was the preferred site for Cajuns and Apaches, and WSMR for Aerobees. NASA launched 200 rockets from Ft. Churchill during this period, supported in varying degrees by PSL.

PSL's telemetry, DOVAP, and data reduction field groups provided the bulk of this support, touring the world in the process. As GSFC's Sounding Rocket Branch began to provide its services to foreign entities and American experimenters desired to expand their horizons, PSL personnel were necessary for support at many new launch sites, including Argentina, Ascension Island, Australia, Brazil, India, New Zealand, Norway, Pakistan, Spain, and Sweden. U.S. launch sites activated in the 1960s included Kauai, Hawaii; Puerto Rico; Eglin AFB, Florida; two locations in Alaska (Point Barrow (northern coast) and Poker Flat near Fairbanks); and the Pacific Missile Range in California (Table 6). The majority of PSL's sounding rocket support, however, occurred at Wallops, with WSMR running a close "second." Unfortunately, dispersion problems prevented the use of higher-altitude rockets such as the Nike-Tomahawk, Black Brant IV, Javelin, and Astrobee 1500 at WSMR (there was no way to assure that impact would be confined to the Range's 40-mile width).

Table 6. PSL Sounding Rocket Support in the 1960s

Location	Year	Participants
Natal, Brazil	1965-1969	L.D. Williams, E. Bedy, H. Fitch
Woomera, Australia	1961	W. Harkey, J. Cole, O. Pace
Lulia, Sweden	1962-1967	W. Harkey, B. Alons
Andoya, Norway	1962-1967	J. Otero, B. Alons
New Zealand	1963, 1964, 1965	C. Watkin
Spain	1969	W. Joosten, B. Gammill, B. Alons, G. Lee
Thumba, India	1964, 1964, 1966, 1967, 1968	E. Jiminez, G. Lee
Hawaii	1967	B. Alons
Ascension Island	1961-1969	B. Alons
Pt. Barrow, Alaska	1965, 1967, 1968, 1969	O. Pace, G. Steele, M. Nuce, B. Gammill, B. Alons, C. Ricketts
Poker Flat, Alaska	1969	W. Joosten, B. Gammill, B. Alons, G. Burden
U.S.S. Croatan	1965	G. Steele, B. Alons
Ft. Churchill, Canada	1960-1969	R. Wagner, J. Cross, W. Harkey, P. Pradzinski, G. Burden, M. Segura, J. Davis, W. Mallar, W. Joosten, J. Cooper, E. Mayfield, C. Marrujo, T. Arellano, F. Lemon, D. Brown, G. Lee
Rio de Janeiro, Brazil	1966	E. Jiminez

DOVAP

As mentioned in Chapter 4, PSL's Ionosphere Section was supporting NRL's ionosphere experiments where radio signals transmitted from sounding rockets provided electron density data. Early in 1957, during the IGY rocket program, the discovery was made that these signals could be used to determine the "range" of the rocket, i.e., its distance from the receiving station at any given time. Furthermore, it was possible to compute trajectories through the use of three or more receiving stations situated to allow triangulation. Since the two components necessary for a rocket tracking system—range and direction—were available, NRL rocket scientists immediately seized upon the opportunity to employ their own "in-house" system, freeing them from total dependency on base radars for trajectory and velocity information. The Ionosphere Section therefore entered the tracking business, helping NRL to develop and assemble a system called "Four-Station DOVAP." This system utilized a ground transmitter, a transponder in the rocket, and four strategically placed receiving stations. The transponder doubled the RF signal frequency from the ground transmitter and sent it back to the ground stations. There the transmitted and transponder signals were heterodyned together and the beat cycles counted—each cycle representing an increase of one wavelength in range. It is the opinion of some that DOVAP trajectory data are more accurate than FPS-16 radar data.

In 1958, Jack Townsend and Carl Seddon of NRL requested that PSL design and construct a SSD tracking system using the interferometer principle to obtain direction information. NRL intended to mount this station in a van for portable use. Robert Sabin, Wes Joosten (and the Ionosphere Section), and Bob Wagner assumed this task. The first of three vans was completed in 1960 and deployed at Wallops Station under NASA's authority (because, by this time, Mr. Townsend and associates had transferred from NRL to GSFC). Two other vans were then constructed within the next year and were used during the 1960s at various remote sites, including Ascension, Puerto Rico, Point Barrow, shipboard, Ft. Churchill, Spain, and Sweden.

The SSD's shipboard use occurred in 1964-1965 aboard the U.S.N.S. Croatan, NASA's mobile range vessel. Six Nike-Apaches were launched from its deck in 1964 just off of the Wallops Island coast. Gary Steele and Bernie Alons took an SSD van aboard to support these firings. In March of 1965, the Croatan cruised through the Panama Canal, and for two months, a series of sounding rockets was fired as it traveled up and down the West Coast of South America. The firing of these 77 rockets was part of NASA's contribution to the International Quiet Solar Year (IQSY) worldwide research effort. The SSD instruments measured the states of the upper atmosphere and the ionosphere during a period of minimum sunspot activity. The "equatorial electrojet" was of special interest.

Robert Sabin participated in the early part of the cruise, disembarking in Panama. He spoke of an odd problem that appeared whenever they attempted to operate the SSD transmitter and receiver on board the ship. Apparently, whenever the transmitter was operating, the receiver picked up a strong RF signal, the frequency of which was double that of the transmitter output. This is normally the case when the transponder/doubler in the rocket is operating; however, the transponder was turned off. Since this mysterious signal caused the SSD system to fail, it was necessary to eliminate it. After much deliberation and testing, Mr. Sabin determined that the rusted joints between the plates and other parts of the ship's structure were acting as diodes and generating a second harmonic of the transmitter signal. The problem was corrected by flushing the deck with seawater, which temporarily shorted out those diodes. It was then possible to fire the rocket.

By the mid-1960s, trajectory determination was the Ionosphere Section's primary business; therefore, the section was renamed Missile Position Instrumentation (MPI) in the 1966 PSL reorganization. The Laboratory's 1967 Annual Report to the President shows the MPI using the SSD stations, which became known as RADINT (RADio INTerferometer), and the Four-Station DOVAP.

The data from these stations were recorded in both analog and digital form and transmitted via data link directly to PSL for reduction and analysis. Co-ops from the Data Reduction Section were stationed at Wallops for these purposes, under the supervision of Charles Gardenhire, who commuted between Wallops and NMSU.

On March 7, 1962, a hurricane brushed the Wallops Island coast, creating difficulties for the MPI and MEI field operations. The tide washed completely over the island, destroying the seawall that had previously provided adequate protection. The DOVAP transmitter trailer was flipped onto its side and the SSD trailer, though it remained upright, was washed completely off of a concrete pad and buried in sand up to floor level. Seawater flooded the rocket preparation area and seeped into the blockhouse to a four-inch depth, damaging or destroying considerable electronic equipment. Several solid-fueled boosters that had been stored in a shed on the island were scattered about the landscape. PSL's telemetry stations suffered only minor damage—the two portable stations had been moved off the island prior to the flooding. The firing schedule was delayed for about a week.

> When asked whether anything exciting ever happened with the rockets at Wallops Station, Gary Steele replied, "Yeah, nearly every time we shot one…I believe it was Don Peterson that was up there one time, and the rocket—it was a two-stage rocket, hanging on the launch rail—and the front stage fell off of it and he caught it. It was already armed and everything. So there he stood with a live rocket, and didn't know what to do with it. He didn't drop it, thank goodness!" (Mr. Peterson remembered the event differently, saying that a fellow from the University of Michigan actually caught the rocket).

One of the Ionosphere/MPI Section's major endeavors during the 1960s was the transistorizing of the instrumentation van, which meant redesigning and fabricating all equipment in the van using solid-state circuitry. The Electronics Shop was heavily involved in this work, which was done at Wallops Station and on campus.

The DOVAP transponder and its antenna were eliminated from the system in the mid-1960s in order to make it capable of tracking smaller rockets and to reduce the weight and drag of all rockets. The RADINT stations then used the telemetry signal from the rocket to determine rocket position. According to Bernie Alons, although this method was not as accurate as using the transponder, it was quite satisfactory for experimenters' purposes. The absent transponder eliminated the need for the DOVAP transmitter, which made the overall system more portable. It was employed on firings in Spain, Norway, Sweden, and Point Barrow. Wes Joosten, Billy Gammill, and Bernie Alons supported a series of shots in Spain in the spring of 1969.
A large number of the launches supported by MPI were so-called "grenade shots," where small explosive charges in the payload were detonated at controlled intervals as the rocket ascended. Measuring the time required for the sound of each burst to reach the ground enabled determination of the air density and temperature. The Nike-Apache, Nike-Cajun, and Aerobee rockets were used

for most of these. Thirty-two rockets were fired in a span of five minutes during a solar eclipse at Wallops Island. Bernie Alons traveled to Ascension Island for some grenade firings.

The grenade experiments ended in 1969 due to NASA funding shortages, resulting in a change in the PSL/GSFC contract's DOVAP task. The Wallops MPI field group then transferred back to Las Cruces; fortunately, they were able to begin supporting a meteorological rocket program at WSMR. This work continued into the 1970s.

PSL personnel traveled on numerous occasions to Point Barrow during the 1967-1969 timeframe (Figure 106).

Figure 106. PSL Co-op Tom White in Pt. Barrow, Alaska, 1968

MEI Section personnel, including Orville Pace, Marvin Nuce, and Gary Burden, assisted the MPI Section on some of these trips. Cessation of the grenade shots resulted in the closing of the Point Barrow rocket range. Its equipment was moved to Poker Flat near Fairbanks, Alaska where NASA/Wallops contracted with the University of Alaska to operate it. The MPI and MEI sections supported aurora shots there in the 1970s.

Tom White's final co-op phase was spent supporting rocket instrumentation at Wallops Island, VA (Billy Gammill was the station manager). Mr. White said, "Probably the neatest thing about that phase was the trips we took to the Naval Research Laboratories in Pt. Barrow. We fired off the instrumentation rockets and used the equipment to locate their paths because they didn't have radar there to track them. We flew into Fairbanks on New Year's Day [of 1968], heading to Pt. Barrow. It ice fogged the next day, so there were no flights out [of Fairbanks]. It was -45 degrees at 12:00 noon. Finally, the fog lifted and we flew into Pt. Barrow. The Northern Lights were just unreal. We initially stayed at the Naval Research Laboratories in Quonset huts, but a facility was built later that was much better. We drove these pickups with very large wheels. When we took them out, we would leave them running because we were 2-3 miles from the main camp area."

Sounding Rocket Telemetry

<u>Instrumentation Development/Missile Electronic Instrumentation Section</u>

A part of the MEI Section's support in the 1960s was very similar to that provided by the MPI Section using their DOVAP system. Both sections supported worldwide launch operations using portable ground stations, and both were asked to design and fabricate state-of-the-art, solid-state hardware to improve the systems they were using.

Numerous and revolutionary technological advances were made in the telemetry field during the 1960s. The advent of the digital computer and transistor created new possibilities for telemetry systems with greater accuracy, increased data capacity, accelerated data processing, lower power requirements, and significantly smaller physical size for airborne transmitters.

PSL's MEI Section completed two major design projects in accordance with these advances: a miniaturized PPM telemeter (Figure 107) and various custom-designed PCM telemeters.

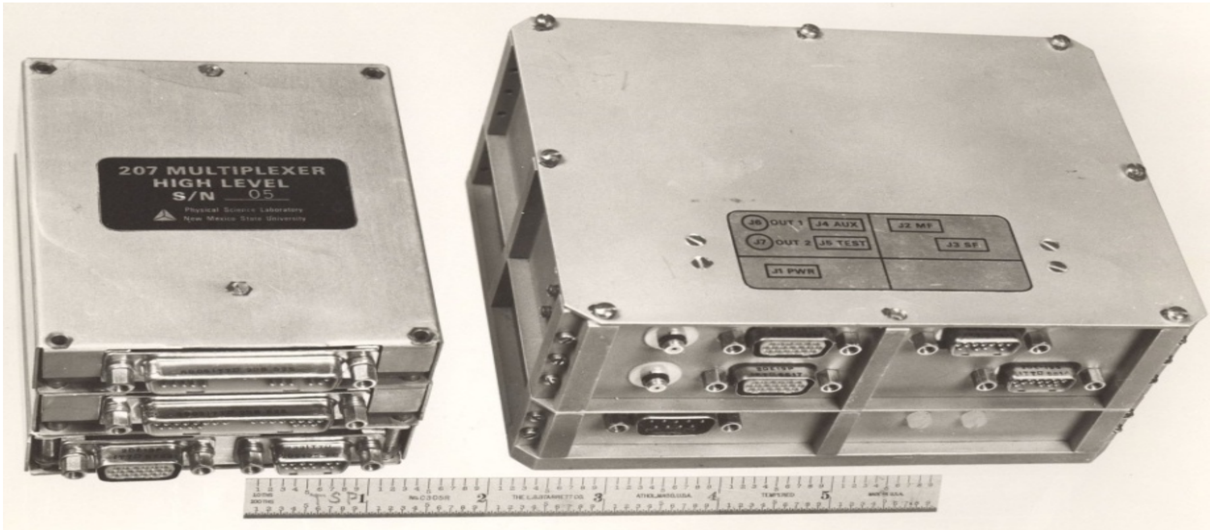

Figure 107. Model 207 PCM Telemetry Encoder

In 1959, NRL concluded that it was possible to redesign their PPM flight transmitter into a solid-state unit, thus saving appreciable weight and space in Aerobee payloads. Bob Wagner, with the help of Roy Sanders and Dale Beach, undertook the effort. The result was the very successful "XN-4" (see Figure 72 on page 144), a unit roughly the size and shape of a two-pound coffee can (its predecessor was rectangular in shape and approximately a cubic foot in size). PSL fabricated approximately 24 XN-4s over the course of several years.

The first XN-4 unit, flown in Aerobee NB3.118 on April 4, 1963, was recovered after impact in perfect condition. NRL scientists were soon installing two of these small units in some of their rockets. The PSL-installed payload recovery system made it possible to re-fly a few XN-4s several times. Usage continued until 1969, when the PPM/AM format was replaced with Pulse Code Modulation/Frequency Modulation (PCM/FM). The latter, which transmits data in digital form, had several advantages over PPM/AM.

The advent of PCM/FM resulted in a significant amount of work for the MEI and other PSL sections, beginning in 1966. Bob Wagner and his development group became heavily involved in the design and fabrication of special-purpose PCM encoders and decoders for NRL scientists. The first in this series, Model 207, was upgraded to Model 208. Many of these encoders were produced and have been flown in many rockets and several satellites. ARC-75 was designed in 1975, and was still in use in 1985. The next volume of PSL's history will address the continuing modernization of these units.

Concurrent with these developments, the Defense Department mandated that all telemetry used by military bases must move to the 2,200 MHz frequency band (otherwise known as, "S-band") by the year 1970. PSL had been using significantly lower frequencies for its telemetry operations, from 220 to 250 MHz. Since NASA's budget was unable to absorb the great cost involved, its request for a waiver of the deadline was granted. The higher frequency with its much shorter wavelength made way for dramatic reductions in the physical dimensions of both flight- and ground-based antennas.

One of PSL's most innovative telemetry antenna developments was the S-band receiving antenna and control circuitry that could automatically track the moving source of the telemetry signal, regardless of whether it was a rocket, airplane, balloon, or parachute. PSL engineers Wes Joosten, Robert Sabin, and the Electromagnetic Section's William Cooper designed the Interferometer Tracker under the NRL contract. The effort began in September of 1967; 18 months later, a finished model was ready for testing (Figure 108). It was installed on the roof of Anderson Hall in an attempt to track a live rocket (NRL Aerobee NB3.205, launched on March 17, 1969 from WSMR). The rocket carried an S-band PCM/FM telemeter, along with two other telemeters. The engineers, technicians, and machinists involved were elated when the tracker locked onto the telemetry signal the instant the rocket rose above the Organ Mountains. The tracker was installed at MEI's Parker Station in April of 1969. In July of 1969, it tracked the Navy's Tartar missile to the point of impact. NRL applied for a patent on the system in 1968.

Figure 108. Interferometer Tracker, 1969

The tracker employed a ten-foot diameter parabolic “dish,” which was mounted on a Scientific-Atlanta servo-driven pedestal. The dish acted as the telemetry receiving antenna only; auto-tracking was accomplished through a two-axis (elevation and azimuth) interferometer system that used a trio of S-band horn antennas mounted on the perimeter of the dish.

<u>Sounding Rocket Operations—Stateside and Around the World</u>

Raymond Bumgarner was assigned the task of distributing skilled personnel to stations worldwide for simultaneous telemetry support. Many times the 60+ MEI Section employees were not adequate for such coverage, and it was necessary to “borrow” individuals from other sections. Adding to the problem was the fact that MEI’s permanent field groups at Cape Canaveral, Wallops Station, WSMR, and the Pacific Missile Range were subject to ever-changing workloads, requiring adjustments in the staffing level. Nevertheless, PSL was able to respond very quickly to its customers' requirements by providing support anywhere in the world, giving it an advantage over its competition.

The Wallops telemetry stations were staffed by the MEI Section through the 1960s with a permanent complement of seven to nine engineers and technicians, supplemented by three or four co-op students. James Cole, Fred Lemon, and Warren Harkey each supervised the group at various times. The PPM/AM, FM/FM, and PCM/FM telemetry modes were in use at these stations.

Bert Blanton began working as an SGI co-op in the summer of 1960. He was assigned to the Telemetry Section at Wallops Station for all of his work phases except for a short assignment at the Anderson Hall Station. Mr. Blanton, who spent some time at Ft. Churchill, Manitoba, as part of his Wallops assignment, related the following story. “Paul Pradzinski (he left later and Warren Harkey came) and I were sent to the Churchill Research Range (CRR), along with a small radar van equipped with the latest transistorized FM/FM telemetry equipment [to support a launch (using a Nike research vehicle (Figure 109)]. This launch was one of a series…conducted by various university and government research teams into the Aurora Borealis to determine its cause and whether it posed a threat to manned space flight.

“Normally all telemetry at CRR was handled by the contractor (Pan American World Airways). Pan Am had a blockhouse full of the latest telemetry equipment, auto-track antennas, etc. We were sort of uninvited poor-folk guests next to their blockhouse, representing NASA.

“During a tour of Pan Am’s facilities, I was shown the connection diagram and the equipment to which their two new auto-track antennas were connected for the first time (all of their high-quality receivers were fed by these antennas). PSL’s policy was to use completely diverse signal paths for its backup equipment—we would never have connected all receivers to the same antennas or to the same electronic device. Well…during launch, these [Pan Am’s] went berserk and they got no data. Guess who did? PSL in its little van! Once you fire a rocket, you can’t call it back for a re-run. We earned our keep that night.

“The time I spent as a co-op student with PSL (especially the three months I spent at CRR) were a wonderful educational experience for a kid from a ranch in New Mexico. Paul and Warren were superb team leaders, teachers, and co-workers, as were all of the techs and engineers in that group. During this particular launch, Warren had enough confidence to allow me to operate the station while he climbed up on the van roof (in 40 below temperatures) to operate the antenna.”

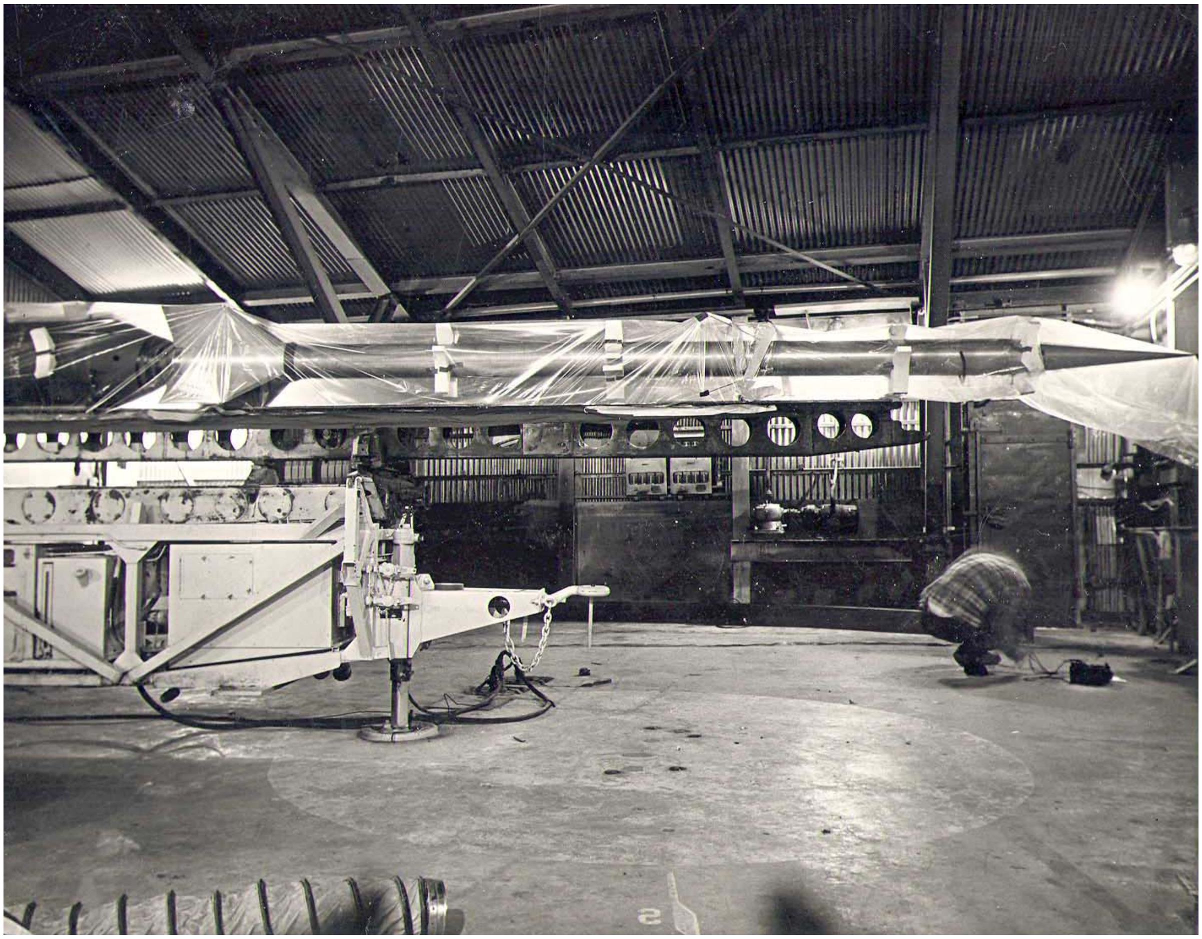

Figure 109. Nike Research Vehicle on Launcher at CRR, Circa March 1963

The new IRIS rocket's initial firing occurred at Wallops Station on July 22, 1960. It could carry 100 pounds to 200 miles, and was used occasionally until 1962. An unusual Aerobee firing occurred at Wallops in June of 1961—although the booster exploded in the launcher, the Aerobee flew for 422 seconds— a relatively normal duration.

In 1964, the Aerobee tower was modified (bore enlarged) to accommodate the Aerobee 350, the main stage of which employed a cluster of four Aerobee 150 motors topped by a single 150. A Nike booster was used. The first firing, a launcher/rocket compatibility test using a dummy upper stage, was somewhat of an embarrassment—the blast from the booster's ignition ripped a significant portion of the asbestos sheeting off of the tower enclosure (Figure 110). Although the first complete Aerobee 350 was fired successfully at Wallops June 18, 1965, it was not used operationally until the end of 1969.

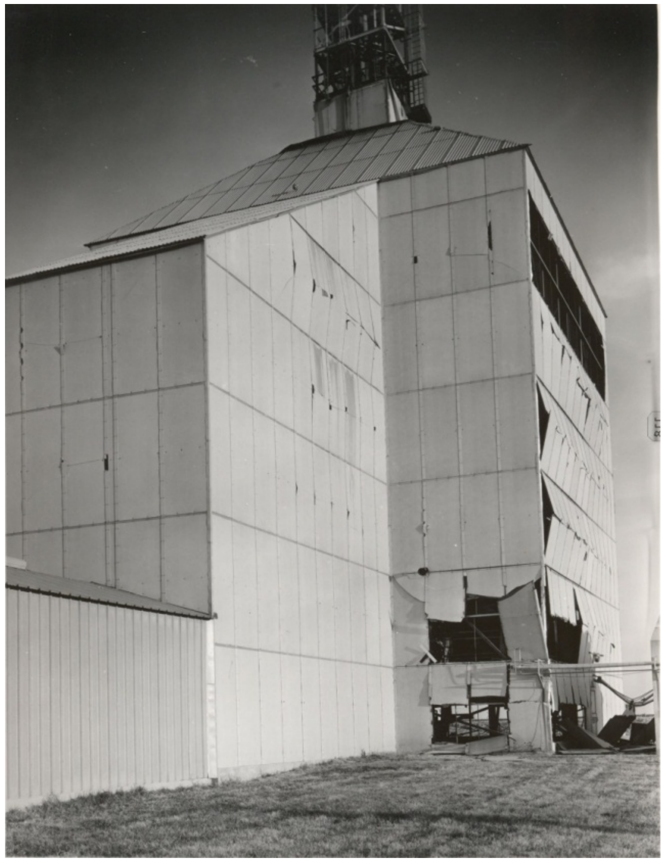

Figure 110. Damaged Aerobee Tower Enclosure at Wallops Island, 1964

One of the Wallops Station telemetry group's major non-routine projects was the refurbishment of several racks of PPM ground station equipment that had survived a fire at Ft. Churchill in 1961. The fire began in the blockhouse, and destroyed everything between it and the Aerobee tower, including the two telemetry trailers, “S” and “T.” All of those trailers and buildings were interconnected via Quonset-type passageways, which enabled the fire to spread. Fred Lemon and his crew spent several months meticulously cleaning the soot off of these units and replacing burned wires and components. A complete telemetry station was salvaged from the charred remains, and was placed into service at Wallops as, Station “J.” Two additional employees were required in order to operate this station. Fifteen Cajun launches were then relocated to Wallops Station.

Telemetered rockets were launched from Wallops Station at an average approximate rate of one per week over the entire decade.

The MEI Section’s WSMR field group managed the bulk of the sounding rocket telemetry at Ft. Churchill, as well as at WSMR. Both of these ranges were used extensively throughout the 1960s (for example, 200 launches were performed at Ft. Churchill during the decade, 79 from 1960 through 1964 alone). In addition to these two sites, MEI Section/WSMR personnel traveled to the majority of the same foreign countries as DOVAP personnel (Table 6) (most of this travel was in support of the NASA contract). During the 1960s, PSL provided telemetry support for approximately 400 sounding rockets (the majority of which were Aerobees) launched at WSMR for several agencies—NASA, NRL, Air Force Cambridge Research Labs, and Kitt Peak National Observatory (some missions were joint efforts involving two of these agencies, and roughly one third utilized two or more telemetry links). The peak year for MEI/WSMR was 1968, during which 53 missions were supported. In November of that year, WSMR personnel began complaining of sounding rocket overwork.

PSL personnel traveled many times to Ft. Churchill to support the 200 rockets launched there during the 1960s (Figure 111). Fully half of these were auroral probes (i.e., night launches that

Figure 111. Ray Young, Don Brown, Ted Arellano, and John Cross at the Pas Airport Enroute to Ft. Churchill

involved a pre-planned "hold" (i.e., halting the countdown) immediately prior to pressing the "Fire" button). All support groups, including telemetry and DOVAP, were then required to stand by while the experimenter watched the sky for a suitable auroral display. If none appeared, the process was repeated the following night. This sometimes went on for weeks, so it was necessary to replace a fatigued crew with a fresh one prior to firing.

MEI Section personnel engineered a couple of significant improvements in the PPM telemetry system, as well as many minor ones. In the spring of 1965, Fred Lemon began a long-term endeavor to modernize the PPM ground stations that had been in operation for almost 20 years. It was necessary to orchestrate this effort, of course, with the heavy launch schedule. A new CRT recording rack was finished in August of 1967 that produced excellent records. In December of 1968, a complete new PPM station (four six-foot racks) was in operation at Parker Station, providing records superior to those of the former stations, with significantly less effort. Concurrent with that project, Bob Wagner and Warren Harkey, in response to requests from C.Y. Johnson of NRL, developed a means of digitizing the PPM video data from the ground station receivers. Mr. Wagner also devised a system for recording the video to magnetic tape, which was no small feat. Keith Hennigh and his Telemetry Reduction Section then attempted to develop a method of processing the PPM digitized data on the Burroughs 220 computer. After solving various programming problems, success was achieved when, on October 4, 1966, Aerobee NA3.160 was fired and all 28 segments of a commutated channel were plotted.

PSL's level of telemetry support at WSMR increased appreciably when NASA/GSFC added two permanent ground station sites—"VAB" and "N-200" (Figures 112 and 113). "VAB" refers to

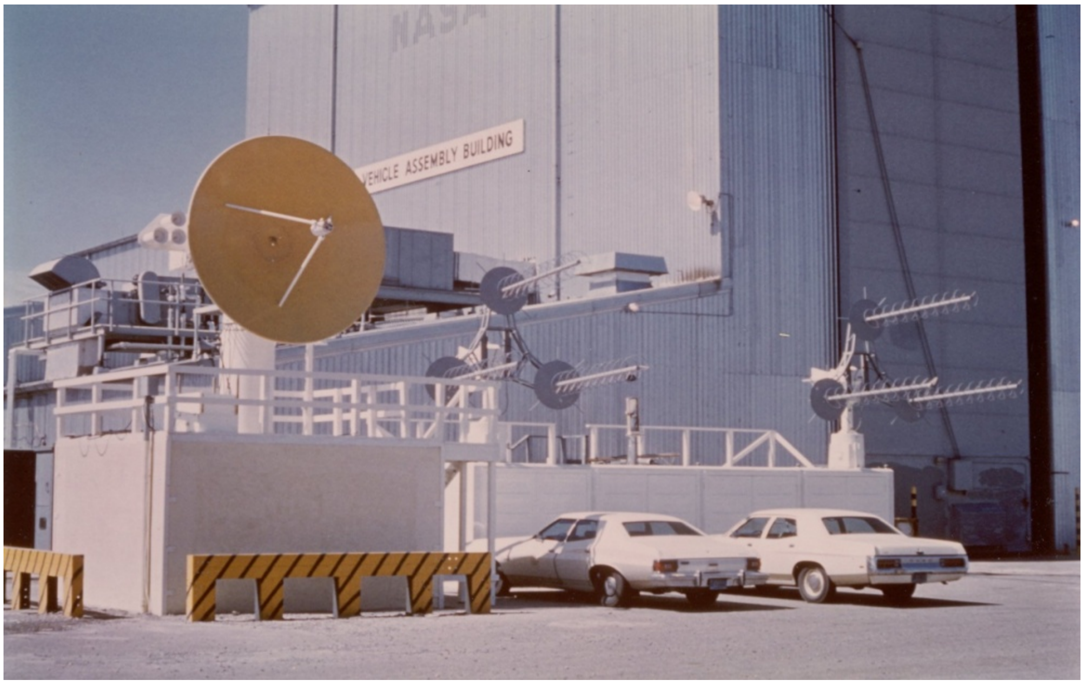

Figure 112. Vehicle Assembly Building

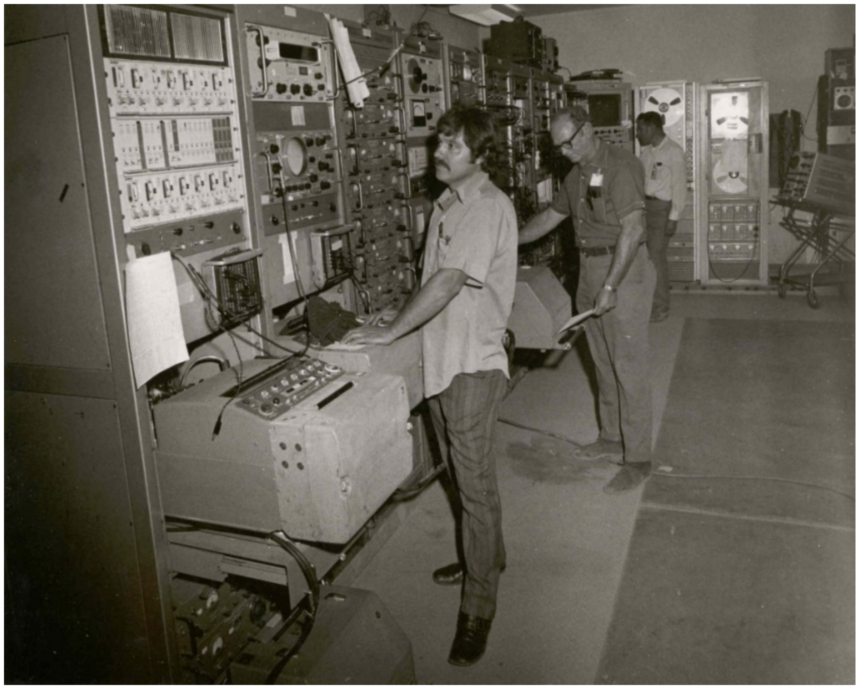

Figure 113. N-200 Ground Station, 1960s

the Vehicle Assembly Building, which was part of Launch Complex 36 (LC-36). NASA/Apollo built this complex in the early 1960s for its Little Joe rocket launches. Since that program had completely ceased by 1968, LC-36 was available when GSFC needed a site on which to erect its Aerobee 350 tower. The VAB then became an Aerobee preparation area, complete with a multi-mode telemetry ground station for checkouts, as well as for flights. The first mission supported was a PPM Aerobee in November of 1968 (Figure 114). N-200, which also contained a complete


Figure 114. First Aerobee Launched From LC-36, WSMR, 1968

complete telemetry station, was erected around this time as the Aerobee preparatory facility in the NOMTF's launch complex (prior to that, this facility was located in the NOMTF's headquarters building in the main post area, several miles away from the launch site).

In 1961, GSFC requested that PSL provide a full-time operator for a telemetry station located at its Greenbelt, Maryland facility. The station was used for payload integration tests, which were required for each GSFC-supported payload prior to use. PSL instituted a 90-day rotation plan for MEI Section personnel for this task. It is believed that David Barnett took the first "turn," and after a few rotations decided that he liked the assignment well enough to remain indefinitely.

The MEI Section provided telemetry support for an Air Force balloon launched from Holloman Air Force Base on July 1, 1965 (a hole in the gas bag had caused the failure of an attempted launch the previous day). Charles Watkins installed the FM/FM transmitter and Parker Station recorded the data. Warren Harkey, James Cole, and Orville Pace enjoyed a three-month stay in Australia in the fall of 1961. They managed the telemetry for four NASA Skylark rockets at the Woomera firing range in the Australian desert (i.e., the "Outback"), where summer temperatures typically reach 112 degrees in the shade. Fortunately, these men lived in the coastal city of Adelaide, which was 35 miles away; unfortunately, the rental cars in Australia were not air-conditioned. They said that the greatest hazard they encountered during their stay was that of colliding with kangaroos on the roads.

Missile Position Instrumentation Section

By the early 1960s, groups had been formed that corresponded with the various sounding rocket functions. The Ionosphere Group (which later became the MPI Section) supported DOVAP missions (the majority of the MPI Section's employees worked in the Ionosphere Group before the Instrumentation Division was created in the mid-1960s reorganization).

Early in the 1960s, the Ionosphere Group, under a contract with J. Carl Seddon of GSFC, built a SSD station that would render the multiple Doppler stations unnecessary and would require complex triangular data reduction. Wes Joosten led the initial system design and construction effort.

The initial system was constructed at WSMR (in order to prove that it would work) and then moved to Wallops Station. It required a four-antenna array, surveyed to 0.1-inch accuracy for the interferometer. Since very precise electrical cable lengths were required for the interferometer system, driving a vehicle across or stepping on these cables was strictly forbidden.

> Dan Nimrod said that the SSD system's construction at WSMR (in 1959 or 1960) was the realization of Mr. Seddon's long-time dream to prove that the complete rocket trajectory could be realized by a single station. To protect the cables, a remote site away from normal vehicular traffic was selected. One day, a dust cloud in the desert indicated the arrival of a vehicle--an Army Jeep, driven by a cigar-smoking Colonel, who got out and stared off into the distance, surveying the situation. He then drove a wooden stake right in the middle of Carl's antenna array, thus announcing the target for an afternoon Nike-Ajax launch. Carl came unglued at this, and the Colonel said, "What the hell are you worried about? We haven't hit a target yet!"

Engineers Billy Gammill, Gene Lee, and technicians Walter Montz, Gary Steele, and Bernie Alons lead the effort to build an SSD station at Wallops Island, VA.

The SSD system used left- and right-hand polarized antennas to separate Doppler and rocket spin (roll) data. The data from the two Doppler antennas provided radial distance to the rocket, but not direction information—this was provided to the rocket by the SSD system's orthogonal antenna array, which provided azimuth and elevation angles. Time tags, azimuth and elevation angles, and velocity/radial range data were used to compute a complete trajectory in space (a trajectory is the actual path of the sounding rocket, from start to finish).

The trajectory computed by the SSD system required refinement using mathematical methods. This refinement, called "smoothing," was a process of averaging over a series of 21 one-second points during the trajectory. John Weinrich, Marge Ottesen, Jon Ottesen, John Byers, Charles

Gardenhire, and others from PSL's Data Reduction Section developed a 21-point smoothing program to clean up the raw data obtained from the SSD.

In 1964, GSFC provided support for several shipboard launches that took place from both the Atlantic and Pacific oceans. The USNS Croatan, a WW II aircraft carrier, would be used for these launches. Although the USNS Croatan was never intended for aircraft launches, it did have elevators through large hatches for storage of aircraft below the main deck. Gary Steele, Bernie Alons, and Dan Nimrod were dispatched to Baltimore to instrument the ship at a pier in Baltimore.

According to Dan Nimrod, the group experienced one of its first "incidents" when Gary Steele plugged a soldering gun into a "standard" looking electrical outlet on this 1940s-era ship. When he pulled the trigger, the soldering gun pretty much melted in his hand. It turned out that, although this older ship had ordinary looking outlets, they were wired for 28 volts DC. Gary's soldering gun was AC, and it presented a direct short to the system.

After the launchers had been installed and the instrumentation readied, the USNS Croatan and crew (NASA's John I. ("Bud") Hudgins and PSL's Bernie Alons and Gary Steele were also present) set out from Baltimore. They traveled down the Chesapeake Bay and out of Norfolk into the Atlantic Ocean, with the intention of conducting pre-launch testing.

As part of the pre-launch radiation testing, an attempt was made to read telemetry data from an instrumented rocket, which dangled from a helicopter flying in circles around the ship (Dan Nimrod was on board the helicopter while these tests were being conducted). Unfortunately, the rocket signals were disrupted because the DOVAP system caused second harmonic radiation problems (every one of the ship's rusty old joints was a diode that acted as a generator for the second harmonic). Someone (Mr. Nimrod thought it was Robert Sabin) suggested flooding the deck with seawater. This shorted the diodes and solved the problem.

Once the second harmonic problem was solved, a trial launch was attempted. Although the launch was successful, the bow of the ship was damaged, so it was returned to Norfolk for extensive repairs. Afterwards, the USNS Croatan made its voyage through the Panama Canal and back, launching several rockets in the Atlantic and Pacific oceans.

PSL's primary areas of support at Wallops Station in the early 1960s were the Grenade program and telemetry support for many projects provided by the MEI Section's Station A. Several PSL supervisors (including Jim Cole, Fred Lemon, Warren Harkey, Billy Gammill, Dan Nimrod, and Paul Pradzinski) headed Station A operations at various times. Station A had supported many orbital launches, and because of its proximity to the launchers, it was often successful tracking a launch when the main base telemetry station failed.

Beginning in 1969 and continuing into the 1970s, the MPI Section provided telemetry support for a special series of small rockets. The purpose of the project, initiated by Mr. Wendy Smith of GSFC, was to probe the atmosphere's ozone layer using the Loki (Figure 115) and Arcas rockets, which were four inches in diameter. MPI designed and built a specialized eight-channel telemetry system for this purpose, including a miniature transmitter only 2½ inches in diameter and 12 inches long. This small size was achieved by installing the electronics on a flexible printed circuit board and wrapping it around a flashlight-size Nicad battery. The first flights of this unit, which transmitted at 1,680 MHz, occurred at Wallops Station. Bernie Alons said that the telemetry signal of the payload, which was parachute-deployed, would persist for 45 to 60 minutes, and occasionally until winds carried it over the horizon.

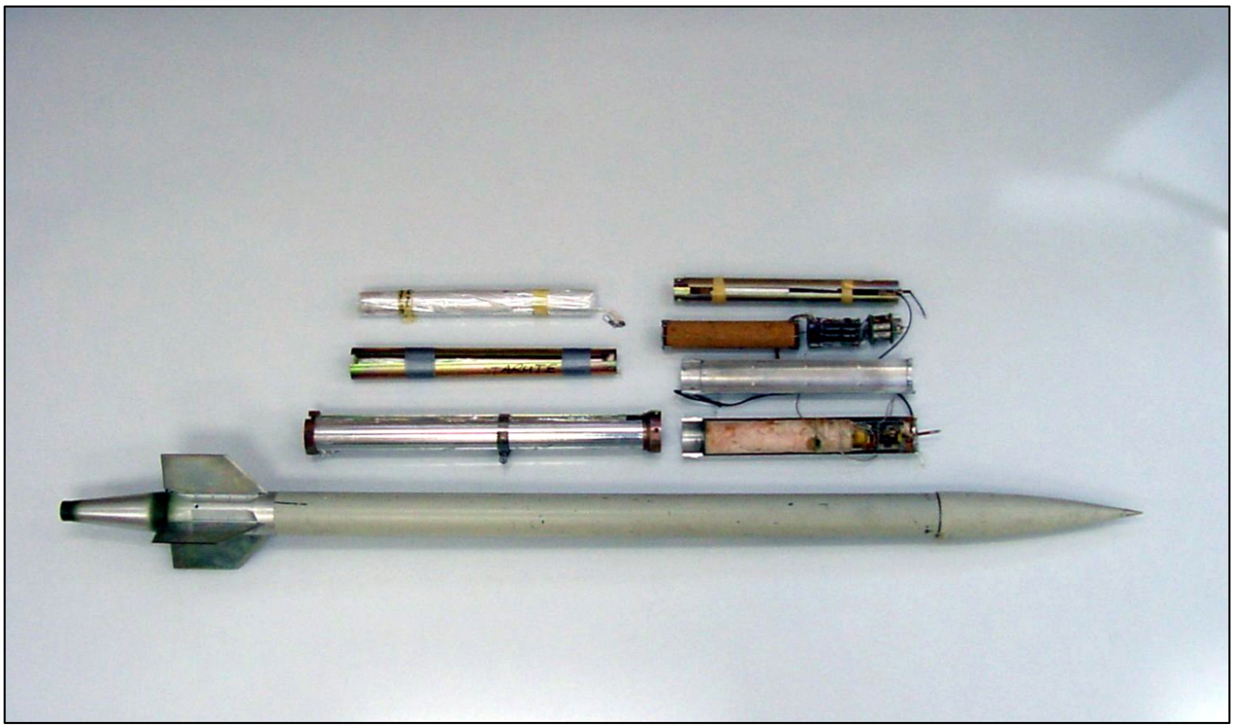

Figure 115. Loki Dart with Parachutes (top left) and Payloads (top right)

PSL's Cape Canaveral field group had a temporary respite from supporting space launches when, in January of 1967, they supported six Nike-Tomahawk shots for NASA/GSFC. Thiokol engineers Gil Moore and Frank Atmore (former PSL employees) were present for the firings.

Sounding Rocket Data Processing

The scope of sounding rocket data processing increased through most of the 1960s, along with sounding rocket activity. This was due not only to an increased number of rockets, but additional payload complexity. As mentioned above, DOVAP and multiple telemeters became commonplace by the mid-1960s, often quadrupling the amount of data transmitted from each flight. Moreover, the supplementary ground stations recorded this same information, and their records required processing as well.

Since greater volume necessitates faster handling, automation of the data processing function became a priority for all of PSL's customers. Fortunately, they were willing and able to fund PSL's development efforts in this area and by the end of the decade, hand reduction of telemetry and DOVAP data was almost completely eliminated. The advent of digital computers, along with digital telemetry systems, made it possible to begin the automation process; PSL's development of "digitizers" for conversion of PPM/AM and FM/FM telemetry data from analog to digital format completed it. All data modes could then be processed by computer.

As mentioned earlier, PSL's Data Processing Section changed mainframe computers several times during the late 1950s and 1960s. The IBM 650 acquired in 1957 was replaced in 1960 by the tube-type Burroughs 220 (this was the first large computer installed on the NMSU campus (Figure 116)).

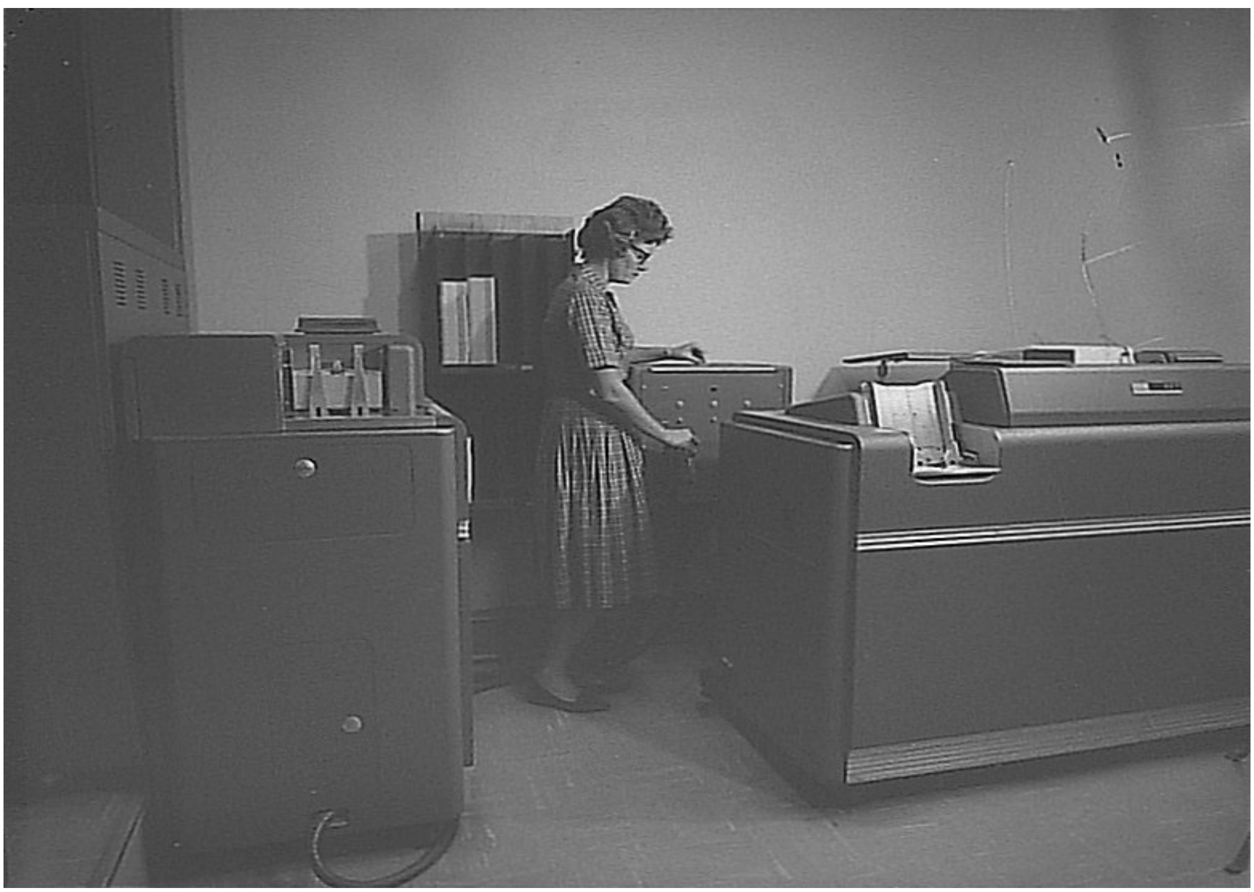

Figure 116. Burroughs 220 Computer Interface Equipment, 1967

The Burroughs 220 was a state-of-the-art machine featuring 25 kilobytes of random access memory (RAM). A rented IBM 407 was added in the early 1960s through an educational discount that Vice President William O'Donnell acquired (PSL unknowingly violated the agreement with IBM by modifying the 407, for which it was fined $3,000 in back rent). An IBM 1401 was added in 1964, replaced in 1966 with an IBM 360, Model 30. A Model 50 quickly replaced the Model

30 after it was determined that the former was inadequate for the increasing workload. The Burroughs 220 was retired from service in 1966 after a crack was found in its 400-cycle generator (and a replacement was not available). A decrease in the computer workload, beginning in 1968 and enduring into the 1970s, necessitated the replacement of the Model 50 with the economical, lower-capacity IBM 360, Model 40.

In 1960 and 1961, the Burroughs 220 computer was used for wind-weighting computations for sounding rockets at WSMR, Wallops Station, and Ft. Churchill. It replaced the IBM 650 used in the 1950s. Wind velocity and direction readings from the launch site were still telephoned to PSL and processed as described in Chapter 4.

> Dr. Gardiner reportedly started the New Mexico Foundation in order to fund the purchase of the Burroughs 220 (the price of which was $1,000,000). If PSL had purchased the computer (on contract overhead), then customers could not be charged for its use; therefore, the Foundation purchased the 220 in 1960 and leased it to PSL.

Don Peterson received the task of maintaining the new computer; Roberta Westhafer was its primary operator. Mr. Peterson's crew included Jerry Cooper, who had been in Florida with the MEI Section for several years but returned to college, thus becoming a student employee. Jerry said that in order "to get the 220 up and running by 7:30 a.m. each day, somebody had to come in at 5:30 and start the complex turn-on procedure. Being the new kid on the block, I was it." Other staff personnel assigned to maintenance of the 220 included Robert Abbott, Gust Johnson, and Ron Yoder. In 1965, with the advent of automation, the Telemetry Processing Section's tape playback station, established in the 1950s, was dismantled.

John Byers, a veteran of the Kent Hall basement era, related a problem with another PSL workspace. "I left PSL in 1960 for Hercules Powder Company back east, then came back to NMSU graduate school in 1962 and got back on at PSL. In the meantime, PSL had rented the Jones House and the Sherburne House next to it. I was put in the Jones House and on my first day back, the house caved in! The water lines under the floor froze and burst and filled the crawl space with water and melted the adobe. The rear of the house just sort of sank into the ground. So they tore that part away and used the rest. It had been the TKE [fraternity] house. I don't know who Jones was."

These two houses were obtained from NMSU to use as interim space when the Telemetry Processing Section outgrew Kent Hall. The plotter and keypunch operations were moved into the Jones House. When Anderson Hall was completed, the Section moved to the second floor and the two houses were demolished to make room for the present west parking lot (Figure 117).

Figure 117. Demolition of Old Houses for Construction of PSL's West Parking Lot

Sounding Rocket Miscellany

Very sophisticated mechanisms are required for aiming telescopes and other instruments at a particular point in space while a rocket with its payload is ascending to its zenith and falling back to earth. The three principal attitude-control devices employed in the 1960s were the University of Colorado's Sunfollower developed in the 1950s; the Attitude Control System (ACS) developed in the early 1960s by GSFC and Space General, a subsidiary of Aerojet; and the Solar Pointing Aerobee Rocket Control System (SPARCS), developed by NASA's Ames Research Center in the 1965-68 timeframe. The high-precision pointing (±15 arc-seconds) achieved by these devices has contributed greatly to man's knowledge of the sun and stars. PSL personnel, while not involved in the design or construction of these pointing systems, were required to travel frequently to NASA/Ames, NASA/GSFC, NRL, and the University of Colorado to support pre-flight integration testing of these units. Although the initial flight test of the SPARCS (at WSMR in December of 1967) was only partially successful, the problems were eventually resolved.

In 1966, NMSU President Corbett, along with Vice President Duncan and PSL Director Harry Posner, initiated communication with GSFC regarding a center for upper air research at NMSU. In a May 1967 meeting at GSFC, NASA urged the University to establish such a center. A proposal was submitted in June for $4,000,000, including an observatory on Magdalena Peak and a $2,000,000 building on campus. NASA rejected the proposal.

The Rocket Section was briefly involved in sounding rockets on two occasions in the 1960s. Stewart Bean's group on Kwajalein Atoll fired several Nike Cajuns carrying atmospheric density measurement payloads that had been provided by the University of Michigan. Mr. Bean and Norris Hannum described the other project (which was sponsored by NRL) as follows:

SB: "The ozone rocket was called OZARK. We were measuring the ozone in the upper atmosphere—just measuring the concentration of it. There was a little glass sphere...called the pazo electric tube, or pazo...anyhow, it was loaded with some kind of fluorescence and if ozone...if light shined through it...I don't remember now what the experiment was, but anyhow, it involved this sphere. You had to have this sphere because it was the filter that allowed the ozone to be detected. There was a detector inside somewhere, a photo detector of some kind. It was not a film detector—it was an electrical measurement as opposed to a film measurement."

NH: "We had a Swiss engineer—he wasn't with us too long—I forget the name."

SB: "Chuck Mozer worked on that one. I guess he took over after the Swiss guy. We went to the Pacific Missile Range (PMR) on those and fired from there, but we had an, 'anxious' motor—our motor was a bit overcompensating. But we had a lot of fun out there."

"To Provide for the Common Defense..."

PSL's support of defense-related testing programs more than doubled in dollar value in the 1960s, increasing from approximately $1.75 million in 1960 to approximately $4.3 million in 1969. This means that defense accounted for the majority of PSL's endeavors, which has been the case since its inception in 1946.

PSL's defense-related work was divided into two principal areas: (1) instrumentation and data processing for guided missile tests and (2) tracking of the Navy's navigational satellites. Army, Navy, and Air Force missiles were involved, with the tests conducted primarily at WSMR, as well as at several other sites. The satellite tracking, covered later in this chapter, took place at locations worldwide.

The Army's Arsenal

The PSL-supported Army missile programs originating in the 1950s continued into or throughout the 1960s. These were the Corporal, Sergeant, Nike-Ajax, Nike-Hercules, Honest John, Little

John, Redstone, Cobra, Lacrosse, and Hawk. New missiles emerging in this decade were the Pershing (successor to the Redstone), Lance (to replace the Honest John), Nike-Zeus, and Nike-X, among others.

Several PSL sections were involved in Army missile testing programs—the Rocket, Missile Radiometric Systems (shown in Figure 73 as the Warhead Evaluation Group), Data Processing, Applied Analysis, Data Reduction, and Electromagnetics sections. The Missile Radiometric System and Data Processing sections worked exclusively on Army projects, while the Rocket, Data Reduction, and Applied Analysis sections considered the Army their largest customer. The efforts of these groups are described individually in the following paragraphs.

Targets By The Hundreds

PSL's Rocket Section, established in the 1950s to meet the Talos project's need for an inexpensive target (see Chapter 4), continued to provide that support with its POGO rockets and parachutes (Army and Air Force missiles also used these targets in the 1960s). According to a 1966 memorandum, the Rocket Section fired 313 single- and 195 two-stage rockets in the period between 1953 and 1966.

By the end of the 1950s, large, long-range intercontinental ballistic missiles (ICBMs) were a reality. Efforts to develop a missile to seek and destroy these ICBMs before they could reach their targets began, resulting in Anti-Ballistic Missiles (ABMs) such as the Nike-Zeus. BTL, in preparation for Nike-Zeus testing at WSMR, expressed the requirement for targets to be placed at much greater altitudes than could be achieved by the POGO. The Rocket Section responded by developing a two-stage vehicle using Thiokol's solid-fuel Apache rocket motor and a Nike booster. The Machine Shop fabricated and assembled the tail fins, nose structure, nose cone, etc. for the Apache. This combination, called SPEEDBALL (Figure 118), could lift a 100-pound payload to an altitude of 100 miles and was the forerunner to the highly successful Nike-Apache sounding rocket referred to earlier in this chapter.

Figure 118. SPEEDBALL Rocket

According to Gil Moore, the first SPEEDBALL launch occurred in 1960 at WSMR. The Apache motor was also used as a single-stage target rocket, called the HIBALL. Both rocket configurations were used extensively in the Nike-Zeus and other missile testing programs.

George Conrad, who succeeded Gil Moore as Chief of the Rocket Section in 1962, said that he thought that the Section developed approximately 30 different payloads for the two rocket types. These included inflatable, metallized spheres for radar exercises (Figure 119), chaff payloads of various sizes, radar beacons, Miss Distance Indicator (MDI) packages, and a payload that ejected five small parachutes in Gatling gun style. These payloads were flown until 1969 for various BTL missile tests: Nike-Zeus (until 1963), followed at WSMR by the Nike X, Sentinel, and Safeguard projects.

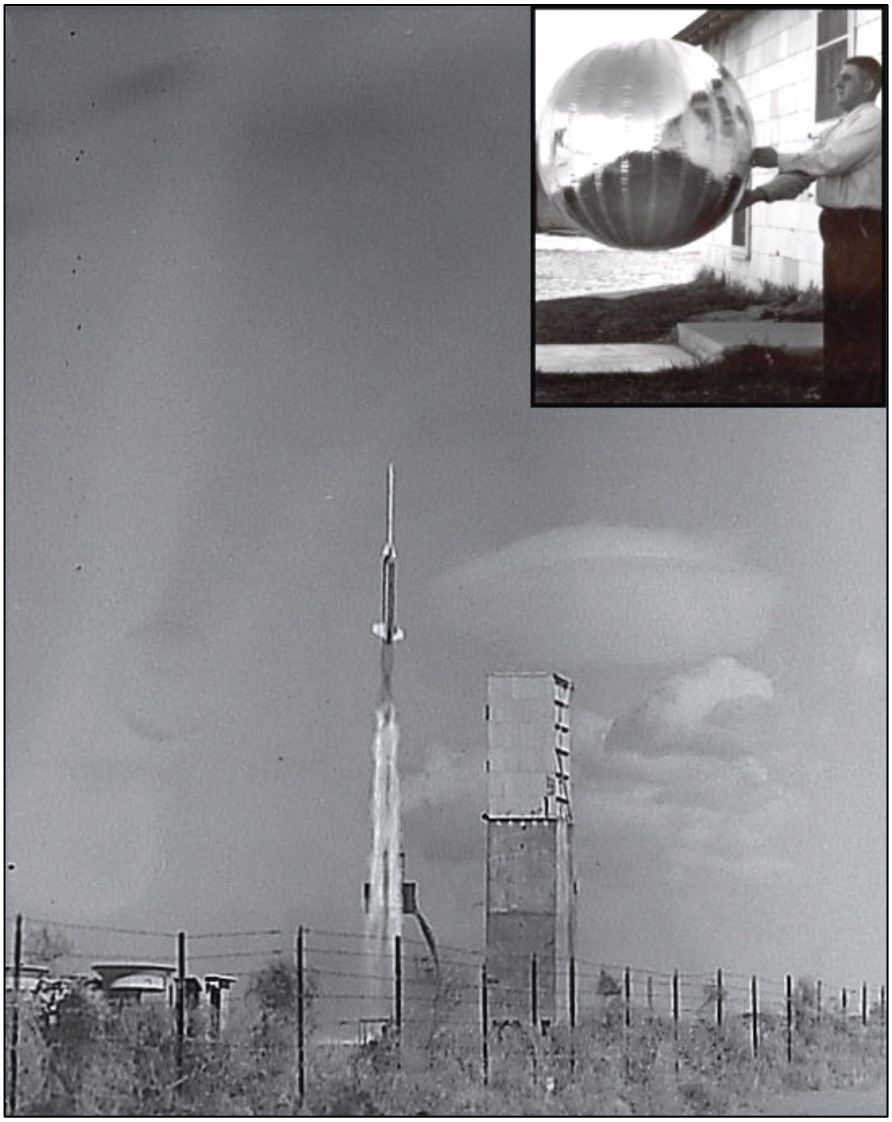

Figure 119. SPEEDBALL Launch (Inset—George Conrad Holding Target Balloon)

One of the Rocket Section's major accomplishments was the design (by Ivan Carbine and Dick Barron) and development of an intercept scoring system, also known as the MDI. This system was used to support BTL in measuring the miss distance as the Nike-Zeus was fired against ballistic missile targets. A Chicago sub-contractor fabricated the MDI flight units. The system included a pair of instrumentation vans that were built by PSL for later use at Kwajalein. Bill Stevens, who was involved in this, recalled that two to four missions a day were flown against aircraft and missiles at WSMR. In July of 1966, Mr. Carbine reported that the MDI units had scored 16 intercepts (all successful) and that a new design was being proposed to BTL. After being modified to enable its use at different frequencies and in different missiles, the MDI remained in use throughout the 1960s at WSMR and Kwajalein. In 1964, it also scored the United States' first satellite intercept.

During the 1963 to 1969 time frame, the Rocket Section supported Lockheed Missiles and Space Company, BTL, and Avco with SPEEDBALL launches from uprange at WSMR. Some of these vehicles deployed a variety of penetration aid devices for evaluation by various sophisticated radars. The penetration aids were to be installed on the Army's Polaris and Poseidon and the Air Force's Minuteman ballistic missiles. Over 100 SPEEDBALL and HIBALL vehicles were launched during the course of these programs, resulting in state-of-the-art Rocket Section developments. For example, Bill Stevens developed a solid-state flight-event timer to replace a troublesome mechanical timer, John Stanley (who later went to work for NASA) developed a simple but effective photocell aspect device that provided a payload's three axes of rotation during flight (versus one axis).

In addition, the Section developed the spin rocket in response to a dispersion problem common to the early SPEEDBALL rockets. Mark Moore described the spin rocket development as follows: "When we were launching rockets from uprange, we had trouble keeping them within the boundaries if we had a shift in the wind—they were unguided. So, our engineers decided to put spin rockets on the missile to stabilize it. These would ignite as soon as [the missile] left the launcher and were mounted on a ring placed around the missile body. On the first one, the engineers told us not to tighten the ring too much because when the rocket ignited, it would expand and tighten itself. So the ring was left sort of loose, and when the rocket took off, the ring slid right down the body and sheared off the fins! The next time around we tightened it as tight as we could and it worked real fine."

Those spin rockets resulted in the only serious injury ever incurred by a Rocket Section member on the job. One day, Pete Markle was at the Speedball Uprange Launch Facility (SULF) Site helping to prepare a rocket for launch. He was running a routine check of the spin rockets' wiring when they ignited, seriously burning his legs. Mark Moore, who was part of the crew, said that since the nearest ambulance service was in Socorro, they were advised to put Mr. Markle in a PSL car and meet the ambulance halfway to save time. They met the ambulance and transferred him into it, but its engine died right after starting back. So, Mr. Markle was put back into the PSL car, in which he was taken to the hospital in Socorro. He was later moved to the Memorial General Hospital in Las Cruces, and after several months of treatment he returned to work.

One particular series of SPEEDBALL launches was described with justifiable pride by James ("Jim") Thomas. In the mid-1960s (immediately after the Johnston Island tests), Lockheed wanted to test a new payload package using 10 rockets at WSMR. They hoped to achieve eight successful flights from which they might successfully retrieve six payloads. When asked if PSL could initiate and accomplish this within six weeks, Jim answered, "Yes." The Rocket Section completed the task, successfully retrieving ten payloads from ten successful flights. Mr. Thomas said, "It meant borrowing hardware from all over the country—six or eight ogives from Eleanor Pressley at NRL, motors from Wallops Island, fin assemblies from the Cape, some stuff from PMR, and a heck of lot of stuff from BTL, our target customer. The rocket was to go up, eject the ogive, despin, and then eject the Lockheed package."

This program did not have a promising beginning—the test payloads failed to deploy during the first two flights. Within 48 hours after each of these flights, George Conrad and Jim Thomas were summoned to Lockheed in Sunnyvale, California to explain the causes of the failures and to reassure Lockheed management. The string of successes began with the third flight, and Director Ricketts warned Mr. Conrad and Mr. Thomas that they would be summoned to Sunnyvale to explain the success.

Mr. Thomas continued, "It was a charmed program—everything that we wanted, we got. It had an extremely high priority with DOD for procurement, so we could get anything—if it was available anywhere in the country, we could get it. Things really happened in a hurry. Jim Boyer was the buyer for the Rocket Section at that time, and Jim put it together—we knew we had the job, but we didn't [yet] have the go-ahead to buy. We went ahead and made out all of the purchase requests—I think Estelle Williams had Purchasing—and she gave us some PR numbers to play around with. Otherwise, you had to go through the whole chain of command and lose a lot of time. So, we sat down and made out a quarter of a million dollars' worth of purchase requests—those were the days when that was real money. So the very day that the contract was signed, we dropped those on Estelle's desk, and they all had to be delivered in two weeks. In those days, not much ordering was done by telephone—a lot of it was still done by mail. I remember I had put a $100 or $200 item in there for long-distance phone calls, and Estelle was astonished—that was just too extravagant. This had never been put in a budget before." The success of this project resulted in several smaller, follow-on contracts.

Toke Rogers said, "We came back here from Kwaj and shot tons of balloons and rockets at WSMR to calibrate the Multiple Array Radar (MAR). Mark Moore, Gus Wofford, and I (and a lot of us that are still here) did a lot of balloon work. We released constant altitude balloons with reflective spheres hung on them so the radars could calibrate—hundreds of them. [We] had to go all over New Mexico to release balloons to get them in the target area. Some we released as far west as Arizona. We put cards on these balloons telling people to call us and tell us where it came down. We had calls from the East Coast, Canada, [and] out in the Atlantic. One time…two old Mexicans…walked from somewhere in Mexico to Juarez carrying one of these balloons, thinking they were going to get some money for it. We couldn't pay them money, but we passed the hat and got enough money to buy them a bus ticket home, and drove down there and gave it to them. One time, a woman called us from Houston, upset because a balloon came down in her back yard."

According to James Boyer, one particular balloon was launched from the town dump in Reserve, New Mexico, and the entire town's population came to watch. Mr. Boyer said a reflective sphere of a specific diameter was required for one test, so a copper float ball from a toilet tank was used—it fit the bill perfectly!

The majority of this work was in support of BTL (in fact, it is said that the MAR undergoing calibration was the first phased-array radar in the United States). PSL fired the rockets from both a portable launcher and a small fixed installation at the SULF Site located in the northwest corner of the Range (Figure 120). The firings with the portable launcher were obviously performed without the benefit of a blockhouse or other shelter. Mr. Rogers also said that the single-stage HIBALL's igniter "...would ignite when it was supposed to, but the rocket would sit there and burn a little while and get warm and then...take off. But you never knew when— sometimes it would be nearly a 30-second delay. [It] would make us really nervous."

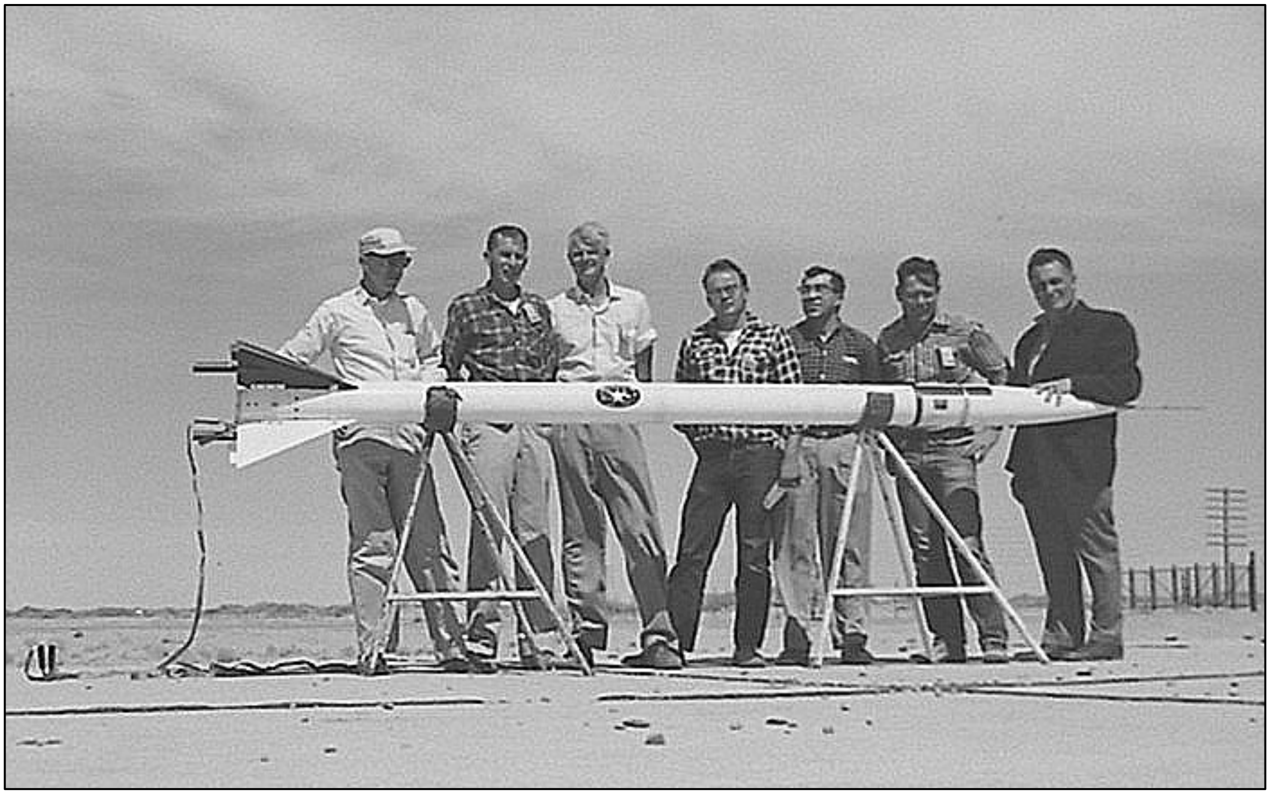
Figure 120. Members of PSL's Rocket Section Pose Behind a HIBALL Rocket, 1960[39]

Lewis ("Lew") Clower added further insight into that problem when he said, "…The Rocket Section...had an igniter problem with our single-stage rocket. The igniter would burn OK, but it wouldn't ignite the fuel grain. Elger Stauber found a fix for it—we would take a tennis ball and jam it up in the rocket exhaust nozzle and that would build up just enough pressure to let the fuel ignite, then the ball would be forced out. One time, we went out to WSMR to fire and we forgot to take along our tennis ball, so all five of us were out there combing the desert for a used tennis ball from previous firings. We found one and got the rocket off on time."

George Conrad said that he and two other employees were given an office in the master bedroom of the Sherburne House. His file cabinets sat in the bathroom shower stall, the drafting tables in the living room, and there was an electronic assembly bench in the kitchen (the Ionosphere Section also occupied the house at the time). The Rocket Section's Assembly and Test building was completed and occupied in early 1962.

Bill Stevens told a rather touching story concerning the HIBALL and SPEEDBALL firings from WSMR uprange. Apparently, on one trip to the SULF Site, the crew discovered that a pair of kingbirds had built a nest on one of the launchers, which had been stowed in its usual horizontal

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[39] Left to Right: Norris Hannum, Doug Moore, Logan Ritchey, Pete Markle, Ted Arellano, and Toke Rogers

position. Two eggs were in the nest, which posed a problem because the nest would slide off (thus destroying the eggs inside) when the launcher was raised to its firing position. Not wishing to interfere with Mother Nature, the technicians removed the nest and placed it on another launcher some distance away, fired their rocket, then brought the nest back and placed it in its original location. According to Mr. Stevens, “This went on for...about five weeks. We'd go out, move the nest, fire the rocket, stow the launcher, [and] bring the nest back. The birds hatched, and we'd carry the nest with the little birds in it. We had to watch for the mother bird—we almost had a 'hold' one day when we couldn't get her off a light pole out there. Here we were, with this multi-million-dollar-a-minute project, and we almost held it for a bird (I don't think we ever [actually] did [hold, though]). She stayed close to the launcher, and was apparently killed by one of the rockets. She disappeared, but we kept moving the nest, and the father raised those kingbirds.

“In fact, we had photographs of that. The Holloman photographer was assigned to cover our shots and took a whole bunch of real quality photos of the birds. But they got classified SECRET with all the rest of the data, so we don't know where they are—probably in somebody’s secret file right now.”

When asked to name their greatest disappointment from those days, various members of the Rocket Section mentioned the Coast Phase Control System (CPCS) (Figure 121). George Conrad and John Stanley theorized that a guidance module placed between its two stages would increase SPEEDBALL's target deployment accuracy. The function of this module would be to control the re-aiming of the second stage during the “coasting” phase (the 18-second interval between booster burn-out and ignition of the second-stage motor). The natural tendency of an unguided rocket to turn into the wind could then be overcome to some extent. This concept was never finalized, primarily due to 1969 and 1970 contract terminations (these were part of the overall aerospace slowdown of the late 1960s). Numerous problems slowed progress on this development, not the least of which was the failure of parts suppliers to meet delivery schedules. Later in discussions with George Conrad, he admitted that the concept was “pushing the limits of the laws of physics” but the whole purpose was to position the target within a known low risk test range zone dictated by Kwajalein Flight Safety. This goal, if accomplished was highly desirable. Apparently there were only two or three test flights that were failures but George knew that such a complex program would require a number of flights and some modification of the early design based on the results of these test flights. The program really did not have a chance.

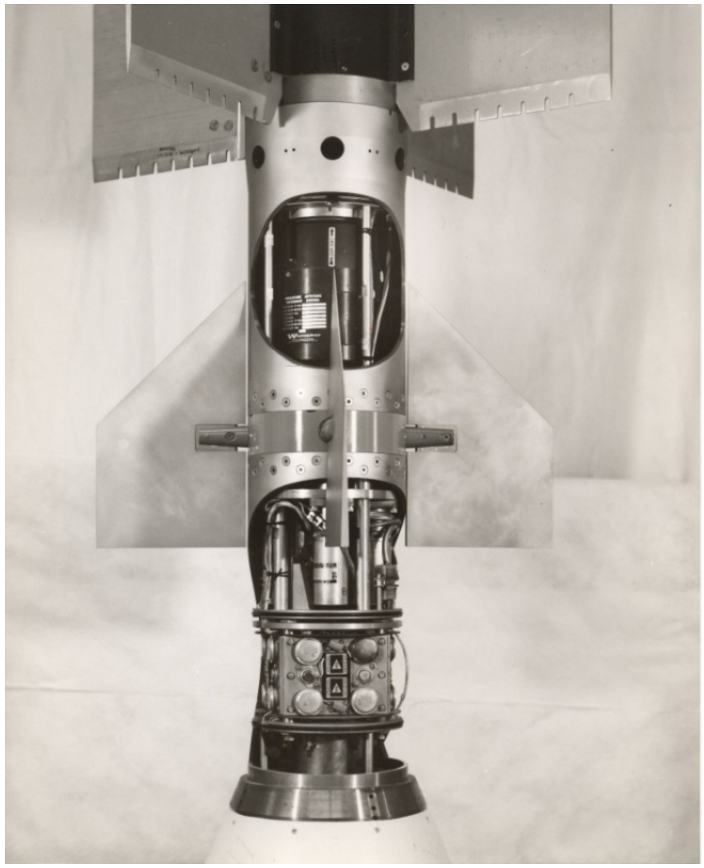

Figure 121. Coast Phase Control System

Bill Stevens, Dr. Tony Hu, and Ron Gleyre made major design contributions employing a great deal of innovation, which was applied to other projects.

Another significant Rocket Section project (concurrent with the CPCS effort) was the Drop Pod development, also for the Army/BTL ballistic missile defense program. As mentioned earlier, the Rocket Section deployed radar calibration spheres in large numbers for calibration of the MAR radar at WSMR. The same capability was required to calibrate the system radars at Kwajalein, but the prevailing winds there precluded launching balloons from any land mass.

Elger Stauber conceived, developed, and delivered a drop pod system that could be ejected from an aircraft through a fuselage door. The pod consisted of a parachute deployed with the aid of a small pilot canopy, a polyethylene balloon and radar calibration sphere stowed on the crown of the parachute, and a high-pressure helium tank suspended on the parachute. Appropriate valving and a flexible hose routed from the tank up the center of the parachute to the balloon completed the system. Upon ejection from the aircraft, the pilot canopy deployed first and payed out the main parachute. Inflation of the balloon was initiated once the main parachute was fully deployed. After inflation, the balloon was released, and it lifted the calibration sphere high into the air. This system provided the necessary flexibility to enable balloon launches from any location within range of the aircraft.

System development and testing was exceedingly difficult, requiring many releases from aircraft staged out of the Las Cruces airport. There were many failures (and thus many modifications required) before success was achieved. Compounding this was the need to build the systems inexpensively, due to the large numbers to be employed (cardboard tubes formed the pod shell, and plastic film was employed for parachute canopies). But, in the end, more than 100 pod systems were shipped to Kwajalein for operational use.

> A group of juvenile delinquents from the Las Cruces/Dona Ana area known as the "Desert Rascals" was enlisted to build components for and assemble the pods on a production basis. The Desert Rascals were under the supervision of the Dona Ana County Probation Officer and a local clergyman. This enterprise created many amusing situations (too many to relate here), but the infinite patience of Elger Stauber and several other Rocket Section personnel enabled the pods to be built and delivered.

Others who worked in PSL's Rocket Section during the 1960s included James Cope, Gerald Dickerson, Ron Gleyre, Anthony Hu, Ron Parriott, J. Primerano, H. Ruth, Jim Thomas, Clay Watkin, Emily Snow, James Strahm, and William Dixon. Drafters/designers Clem Jellison, Donn Comte, Frank Owen, and Larry Girault also made major contributions. Many technicians assisted the Section during the period, including Roy Tucker, Dale Gantz, Bronson Woods, Ed Eichner, Devon Bailey, Durward Wofford, Bill Muncrief, Lynville Brown, Doug Moore, and Bill Laird. Secretaries and clerks included Bunner Custer, Tina Hidalgo, Ruth Sparger, Marilyn Morrical, Jo Anne Haden and Diane Calhoun. Dozens of students were employed in the Section during the 1960s, including Floyd Adams, John Sullivan, Yayah Safdari, Joseph Augustus, Karl Hammons, Terry Yaryan, Don Kilmer, Bob Tegmeyer, George Sharp, Jessie House, and Marshall Salyers. Some of these individuals worked for PSL during the 1950s, as well as the 1960s. The late Bobby Vaughn made major contributions—he helped the Section in a contract administration capacity.

The Kwajalein Story

The Rocket Section's Kwajalein Atoll group was a remote PSL field group less permanent than those at Wallops Station, the Cape, and Vandenberg, but it remained on site for three years (1961-1964). Kwajalein is part of the Marshall Islands located roughly 2,000 miles southwest of Hawaii. Stewart Bean supervised this group, which included Bill Stevens, Frank Atmore, Jim Thomas, Clay Watkin, Jesse Vaughn, Lew Clower, Doug Moore, Art Puffer, Logan Ritchey, Lee Kallenbach, Pete Markle, Mark Moore, Ted Arellano, Ed Havenor, Toke Rogers, Dick Lara, and Dave Christiansen.

The mission of the Kwajalein group (under contract with BTL) was to support field-testing of the Nike-Zeus ABM system. This support consisted of two major efforts: (1) provide radar targets for proving in the radars on Kwajalein and (2) operate the above-mentioned intercept scoring system (MDI).

Although these radar targets occasionally consisted of a reflective sphere suspended from a balloon, the primary activity was the launching of SPEEDBALL rocket vehicles, which deployed a variety of radar exercise targets. For high-velocity target exercises, the SPEEDBALL vehicle itself became the radar target. The rockets were all launched from Roi Namur, one of the islands in the Kwajalein Atoll that was approximately 40 miles from the main island. Roi Namur is actually a pair of small islands between which a causeway was built during the Japanese occupation (Figure 122) and substantial enough to accommodate a runway for large aircraft.

Figure 122. Aerial View of Roi Namur

Stewart Bean said that his group fired approximately 100 rockets and launched close to 400 balloons during their South Pacific endeavor. Clay Watkin said that the group, "did a lot of off-island work—released balloons from tugboats or from other islands—[and] went up to Eniwetok and released balloons."

The MDI operations involved placing a PSL-developed transmitter unit in both the Nike-Zeus ABM missile and the target vehicle. The targets were ICBMs launched from Vandenberg AFB on the California coast. As the two missiles passed one another, the Doppler shift in one of the units was detected by the second and transmitted to the ground stations (i.e., the two MDI vans mentioned previously). These vans were shipped from PSL to Kwajalein; one was placed on Roi Namur and the other on a small island called Ennylabegan. The latter island was covered with palm trees, which caused Bill Stevens a problem when placing the antennas for the van. He, Mr. Carbine, and Mr. Bean concluded that determining the height of those trees was necessary in order to design and construct an antenna tower. The BTL management's solution for obtaining this measurement was to use a crane to hoist Mr. Stevens in a bosun's chair up to treetop level, at which time he would drop a tape measure to the ground. Mr. Stevens said, "They loaded a gigantic crane onto one of these big landing craft (they had a lot of old surplus ships down there)—this one was big enough to haul several Army tanks. They drove the crane onto it on Kwaj, sailed across the atoll to Ennylabegan, and offloaded it onto the beach. I got into the bosun's chair, they lifted me up, I dropped a tape down to Pete Markle, and we got our measurement." That landing craft proved worthwhile for PSL another time, when it was used to transport an old harbor surveillance tower, described by Mr. Stevens as "a great, big, monstrous wooden structure with a house on top" from Kwajalein to Ennylabegan. The railing on top of the house made it an ideal antenna tower, and Mr. Stevens said it also provided him and Ted Arellano a fairly decent place to sleep at night.

This antenna tower enabled PSL's MDI station to consistently receive signals from the missile flights that were far superior to those received by a nearby telemetry station operated by another contractor whose antennas were not above tree height.

The Data Processing Section sent a group of programmers and co-op students to Kwajalein to manage the Nike-Zeus test data processing. Nash Garcia was in charge of this function. He lived on Roi Namur, as did the students and other unmarried PSL personnel (married employees were provided family housing on Kwajalein itself).

Another amusing story from the Kwajalein days follows. A shell was found in an old, five-inch shore battery gun left on the island of Roi Namur from the Japanese occupation. The U.S. Army, who considered this to be a dangerous situation, decided to disable this gun and shell (presumably rusted in place) with an explosive charge. Although they succeeded in doing this, when the charge was set off, the breechblock of the gun went flying through the air, plunging through the roof of one of their brand new barracks buildings. According to Jim Thomas, the gun had been left in place at the request of two ladies from the Historical Society.

Jon Ottesen of the Applied Analysis Section told of a trip he took to Kwajalein in 1967. "Kwaj was a fun trip. [I] was down there about a week, trying to work with an ancient computer, with no documentation for it. We were firing two-stage Nike-Apaches and were having trouble with booster dispersion—something was wrong with the computations of wind effects on the booster. When one landed about 200 feet from the cook shack, everybody got pretty excited. So I went down there, found the problem, and fixed it."

Years ago, a giant clamshell was on display in the lobby of the PSL building. The story behind that shell, according to Jim Thomas, involves Dick Lara, one of the Rocket Section technicians who traveled to Kwajalein. PSL personnel stationed on Kwajalein were given the privilege of using a boat to use for fishing in the lagoon. It seems that one day Mr. Lara, Mr. Thomas, and others were out in the boat in about five feet of water. For reasons unknown, Mr. Lara jumped into the water and landed on this clam, which clamped its shell closed on his foot. Mr. Thomas and his companions, who pulled Mr. Lara back into the boat, had to kill the clam in order to free the foot. Apparently, Mr. Lara suffered only a good scare (and endless teasing) from the incident.

When the PSL crew initially arrived on Kwajalein, buildings, equipment installations, and housing were still under construction. The crew soon discovered that their own pre-departure suppositions regarding which equipment and supplies would be necessary there were more realistic than those of some of the larger contractors. According to Bill Stevens, these contractors borrowed a great deal from PSL in order to make operational items such as RCA's large TRADEX radar. PSL machinist Lee Kallenbach "did a lot of work for some of those other people to get them on line." A similar scenario developed on Roi Namur involving Lew Clower, a heliarc welder, and a milling machine. Jim Thomas said, "Those became about the most valuable items on Roi. Big contractors like BTL, RCA, and Kentron were coming to Lew to get something welded or machined. He became known as `King Lewie' to everybody because they needed to stay in his good graces to get things done."

The first installation on Roi Namur was the SPEEDBALL launch pad and a revetment that was named, "The Mountain" (Figure 123). For a long time, PSL occupied the highest mountain in that part of the South Pacific.

Figure 123. Roi Namur SPEEDBALL Launch Pad

PSL's foresight was also demonstrated when Bill Stevens, with Mr. Ricketts' approval, placed amateur radio gear in one of the MDI vans before it left PSL. This equipment turned out to be the only reliable means of communications with people in the United States. Mr. Stevens, who operated it, said that he was the primary connection between the people on Kwajalein and their families at home. He fell into the routine of calling Hugh Gardner in Las Cruces every day at 5:30 Kwajalein time (10:30 p.m. MST). Mr. Gardner would then run a phone patch to any requested location. Mr. Stevens said, "One morning, a chaplain came over to where we were, in the midst of assembling a rocket, and said he had a mechanic from one of the service companies who had heard through his company grapevine that his wife had died in Colorado (in Durango, I believe)…would I please try to get ahold of Colorado and find out what was going on? So we closed down our operation—we couldn't handle explosives and operate the radio transmitter at the same time. At 10:00 in the morning, [which was] late afternoon in the States, you have no idea who you can reach. So I got on the radio and starting calling, and believe it or not, in about five minutes I found a station right in his home town, and in about ten minutes I had the fellow's wife on the line. Talk about an emotional moment. I'd never experienced anything like it before—or since."

Although various struggles between PSL personnel and the military and the Civil Service bureaucracy had been customary since the Laboratory's inception, they were more numerous in environments outside the United States, such as Kwajalein. Stewart Bean described some of the struggles encountered by him and his crew on the Kwajalein trip. "Every once in a while, you travel away from the Lab and this environment and go out and work, like I did, on board a ship...The people on the ship, one of the things they want to know is where your rank is compared to theirs. So, we were always having to come up with some kind of a relative rank so that I could eat at the Captain's mess rather than the 'enlisted mess'. At Kwaj, we had to establish where we stood within the relative rank of the Army, and BTL, and PSL and the Logistics people down there...and that relative rank determined whether we had housing for families or not. It also determined whether we slept in barracks or air-conditioned places, dorms, or...what facilities on the island we could use. The people that were excluded were the Hawaiian workers, the manual laborer type people, and the Marshallese local type people. There was this hierarchy of status there, so they could then allot to PSL or to Western or BTL—anybody—relative status for benefits or whatever. When you first run into this, you tend, like I did, to poo-poo the fact that you had to establish what your status was. But, after the first time, I didn't poo-poo it at all because it was very important in the eyes of those people you're talking to...whether you had a GS-13 or GS-14 equivalent. ...If you had an enlisted man equivalent, you might as well just go drink with the enlisted men—they wouldn't pay any attention to you. It depends on how close you are to the managing echelon...how important this is—whether you are close enough to them that they can see you and you can see them. Anyhow, it's just part of the game—if that is part of the game you have to play, you play it."

Lew Clower related the following story describing life on the islands: "One time at Kwaj, we were getting up a going-away party for Clay Watkin—he was leaving for the States. We decided to roast a pig for the occasion. Art Puffer said he knew how to butcher a pig, so he and I bought one from the Marshallese. We had to take one of these "Mike" boats from Roi Namur over to one of the other islands to get the pig. The first time we went over, we couldn't find the pig or the natives. We went over again and got the pig, and it made a mess in the boat. We killed the pig and used our five-ton wrecker to hang it up to clean it, and a couple of new garbage cans to singe it in. We got it all scraped and took it to the mess hall for them to keep it cold for us. Then we hauled it on the airplane to Kwaj and cooked it over a fire. I found an old electric motor in some of our junk and made us a little rotisserie for it. So, we had our party, but it took us about a week to get everything ready for it. One of the co-ops, Johnny Mann, was doing our weekly reports to PSL, and he wrote up a very funny account of all that—I think Stewart kept a copy of it—the 'Pig Blurb' we called it."

Jim Thomas said, "In the late 1960s, we did a lot of target work for BTL/Nike-Zeus. A lot of our Lockheed/Navy work was in calibrating new super radars. I designed a radar enhancement package for a flight on Kwaj. I figured the best way to enhance radar return was to inflate a balloon after the target left the atmosphere. Elger Stauber did the balloon design; I devised a pyrotechnic scheme to time the balloon release. Bill Stevens and I went to Kwaj, [and] fired two successfully—they made some changes to the radars based on those. That was my last trip to Kwaj."

A discussion of "Kwaj" cannot end without the "Jungle Club" story, as told by Jim Thomas. "Lewie (Lew Clower) and his gang organized this thing they called the Jungle Club on Roi Namur. It was made up of...just the 'good guys,' and it was an honor to be even invited as a guest to the Jungle Club. Once a week—they rotated—...somebody had to fix supper. They had gone back in the bush and found a little building that...had walls and screen and had a good roof on it, and they had gone to Kwaj and picked up a salvaged stainless steel sink and refrigerators. It was just like a restaurant. They built a big barbecue to [cook] steaks on—used coconut husks—that's a good grilling fuel. [It's] really fantastic how in that harsh a place, people find a way to have comforts, to have friends, close relationships, you know, and to not just vegetate. There were people down there that just drank and never enjoyed any of it—[they] would spend a six- or eight-month tour down there and have no enjoyment at all. We had co-ops down there at the time and I think that helped, too, because these young kids would come in and were a pretty feisty bunch—evil, some of them, pulling tricks and things...[it] kept our guys on their toes, to have those students around.

"Later, the Jungle Club became so popular (or notorious, or famous)…that the bureaucracy decided to take this little building and use it for paint storage. It was just a sham to break up that little group and get them back into the club on the island."

<u>Memories of Johnston Island</u>

In July 1963 the United States, Great Britain, and the Soviet Union, after lengthy negotiations, signed a limited nuclear test ban treaty that only permitted underground testing of nuclear warheads. The treaty would take effect on October 10 of the same year. The U.S., anticipating the signing of the treaty, began in 1962 to accelerate efforts to complete a series of nuclear warhead tests in the stratosphere over Johnston Island in the Pacific (Figure 124).

These tests bore no relationship whatsoever to the operations taking place at Kwajalein. Johnston Island, a remote barren rock about a mile long and a quarter of a mile wide and located about 700 miles southwest of Hawaii, was used as the launch site for the nuclear missiles. The nuclear detonations were to occur at a 200-mile altitude, high enough that observers on the surface would not hear any sound or feel any impact—only a surge of warmth on the skin. The immense intensity of the fireball could not, of course, be viewed directly.

Figure 124. Johnston Island Launch Facilities

This crash program involved the PSL Rocket Section, who was asked to furnish and launch approximately 20 two-stage sounding rockets during the nuclear tests. The rockets were to be instrumented by Sandia and Kentron for atmospheric sampling during and after the detonation. PSL was given only four months to design and fabricate the payloads, check them out at WSMR, assemble a crew of 10, move personnel and equipment to Johnston Island, and configure a complex of five launchers on the island (including all the necessary ground-support facilities). PSL contracted the launcher fabrication to a California company, but performed the on-site assembly. Mark Moore described the preparations: "That was probably the most challenging project I've been on with PSL. We went down there and had to completely assemble all [of] our rockets and launchers in about a month's time...we worked a lot of 20-hour days, seven days a week for a while, trying to get everything ready."

George Conrad was responsible for the launchers, and George Baker said that he did a good job completing the project on time. Clem Jellison was another key team member, supporting the demanding documentation tasks. Since the launchers were fabricated in California, Mr. Baker went there with Mr. Conrad to inspect them. After manufacture, they were shipped to Johnston Island, where they were installed. PSL personnel who traveled to Johnston Island included Bill Stevens (October and November of 1962), Bob Sabin, Frank Atmore, Mark Moore, Logan Ritchey, Toke Rogers, Doug Brown, Gus Wofford, Don Alliman, and Doug Moore.

Bill Stevens said, "I went to Johnston after Kwajalein. In fact, I guess they'd started some of those tests while I was still at Kwaj. …Our movie theater at Kwaj was outdoors, and I remember the first shot they had. We knew it was going to happen so we watched, and the whole sky down there lit up like daylight. I don't know how far away we were—three or four thousand miles.[40] I was at Johnston for about 45 days. The island was very small, and the whole side of it was lined with launchers. I don't know who all had launchers there—Sandia Corporation had something there, and Douglas was firing the Thor that was carrying atomic bombs. We had five launchers, and an underground bunker where our instrumentation was."

One memorable Johnston Island incident was the failure of a Thor missile with a nuclear device on board. Although this had great potential for disaster, no one was injured. Mark Moore described this event, which occurred early in the 1960s: "We were in bunkers while the blast went off in space over our heads; they would usually let us go out and look right after. On the first one [that PSL supported], their missile failed, and this device was laying out on the runway burning away, about 300 yards from where we sat in a bunker (but we didn't know enough of what was going on to be worried). The second one was successful. The third one also had vehicle failure."

Jim Thomas, who was not present at the time, described the same event: "There was one incident that I heard about—I'm glad I didn't see it—they had an accident on the pad of the Thor missile. The missile was burning and the nuclear device was out there in the fire. The sounding rocket people were in their bunkers, which are close to their launchers, but certainly within the danger zone if they had a nuclear accident. There were people running around trying to get out, people trying to swim away, people collapsing...one fellow I talked to later said it was really great to look over and see the PSL people just playing poker. Don Alliman was one of those—he worked for George Baker as an inspector."

Bill Stevens told it this way, "We watched a Thor go up one night and it got right above us and exploded—not the bomb, the missile...I guess the radioactive material was scattered all over the place, but they got all the GIs out there—Air Force, Army—and had them line up and walk the runway, picking up pieces. And nobody was hurt that we know of."

Most Johnston Island residents were housed in barracks, but since PSL personnel were fortunate enough to receive ratings of GS-14 or -15, they were afforded some of the better housing. There

40 Author's note: maps show Johnston Island to be about 1,500 miles away from Kwajalein.

were few sources of amusement, as Mark Moore described. “Lots of interesting things happened on this island one mile long and 1/4 mile wide. There were 4,000 men there, and no women. We'd been there about two months when word got out that a woman was coming in on a plane. Four thousand guys lined the fence to get a glimpse.., and she turned out to be a WAC about 55 years old!

“Some British subjects were there...one guy from Ireland played the bagpipes. Every afternoon he would walk up and down the runway, blowing his pipes. The first few days, everybody hollered at him to shut up (a bagpipe is very loud). But, after a month or so, he began to have a following...people marching along behind him… By the time we left the island, his procession was about a mile long every afternoon. Entertainment was scarce.”

Toke Rogers said that he returned to Kwajalein and Johnston Island several times when nuclear bomb tests were being conducted. “There was a whole series of these tests and we got to be old hands at it, to where seeing an atomic blast was no big deal. We were shooting rockets up through the cloud and were allowed to stand outside and watch as long as we wore dark glasses and looked down at the ground during the explosion. The weather was hot, so we usually wore shorts, thongs, and no shirt. One day we were out watching the next to the last one in the series, a smaller bomb, [and] were very casual about it. But that one was set off lower in the atmosphere and it burned us, like somebody touched a hot light bulb to our skin. We didn't expect that, so we all dashed for cover!”

Bill Stevens recalled, “A funny thing happened with one of our five launchers one night. We had a series of firings, and afterward we left the bunker and went out and found [that] one of our launchers was pointing backwards—over the island instead of toward the sea. We concluded that a rock from one of the other launchers must have hit the start switch on the azimuth motor and swung the launcher around, but we still don't know whether it happened before or after that particular rocket was fired.”

Robert Sabin described Johnston Island as the worst place he visited in all of his worldwide travels, saying that “there were only two trees on that remote piece of rock.”

George Conrad remembered the difficulties encountered while trying to communicate with the Rocket Section personnel on Johnston Island. He said that a long-distance telephone call was placed to RCA/Moorestown, N.J., where a patch was made with an HF radio link to a Range Instrumentation ship (the American Marine) anchored offshore at Johnston Island. Another patch was made via ship-to-shore telephone to the Island. Once the connection was established, it was usually poor, fading in and out. Conversations were necessarily very brief.

MRS Section

The Warhead Evaluation Group, established in the 1950s to support the Army's proximity fuze testing program at WSMR and Yuma Test Station, continued this work for the customer, HDL, throughout the 1960s and beyond the 1970s. Flight testing of safety and arming devices was also performed, along with some fuze electronic countermeasure work for which the MRS Section designed and built the necessary test equipment.

Two additional customers, that were research organizations within the U.S. Army, were involved. The first was The Chemical Research and Development Laboratories (Edgewood Arsenal), who continued its contract with PSL to field test its warheads at WSMR and Dugway Proving Grounds, Utah. The other was Picatinny Arsenal in Dover, New Jersey, who requested continued nuclear warhead testing and warhead telemetry.

The Section supported the Corporal, Sergeant, Redstone, La Crosse, Honest John, and Little John missile programs carried over from the 1950s. In the early 1960s, the Pershing and the Lance were introduced. In 1969, an improved Pershing, called the P1a, was introduced. This missile was field evaluated in Germany by APL. PSL is estimated to have supported over 400 Pershing firings at WSMR, Ft. Wingate, Blanding, and Green River.

In the late 1960s, the Warhead Evaluation Group became the Missile Radiometric Systems Section (MRS), and Hal Ware was its first supervisor. After Mr. Ware left PSL in the late 1950s, Edward McDowell supervised the Section until he resigned in the early 1960s. Harold Connell and Bud Monjar then became co-supervisors. Mr. Monjar left PSL shortly afterwards, and Mr. Connell became Section Chief as part of the 1966 reorganization.

The chemical warhead contained a number of bomblets that were ejected prior to missile impact and dispersed over a wide area. These bomblets were designed to release either a chemical or a biological agent upon impact with the ground. Harold Connell related (with justifiable pride) how the Section helped to solve a bomblet dispersal problem on the Honest John by developing a state-of-the-art, high-speed color camera pod for mounting on the missile. The camera, the purpose of which was to record the opening of the warhead to show what was happening to the bomblets, worked correctly on the first attempt. This was no small feat, considering the previous failed attempts to develop such a camera and that neither Mr. Connell nor the others in the Section had prior experience with camera pods or high-speed cameras. This occurred in 1967, and the pods were ejected and recovered by parachute.

One interesting function that PSL performed for these bomblet firings was post-flight bomblet recovery and rough surveys of bomblet impacts. This involved taking 20 to 30 employees uprange (often to Lake Lucero (when dry) or further north), where they would spread out in a straight line abreast, and walk through the desert retrieving and noting the bomblet locations. Individuals were routinely borrowed from other sections to support this endeavor.

Ted Hoy told an amusing story about those expeditions. “Sometimes we would be in the impact area when the missile was fired. We would crawl under the truck to keep from getting hit by bomblets (we never had a truck get hit). One day Ted Arellano, Rudy Estrada, Bob Harris, and I were up there—we had been cleared by Range Control to be in a certain area to pick up bomblets from a previous firing. Three Nikes were scheduled for firing that day, but were not supposed to land near us. But they did—all three landed within one hundred yards of where we were standing. We were...looking over the debris when the MPs drove up; they, of course, wanted to know what in the world we were doing there! There was quite a flap over that for two or three days.”

As in the 1950s, PSL’s warhead telemetry support for Picatinny Arsenal included both transmission and receipt. The Section inspected the FM/FM telemeters and installed them in the missiles, and operated three ground stations for acquisition of the telemetry data. The ground stations, housed in four-wheeled trailers, were equipped by PSL and deployed in various uprange locations for coverage of firings. PSL’s Data Reduction Section provided reduction of the telemetry data.

The Little John was the culprit in an incident that could have ended tragically for one PSL technician. Ted Hoy said, “One time, Henry Hoffman was at Yuma working on a Little John on its launcher. He turned around and bent over to get a tool, and the missile took off. The blast knocked him off the launcher, but he wasn't hurt except for singing his hair a bit. Closest call we ever had on the job—it could have been very serious! Bridwell was [the] PSL man in charge. [I] don't think they ever figured out what made the thing take off.” Harold Connell said, “HDL was using an old, two-wire-plug electric fan to blow air over ice in a cardboard shroud to cool the fuze section. It was thought that leakage from this fan into ungrounded firing lines caused the early firing. After this, all of the old firing lines were torn out and replaced with a properly grounded and shielded system. An HDL man standing behind the missile was also burned.” Mr. Hoffman said that they loaded him into an old World War II, four-wheel-drive ambulance and “rushed” him to the hospital at 20 miles per hour.

An event that helped strengthen PSL’s relationship with the University faculty occurred when the NOMTF at WSMR requested that PSL design a tower for a rather large dish antenna. Harold Connell conveyed the request to the Civil Engineering Department, and Professor Roger Zimmerman provided an adequate, cost-effective design.

As noted at the beginning of this chapter, testing for two new missiles—Pershing and Lance—started in the 1960s. These missiles were intended to replace the Redstone and the Honest John, respectively. The following descriptions were acquired from fact sheets published by the WSMR Information Office in the 1968 to 1972 time frame.

“Pershing (Figure 125) is a two-stage, solid-propellant ballistic missile with selective range capability. It replaced the Redstone and is now deployed with Army units. It has a range of up to

Figure 125. Pershing Missile

400 nautical miles, is 35 ft. long, and weighs approximately 10,000 pounds." Launch sites were established in southeastern Utah with flight corridors extending over parts of Colorado and New Mexico to the WSMR range approximately 400 miles away. The first Pershing flight, launched from Blanding, Utah, impacted at WSMR on September 24, 1963. In September of 1967, a Pershing launched from a Utah site overflew the range and landed about 250 miles south of the border in an isolated area towards Chihuahua, Mexico.

"Lance (Figure 126) is a 20-ft long, 3200-lb. surface-to-surface missile which...replaced the Honest John rocket. It is designed to have faster reaction, increased mobility, and more accuracy. It is the first Army missile to use prepackaged, storable liquid propellants. R&D testing began in 1964 at WSMR under the management of the Redstone Arsenal. The Lance is built by the Chance Vought subsidiary of LTV."

Figure 126. Dual Launch of Lance Missile

Ted Hoy told of another incident that happened in those days: "I remember 1966 very clearly. One night, we were coming in from work in a PSL car, with Connell driving, and we had a terrific wreck [near] the Hitching Post bar. We took a car broadside [after slowing down from] 70 miles an hour. He was driving and he bounced straight up and cut his head. I happened to be riding in the right-hand front seat and had slid down in the seat and was asleep, with the seat belt up around my chest. When we hit, I broke ribs and started through the belt and it hung around my legs and I hit the top of the dash with my head—bashed my face all up. That was in October…"

Army Data Processing

The Data Processing effort for the Army involved three PSL Sections—the Data Reduction and Applied Analysis sections located on campus, and the Data Processing Section at WSMR.

<u>Data Processing Section</u>

As described in Chapter 4, the Data Processing Section began as a photographic film-processing group at WSPG under Dr. Gardiner. This nocturnal operation, consisting of one PSL staff member (Leonard Ward) and a few students, was, by the end of the 1960s, the largest Section in the Laboratory, with over 200 students, student spouses, and staff employees. Fiscally speaking, the contract increased from $50,000 per year to well over $2 million by 1969.

Walter Allen, who joined the group in January of 1959 as a Student Aide, said that work in those days consisted of processing all of the film for Army missile tests at WSMR. The group operated a high-speed machine that developed motion-picture film in 16mm, 35mm, and 70mm sizes. Group personnel performed DOVAP data reduction (which involved manually counting the DOVAP signal waveform cycles that had been recorded on film and converting this data to missile velocities) and provided some basic telemetry data reduction support as well. Larry Moss and David ("Tim") Timmons operated the Univac 1103/A, which was one of the first computers installed at WSPG, in the basement of Building 1512. This computer, which was the size of a semi-trailer, used steel tape for its data storage medium.

According to a PSL capability brochure published in 1971, by the end of the 1960s, the Data Processing Section was responsible for the operation and management of all WSMR Army computer systems. In addition to computer operations, the Section handled computer interface equipment, including data checks and real time functions, interface facilities, data plotters, and remote terminal operations. Personnel also performed computer setup and job scheduling, maintained magnetic tape and computer program libraries, operated computer support equipment, and provided courier service in connection with computer support.

In the mid-1960s, government concern regarding quality resulted in the implementation of a Quality Assurance (QA) function, and a group called, "Standards Management" was formed within the Data Processing Section. Tim Timmons, who was put in charge of this function, said that he was very glad to be released from machine operations.

The management of the Data Processing Section underwent a rather rapid series of changes during the 1960s. Maurice Cummings replaced Leonard Ward, the group's first supervisor, early in the decade. The group became a part of Anna Gardiner's Data Reduction Section, where it remained until Ray Chavez succeeded her in 1961. Shortly thereafter, Rick Ricketts became the Director of PSL and elevated the group to a Section under Maurice Cummings. Walter Allen was promoted from Assistant Supervisor to Section Chief in 1965 after Mr. Cummings was killed in an automobile accident when driving to Las Cruces from WSMR one night. In 1969, Mr. Allen left PSL and Tim Timmons was promoted to Section Chief. Mr. Allen returned to the Data Processing Section in August of 1970, where he worked for his successor.

Most of this Section's growth occurred in 1965, when a change in Federal regulations prohibited Civil Service and contractor personnel from performing the same duties. As a result, PSL assumed the daytime shift in addition to the two night shifts, and computer operations became a 24-hour endeavor. Meanwhile, all data reduction functions being performed by the group were transferred to Civil Service personnel.

Another function managed by the Data Processing Section in the early 1960s was the operation and maintenance of a telemetry playback station on the second floor of Building 1512 in the Army Technical Area. Leroy Grizzel worked in that station as a student for about a year with Maurice Cummings, Dave Lamew, Art Haverall, and other students. Mr. Grizzel went on to operate an IBM 1401 computer on the second shift, running printouts from tapes that were brought in.

Several Section personnel enjoyed a year's respite from missile testing during 1969. The New Mexico Bureau of Revenue requested that NMSU assist them in setting up an automatic data processing system. Keith Hennigh traveled to Santa Fe in 1968 to assess the situation. When Mr. Hennigh asked Walter Allen for some assistance, Tim Timmons and Franklin Jones (along with three or four others) "went up there in 1969 to straighten them out and automate their accounting. It was supposed to be a short job, [but] it lasted a whole year. [It] was a really good experience." George Hackler, Bob Vaughn, Madie Faulk, and Mary Lou Kearns provided occasional assistance as well. John Byers joined the effort at a later time; in fact, he and Mr. Timmons designed the state income tax form that remains in use today. Mr. Timmons brought his family to Santa Fe for the summer, where they lived in a camping trailer.

Staffing of a large operation such as the Data Processing Section's WSMR support was difficult much of the time. Mr. Timmons said that a person could perform computer operations work for about three years before "burnout" occurred. Because of this, turnover was always a major problem, making use of students, according to him, "our best bet." "When we took over the daytime shift, we set up the student spouse program and hired them as staff people. This worked out very well, until EEO came along and said that this was discriminatory. So, we dropped the student spouse program."

Former New Mexico Governor Garrey Carruthers participated in PSL's student program as a film reader in the Data Processing Section. Several people who later became high-level WSMR officials were introduced to the missile field through participation in this program.

Various Data Processing Section personnel became involved in computer operations at the Army's Yuma Proving Ground near Yuma, Arizona during the 1960s.

> Tim Timmons told an amusing story: "One night out there (at WSMR) some students and some Civil Service guys got to horsing around a little, and one of the students got a bit teed off. When he said he was going to the restroom, the others figured he was going to get a bucket of water [to] pour on somebody, so one of the civil servants got a water-filled fire extinguisher ready to douse back. The door into the hall had louvers in it, and they could see someone standing out there. So, he sprayed water through the louvers. Nothing happened. So, they opened the door and there stood a very wet Army officer. I was sure glad it wasn't one of our people that did it!"

Data Reduction Section

In 1961, the functions performed by the Ballistic Reduction and Telemetry Reduction groups were merged and a new section, called Data Reduction, was created (this action was triggered by Mrs. Gardiner's retirement). Ray Chavez, who had worked in Mrs. Gardiner's group, became Chief of the newly formed section, which continued to provide the same support as it had prior to the merger, primarily on defense-related contracts.

The Section's growth with respect to Army missile support is similar to that experienced in sounding rocket data reduction—the number of firings increased significantly and major advances were made in computer and film-reading technology. By the end of the 1960s, the Army was firing between 2,000 and 3,000 test missiles annually, providing the Data Reduction Section with millions of frames of photographic film to be individually reduced to determine missile position, velocity, and attitude (Figure 127). Although some of the cameras in use at WSMR could produce 35,000 frames per second, the majority of them output 60 to 360.

Figure 127. Film Reduction

This group reduced film data for virtually every missile launched at WSMR. Mary Lou Kearns said, "We can reduce data for unexpected events on a missile flight that White Sands cannot..."

The optical data reduction performed at Yuma Proving Ground in Arizona that began in the 1950s continued through the 1960s, enduring for a total of 15 years. An on-site field group emerged from this effort. The Army's artillery missiles Little John and Honest John were fired at Yuma.

PSL engaged in data reduction support for tests at the Atomic Test Range in Nevada, where BTL was conducting survival tests on electronic equipment and components at various distances from ground zero.

In the early 1960s, Nash Garcia and a small crew were sent to Kwajalein Atoll to analyze data from the Nike-Zeus acquisition radar (Mr. Garcia was also involved in programming the Tactical Intercept Computer (TIC)). This trip occurred at the same time that the PSL's Rocket Section was providing support on Kwajalein.

The Data Reduction Section took on a major new type of data reduction, radar cross-section analysis, in the early 1960s. This work, under a contract with Lockheed Missiles and Space Company, involved analyzing radar return data from Athena warheads re-entering the Range. Harvey Adam was in charge of this "Radar Group," which consisted of several employees. The Air Force Athena, which was launched (from Green River, Utah) onto WSMR, was being utilized as a re-entry systems test bed. The first launch occurred on February 10, 1964—the hundredth took place on March 28, 1968.

Meanwhile, beginning in 1965, Jim Hulsey supervised about eight people (primarily students and student wives) performing similar work for the Army's Missile Electronic Warfare Test Agency (MEWTA) at WSMR. Mr. Hulsey defined radar cross-section as, "...a measure of how big a particular target looks to a radar. We used the AGC record from the FPS-16 radar as it tracked a missile and compared that to the return from a calibrated sphere, usually a six-inch sphere hung from a balloon." Mr. Hulsey's group operated digitizing machines located in a large room on the east end of Anderson Hall's second floor.

Mr. Hulsey assumed leadership of the group when Harvey Adam left PSL in 1969, putting him in charge of all radar cross-section analysis. Mr. Hulsey said, "The range had several multi-million-dollar radars, and they did a beautiful job. I acted as a Lockheed rep[resentative] at one of the radars, usually at Stallion Site, for the Athena missiles. Most shots were about midnight, so I would get to PSL about 2:00 a.m. and start reduction at 8:00 a.m. That was a fun project—I enjoyed it. I was on it about eighteen months, until sometime in 1970."

Keith Hennigh spoke of a large but short-lived data reduction effort for MEWTA's Bob Clawson, who traveled to Johnston Island in connection with the aforementioned atmospheric nuclear tests. Mr. Clawson and his crew installed a large number of interferometer monitor systems to measure the phase difference between two antennas that were part of the installations on the island. Mr. Hennigh said, "Clawson brought back a trainload of oscillograph records for us to reduce in Kent Hall. That was the first contract on which I over-ran my budget."

In addition to those mentioned above, staff members involved with Army missile data reduction in the 1960s included Charles Gardenhire, Keith Guard, Mary Lou Kearns, Larry Higgins, John Weinrich, Emily Good, Betty Doil, John Byers (in charge of the Lance missile data reduction), Stanton Needham, Jon Ottesen, Margaret Ottesen, Squire Seagraves, Roberta Westhafer, Al Carver, Stuart Tracy, Allie Snodgrass, Ilene Arnold, Mary Durio, Blanche Goodman, Betty Robinson, Joyce Holland, and Linda Peckham. John Weinrich handled the data reduction for the MPI Section's tone ranging system.

PSL was also involved in what was referred to as the "golf ball" project at WSMR. The strange object in the middle of the desert resembling an enormous golf ball several stories tall was actually an experimental antenna. It was a Luneberg lens formed by imbedding metal particles in a huge Styrofoam sphere, which was mounted on a turntable so that it could be rotated. The antenna was being evaluated for use with the Nike-Zeus acquisition radar, and PSL's Data Reduction personnel were asked to reduce data for those tests. A field group was established at the site (now known as the MAR Site). This antenna was later discarded in favor of a multiple-array system. The Styrofoam was then sold to Burn Construction of Las Cruces, who unfortunately deemed the material as too flammable for construction use (in fact, Burn was cutting the Styrofoam into large blocks with a hot wire and set the remaining sphere on fire, which was very costly). The PSL field group remained to support the MAR tests and evaluations.

Jon Ottesen related a humorous story. "...I had somewhat of a reputation as a troublemaker. It all started way back when I was working in Kent Hall. I used to go in there and work at night sometimes—we had quite a bit of work. At the time it was a girls' dorm. We were in the basement there, and there had been a complaint that someone was playing bongos down in our area late at night...I got called into the office and [Keith Hennigh] asked, `What are you doing playing bongos?' I said, `I don't have any bongos!' He was sure I had been playing bongos down there. I had no idea what was going on at the time, but a couple [of] years later I was thinking about it—then I knew what it was. We had these steel, government-issue trashcans—they were a little taller than regular ones. The janitors would come in around 10:30 every night and empty the trash...into a bag and drop the can back on the floor—bong, bong, bong—as they went through the whole area. There were at least 15 of these trashcans in there, so that was where the 'bongos' came from.

"Another time, there were eight of us trying to catch up on a missile we were working on. This time it got crazy—we had worked many hours without a break. We had decided to take [a short one], and we had these roll-around chairs, and we had a convoy going with these chairs, when somebody in charge ([I] think it was Larry Higgins) walked in, and he was petrified. We were just trailing down one aisle there, but he didn't like this kind of behavior."

Marge Ottesen commented, "For many years, I did the DOVAP reduction alone, then it got to where the only time I was needed on it was when something went wrong. Many things could go wrong...the transponder sometimes went out,...[a] couple [of] times, the four antennas were interconnected wrong (like north to east versus north to south),...sometimes there were big gaps in the data,...or the digitizing was bad. I recall we had only three Nike-Cajuns where we had perfect data...10.45,10.46, and 10.47—those three numbers stuck in my memory."

Applied Analysis Section

As mentioned earlier, the Applied Analysis Section was formed in 1960 and Keith Guard was its first Chief (Jon Ottesen and Bill McCool worked for Mr. Guard). Mr. Guard left PSL in 1962 to work with former PSL employee Gil Moore at Thiokol. David Mott, who transferred into the Section in 1965, said that his work at that time primarily involved analysis of sounding rocket trajectory data.

A 1969 document specified the mission of the Section as, "a problem-solving and study group that works in the areas of applied physics and mathematics. Tasks include system mathematical modeling and the development of data analysis procedures."

The group became involved, in Keith Hennigh's words, "in some real cloak and dagger stuff": (1) attempting to determine an unknown missile's signature via a spectrum analysis of its flame (the U.S. Army hoped to be able to identify Soviet missiles from monitoring sites in Turkey) and (2) examining a missile trajectory segment via radar and using this data to attempt computation of the launcher's location.

According to John Byers, the Applied Analysis Section created a data collection system for WSMR's electronic countermeasures tests. This involved simulation of missile flights on a software-controlled, three-dimension motion table.

Army missiles studied by the Applied Analysis Section included the Honest John, Little John, Nike, Nike-Ajax, Nike-Hercules, Nike-Zeus, and Sprint. According to Stanton Needham, the Section also performed several re-entry studies on the Athena warhead.

U.S. Navy Programs

PSL's involvement in Navy military programs focused primarily on two very different areas: flight tests of guided missiles and tracking of navigational satellites.

<u>Navy Missiles</u>

PSL's Navy missile test support at WSMR was largely comparable to that provided in the 1950s. However, some missiles were added to the firing load, and considerable labor and money were expended to convert from analog to digital computers in the mid-1960s. APL continued as PSL's primary customer on these Navy programs. NOMTF ("Desert Navy") personnel continued to handle missiles, as well as launch them from the Desert Ship, throughout the decade (Figure 128).

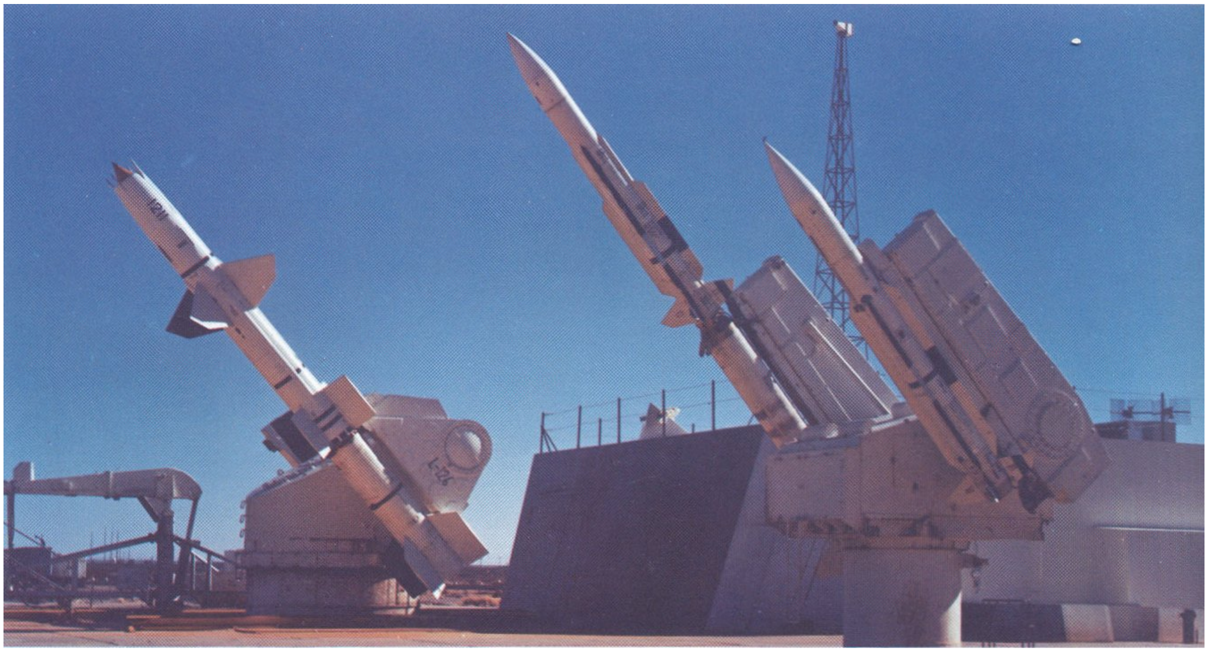

Figure 128. Talos, Terrier, and Typhon Missiles

The Navy achieved a monumental milestone through its missile development efforts on October 21, 1960, when a Talos missile launched from a ship (the U.S.S. Little Rock) shot down the first drone aircraft.

The Typhon, a potential successor to the Talos, was launched twice in 1958. This missile reappeared at WSMR and was launched 13 times in the 1961 – 1963 timeframe. It served as a test bed for many advanced guidance and control concepts for use in more sophisticated versions of the Tartar, Terrier, and Standard Missile (SM). The name "Typhon" was intended to identify a weapons system rather than one particular type of missile. The system, consisting of a state-of-the-art, phased array radar; a delta-winged, long-range ramjet missile; and a short-range, solid-fueled missile, was to provide immediate response to an attack and handle multiple targets simultaneously. It never reached operational status and was shelved, considered too advanced for its time. In 1953, the Navy diverted funding from Typhon in order to initiate an emergency improvement program for the previously deployed Terrier, Tartar, and Talos weapons. Some of the Typhon design concepts were employed a few years later in the Aegis fleet defense system, one of which was the use of digital circuitry in the control and guidance hardware.

In 1965, the Navy's Bureau of Weapons consolidated its surface-to-air missile flight tests by moving the Tartar and Terrier projects from NOTS/China Lake in California (where flight tests had been conducted throughout the 1950s) to WSMR. Like the Talos, these two missiles were part of APL's Bumblebee program.

The Terrier, with beam-rider type guidance, was developed concurrently with the Talos to handle closer-range targets. It was a boosted missile one foot in diameter and 15 feet in length (half the length of Talos) that featured two solid-fuel stages and a range of about 30 nautical miles (half the range of Talos). Terrier I had Talos-like fixed wings and tail fins for steering; Terrier II had dorsal fins instead of wings to facilitate shipboard handling. Built by the Convair division of General Dynamics in a new plant located in Pomona, California, Terrier was transported to sea aboard the U.S.S. Boston and U.S.S. Canberra in the mid-1950s. Apparently, a homing capability was added to this missile at about the time that the project relocated, because the first one that flew over WSMR in 1966 was nicknamed Homing Terrier (HT). Tests ended in 1970 after seventeen shots; Terrier's mission was assumed by its successor, the SM.

The Tartar, which was essentially a Terrier minus a booster, was created by APL to fulfill the Navy's requirement for a compact missile system to install on destroyers that was capable of reaching targets at ranges of up to ten nautical miles. The Convair-manufactured Tartar, equipped with homing guidance only, used a new solid-fuel, "dual-thrust boost/sustain" motor, eliminating the need for the separate booster used by Terrier and Talos. Tartar missiles were initially put aboard ship in December of 1960, and production Tartars were successfully fired at sea in June of 1961. Ten Tartars were fired at WSMR—five in 1966 and five in 1969.

In the mid-1960s, the Terrier/Tartar series missiles were re-designated "Standard Missiles." The Terrier and Tartar were renamed "Extended Range Standard Missile (ER)" and "Medium Range Standard Missile (MR)," respectively. The first test of an officially labeled SM at WSMR took place in 1964; a total of 58 had been flown by the end of the decade.

The Missile Ground Systems, Rocket, Applied Analysis, Telemetry Processing/Data Reduction, and Electromagnetics sections were all involved in various Navy guided missile programs.

MGS Section

As mentioned earlier, PSL's MGS Section, which evolved from the 1950s Talos Group, became part of the Engineering Division during the 1966 reorganization. James E. Masterson retained his position as Section Chief throughout the 1960s. Section personnel in this decade included Leslie ("Les") Fields, Leroy Grizzel, Craig Erickson, Thomas Clark, Robert LaPierre, and James McLimans (Jim Hulsey joined in 1971). A 1967 list of PSL positions indicates that MGS was comprised of seven employees—an administrator, three engineers, two technicians, and a secretary. The administrator and secretary, however, were shared among PSL sections at WSMR; therefore, much of their time was charged to customers other than APL.

Direct participation in Talos test firings remained the MGS Section's primary duty throughout the 1960s (this ended in 1972). Interspersed with Talos shots were those of the newer missiles mentioned above, creating a heavy schedule of up to sixty launches per year. As in the 1950s, support consisted of design, fabrication, and evaluation of missile computer systems. A 1969 document describes the Section's mission more specifically, as follows:

- Sustain the fire control computer capability (analog and digital) in support of Naval operations at WSMR

- Develop the mathematical model and ensuing software for the Tartar-Terrier-Standard (TTS) missile computer system utilizing a militarized digital computer system (the UNIVAC 1218) to eventually replace all analog equipment
- Utilize the capacity of the 1218 to gather, store, and analyze data for evaluation, control, and operational displays in a manner limited only by good engineering practices

In the early 1960s, supporting Talos firings included operating, maintaining, and programming the TACOS analog computer, a carry-over from the 1950s (Chapter 4). A massive giant compared to today's computers, the TACOS, which was programmed via a large patch board, was described at the time as, "extremely flexible." Les Fields said that, "the computer was a commercial model, and APL had built a servomechanism system used in combination with it to handle the Talos. In the early 1960s, we reprogrammed the system using an algorithm that we developed for the cruise portion of the flight. It kept the missile at its optimum altitude for its ramjet engine to minimize fuel use, so that it could reach its maximum range. Our algorithm was used later in the shipboard fire control systems."

Les Fields provided more details about the work that he and Jim Masterson did to modify this algorithm, called the C Trajectory (and originally developed by APL): "The C (long range) Trajectory that came with the computer from APL (in the TACOS computer patch panel) was picking a launch angle which was just a long ballistic curve. Well, Jim and I didn't like this —the Talos was a ramjet and had to pull in oxygen from the atmosphere to burn with the fuel to propel [the rocket] through the air (it was most efficient at around 60,000 feet)—so we got into the TACOS and started playing games. Our goal was to take the launcher at a given position and set that position (primarily the elevation angle) so that the C Trajectory would come up until it was tangent to the desired cruise altitude. Then we worked out the program to transition from the C trajectory to the cruise trajectory. We played with that all through one 24-hour period and flew a missile with it the next day. [The algorithm] took it downrange further than any missile that they'd flown before…"

Mr. Fields continued, "In 1965, APL began the task of changing over to digital computers and bought a Univac 1218 with a console and a tape machine. They built a D/A and A/D converter, which was required to interface with the Navy analog world on ship. That was called TACE - Talos Analog Conversion Equipment. APL eventually took it on board ship, and I think they flew three or four missiles with it and showed that the missile could be flown with a digital system. The system then came to WSMR, and we were given the responsibility to operate and maintain it. At the time, the Navy world was all analog and they were reluctant to switch." The first Talos launch utilizing this digital equipment occurred in December of 1966.

The Navy eventually accepted the digital system, gradually phasing out the analog. Mr. Fields said that when the Terrier and Tartar missiles were brought to WSMR, MGS Section personnel "quietly set to work to copy our analog algorithms into digital form. When we had something that looked good in simulated flights, it was used to successfully fly a Terrier, and then two or three more. That surprised NAVSEA when they heard about it—we didn't bother to get their permission to fly Terriers and Tartars with a digital computer."

In November of 1969, the NOMTF launched the U.S. Navy's first SM-1 missile using a real-time machine-language digital program. The MGS Section developed this software from proven analog concepts.

In 1971, the Navy began developing the SM-2, which represented a significant change in philosophy from SM-1. According to Les Fields, "SM-1 worked similar to Hawk in that it was a CW homing system that had to acquire the target while the missile was still on the launcher, go through a boost phase to begin the firing system to get it off the launcher, and then continue to track that target all the way to intercept. SM-2 was different in that the missile didn't even know where the target was at all when it was launched. It flew via command guidance (i.e., a computer system on the ground or on the ship actually told it where to fly), and when it had been flown within a reasonable distance of the target, then it was given commands to tell it where the target was. It would then go into seeking mode and acquire and home in on the target. So this extended the range of the missile considerably beyond what SM-1 could do." The MGS Section borrowed Jim Hulsey, who was working as a programmer in Doty Telles' Section at the time, to help develop the software to get the SM-2 off the ground. Craig Erickson and Bill Hyde were also involved in this effort.

Another of the MGS Section's achievements involved solving a problem with an analog fire control system for shipboard use. Sperry Gyroscope Company built this system in the days of the Talos. The fire control system was brought to WSMR as a series of modules, or cabinets. When a serious problem was discovered in the Ground-Aided Acquisition (GAA) cabinet, Sperry's proposed solution was to add approximately $1.5 million more in servos. Les Fields said that he and Jim Masterson, along with Bob Thompson of APL, "put our heads together and cured the problem with some relays and a few wiring changes."

Leroy Grizzel described the tribulations faced by a new employee in a large group as follows: "In about 1965, I went over to the MGS Section, where I am now. One of my first jobs was to sort out about a dozen drawers full of miscellaneous nuts and screws that had accumulated over many years. So, I got a bunch of boxes and spent several days sorting. Then one day I came in and found that somebody had evidently needed the boxes, so they had dumped all the stuff back in the drawers."

The MGS Section enjoyed a remarkable success record. Mr. Fields said, "All through the Talos test firings and the SM series firings, we never had our system to fail during a flight."

OTHER SECTIONS

In the late 1960s, the Rocket and Applied Analysis sections entered into a contract with the Naval Ordnance Systems Command, through the NOMTF at WSMR, to perform analysis and experimentation to improve the chaff dispersion from rockets and projectiles at sea level. The purpose of the resulting Tactical Electronic Warfare Decoy System (TEWDS) was to lure enemy anti-ship missiles away from the United States fleet by deploying chaff clouds several miles away near the water's surface (Figure 129). The propulsion system on the TEWDS was a Sidewinder rocket. Stewart Bean was the Project Engineer, George Baker managed fabrication, and Dr. David Mott of the Applied Analysis Section analyzed the problem and the test data.

Figure 129. TEWDS Rocket

Robert DeLucia was apparently part of this group as well. PSL ultimately developed several rocket payloads and five-inch projectiles for this program, and used balloons to carry chaff payloads. Examination of NOMTF's history reveals that the TEWDS program was responsible for the launch of 29 balloons and six rockets in 1968.

Mr. Bean and Dr. Mott said that they traveled many times to the Naval Ordnance Test Station at China Lake, California, for chaff tests in 1967, 1968, and 1969. They especially enjoyed a week's cruise on the U.S.S. Norton Sound for shipboard testing of the chaff rockets. According to Dr. Mott, "We reduced a lot of data for that. That ocean trip was the most fun I ever had at PSL. They had a little fleet out there. They had an aircraft carrier, two or three destroyers, and it was a major test. Just being out there, sailing around the Pacific, that was neat!" Cecil Post of the Electromagnetics Section also participated in these shipboard tests.

The Talos program, through the POGO target rocket development, sustained the Rocket Section in the 1950s. PSL continued to provide these targets for the Talos and SM missiles at WSMR until the early 1960s, when the function was turned over to the Navy and the Army. The final POGOs were fired at the Range in 1968. The Rocket Section, meanwhile, transitioned into providing support for Army projects at WSMR and in the Pacific, which was discussed earlier in this chapter.

David Mott was also directly involved in support of the Navy missile program at the Desert Ship, in a study contract requesting analysis of the real time flight tests instrumentation requirements and the coordination of these requirements with existing real time range facilities. Other segments of this study examined the performance characteristics of the range radars and the digital filtering of radar data in real time.

The Talos program was the most extensive user of PSL's Telemetry Processing Section's services in the 1950s (Chapter 4). This is believed to have been in the 1960s as well, even though this section and the Ballistic Reduction Section combined to form the Data Reduction Section in 1961. The group's telemetry processing station, located on the top floor of the library building, was used to convert magnetic tapes containing telemetry data to paper records until the station was rendered obsolete in the mid-1960s. Ray Chavez said that he had a special group of people reducing strip records from Talos flights—reading out missile parameters for NOMTF. The Section also reduced radar data to paper records.

The Electromagnetics Section provided antennas for these various Navy missiles at WSMR to some extent, but details concerning this work have not been located. The group received a contract in 1960 to design, develop, and fabricate 20 radar beacon antennas for flight use on the Typhon missiles. Telemetry and command antennas were provided in the 1950s, but there is no evidence that this continued throughout the 1960s.

Navy Navigational Satellite Program

The U.S. Navy's series of Transit satellites (Figure 130), officially referred to in those days as geodetic satellites, were placed in orbit for a two-fold purpose. The first was to precisely locate

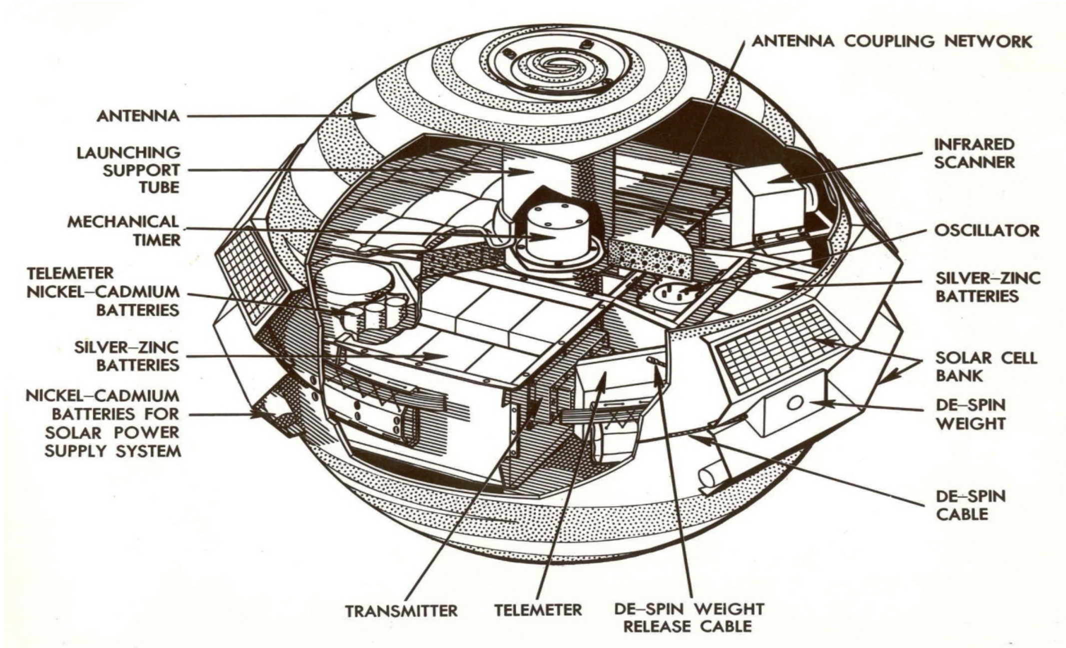

Figure 130. Transit Satellite

and map points on the earth, and the second was to enable ships at sea to fix their positions accurately through regularly updated satellite ephemerides at any time of the day or night and in any weather. The latter use was a closely guarded secret for many years.

As mentioned in Chapter 4, the Laboratory's Satellite Ground Instrumentation (SGI) Section was created in 1959 to provide operational field support for the radio Doppler tracking of these satellites. This support continued throughout the 1960s and beyond, developing into an actual worldwide operation early in the decade.

The program's dual purpose dictated the use of two types of tracking stations—permanent (fixed location) for the navigational application and mobile for the land surveying application. At the beginning of 1960, the SGI Section was staffing three tracking stations—a fixed station in the library building on the NMSU campus (Figure 131) and two mobile stations in vans—one at Argentia, Newfoundland; and another near Seattle, Washington. By the mid-1960s, the number of permanent sites had grown to 11 and the number of mobile units to 12; by 1969 the number had dropped somewhat to five mobile and 10 permanent stations. These sites and operations are described in further detail in the following paragraphs.

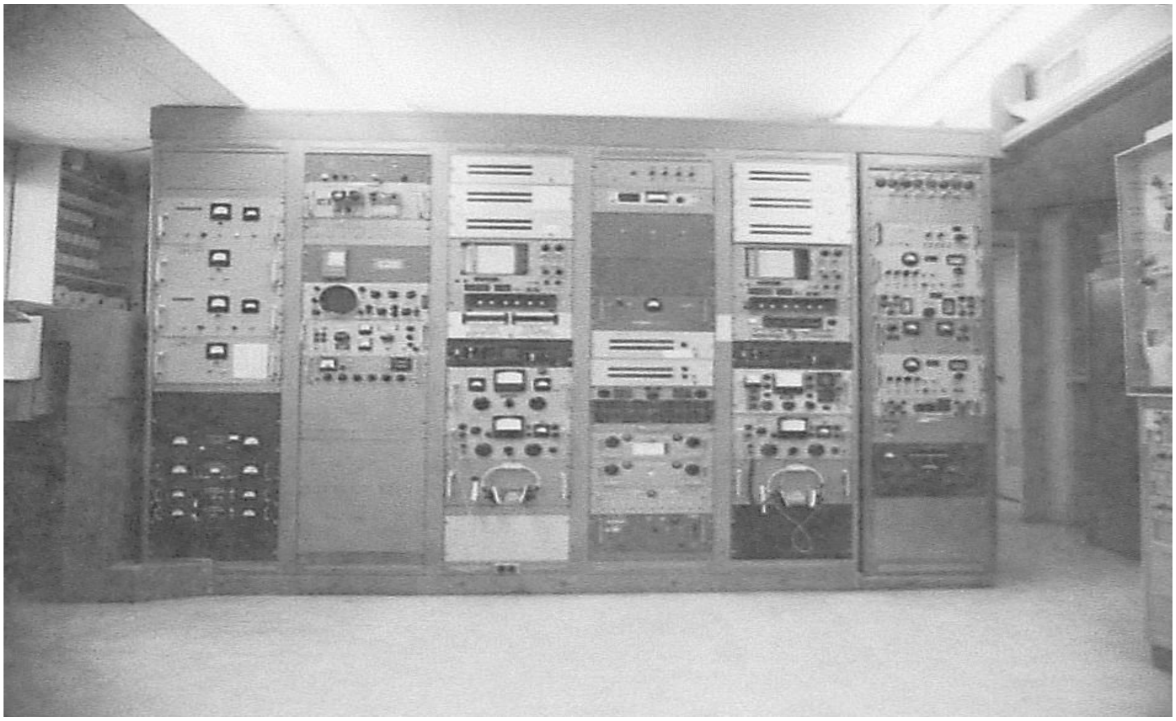

Figure 131. Permanent Tracking Station O3, Top of Branson Hall

The initial error in the location of either the tracking station or the satellite was approximately 1000 meters using data from only a few stations located in the United States. The error fell to about 100 meters in the mid- to late-1960s after the worldwide tracking station was in place. By the mid-1970s, the error had fallen to about 10 meters. From the late 1970s to the end of the program, the accuracy slowly dropped to approximately ½ meter. The accuracy was about 50-100 meters for a slow-moving ship.

PSL's function was primarily to install, operate, and maintain the ground stations for 24-hour receipt and recording of data transmitted from the Transit satellites during each orbital pass over or near the site. These data were relayed in near-real time from each station to a central collection facility at APL/JHU via Teletype or various other forms of land communication. Each station tracked 1-10 daily passes every day of the year. The effort soon expanded to include design and construction of sophisticated tracking equipment.

As in the late 1950s, APL/JHU provided technical and scientific direction for the program. That agency contracted PSL support until early in 1961, when administrative control of the contract was switched to the Navy's PMR at Pt. Mugu, California (this remained the case until well into the 1970s). PMR, through its newly created Doppler Satellite Office (DSO), handled logistic matters such as site surveys, communications, transportation, visas, etc., for PSL personnel at the tracking stations. The appropriate offices within PMR managed property control and contract funding. APL coordinated the effort between the data gatherers (PSL), the data processors, and the data users, as well as setting standards for data collection. Whenever new tracking equipment was required, APL would normally determine the operating format and the specifications for that equipment.

The Naval Ordnance Test Station (NOTS) at China Lake, California was another agency involved in the early days of the program. PSL worked closely with NOTS during the fabrication and testing of the first series of NACODE stations and subsequently in the design, building, and installation of the second-generation equipment. By late 1962, all of the first-generation NACODE units had been replaced. PSL's direct relationship with NOTS ended in 1965.

The SGI Section began the 1960s with Al Bowers as its Chief (Figure 132). Employees working for him included Don Peterson, Robert Ecklund, Robert Yarbrough and Hugh Gardiner.

Left to Right - Back Row, Gerald Welch, Sta-014; Norman Takashiba, Van-311; Bernie McCune, Van 307; Nyle Groth, Sta-100; Ray (Pancho Villa) Spiller, Sta-008; Mack Haley, Van-312; Bob Raby, PSL/Sta-103; Gerald Holmes, PSL/Sta-103; Richard Rudd, Sta-121; Ed Schmidt, PSL/Sta-103; Doug Robinson, PSL/Sta-103; Tony Welch, Sta-018; Left to Right - Front Row - Ian Cooke; Sta-106, Curtis Anderson, Sta-111; Alex Stembridge, Sta-106; Gil Seymour, APL/JHU; Pete Marvin, PMR; Jake Kerr, Sta-112; Dan Martin, PSL/Sta-103; Bob Ecklund, PSL/Sta-103; Hal Wetter, Van-314; Wayne Harper, Sta-115; and Colman Polvado, Sta-117.

Figure 132. SGI Section Staff, 1969

Staff appointees during the 1960s included William Bridges, Calvin Buerkle, L. R. Cammack, Bill Dodson (who succeeded Mr. Bowers as Section Chief in 1964), Earl Downing, R. E. Engle, Handy Fairchild, Arthur Gilcrease, N. L. Groth, Mack Haley, Wayne Harper, E. F. Hines, C. L. Hoggard, Fred Hogsett, Gerald Holmes, Fred Kidd, Kenneth Lane, John Linder, John D. ("Dan") Martin (who became Section Chief when Mr. Dodson resigned in 1965), Bernie McCune, James McLimans, Colman Polvado, Robert Raby, Douglas Robinson, Richard Rudd, Ed Schmidt, Ray Spiller, Norman Takashiba, J. K. Togami, G. E. Welch, Tony Welch, Hal Wetter, and Herman ("Bud") Wyman. A 1969 document indicates that the Section's staff included 16 engineers and eight technicians.

As with the majority of technical organizations, automation became the focus of the SGI Section's efforts in the 1970s. The Section designed and built automatic tracking stations, reducing the personnel required at each site from 6-8 to 2-3.

The function of each tracking station was to obtain Doppler data from one or more geodetic satellites as well as from up to 5 or 6 Navy Navigational Satellites. This was done by comparing the frequency of an RF oscillator in the satellite with that of the master oscillator in the ground station. The difference in the two frequencies contained the Doppler shift information, ionospheric and atmospheric refraction, information concerning the gravity gradients of the earth, and disturbances caused by the influence of the moon, sun, and planets.

Corrections were made at each tracking station to eliminate the majority of the ionospheric effects and at APL to remove the atmospheric effects, using weather data relayed by the tracking stations.

PSL's SGI Co-Op Program

PSL originally hired students in 1947 to support WSPG's data reduction contracts; however, this changed in the early 1960s. PSL had been actively seeking a government contract in the space industry that it could support using NMSU students. The Navy's Transit Satellite program provided the perfect opportunity to do so, resulting in the initiation of the SGI co-op program. This program utilized over 1000 students (initially known as "transit co-ops"[41]) in some very demanding and interesting work throughout its duration.

A promotional flyer dated 1960 announced the beginning of the program, which was expected to take five years, alternating school sessions with worldwide support of PSL tracking stations. Only applications from single male freshmen who had graduated in the top 1/3 of their classes were considered (the program was finally opened up to include female students in 1974). Three Personnel Rating Sheets had to be submitted along with each application—one completed by the student's high school principal or superintendent, one (preferably) by the student's Science or Mathematics instructor, and one by a prominent community citizen who knew the student well. This thorough screening process provided PSL with an excellent student work force. Freshmen entered a training program, were paid $200 per semester, and were guaranteed a minimum of $1.65/hour and approximately $10 per diem during travel (compensation for a work phase in these early years would total approximately $2360).

SGI co-ops were trained during their first year at NMSU (students participating in the program were required to maintain a minimum of a 3.0 grade point average during this period of time), then sent to support worldwide satellite tracking. Others were deployed for service to tracking stations located in the United States, including Wallops Island, Virginia; Cape Canaveral, Florida; Johns Hopkins University's Ballistic Research Laboratory in Maryland; China Lake Naval Weapons Center; and Vandenberg Air Force Base, California.

The first semester's training included basic electronics and familiarization with the tracking system, and in the second semester, the co-ops learned how to operate the satellite tracking station

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41 The Transit (TRANET) System evolved through the years to become what is now known as the GPS, or Global Positioning System.

in Las Cruces. Early in the 1960s, as stations were added to the tracking network, each station had 2-3 staff personnel and 4-7 students to support non-stop operations. When operations peaked in the mid-1960s, approximately 70 students were deployed to sites worldwide.

Dan Nimrod related the following: "…The co-op students [not only] provided a valuable service to PSL, they also provided a Tom Sawyer/Huckleberry Finn point of view that can only come from youth, and often to the consternation of their supervisors.

"The co-op program was [initially] delayed…while federal funding came through; complications undoubtedly arose due to [procuring] new passports and security clearances for students. [This] required several students to delay their departure (and income) and [enroll in] a six weeks' summer session. It is legendary that students can manage their income to the last dollar until new revenue is due to start, but a delay of six weeks calls for drastic measures for survival."

Mr. Nimrod said that two of these co-op students lived near the campus in a shared apartment. As the co-op program was gearing up, they had estimated that their money would last until they finished their term in May of 1961. But, when they found out that they would have to complete an additional six-week summer term before deployment, they were devastated. In order to prevent starvation, Mr. Nimrod said that they took a goose from Stahmann Farms and had used a string to tie it up in their back yard. After other students expressed concern that they would be caught with the stolen goose, they took it several blocks into town one night and released it. About a half-hour later, a policeman showed up at their door with the goose, announcing that their goose had escaped, but he had caught it for them. According to Mr. Nimrod, the students "eventually did eat the goose."

The co-ops' duties varied with the station, but generally included operating and maintaining tracking equipment (Figure 133), Teletype or other communications equipment, and in some cases communication transmitting and receiving equipment. They also operated and maintained electrical generation equipment, station vehicles, helped with building and grounds maintenance, and modified tracking station equipment. Students traveled to the various worldwide stations for two semesters and returned to school for two semesters. Some worked for only one phase, others worked for four, and many paid for their educational expenses entirely from the income they received during these work phases. A number of students ended their field work and became student trainers in Las Cruces while they completed their educational requirements and graduated. Travel and work in foreign lands for these young people were often exciting and bewildering.

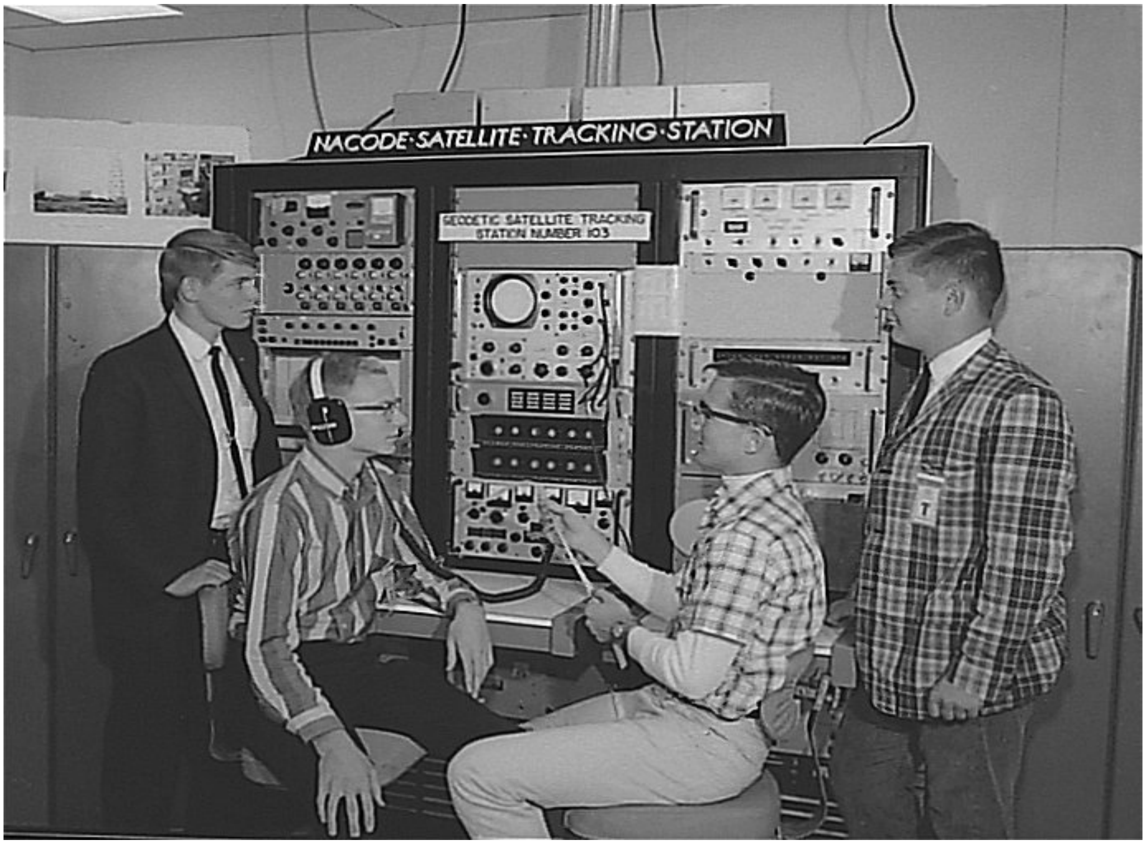

Figure 133. SGI Co-op Students Larry Washam (Standing, Left), John Fowler (Seated, Left), and Grant Newman (Standing, Right) in Station 103, Anderson Hall

Don Purdum, one of the first co-ops in the program, told of his arrival at the van station in Washington state. "In 1960, I was just a 17-year old kid from a south Texas town of about 3,000 when I got on a plane in Corpus Christi enroute to El Paso and points west. I had never traveled anywhere much before. I was supposed to meet another student in El Paso and get my tickets for Seattle. The other student wasn't there, but a stranger with a sign… gave me my continuing tickets and told me that "someone will be at the airport to meet you." I arrived at the Sea-Tac airport in the evening, and there was no one to meet me. I even tried looking up vans in the phone book which, of course, was a useless endeavor. I waited around for about an hour and then wandered out to the front of the airport, where a taxi driver asked me where I wanted to go. I told him that I wasn't sure but that I was supposed to go to the van where there was a satellite tracking station. The only tracking station that I had known was the 03 station in the top of the library at NMSU. I really didn't know that the van looked like a large trailer rig that you see on the highway. The closest the taxi man could figure was 'The Vance' in downtown Seattle, so I said, 'Sure, let's try that!' The Vance was an office building, and I still "had hope that the station was maybe in the top of it like 03 was in the top of the library. It was late and the place was closed, so the taxi driver suggested that I probably should find a place to stay. He deposited me in front of the New Hungerford Hotel, which turned out to be pretty seedy and probably cost $5 or $10. I spent a fitful night, and in the morning called PSL and was given an address in West Seattle. I packed up and found a cab and told the driver where I wanted to go. He said it was pretty far to West Seattle, but I said that I didn't have much choice, and off we went. We finally came to place with a fence with barbed wire around it that enclosed a bunch of poles with many rhombic antennas strung on them. The driver came to the gate and stopped. There were a bunch of signs [saying] "Do Not Enter"—it was a restricted area and the property of the University of Washington. I insisted that he drive me in, he did, and we quickly found the van. Bob Ecklund stepped out, and I was VERY relieved. Of course, no one had told Bob that I was coming."

Students with more experience often took advantage of first-phase students, but they usually caught on rather quickly, becoming world travelers in a short amount of time. The varied experiences of both staff and students during all of their travels and working situations could fill another volume.

Although the work involved in tracking some of the first satellites placed in orbit was quite interesting, far more so were the experiences of traveling to and working in remote locations. Upon graduation, the work experience gained by these SGI co-op students increased their chances for finding more attractive and lucrative technical positions. The SGI co-op program was comprised of only male students in the 1960s and early 1970s; however, female students were allowed to join the program in the mid-1970s.

PERMANENT TRACKING STATIONS

The permanent tracking stations were placed at various locations such that maximum worldwide coverage of geodetic satellites was provided on a full-time basis. These stations produced the bulk of the geodetic data, and since their geodetic positions were well known, their data were used to update the satellite orbits. Table 7 shows the locations of these permanent stations and the year that each was established.

Table 7. Permanent Tracking Stations

Locations	Year Established
Elmendorf AFB, Anchorage, Alaska; Sao Jose dos Campos, Brazil	1960
San Miguel, Philippines; Misawa AFB, Japan; Smithsfield, Australia; Pretoria, South Africa; Hawaii	1961
American Samoa	1962
Thule AFB, Greenland	1963
Seychelles Islands	1964
McMurdo, Antarctica	1965

The SGI Section installed all of these stations, the majority of which they staffed throughout the 1960s and beyond (Figure 134).

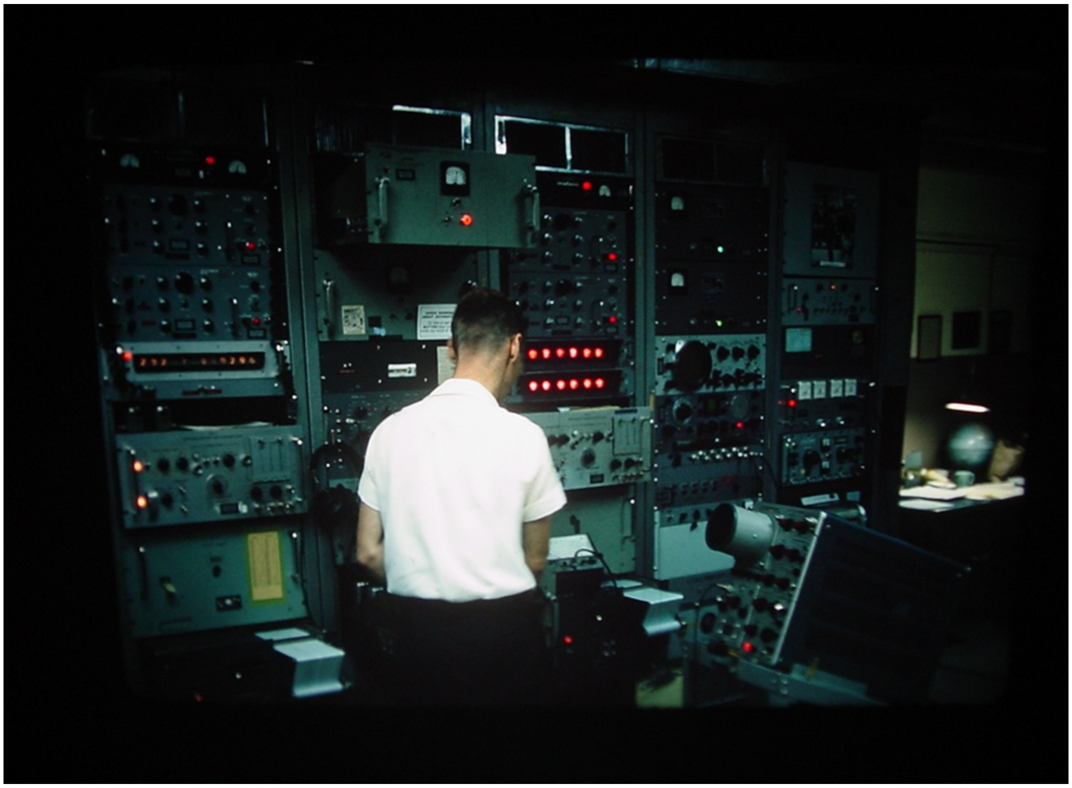

Figure 134. Gerry Welch at Permanent Tracking Station at Elmendorf Air Force Base, Alaska, 1967

Tom White's first co-op assignment was providing support for PSL's satellite tracking station at Elmendorf Air Force Base in Alaska. He related the following story: "I was going to work one morning—it was the middle of winter, and the roads were all snowy. The Air Force had given us one of the carry-alls, which is like a Suburban without windows. It was a four-wheel drive vehicle with chains. We were going a little fast out to the station, and we basically spun that dude 360 degrees and ran into a snow bank. I was alright, but I got out and was looking at the carry-all, thinking, 'What am I gonna do?' The station manager drove by, swung around, backed into the snow bank, and said, 'Get into the car!' We went to the station and called the motor pool, which sent a wrecker to tow the carry-all. There was no damage to the vehicle. The station manager didn't say much to me, but after that I did slow down a little."

The Australia station was operated by Australian personnel under the guidance of a PSL representative until 1967, when he was dismissed. The SGI Section continued to provide technical and logistical support to this station throughout the 1960s.

Until 1972, the South Africa station was staffed by RCA personnel, again under the guidance of a PSL representative. At that time, PSL assumed operation of that station, staffing it with permanent employees and co-op students.

Dan Martin was the Hawaiian station's first manager. It was installed by PSL for the Naval Astronautics Group (NAG), but operated by Mr. Martin and his crew while training Navy personnel. NAG personnel operated the station until September of 1965, when it was turned back over to PSL. The NAG had established its own tracking station nearby; both were in operation until the PSL station was moved to Wake Island at the end of 1969. Mr. Martin said that he took his family to Hawaii, where they lived for 18 months, then moved the station to the island of Oahu, staying there for four months.

PSL supported operations at the Antarctic site for slightly less than two years. This work was funded by the National Science Foundation, and the Laboratory's inability to renegotiate the contract with that agency at the end of 1966 resulted in cessation of the operation. Operations were assumed by the University of Texas at Austin and the station was reopened in 1968. After that time, the SGI Section supplied spare parts and technical information to the station.

The Seychelles experience was unique in that the lack of an airport required the use of an HU-16 seaplane for transportation to and from the island (Figure 135). A jet-capable runway was constructed in 1972.

Figure 135. HU-16 Seaplane, Seychelles Islands, 1967

When asked to relate his experience traveling to the Seychelles Islands to support the tracking station there, Bernie McCune said, "Dan Martin wanted me to go to Seychelles and relieve Nyle Groth as manager. I was working on mobile vans at that time, and enjoying the travel and extra money; however, after some persuasion, Dan convinced me to go. One fall morning in 1967, I boarded a plane in El Paso, flew to New York's John F. Kennedy Airport, and after several hours of layover, boarded the evening flight to Paris.

"I arrived in Paris early the next morning, but my flight to Africa wasn't due to leave until that evening. One of my college acquaintances had a friend in Paris, so I called him and we spent the day seeing the city. He returned me to the airport, where I boarded an Air France 707 flight. I slept until we arrived in Athens, where we refueled (but did not leave the plane). The plane took off again and I went back to sleep, waking in the middle of a thunderstorm over Egypt. All of the announcements on the airplane were made in French and various other languages, and I had a good time trying to determine what was going on. I did know that the flight was bound for Madagascar and that I needed to deplane in Nairobi, Kenya.

"I slept again and when I woke up, the sun was rising. I was pretty disoriented, but when I looked out the window and saw what I thought to be the Indian Ocean, I decided that I had slept through my Nairobi stop, which upset me greatly. Since there was not much I could do at that point, I made a plan to find someone who spoke English when we landed and ask where we were.

"We landed at a beautiful airport surrounded by a deep emerald jungle. It had just rained, and we left the plane and walked across the wet tarmac to eat breakfast in a nice airport restaurant. There I learned that we were in Entebbe, Uganda, and that the "ocean" I had seen was Lake Victoria. I realized at that point that I hadn't missed my stop at all. After breakfast, we flew on to Nairobi. As we landed, we looked down and saw giraffes, lions, and other wild animals roaming free in the game preserve surrounding the airport.

"I had about four hours before my plane for Mombassa was due to leave, so I wandered around the Nairobi airport. I noticed dozens of elderly black ladies cleaning the airport facilities. A couple of hours later, I heard a heavenly sound coming from the front of the small airport terminal. I hurried out to find several busloads of these cleaning ladies singing and harmonizing free style, with very complex rhythms and beautiful tunes. The sound was unbelievable—a busload would begin one part and another would blend and counter with the first in some amazing improvised sounds. Unfortunately, they soon drove away, their music trailing behind until I could no longer hear it. Soon after, I boarded a twin-engine propeller plane that flew at a low altitude so that I was able to watch the changing African plains. When we arrived at the Mombassa airport late that afternoon, I checked in with the pilot of the HU-16 that would take me to Mahe, Seychelles, in a couple of days. This plane flew to the island once/week to transport U.S. passengers and data tapes. After an interesting few days in Mombassa (a port town in Kenya on the Indian Ocean), I boarded the HU-16 on the appointed day for a routine wheeled departure from the Mombassa runway."

MOBILE TRACKING STATIONS

The mission of the mobile tracking stations was to pinpoint various remote locations, first within the United States and, beginning in 1964, worldwide. Over 100 sites were surveyed during the 1960s. Using satellite orbits provided by the permanent stations, computers could determine the unknown position of the mobile station with the same accuracy as that provided by the permanent site. The mobile stations were normally on site for a period of four to eight weeks to ensure that sufficient good data was available for reliable location computation. In the beginning, these surveys were accurate to about one mile; however, their accuracy improved considerably over time as technology advanced.

Requests to gather data from specific areas were generated by many U.S. Government agencies, as well as foreign governments. The majority of the sites had conducted previous surveys using cameras, the SECOR system, or astronomic observations.

A few of these sites were so remote that housing, dining, communications, and power-generating facilities were imported along with the tracking van. This, of course, required extra operating personnel. In most cases, however, the mobile equipment was configured in locations where commercial power and either military or commercial communications were available. In these cases, personnel lived on military bases or in the local community.

PSL brought mobile tracking stations to every continent and to virtually every country in the world (Figure 136). The foreign countries or provinces involved included Antarctica, Argentina, Australia, Brazil, Canada, Chad, Curacao, Chile, Denmark, Ecuador, England, Ethiopia, Germany, Greece, Greenland, Iceland, Iran, Japan, Mexico, New Zealand, Norway, Pakistan, Portugal, Senegal, Sicily, Spain, and Surinam. The locations of well over 100 islands were verified by these tracking stations; in fact, one island in the north Atlantic was found to be about 50 miles away from its location on the charts.

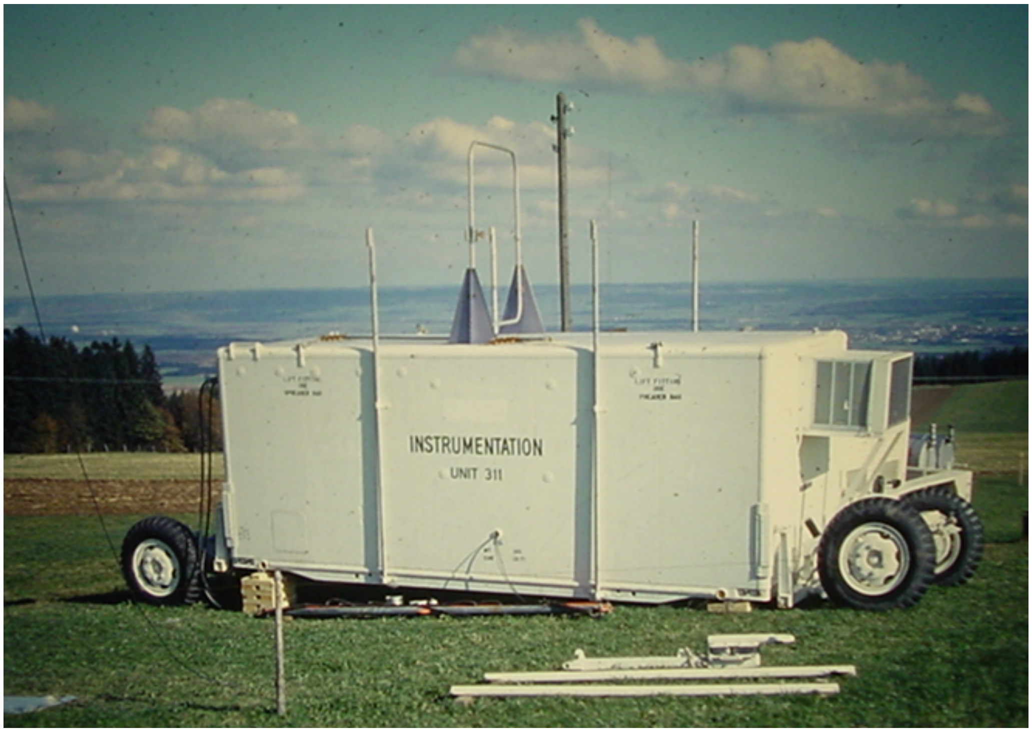

Figure 136. Mobile Satellite Tracking Van, Germany

The mobile stations participated in the World Geodetic Survey, a worldwide, international effort begun in the late 1960s.

> Tom White supported PSL's mobile tracking station in Oslo, Norway, in the summer of 1967. He stayed in what he called an unused Norwegian national reserve camp, which was a 30-minute ferry ride or an hour car ride away from Oslo. Ken Lane was the station manager and Bob Raby was the station technician. Mr. White said that one evening, they, along with Mrs. Lane, came to Oslo to eat at a hotel restaurant that they frequented. "We all sat down and they brought out this covered tray, which they set down on the table. They uncovered the tray and there was this huge fish with the head still on. I think it was Ken Lane's wife that gasped—they immediately took that fish back into the kitchen, cut the head off, and brought it back to us."

SGI Instrument Development

The original set of equipment that was installed on the top floor of the library in the early 1960s occupied 6-7 racks. By the end of the decade, a number of improvements had been made and more modern technology integrated into the tracking stations, reducing the number of equipment racks to 3-4.

There were two types of Doppler tracking equipment used in the 1960s. One, which was called a tracking filter station, used a video phase lock loop. The other, called Naval Correlation and Detection (NACODE), used a modified commercial receiver with a phase lock loop added. Several of the tracking filter type stations were built at PSL, based on designs provided by Johns Hopkins University. The original versions of both types of stations produced only Doppler data. The first tracking stations contained a large number of vacuum tubes, along with transistorized circuits, making constant maintenance necessary. Temperature and voltage control were very critical.

PSL was directly involved in modernizing the tracking stations throughout the program's life span (which was greater than 30 years). Some of PSL's engineering efforts in the 1960s included specifying and integrating more current data digitizing equipment and designing, building, and installing battery backup systems in all of the stations. A Satellite Time Recovery Unit was improved, specified to an outside vendor, and installed in all of the stations. The early, cumbersome large ground antenna arrays that required manual pointing were replaced by PSL-designed compact, omni-directional, drooping dipole antennas. Four separate antennas cut to each of the characteristic frequencies and mounted on four separate poles (no pointing required) were all that the new design required. Old tube-type preamplifiers were replaced by PSL-specified solid-state pre-amps. Bernie McCune said, "There was an open 300-volt bus in the tube-type Resdel pre-amps that 'bit' me several times during my early learning experience repairing them. I found it best to keep away from those exposed, high-voltage terminals and bare wires." In general, tube type equipment was completely replaced by transistorized equipment by the end of the decade.

Additional SGI Section accomplishments in the early 1960s included assisting in the design fabrication, installation, and checkout of Injection Stations for NAG, assembling the TRANSIT Doppler Digitizer System, building Reference Injection Units for tracking filter stations, designing and building test equipment for calculating and plotting second differences of Doppler data points, and building frequency generators for coherent pairs of 150/400 MHz and 162/324 MHz.

Work completed by the Section from 1965 to the end of the decade included modifying ABACUS digitizers for 10 microsecond resolution of satellite time, designing and building Satellite Identifiers, assembling NACODE N-3 stations for mobile use, building and installing refraction monitors for mobile vans, building Visual Displays using ICs, and developing fixed tuned receivers for mobile vans. Another major task (completed in 1971) was to modify all NACODE stations for automatic operation and Continuous Count Integrated Doppler (CCID) data format. This included

1) Design and fabrication the of Automatic Control Unit (ACU)
2) CCID modification made to ABACUS digitizers for new Doppler data format and modification of digitizers for automatic operation
3) Modification of phase lock receivers for automatic operation

Overall, the largest SGI Section project during the early 1960s involved the building of semi-portable tracking stations mounted in wheeled shelters that could be shipped worldwide to determine geodetic positions. All of these stations featured the basic tracking filter design, with solid-state equipment added over time.

Every SGI Section staff member acted as a station manager and operated a tracking station at some point in his career. This included the design engineers that returned to Las Cruces and used the distinctive ideas that they gained in the field to improve existing equipment. The fact that all PSL engineers in general possessed practical, hands-on experience in field operations provided them with great insight into designing and building very useable and often superior field equipment. Improvements to commercial equipment were common in PSL and SGI field operations.

The following list summarizes some of the major design and fabrication projects managed by the SGI Section in the late 1950s and 1960s.

1958	First Doppler tracking station assembled at PSL
1959	PSL personnel helped to assemble and modify first two mobile vans at APL
1961-63	Helped design, fabricate, install, and check out NAG injection stations
1961	SGI assembled the Transit Doppler Digitizer System (TDDS)
1961	Built reference injection unit for tracking filter system
1962	Built Vans V1 and V-2 at PSL, including assembly of 3C digitizers
1962	Designed and fabricated test equipment for calculating and plotting second differences of Doppler data points
1963	Built mobile Vans 307, 311, 312, and 314 at PSL
1963	Constructed Satellite Time Recovery Systems (STRUs) for mobile vans at PSL
1963	Fabricated frequency generators for coherent pairs of 150/400 MHz and 162/324 MHz
1964	Built quarter-wavelength drooping radial-stub antennas for all stations
1965	Modified ABACUS digitizers for 10-microsecond resolution of satellite time
1965	Fabricated Coherent Clocks for all stations
1965	Built Satellite Identifiers for all stations
1965	Assembled NACODE Station N-3 for mobile use
1966	Modified ABACUS digitizers, dual-Doppler phase-lock-loop receivers, and synthesizers for DODGE tracking mission
1969	Designed and fabricated LORAN Receiver

Special Operations

The widely dispersed tracking station network proved useful for a variety of projects and studies other than navigation and geodesics. Some of these that PSL supported in the 1960s are described in the following paragraphs.

SMTP

In October of 1969, PSL was notified that a total of 17 stations—nine permanent and eight mobile—would be necessary for an effort called the Special Mission Tracking Project (SMTP), that was supposed to begin early in 1970. Several new domestic and foreign locations were involved, requiring a great deal of concentrated effort on the SGI Section's part to rearrange equipment in order to configure the necessary number of stations. Van 312, recalled from Easter Island, was the first station to be equipped with the new PSL-built, fixed-tuned receivers. It was then shipped to Kabul for SMTP (SMTP support will be detailed in Volume 2 of PSL's history).

APL Ionospheric Refraction Study

Significant new ionosphere density data were obtained by employing the stations' capability to measure the degree of refraction, or bending, of the satellite radio signal as it passed through the layers of the ionosphere and the troposphere. In 1965, APL initiated a study, the purpose of which was to determine the daily and seasonal variations of the ionospheric density at several sites worldwide. To accomplish this, the output of the Refraction Correction Unit in each of several selected stations was recorded and furnished to APL for each satellite pass. The study, which covered a period of approximately three years, ended in late 1968.

ARL Third Order Refraction Study

In 1965 and 1966, PSL assisted the Applied Research Laboratory (ARL) of the University of Texas/Austin (who was also operating a TRANET station) in an effort to obtain third-order ionospheric refraction data. PSL's role consisted of modifying and loaning equipment to ARL so that a separate tracking station could be assembled. This station was then alternated among the sites in the Philippines, Brazil, and Alaska for two years.

DODGE Project

In July of 1967, APL placed an experiment aboard the Department of Defense Gravitational Experiment (DODGE) satellite to test a means of passive stabilization using retractable booms (Figure 137). PSL modified three of its TRANET stations to receive a special 240-MHz signal from the satellite and incorporated APL-provided time recovery equipment. The satellite's orbit could then be determined using Doppler and timing information separately, so that these two methodologies could be compared. The tracking continued occasionally until February of 1970. The time and Doppler tracking, which was a low-priority experiment, was performed only when the satellite was not in use for other experiments.

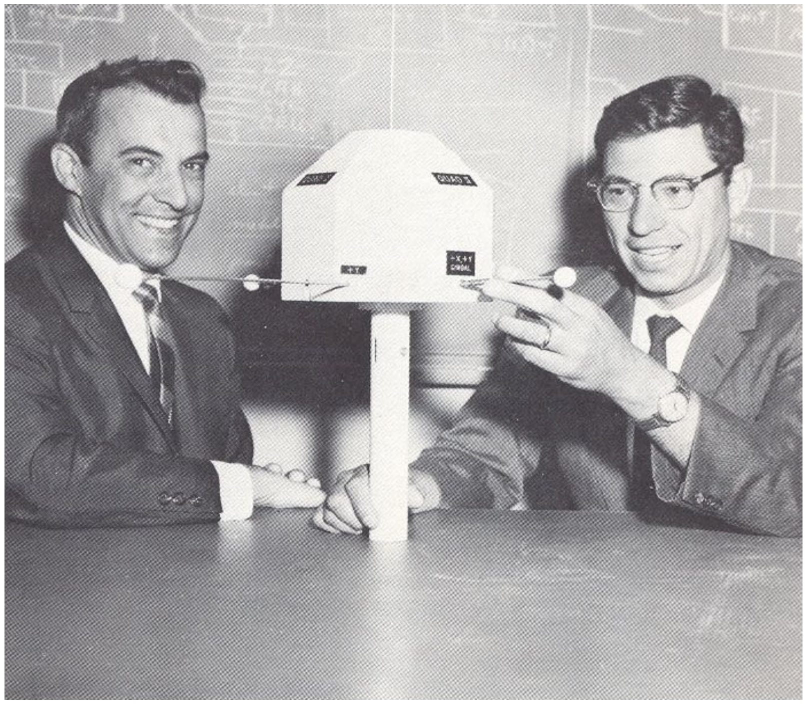

Figure 137. DODGE Satellite

NAVAL ASTRONAUTICS GROUP

Operation of the Navy's navigation satellites was to be performed by an organization called the NAG, which would institute its own network of tracking stations and injection stations. The on-going function of the civilian TRANET stations, including those operated by PSL, would be to furnish data for research to provide increased accuracy of navigation.

The NAG's four tracking stations were established in Maine, Minnesota, California, and Hawaii. From 1961–1965, PSL was heavily involved in locating, assembling, and installing these stations and training Navy personnel to operate and maintain them. Similar support was provided for two injection stations—one in California and one in Minnesota. The NAG assumed complete control of these stations in early 1965.

NASA GEOS SUPPORT

PSL took part in a NASA experiment involving two satellites, GEOS-A and GEOS-B, the purpose of which was to compare various tracking systems, including Doppler and radar (Figure 138 shows the GEOS-C, which was a later version). Data from the TRANET stations were used in this comparison; in addition, for a few months in 1968, SGI Section staff transported a mobile van to PMR and installed it next to a C-band radar. Section personnel also transported a NACODE station to San Nicolas Island off of the California coast.

Figure 138. GEOS-C Satellite

NASA REPORT

In 1967, NASA contacted PSL's SGI Section regarding the preparation of a report or manual describing the Doppler geodetic system. This manual was to provide the information necessary for any University-based laboratory to assemble and operate a Doppler tracking station. The completed document, entitled "Doppler Geodetic System," was delivered to NASA in October of 1968. After NASA circulated the report worldwide, PSL was contacted by several other organizations for further information about Doppler tracking.

NAVAL OBSERVATORY STATION

The SGI Section operated a special type of tracking station located at the Naval Observatory in Washington, D.C. from 1963-1965. This was the master reference station for the TRANET and NAG tracking networks and therefore was synchronized with the Observatory's master clock (a tracking station at the Observatory eliminated one of the variables in the reduction of timing data for all stations). The master reference station was staffed by one regular employee and two co-op students. Operations ended in late 1965, when the tracking station at APL in Silver Spring assumed the reference timing function.

NRL TIMATION SATELLITE

In 1969, the Naval Research Laboratory placed a "Timation Satellite" in orbit (a Timation Satellite is a device that transports several clocks operating at different frequencies). These clock signals were transmitted to the stations via a telemetry link and, after reduction, could be used to determine the satellite's position using interferometer techniques. The satellite also transmitted two special frequencies that were used by TRANET to confirm the satellite's position. Several TRANET stations were modified to track these two frequencies, which continued well into the 1970s.

PROJECT ANNA

Project ANNA was an inter-service program that included the Army, Navy, NASA, and Air Force. The purpose of the project was to combine all systems used by these various agencies for their satellite geodesy studies into one satellite. The experiments included Doppler beacons at 162 and 324 MHz, a system of flashing lights, and a SECOR transponder. PSL's TRANET stations tracked the Doppler beacons in the usual manner, and operated NAVOCEANO's mobile camera vans in Brazil, American Samoa, Japan, and the Philippines to photograph the flashing lights. Very few plates were made of the lights because of adverse weather conditions, which resulted in suspension of the effort after a few months. The ANNA satellite (Figure 139), which was tested at PSL's antenna range, was launched in late 1962.

Figure 139. ANNA Satellite

> Cecil Post said that prior to the launch of the ANNA satellite, a model of this 3-4 foot diameter ball was received at PSL for antenna testing (the antenna is the metal spiral wrapped around the ball in Figure 122). Mr. Post, the Project Engineer in charge of the antenna testing, noticed that a value of $85,000 was written on the shipping papers that were enclosed with the model. He asked Dr. Gardiner if the item could be insured in the event of any mishap. Dr. Gardiner said, "No, we cannot insure government property—our insurance is the people we hire to do the job." Mr. Post said, "That afternoon, they were mounting the satellite when one of the securing ropes broke. The satellite swung out and was going over the side. One of my student helpers desperately held on to his rope and was almost dragged over the side to a very serious (if not fatal) fall. I called out, 'Let it go!' We picked up the unit (which was quite damaged), and I went in to report [the incident]. When I sheepishly told Dr. Gardiner what had happened, he asked if we could fix it [well] enough to do the antenna measurements. When I told him, 'Yes,' his only comment was, 'Well, get to it Cecil.'"

Alaskan Auroral Study

PSL operated a satellite command transmitter located at Ft. Richardson, Alaska, from September of 1963 to November of 1965. Commands were sent to certain satellites in connection with an APL experiment to investigate the Aurora Borealis at night, as well as the daytime magnetic disturbances at the 1,100 km level.

Shipboard Operations

A mobile tracking station was installed aboard the U.S.S. Compass Island for use in a series of sea tests, the purpose of which was to demonstrate the feasibility of using satellites for marine navigation. The positions obtained using a satellite were compared with those obtained using the ship's SINS and LORAN. The ship sailed out of New York in December of 1960 for a two-week cruise and for one week in September of 1961. A second ship, the U.S.S. Observation Island, was used for similar tests during the summer and fall of 1961.

Southeastern United States Survey

The purpose of the Southeastern United States Survey was to compare the three basic satellite surveying methods: the SECOR system, cameras, and the Navy Doppler method. Three of PSL's vans were transported to APL for modifications, after which they were positioned at three sites in the southeastern United States—Homestead AFB, Florida; Hunter AFB, Georgia; and Semmes, Alabama. The tracking exercise continued for approximately two months. A comparison of data from the various tracking systems revealed that the Doppler method was the most accurate and reliable.

Satellite Telemetry

The TRANET stations in Las Cruces, Brazil, and Alaska were used to record telemetry data from various satellites during the majority of the 1960s (the telemetry tapes were collected by APL).

Miscellany

Earl Downing, who joined the SGI Section in 1959 as a student, said that "the U.S. was getting ready to launch the Transit series of satellites, and we helped build up the equipment for the tracking stations. A group of us went to Argentia, Newfoundland, for the first launch in 1960. The satellite failed to orbit. Hugh Gardner was in charge of that station. Bob Ecklund went up. It was about a year before they launched another one, but I stayed there about six months, maintaining the station. Jerry Holmes was there too. I came back here and worked part time in SGI.

"Then they put a station at Seattle, Washington, and I went up there for a summer. Ecklund and Fairchild were there. That was a very nice place—[I] enjoyed it."

Cal Buerkle added, "In 1961 in the Philippines at Clark AFB, they had a party and they went around with a truck with a loudspeaker. When they went by our house, they said, 'All you moon men are to be at the party!' It was a direct order. So even today—23 years later—we're still known as the 'moon men.' [As a] matter of fact, the tracking station has a sign that says 'Moon Locker' on the door."

When asked if he had ever encountered any travel problems, Ed Schmidt responded, "Not many. I guess the worst problem I had was up in Thule on a short trip. I was supposed to fly on an Air Force plane from Thule to Nord, Greenland, which is across the ice cap to the northeast of Thule. The Air Force sent up a C-130 to transport me up there. A Danish policeman was the only other passenger. We got on the plane about noon. The only cargo on the plane was mail and a few supplies for the people at Nord. We took off, and I noticed [that] we were headed northwest, not northeast. I figured they must have decided to fly along the coast rather than over the ice cap. After a couple of hours, I noticed [that] we were circling and one engine had been shut down. [It] got colder and colder in that cargo bay, so the Dane and I got down couple of sleeping bags and I went to sleep. Four hours later, I woke up, and could see lights on the ground. I asked the Dane if that was Nord. He said, 'No.' I said, `Then where are we?' He said, `I don't know, perhaps somewhere in Canada.' Sure enough, we landed at Alert, Canada, which is the farthest north outpost in Canada. It turns out that we had gotten lost, and we were headed northwest just like I thought, straight for Siberia without enough fuel to make it. Luckily, in the twilight, the crew managed to see a contrail from a Dutch airliner on a polar flight, raised him on the radio, and got a fix on our position. Then they managed to navigate by the stars into Alert. This plane had two inertial navigation sets on it, but for some reason or another they still got lost. The crew of course said it was a mechanical failure—whether it was that or human error, I couldn't say."

Mr. Schmidt added, "When we first set up a station, we have to determine the coordinates of that site by tracking satellite passes. When I went to Eniwetok, I obtained the coordinates from the Navy people there and sent them in to APL. In about a week they got back to me and said to re-check those coordinates—they appeared to be off by about half a mile. When I went back to the Navy people, it became quite obvious that they had given me the wrong coordinates on purpose! [I] don't know whether it was meant as a joke, or they were seeing if our system could detect it. We proved that it could."

PSL in Space

Although PSL's involvement in U.S. space exploration programs began long before any craft were placed into orbit, this section is confined to the era of the man-made satellites, i.e., the class of hardware referred to as, "spacecraft." The V-2 rocket payloads supported by PSL in the 1940s probed the upper atmosphere for a few minutes and fell back to earth; therefore, they were not designated spacecraft. That term came into widespread usage in the late 1950s in reference to orbiters such as the Vanguard and Sputnik. In the 1960s, the term referred to manned and unmanned orbiters and deep-space probes.

The SGI Section's tracking effort, chronicled in the previous section, was initially devoted to Transit satellites (which was a Navy program). The Section soon began to support geodetic satellites used to initiate the determination of the earth's shape and other parameters. As noted in the previous section, this group supported worldwide operations into and beyond the 1970s. A technical history of this section is provided in the PSL document, History of the Satellite Ground Instrumentation Section, 1958 to 1993.

The PSL sections that were involved in supporting civilian scientific spacecraft missions during the 1960s were MEI, MPI, Electromagnetics, Applied Analysis, and Data Reduction. As mentioned Chapter 4, NASA was founded in the late 1950s after the Soviet Union and the U.S. had placed satellites into orbit. Many of PSL's advocates in more established government agencies (primarily NRL) transferred to high-level positions in NASA, since that agency was staffing up. These individuals continued to request the same types of support provided by PSL at WSPG and Cape Canaveral during NRL's Vanguard project (this relationship endured throughout the 1960s). The MEI Section's field groups in Cape Canaveral, Florida and Vandenberg AFB, California remained in place during this time and into the 1970s. Similarly, the Electromagnetics Section's worldwide Minitrack support contract (which continued into the 1970s) transferred to NASA.

Many NASA spacecraft were launched in the 1960s from both the Florida and the California beaches. PSL's involvement consisted of (1) operating and upgrading on-site FM/FM telemetry, PWM/FM telemetry, and Doppler receiving stations, (2) data reduction and analysis at PSL and at GSFC, (3) designing and fabricating specialized antennas for flight and ground use, and (4) designing and fabricating electronic subsystems for satellites.

Each military missile range on which NASA launch operations were based contained its own network of telemetry stations to provide NASA with in-flight coverage. However, NASA wanted in-house, project-dedicated telemetry systems that were always available during the weeks or months required for pre-flight testing of each spacecraft; these were the telemetry stations operated by PSL. PSL's presence was therefore tolerated by the Range telemetry personnel at RCA (Cape Canaveral) and Federal Electric Company (Vandenberg AFB) and by Army Civil Service personnel at WSMR, as long as it did not usurp the need for *their* launch services.

Spacecraft flights involved a minimum of two (but usually more) telemetry links. At least one link was dedicated to monitoring the spacecraft and/or transmitting scientific data, and at least one to monitoring launch vehicle performance during the launch phase. The NASA/PSL stations, at NASA's direction, would record data from as many of these links as possible during the actual launch phase with the available equipment. On more than one occasion, PSL obtained the only usable data from the payload and/or from the vehicle. For example, after a GEOS launch from Cape Canaveral in November of 1965, Mr. Rosenberg of NASA said to Rick Ricketts, "You guys saved my life by getting good data from shipboard and the San Marco stations." Ted Arellano and co-op student Michael Hankamer were the shipboard operators for this mission.

A Brief History of Cape Canaveral

Following World War II, the Joint Chiefs of Staff realized the necessity for the U.S. to develop a long-range missile capability, and a committee was appointed to select the most suitable test location. Cape Canaveral was chosen because of two features that existed there: a base of operations (the inactive Banana River Naval Air Station) and the potential for over-water flights of almost unlimited length to the southeast. Another advantage was the number of conveniently located islands (primarily the Bahamas and the West Indies) that could serve as missile tracking station sites.

In 1947, the U.S. Air Force was directed to develop this Range, and construction of launch pads and instrumentation sites began in 1949. The first missile was launched from the Cape on July 24, 1950; it was one of the Bumper project rockets mentioned in an earlier chapter—a German V-2 with an Army Wac Corporal second stage. The old naval air station was renamed Patrick Air Force Base at approximately this same time, and the entire complex (including the launch pads 15 miles north of the base) was called the Air Force Missile Test Center (AFMTC). In 1951, the Air Force began test firings of its first operational missile, the Matador, from the AFMTC.

In the late 1950s, the name Atlantic Missile Range (AMR) was given to the 5,000-mile-long facility that extended all the way to Ascension Island (a British Crown Colony in the South Atlantic). By 1959, tracking stations had been established on the islands of Grand Bahama, Eleuthera, San Salvador, Mayaguana, Grand Turk, the Dominican Republic, Puerto Rico, Antigua, St. Lucia, Fernando de Noronha, and Ascension. In addition, a number of ocean-going vessels were modified to serve as floating tracking stations and special aircraft equipped to gather mid-course and re-entry data.

The AMR soon became a multi-service facility, having built additional launch pads for the (Army's) Redstone and Pershing, (Navy's) Polaris, and (Air Force's) Saturn, Titan, Atlas, Atlas/ Centaur, minuteman, Thor, Jupiter, and Blue Scout missiles. The Range was subsequently extended to the Indian Ocean (a distance of more than 10,000 miles) and renamed the Air Force Eastern Test Range (ETR).

> The Rose Knot Victor (RKV) was one of two tracking ships (the other was the Coastal Sentry) operated by the U.S. Air Force. PSL co-op Mike Hankamer and Ted Arellano were assigned to monitor a GEOS satellite launch from a ship in the south Atlantic (the GEOS was launched on a Delta rocket from Cape Canaveral, Florida). The two PSL employees flew from Lima, Peru to Rio de Janeiro, and on to Recife, Brazil. They took a taxi to the dock and saw the RKV (an Apollo tracking ship), anchored offshore. A small boat was required to get to this ship. Mr. Arellano said, "A member of the RKV crew was at the dock—then we inquired about boarding "the ship. The crewmember stated that the RKV had just returned from an Apollo tracking mission and that we would have to see the 'SOM,' as well as the 'SIM,' who could be found at the 'HOS.' We said, '*What*?' He explained that the SOM was the Ship's Operations Manager, the SIM was the Ship's Instrumentation Manager, and the HOS was the House on Stilts. He said that the House on Stilts was an 'entertainment center' comprised of six floors, and that the class and beauty of the hostesses increased along with the floor number.
>
> "We took a taxi to downtown Recife, received instructions and authorization, and proceeded to bring our instrumentation aboard the RKV. A few days later, the ship departed and dropped anchor off the coast of Brazil in the south Atlantic. The launch took place seven days later, and two days after that we returned to Cape Canaveral. We discovered years later that the Indian Ocean Tracking Station (Seychelles) and the RKV were the only two worldwide stations that had good data, which meant a successful mission had been accomplished."

In 1954, Pan American World Airways (Pan Am) received a contract to maintain and operate the AFMTC under Air Force supervision. Pan Am then subcontracted with RCA for the technical instrumentation and data reduction work for the entire Range. Both of these contractors remained in place through the mid-1960s, after which Trans World Airlines became the prime maintenance contractor and Federal Electric Corporation assumed the instrumentation and data acquisition services.

The NASA Space Program

The AMR became the United States' port for space exploration with the launch of the Jupiter and Vanguard satellites in early 1958 (see Chapter 4). NASA was formed that same year and established the GSFC in Maryland, just north of Washington, D.C. The GSFC was commissioned to plan and coordinate NASA's unmanned spacecraft launches. This resulted in an AMR field group called the Goddard Launch Operations Group (GLO), and Robert H. Gray was named as its Director. The GLO's core personnel were long-time PSL supporters from the NRL/Vanguard project.

In the early 1960s, the GLO was assigned an additional responsibility of handling certain launches from Vandenberg Air Force Base on the California coast (PMR). The GLO installed a branch group there known as the Pacific Launch Operations Office (PLOD), which was headed by Joe Schwartz. The PLOD requested that PSL provide essentially the same telemetry support at PMR that it provided at AMR.

In 1965, NASA made the decision to make its Cape Canaveral facility a separate entity, and renamed it the Kennedy Space Center (KSC). This meant that KSC assumed control of the staff and PSL's contract. Dr. Kurt Rebus (one of the imported German scientists from the V-2 days) was named Director. Bob Gray became Assistant Director of Unmanned Launch Operations (ULO); his duties and those of his staff remained virtually unchanged.

In 1967, the KSC was listed as employing approximately 24,000 Civil Service and contractor personnel.

NASA would require larger launch facilities than those installed by the Air Force at ETR in order to meet the needs of the Apollo program. This resulted in the purchase of 88,000 acres of land on Merritt Island (across the Banana River from the Air Force launch area) in 1962. In 1963, construction began on NASA's Merritt Island Launch Area (MILA); major components of the new facility were completed in 1965. Included were a complex large enough to assemble and launch the 364-ft. Saturn V Apollo vehicle; a multi-mission, four-story Launch Control Center; a new KSC headquarters building; and many smaller structures. A mobile, self-propelled launch platform was a unique feature of this complex; it carried the completely assembled Apollo vehicle (in an upright position) from the assembly building to the launch pad a few miles away.

Several more NASA centers originated across the U.S., some of which played important roles in the area of space exploration (this continues today). The George C. Marshall Space Flight Center in Huntsville, Alabama oversees research and development of launch vehicles. The Manned Spaceflight Center (now called the Johnson Space Center) in Houston, Texas performs research and development (R&D) of manned spacecraft and life support systems, trains astronauts, and conducts manned flight operations in space. Unmanned lunar and interplanetary spacecraft are developed and managed by the Jet Propulsion Laboratories (JPL) in Pasadena, California. In 1961, President Kennedy mandated that the U.S. put a man on the moon by the end of the decade. This resulted in Project Apollo with its great achievements; Neil Armstrong stepped onto the moon's surface in July of 1969.

Vehicles

The various rockets and missiles used as NASA launch vehicles for spacecraft in the 1960s are listed in Appendix B. Some were modified military hardware, and some were designed from inception as spacecraft boosters.

Spacecraft

Appendix D lists the spacecraft projects supported in varying degrees by the PSL-operated ground stations at the AMR and PMR. Many of these spacecraft were equipped with antennas designed and constructed by PSL's Electromagnetics Section.

MEI Section Field Operations

MEI Section personnel worked alongside the GLO at both the AMR and PMR. GLO's primary responsibility at both ranges was to conduct pre-flight tests on spacecraft, for which a special building, or hangar, was used. The PSL-operated telemetry stations, the sole purpose of which was to support pre-flight testing, were located in these hangars. More complex satellites could require dozens of formal tests; in some cases, if a satellite developed problems, hundreds of unscheduled tests would be conducted.

A NASA engineer at each site was responsible for coordination of telemetry and Doppler coverage (Arthur J. ("Skip") Mackey at AMR and Gene Schlimmer at PMR). Since each man's office was located in the same building as the ground stations, they were available on an hour-by-hour basis. They participated in countdowns, scheduling of tests, trouble-shooting, and even occasionally filled in when one of the PSL operators couldn't be there. PSL personnel worked so closely with these men that often visiting people from other organizations would assume that they were NASA employees. Each PSL/MEI field group was headed by its own resident supervisor, who reported to the NASA engineer and to the MEI Section Chief on campus.

In 1960, the official scope of work for PSL's contract task was extremely brief: "Provide technical instrumentation support for the NASA Delta vehicle at the AMR in angle and Doppler tracking, pulse width telemetry, and digitizing fields." The PMR support was added in 1962, but otherwise this scope remained virtually unchanged throughout the decade. In reality, PSL's efforts ranged from the very exciting and challenging design of specialized equipment to the more mundane task of running playbacks of magnetic data tapes.

Atlantic Missile Range

As mentioned in Chapter 4, PSL's Florida operations began in 1956. Personnel in 1960 included Tom Noda, Joe Mattock, Jerry Cooper, Ray Young, Doug Williams, John Sullivan, and Robert Becker. Permanent staff assigned later in the decade included Ted Arellano, Frank Belcourt, Michael Hottey, Don Brown, David Campbell, Phillip Freeman, Arthur Fuller, Thaddeus

Grimshaw, David Guyse, Kenneth Hardison, Warren Harkey, Donald Helfrich, Robert Hughes, Valentin Orona, Victor Parkerson, P.R. Reid, James Willis, and Frank Wong.

Co-op students who worked at either the AMR or PMR in the 1960s included Richard Aldridge, R. Barrett, D.E. Bratton, H. Brown, Robert Brown, Richard Bruner, Wallace Byrd, Ray Chowning III, Russell De Haven, Lewis Downey, David Fitzpatrick, James Gallivan, Michael Hankamer, Douglas Jameson, Robert Jensen, Richard John, Gary Lindsey, Charles Morehouse, Jack Satterfield, Robert Schmiedeskamp, Harold Shaw, Charles Townsend, and Billy Wood.

The, "angle tracking" mentioned above in the scope of effort referred to PSL's operation and maintenance of a Minitrack station secluded in the jungle on Cape Canaveral. It was called, "Satellite Tracking Station" (STS), and three PSL technicians were permanently assigned to it. It is believed that this is the only station in the worldwide Minitrack network operated by PSL on a full-time basis. Joe Mattock was in charge of the station for several years, and was supported by Jim Davis, Arthur Fuller, John Sullivan, Ernest Jimenez, and others (a co-op student usually worked there as well).

The conversion of the Minitrack network to the new 136 Mc frequency (which included the STS) was performed by MEI Section personnel in 1961-62. Appendix E lists, in chronological order, 1960s events significant to PSL's work at AMR as logged by Raymond Bumgarner.

Jerry Cooper made the following comments about the early Cape Canaveral days: "I drove a PSL car to Florida with [Valentin] Orona—soon after the first contingent went down—[I] don't recall the year.[42] We stayed in Rick's house. We ran cables, put up antennas, etc. NRL had built the "T-Pad" for parking telemetry vans—a wooden platform on poles [with] two tri-helix antennas on it that PSL had built. The T-pad was less than a mile from the launch pad, but NRL decided they needed to run a big coaxial cable to make certain the T-pad could get a good telemetry signal from the blockhouse [for pre-launch checks of rocket and payload]. This cable had to be buried, but for some reason we couldn't get the contractor people to dig the ditch—I don't recall the reason. But the story has it that Rick…persuaded [the contractor] to leave a trenching machine at the site where we could use it over a weekend—then Rick himself got out there and operated that trencher, dug the ditch, and we got the cable in by the deadline. The NRL people there were Dan Mazur, Al Jones, Francis X. Downey, Skip Mackey, Joe Purcell, Bob Muller, Bob Pickard, Mason Comer, and Don Sheppard.

"I worked under Purcell in the PWM/FM van. He taught me a lot about electronics—[he was] a very capable man. He moved on to a better job, after which Ray Young and I operated the van for a long time. I took my family to Florida when Rhonda was about three years old, for a three- to six-month stay; [I] stayed five years. I took courses at Brevard Engineering College in Melbourne, trying to get a degree."

Concerning the latter 1960s, Mr. Cooper said, "We were very, very busy—[we] were supporting two Delta launch pads, two Atlas/Centaur launch pads, and later a Titan pad. We had a huge

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42 According to Raymond Bumgarner, this occurred in September of 1956.

ground station in Hangar AE. I did a lot of design work on high-speed data transmission circuits, and got ahold of a stored-program decom that somebody at GSFC had clobbered—a million-dollar item. [Jim] Willis and I spent months…getting it…to work."

Mr. Willis added, "I was…at the Cape from 1963 to 1973. My first launch was Atlas/Centaur II. I started as a station equipment operator, [and] later got into design work as PCM came in to replace PAM/FM. Then we computerized the station; kept bringing in new hardware. We built some, bought some, and converted some old surplus gear. Near the end of my stay, we got into some Titan/Centaur launches. We were involved in moon shots, Pioneer, unmanned spacecraft, commo and weather satellites, Ranger and Surveyor. There was a very intense effort to get a man on the moon and to catch up with the Russians. [There was a] lot of media coverage. A lot of booster failures caused very intense research to find and fix the problem."

Warren Harkey said, "In about 1961, Raymo [Bumgarner] sent me to the Cape and I spent about two years…there. That was the start of the Atlas/Centaur program under NASA. I worked in a telemetry ground station—FM/FM and PDM/FM. Those were exciting times—the manned shots were just being talked about. I made a number of short trips from there—[I] spent one summer at GSFC helping [to] integrate a satellite, and went to Wallops to support launches.

"[In] about 1969, HERO came along and we spent three or four years on that project—maybe longer—at White Sands and [on] campus."

Raymond Bumgarner related an incident that occurred when he and Jim Davis were driving a PSL car from Florida to New Mexico and came upon an overturned truck near Ft. Stockton in west Texas. He continued, "A little further on, there was a pickup on its top. We decided to stop to see if there was anyone in it, [and] when Jim and I got out of the car, we discovered that the pavement was covered with a solid sheet of black ice, invisible to a driver. And we had been roaring along at 60 miles per hour on that ice. We were the lucky ones! Fortunately, the road was quite straight and level on that stretch, and the icy conditions lasted only a few more miles. There was no one in the…pickup."

Pacific Missile Range

NASA began launching at PMR because it is the only mainland launch site in the U.S. where the depleted booster from a spacecraft placed in polar orbit can land in the ocean (polar orbits are necessary for many spacecraft, including weather and intelligence satellites, where detection of 100% of the earth's surface is required). Therefore, PSL's support at the PMR was primarily for launching of satellites such as the TIROS, NIMBUS, ERTS, and LANDSAT.

Also involved were a sizeable number of foreign satellites sponsored by the European Space Research Organization (ESRO), of which the United States was a member. Included were the French FR-x series, the Canadian Alouette series, the British UK-x group, and some German satellites.

PSL staff members originally assigned to PMR included Frank Wong, Joe Otero, Fred Lemon, and Valentin Orona. Elsworth Barnes, Douglas Bossert, Ron Brush, Jerry Cooper, Donna Davis, James Davis, Mitchel Farr, Arthur Gilcrease, Richard Jakl, Carl Jensen, John Masterson, Joe Matlock, M. M. Murray, Tom Noda, Robert Olson, Paul Pradzinski, Richard Rahto, Alfred Snider, Charles Townsend, and James Willis were assigned later. A list of co-op students who worked at AMR and at PMR is provided in the Atlantic Missile Range section above.

The MEI Section began its efforts at PMR in the spring of 1962, with personnel from the other field groups traveling to PMR to install FM/FM and PCM/FM telemetry stations and a Doppler station. The majority of this work was performed by Tom Noda, Joe Matlock, and Don Brown from the Cape; Fred Lemon, Ernest Jimenez, and Charles Townsend from WSMR; and Joe Otero and Rudy Guzman from Wallops Island. The work was hazardous, involving installing and stringing cables to antennas at the top of a 450-foot steel tower (Figure 140), which was necessary because of the terrain (there is a hill between the receiving site and the launch pads).

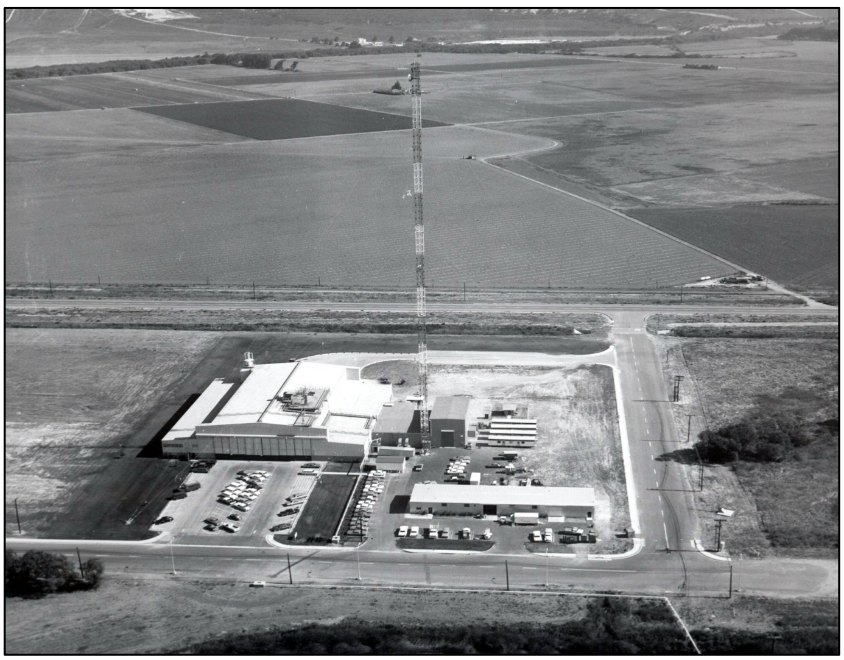

Figure 140. Pacific Missile Range 450-Ft. Tower

Art Gilcrease summarized the ongoing effort as follows: "PSL operated a telemetry station in the building where all [of] these spacecraft went through their pre-flight checkouts. We designed and built equipment, participated in all the countdowns and flights with our telemetry station, [and] tracked the spacecraft for the first few orbital passes where we could monitor its performance and pass the information along to NASA. [It was] very interesting work."

Appendix F lists, in chronological order, 1960s events significant to PSL's work at PMR as logged by Raymond Bumgarner.

Jerry Cooper made the following comments about his years at PMR: "I discovered that curricula changes would cause me to take longer to graduate than planned. My money ran out, so I went back on staff full time on the 220. Then Raymond [Bumgarner] and Rick called me in one day and said…somebody [was needed] to run a field group at Vandenberg and was I interested? I said, 'Yes.'...Others in the group were Joe Otero, Carl Jensen, Jack Masterson, Doug Bossert, Elsworth Barnes, Paul Pradzinski (maybe he came later), [and] Joe Matlock. The NASA boss was Joe Schwartz, who was with GLO… [The] rest of [the] NASA types there worked for PLOO.

"My first big launch was [the] NIMBUS. It took 8-12 weeks prior to each launch to check out the spacecraft. I was Group Supervisor from May until [the] end of year—[I] think it was 1964. Raymond [Bumgarner] had picked Art Gilcrease to be permanent supervisor, and he came there from Florida in September. We were sort [of] co-supers for a while. I ended up staying there for five years, then transferred back to Florida for about four years.

"When PSL lost the contract in Florida, I went back to Vandenberg—so did Willie and Noda. There I was in charge of the ground station, Noda was general supervisor, and Willie got heavily involved in a computer facility trying to interface everything to the computer. The ground station crew was me, Jensen, Bossert, and Otero. [I] stayed at Vandenberg until we lost that contract due to a small-business set-aside; PSL was barred from bidding on it. That was [in] about 1978."

Electromagnetics Section

<u>Spacecraft Antennas</u>

In 1960, PSL's Electromagnetics Section received a contract from NASA to develop antennas to fly on various types of satellites. This work continued throughout the 1960s and 1970s.

A very large and challenging portion of the Section's work involved the NIMBUS series of weather satellites, in which each spacecraft was uniquely shaped and contained a different number of antennas (Figure 141). Initial requirements were for (1) an S-band antenna to operate over the range from 1700 to 1710 Mc, with the capability of adding one, two, or three transmitters operating simultaneously; (2) a VHF antenna or a group of antennas to operate at 136 to 137 Mc, with the three-transmitter option as described above; and (3) an interrogation antenna to operate near 120 Mc. The radiation pattern requirements specified by NASA, along with the mechanical constraints dictated by the spacecraft structure, required a prolonged, state-of-the-art effort. A number of scale mockups were built by the PSL Machine Shop and used on the Antenna Range. Approximately 36 prototype antennas were constructed, tested, and discarded before the designs were finalized. Cecil Post headed up this work, assisted by Frank Hsu and Joe H. Diel.

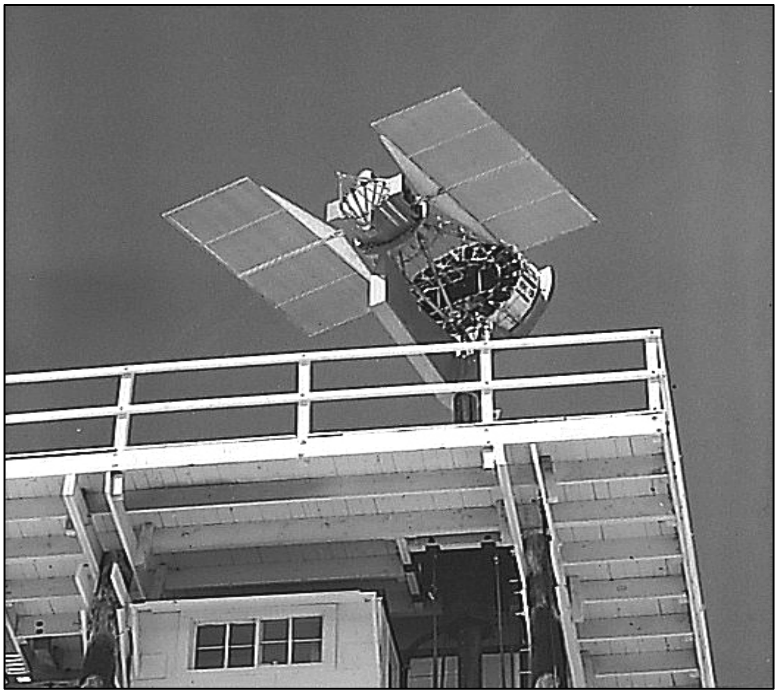

Figure 141. NIMBUS Weather Satellite

By 1963, seven vehicle antenna systems had been designed and developed to prototype stage, including those for NIMBUS A, B, C, and D. All were accepted by NASA and incorporated into the spacecraft by General Electric, the vehicle prime contractor. Since new frequencies and other parameters were introduced in the mid-1960s, design efforts were continued throughout the decade. Proof tests of various designs were conducted in 1968 and 1969 under contract to General Electric, while prototype antennas were being developed for the NIMBUS D satellite configuration.

In January of 1965, designs were completed on two experimental NIMBUS antennas: a log-spiral radiator on a truncated cone and a log-spiral radiator on a nine-inch-diameter hemisphere. These were proven concepts, but the challenge was to make them physically small enough to fit into the NIMBUS satellite. Two truncated cone models were patterned, after which the discovery was made that the front-to-back ratio was too low. Nine truncated cone models were built and tested, apparently using two frequencies, 400 and 465 Mc.

The Antenna Section designed and tested antennas throughout the NIMBUS series (totaling 8-10). Testing was also performed on antennas built by other companies (e.g., microwave radiometer antennas) to determine how they affected all other antennas on board the satellite. The NIMBUS was slightly modified, after which time it became known as Landsat. PSL designed antennas and tested those from other companies (primarily General Electric) for antenna pattern measurements and mutual coupling. PSL was involved with Landsat through A, B, C, and D.

NIMBUS was originally intended to replace the weather satellite; however, this never occurred. Instead, NIMBUS became the ground-search satellite that checked for phenomena such as healthy orchard growth, proper watering of crops, snow level, amount of forest and what type, etc. NIMBUS was also used to trace floating bodies at sea and various animals (such as polar bears) that had been equipped with transmitters. This type of tracing could be conducted worldwide.

The first of the Telemetry Data Systems (TDSs) for real-time telemetry was tested on a NIMBUS satellite. Cecil Post was involved in a minor way with the original TDS antenna that was designed and constructed by the General Electric Company.

Other satellites for which antennas were developed included the S-51, S-52, RELAY I, RELAY II, Orbiting Astronomical Observatory (OAO), Orbiting Solar Observatory (OSO) (Figure 142), Orbiting Geophysical Observatory (OGO), and REBOUND. As with NIMBUS, the contracts called for design to the prototype stage only, with the spacecraft prime contractor to fabricate and install the antennas. The exception was the OAO; PSL was asked to evaluate antennas designed by the prime contractor. All of these efforts required construction of scaled-down mockups of the satellite, as well as full-scale mockups in many cases.

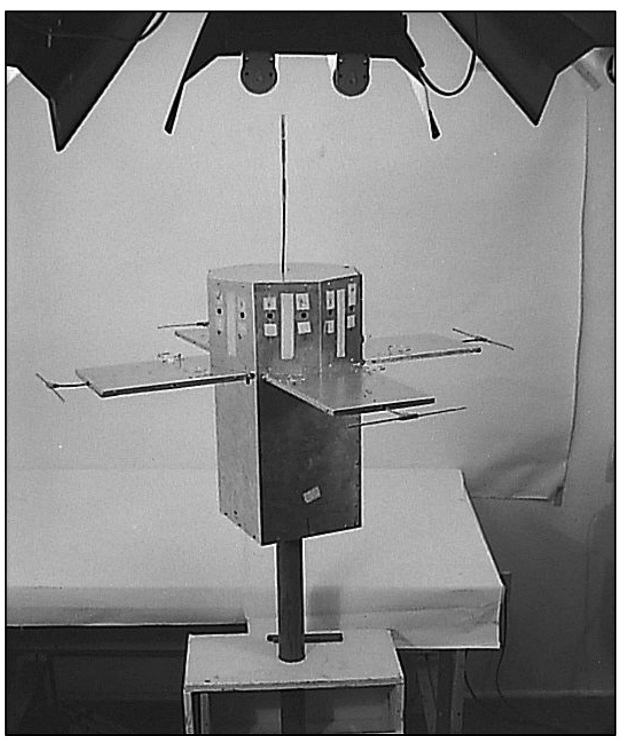

Figure 142. Mockup of OSO Satellite, 1963

The S-51 and S-52 tasks only required adaptations of the Quadraloop antenna that had been in use on rocket bodies for years; this work was completed within one year.

Quadraloops were also used in another space application—on the body of the Thor-Delta booster for vehicle telemetry.

The development of RELAY satellite antennas was another problem, starting in 1962 and taking about 2 ½ years to complete. Frequencies of 4.08 and 6.0 Gc were involved. The effectiveness of a slot radiator (antenna) cut in the body of a solar panel was investigated in the course of completing this work. The presence of the solar cells on the panel surface did not result in loss of antenna gain. The April 1964 progress report revealed that an antenna composed of an aperture fed from a coaxial cavity was designed and prototyped and that it "should be patented." The following month's report stated that the prototype tests indicated insufficient bandwidth and that efforts to improve it were under way. Final testing of the prototype antenna was conducted in June of 1964, and the final report was drafted (Bill Cooper and Herb Haas took the antenna and the report to GSFC).

In 1963 and 1964, the Electromagnetics Section performed radiation pattern analysis and precision bore sight calibration of the Gemini rendezvous radar (a version of which was sent to PSL by NASA) for the McDonnell Aircraft Company. Cecil Post obtained a closed circuit television and had a telephoto lens designed with a special cross hair that could be projected onto the image of the television view of targets, which PSL set up on telephone poles about a mile away from the rendezvous radar. The targets were spread ± five degrees to represent the Gemini test target.

Phil Manz was asked to design and build a roll-bearing mount with the roll angles engraved onto circles. This allowed accurate measurements of the Gemini test model roll position. After the PSL measurements were completed, the roll mount was taken to WSMR, where the measurements were repeated using the WSMR FPS-16 radars that tracked the over-flying aircraft for comparison with the radar data. To Mr. Post's dismay, the television camera system was then sent to Cape Canaveral for use there.

The Westinghouse Company built the radar, and tested its pointing accuracy. PSL measured pointing accuracy and WSMR tested it. Cecil Post was told later that all three measurements were in exact agreement.

In addition, PSL built a full-scale model of a simulated rendezvous target vehicle. Antennas that were to receive the rendezvous radar signal and then return a signal to the radar were tested during this same period of time. Cecil Post was responsible for these tests at PSL, with assistance from Joe Diel. NASA personnel operated the radars during the testing.

Minitrack Antennas

As mentioned in Chapter 4, PSL developed the Minitrack antenna arrays and maintained them at fourteen Spacecraft Tracking and Data Acquisition Network (STADAN)[43] sites worldwide. Although some sites were removed from the network in the 1960s, the Electromagnetics Section's calibration activities continued on into the 1970s. For example, stations in Newfoundland, South Africa, Madagascar, Australia, Alaska, and South America were calibrated in 1967, and one was later moved from Blossom Point, Maryland to NASA/GSFC.

In early 1961, NASA tasked the Electromagnetics Section with conducting a feasibility study of a Minitrack system capable of very high accuracy. PSL was to, "look into the general tracking problem, examine existing systems such as Minitrack, Azusa, Mistran, etc., and then propose a system with maximum reliability, accuracy, and simplicity of operation." One of the primary evaluations performed involved antenna systems suitable for precision tracking. Dr. Richard Duncan and Dr. Kaiser Kunz were directly involved in specific parts of the study concerning the effects of RF noise on satellite tracking. The study was completed in October of 1961, and the final report distributed in March of 1962.

A related task was assigned to the Section in 1961—the development and testing of a revised version of the Minitrack array to operate at 136.5 Mc. This work was in progress in March of 1962. Additional research and development was requested by NASA/GSFC in 1967 to broadband the system (it had not been updated since its inception). From 1967 to 1969, a 136- to 137-Mhz prototype was developed; the Electromagnetics Section then consulted for NASA during the manufacturing phase. This work extended into the 1970s.

In mid-1962, the need arose for a portable test unit that could be placed at each Minitrack site, for measuring of signal phase and amplitude (Figure 143). Such a unit was designed and fabricated, and the prototype was completed in March of 1963. It was then used to test the Goldstone and Ft. Myers antennas. PSL recommended that NASA purchase one of these "136.5 Mc Minitrack Array Phase-Amplitude Test Units" for on-site use at each Minitrack location as a cost-saving measure.

[43] STADAN was the precursor to the Tracking and Data Relay Satellite System (TDRSS) used by the NASA Johnson Space Center at WSMR.

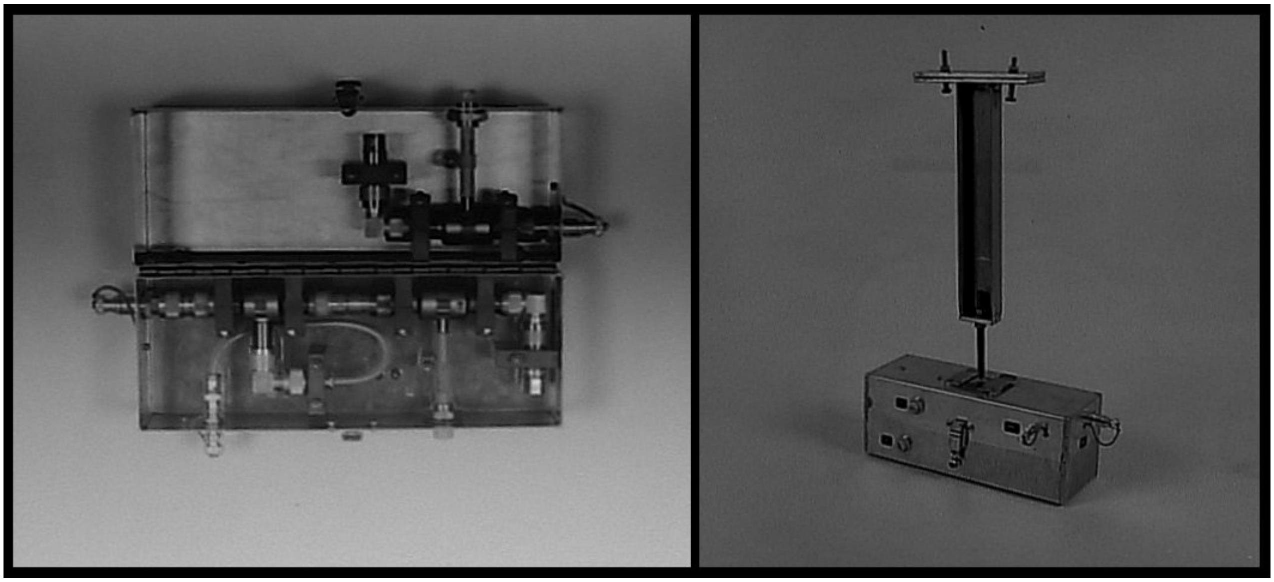

Figure 143. Minitrack Portable Test Set

Data Reduction

In late 1959, at the request of Drs. Stampfl and Vonbun of NASA, PSL's Applied Analysis Section attempted to determine the aspect of the Vanguard II satellite through the use of signal strength records. This state-of-the-art effort, led by Keith Guard, introduced the Section to the theory, design, and construction of digital filters. In early 1960, the IBM 650 computer was being used for this work. However, since all programs were converted to run on the Burroughs 220 after it arrived, this was probably one of its initial applications. Within a few months this approach was determined unfeasible for Vanguard II, and work was reduced. However, effort continued on refining methods of spectral analysis via the use of digital filters.

The scope of effort as of May of 1961 included an item called, "Satellite Analysis" under which PSL was to "provide the services of one staff member and one year of student labor for work in Washington, D.C." Details of work performed on this task have not been located, except for the fact that six coop students were working at GSFC by 1964. In October of 1963, David Mott traveled to GSFC to perform data analysis on synchronous satellites.

That same 1961 NASA contract requested reduction of Minitrack data as follows: "Reduce photographic plates of star and airplane flashing lights obtained by Minitrack stations. Reduce Minitrack calibration records and correlate with photographic data." Progress reports show that several dozen of these plates were being reduced each month.

Cecil Post described the method of data reduction required by this contract as follows: "The [Burroughs 220] computer [used by PSL's Data Processing Section] featured a star map. A sidereal mounted camera capable of tracking the stars and compensating for Earth's rotation was located in the center of the Minitrack antenna arrangement at each station. An airplane transmitting the Minitrack radio signal flew over the site at night with a blinking light that was visible to the camera. This created a trail of spots of light recorded over the background of the star field showing the position of the aircraft relative to the stars. These data were delivered to PSL, and the Data Processing Section used them to calculate the direction cosines for the radio tracking system, thus calibrating the radio tracking accuracy of the Minitrack system."

Reduction of Explorer VIII data began in February of 1961 on (1) solar-horizon aspect data and (2) ion and electron currents (experiment data). These data were recorded at 12 Minitrack stations around the world. The aspect reduction was performed manually. The data processing final product was estimated to be 7,200 graphs.

Explorer VIII experienced a problem—aspect data were available only through certain phases of the satellite rotation and orbital position. The solution was to use the experimental data for periods when aspect data were not available.

Space Miscellany

3/11/63	Senator Clinton Anderson (Deming, NM), Chairman of Senate Committee on Aeronautics and Space Sciences, questioned NASA's request for $55 million for space communication research that would benefit a private corporation (Comsat).
3/17/63	VANGUARD I still transmitting data. Scientists predict life of 2,000 years.
3/63	UK announced plans for commo satellite network to compete with United States. Washington astonished.
5/16/63	L. Cordon Cooper completed 22 earth orbits in final Mercury flight.
10/1/63	NASA's fifth anniversary. Over 50 satellites have been launched, 30 of them by GSFC.
Late 1960s	APL satellites were launched from a steel platform known as San Marco in the sea off the coast of Kenya.

Twenty-four weather satellites were placed into orbit in the 1960s.

EPILOGUE: PSL's SUBSEQUENT YEARS

The early 1970s was a time of slowdown for both PSL and the United States as a whole, particularly in the areas of Aerospace and Defense. The Vietnam War, Watergate, and inflation caused a decline in morale, which reached its lowest point in the mid-1970s. PSL's numerous small contracts during this period helped to soften the blow experienced at a national level. Fortunately, resurgence occurred at the end of that decade.

In the time period covering 1970 through the present, PSL's multiple changes included a reduction of the number of data analysis groups, a gradual decrease in rocket work, and the advent of the Air Force and NASA balloon contracts. In the early 1970s, Ivan Carbine was involved in an effort to bring the Space Shuttle launch and landing site to New Mexico (Mr. Carbine became ill with cancer and passed away in 1971). Unfortunately, his effort did not survive but in early 1990, the concept was reinitiated via Spaceport New Mexico and the advent of Reusable Launch Vehicles and the testing of Delta Clipper Experimental (DCX) at WSMR. Testing of the DC-X continued into the mid-1990s, while the Spaceport effort is still ongoing today.

By mid-1970, PSL was shifting from work that strictly involved sounding rockets into satellite fabrication and Space Shuttle support. Satellite flight instrumentation was developed early in the 1970s for two NRL satellites, SOLRAD 10 and 11. Support of the High Energy Astronomy Observatory (HEAO) satellite subsystems began in the 1970s, and Shuttle Get-Away-Special (GAS) and SPARTAN programs in the 1980s.

For the next 30 years, PSL continued its support of the NASA sounding rocket and Navy missile programs. PSL also developed and expanded its Army Electronic Warfare program support, which began with the Army's Missile Electronic Warfare Test Agency. Antenna development and testing continued in support of the sounding rocket and satellite programs. Telemetry efforts for both large and small systems were initiated and completed during this period. The SGI Section continued to function into the mid-1990s, at which time PSL's portion of the tracking system was shut down. Currently, at the beginning of the 21st century, PSL continues working in traditional programs maintained from its inception, as well as exploring completely new areas of growth.

The new millennium brought a wider variety of changes for PSL. New areas of endeavor included Intelligence and in flight and ground testing of unmanned aerial vehicles on an FAA approved UAV range near Las Cruces. Existing areas that continued included ongoing NASA ballooning and traditional and new rocket testing (a new area involved using rockets as targets).

Work has begun to document PSL's history from 1970 to present—a relatively comprehensive draft version has been completed. Only time will tell whether or not there is sufficient "corporate" interest to ensure that this draft is finalized.

Raymond Bumgarner wrote a final note in the draft version of the PSL history document, which was included in the 9/24/92 PSL Time Capsule. This note read as follows:

"Dear Finder:

What year is it now? I assume I shall be long dead and buried – I was 68 years old at this writing. This unfinished draft is to be placed in a sealed box in the wall of the new Anderson Hall expansion within the next few days. I hope that there is still a Physical Science Laboratory and that you are an employee, and that you have read the finished book. It hopefully will have been published within the next couple of years covering PSL's saga through the 1980s, complete with many photographs. If you enjoyed the reading of it, please look heavenward and smile – perhaps my wife up there can then get the message to me down below."

Raymond "Raymo" Bumgarner

APPENDIX A

Following is a list of customers as of 1969.

NASA

1. Ames Research Center - California
2. Goddard Space Flight Center - Maryland
3. Kennedy Space Center - Florida, California

U. S. ARMY

1. Defense Atomic Support Agency - Washington, D.C.
2. Edgewood Arsenal - Maryland
3. Electronic Command - Ft. Monmouth, New Jersey
4. Harry Diamond Laboratories - Washington, D.C.
5. Picatinny Arsenal - New Jersey
6. Redstone Arsenal - Alabama
7. White Sands Missile Range - New Mexico
8. Yuma Proving Ground - Arizona

U.S. NAVY

1. Naval Oceanographic Office - Washington, D.C.
2. Naval Ordnance Missile Test Facility - WSMR
3. Naval Weapons Center - California
4. Pacific Missile Range - California
5. Office of Naval Research - Washington, D.C.
6. Ordnance Systems Command - Washington, D.C.
7. Undersea Warfare Center - California

U.S. AIR FORCE

1. Systems Command, Electronic Systems Division - Massachusetts
2. Charting and Information Center - St. Louis
3. Cambridge Research Laboratory - Massachusetts

OTHER GOVERNMENT AGENCIES

1. German Research Institute for Air and Space Travel - Sweden and Germany
2. Kitt Peak National Observatory - Arizona
3. Los Alamos Scientific Laboratory - New Mexico
4. State of New Mexico, Bureau of Revenue - Santa Fe, New Mexico
5. U.S. Dept. of Health, Education and Welfare -Washington, D.C.
6. U.S. Dept. of Transportation - Washington, D.C.

INDUSTRY

1. Aerojet General Corporation - California
2. Aerospace Research, Inc. - Massachusetts
3. Bell Telephone Laboratories - New Jersey
4. Dorne and Margolin
5. Douglas Aircraft Company
6. Fairchild Hiller Corporation - Maryland
7. General Electric Company - Pennsylvania
8. Globe Exploration Company, Inc. - El Paso, Texas
9. International Business Machines - Alabama
10. Kentron Hawaii, Ltd. - Alabama and Hawaii
11. Lockheed Electronics Company - WSMR
12. Lockheed Missiles and Space Company - California

13. LTV Electrosystems, Inc. - Texas

14. Radiation, Inc. - Florida

15. Sandia Corporation - Albuquerque

16. Space Data Corporation

17. Thiokol Chemical Corporation - Utah

UNIVERSITIES

1. Applied Physics Laboratory, Johns Hopkins University - Maryland

2. Electronics Laboratory, Oklahoma State University

3. University of Iowa

4. Lowell Technical Institute - Massachusetts

5. Massachusetts Institute of Technology

6. University of Michigan

7. Oklahoma State University

APPENDIX B

AGENA, Air Force/Lockheed. Diameter 5 ft., length 25 ft. Designed as a second stage space launch vehicle and orbiter, the Agena can be mated with either the Thor IRBM or the Atlas ICBM. Liquid-fueled engine capable of re-starting in space. NASA initially purchased 16 Agenas, which were delivered over a three-year period. In January of 1967, NASA announced that it would fire Centaurs instead of Agenas; final Agena fired at Cape Canaveral March 7, 1968.

ATLAS. ICBM, General Dynamics/Convair. Length 66 ft., diameter 10 ft., 389,000 lbs. of thrust. Successfully used in the Mercury manned space flight program. Fueled by refined kerosene and liquid oxygen.

ATLAS/AGENA. Length 91 ft. Used primarily to transport heavier cargo into space, it can put 5,000 lbs. into a 300-mile earth orbit, or dispatch an 800-1b. craft on deep space missions. Launched the Ranger moon probes and the Mariner interplanetary spacecraft, along with the OGO, OAO, and ATS satellites.

CENTAUR. General Dynamics/Astronautics and NASA/Lewis Research Center. Length 46 ft., diameter 10 ft. Liquid hydrogen fueled and featured the significant capability of restarting in space. First upper-stage vehicle to employ the liquid-hydrogen/liquid-oxygen combination of propellants.

ATLAS/CENTAUR, General Dynamics Corporation. Length 100 ft., diameter 10 ft. Capable of placing 8,000 lbs. into low earth orbit, boost 2,300 pounds to the moon, and launch 1,300-lb. probes into deep space. Primary mission was to soft-land the Surveyor craft on the moon's surface; it was also used to send Mariner probes toward Mars and Venus.

DELTA, Douglas Aircraft Company. Length 90 ft., weight 57 tons. First launch May 13, 1960. First successful orbit: ECHO I on August 12, 1960. Smallest of GLO's four standard launch vehicles, the Delta was a three-stage vehicle and the United States' most reliable space booster. Delta's first, second, and third stage were a modified Thor IRBM, modified Vanguard second stage (19 ft. in length X 2 1/2 ft. in diameter), and an 18 X 60 inch solid-fueled rocket, respectively. Primarily used for orbiting smaller satellites, it could launch 800 pounds into a 450-mile circular orbit or free 110 pounds from the earth's gravity. Its payload capacity was greatly increased when the Thrust Augmented Delta (TAD), with its three strap-on solid-fueled rockets, was introduced.

In the 1960s, the Delta program achieved a launch success rate of 90%. Included in this record were such satellites as the OSO, Echo, IMP, Explorer, TIROS, Ariel, Telstar, Relay, Syncom, and Early Bird. Information gathered by these satellites has helped to solve some of the mysteries of the space environment and has laid the foundation for operational weather and communications satellites.

The Delta project was the primary program supported by the PSL/MEI team at the Cape in the 1960s. According to a GSFC report entitled "Chronology 1963," as of October of 1963, "The majority of NASA's satellites have been launched by GSFC-managed Delta vehicles." The Delta vehicle is still being used by NASA today.

JUNO. Jupiter IRBM first stage with three solid-fuel upper stages.

SATURN Series I – V, Boeing, Chrysler, McDonnell Douglas, North American Aviation. First launch October 27, 1961. Saturn V, 364 ft. in length, was developed as the booster for the Apollo moon landings. Capable of placing a 140-ton satellite into earth orbit.

SCOUT. Length 65 ft. Highly reliable, four-stage, solid-propellant vehicle for small satellites and probes capable of placing 350 pounds into a 300-mile orbit or boost a vertical probe up to 4,000 miles. The United States' only completely solid-fueled launch vehicle. Some of these were launched from Wallops Island, as well as from the AMR and PMR. A fifth stage was available for highly elliptical and solar orbit missions. First launched in 1960.

THOR, Douglas. IRBM. First launch January 25, 1957. Used only as the first stage of the THOR-ABLE and THOR/AGENA space vehicles described below.

THOR-ABLE. Early satellite launch vehicle. Second and third stages were Vanguard type liquid-propellant rockets.

THOR/AGENA, Douglas/Lockheed. Height 76 ft. First to return capsules from space with successful sea and aerial recoveries, first to be placed in the difficult polar orbit, first to attain a nearly circular orbit, and first to re-start in space. Payload capacity over 1,500 pounds. Launched only from PMR, it was used to launch Echo II, the NIMBUS series of weather satellites, Alouette, and OGO. By 1970, Thor/Agena had achieved 155 successes.

TITAN I, U.S. Air Force ICBM; Martin Company, Denver. Dimensions 98 ft X 10 x 8, weight 220,000 lbs., range beyond 6,300 miles. Two-stage, silo storage, surface launch.

TITAN II ICBM, Martin Company, Denver. Dimensions 103 X 10 ft., weight 330,000 lbs. Two-stage, housed in silo, launched in silo. Utilized a type of liquid propellant capable of remaining indefinitely in its fuel tanks.

TITAN II/Gemini, Martin Company, Baltimore. Two-stage, overall length 110 ft., diameter 10 ft., weight 150 tons. Phase following Project Mercury in NASA's man-in-space program. Payload capacity of four tons.

TITAN III, Martin Company, Denver. Designed as a space launch vehicle, this was a TITAN II with up to five stages including two strap-on, solid-fuel rocket motors each 10 ft. in diameter. Payload capacity 10 tons in 100-mile orbit. USAF project.

APPENDIX C

Rocket & Missile Types Supported By PSL:[44]

Aegis

Aerobee 100, 150, 170, 200, 250

Apache

Arcon

Arcas

Aries

Astrobee D, F

Black Brant

Cajun

Cobra

Corporal

Deacon

Falcon

Firefly

Hawk

Honest John

Hugo

Iris

Iroquois

Javelin

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44 Does not include space vehicles listed in Chapter 5.

Lacrosse

Lance

Little John

Little Joe

Loki

Malamute

Nike-Ajax

Nike-Hercules

Nike-Zeus

Orion

Ozark

Paiute

Pershing

POGO

Redstone

Sergeant

Sidewinder

SM-1

Spaerobee

Sparrow

Spartan

STRYPI

Talos

Tartar

Terrapin

Terrier

Tomahawk

Toro

Typhon

Ute

V-2

Vanguard

Viking

Zuni

APPENDIX D

ANNA (Army Navy NASA Air Force). Flashing light geodetic satellite.

ALOUETTE. Canadian-built topside sounder satellite, first orbited by a NASA vehicle September 28, 1962. Measure electron density in ionosphere, detect energetic particles. Five were planned.

ARIEL. United Kingdom satellite; Ariel I launched by NASA April 26, 1962. World's first international satellite. Ariel II orbited March of 1964.

ASSET. Late 1960s.

ATS. Five launched in the late 1960s.

BIOSATELLITE. BIOS I attempt on December 14, 1966 failed to orbit, fell into the ocean. BIOS II successful September of 1967. BIOS III contained a 14-1b. monkey, which was recovered safely but died the next day from apparent heart failure.

ECHO I. Passive commo reflector launched August 12, 1960. 100 ft. diameter aluminum-coated Mylar sphere inflated after being placed into orbit. Became distorted, ineffective for communications; however, provided much valuable data on drag and solar radiation pressure. Re-entered atmosphere and burned in May of 1968.

ECHO II. Rigidized balloon commo reflector, 135 ft. diameter. Launched from PMR January 25, 1964 into near-polar orbit.

ESRO. Satellite program by the European Space Research Organization. Orbited by the Scout rocket.

ESSA Series. Nine were flown.

EXPLORER. Explorer I was first U.S. satellite to achieve orbit. It proved the existence of the Van Allen radiation belts, which are bands of electrons and protons circling the earth and extending out to many thousands of miles. Explorer VII launched in 1960; XII confirmed low-energy proton current ringing earth; XIV was energetic particles experiment; XV carried radiation investigation experiments; XVI micrometeoroid detector; XVII (April of 1963) studied atmospheric structure and was first scientific satellite to employ PCM telemetry. Thirty-seven of these craft, with widely varying purposes, were launched, with the last shot on March 5, 1968.

FR-1. French satellite that studied propagation of VLF waves in the ionosphere.

IMP (Interplanetary Monitoring Platform). First shot November 26, 1963. Primary purpose was to develop method of anticipating solar flares. IMP-F shot from WTR in May of 1967.

INJUN. ONR/State University of Iowa. Study of auroral zones and radiation belts.

INTELSAT I, II, III, IV. Advanced communication satellite. By 1970, five INTELSAT IIIs were in full operation around the world. Property of Communication Satellite Corporation (Comsat); launched by NASA, reimbursed by Comsat.

ISIS (International Satellite for Ionosphere Studies). Used to determine the amount of hydrogen, helium, and oxygen present at satellite altitudes.

MARINER. Mars and Venus fly-by probes. MARINER II flew within 22,000 miles of Venus in December of 1962, and completed its first orbit of the sun in August of 1963. MARINER IV provided first close-up photos of Mars' surface in July of 1965.

NIMBUS. Successor to TIROS, much larger, with solar panels. Polar orbit enabled coverage of clouds over every portion of the earth every 24 hours. Transmitted photographs continuously to inexpensive ground stations anywhere in the world. First launch late in 1964.

OAO. Purpose was to place telescopes above the interfering haze of the earth's atmosphere. OAO I launched April of 1968 failed to return data. OAO-2 in December of 1968 observed a nova (exploding star) not visible to telescopes on the ground.

OGO. OGO I launched from Cape Canaveral September 4, 1964. "A Successful Failure," it achieved perfect orbit; however, two of its 13 solar panels failed to unfold, obscuring its view of the earth. However, GSFC controllers were able to maneuver the craft in real time sufficiently to obtain far more scientific data than initially expected. At least six OGOs were launched in this decade. Those placed in polar orbit were called POGOs.

OSO. Six were placed into orbit in the 1960s. OSO I launched March 17, 1962, still working one year later. Pointed its instruments at areas of the sun's surface with an accuracy equivalent to hitting a penny .5 miles away with a rifle bullet.

PEGASUS. Huge satellite with 96 ft. X 14 ft. wing that weighed 23,000 lbs. Meteoroid detector.

PIONEER. Interplanetary probe; provided data on magnetic field, plasma, ionization levels, solar radiation particles, effects of the "quiet sun" on radio propagation. Supported lunar landings. PIONEER I launched October 11, 1958; PIONEER VIII on December 13, 1967.

RAE. GSFC's series of Radio Astronomy Explorer satellites.

RANGER. Series of moon probes. RANGER VII returned first television pictures of moon's surface in July of 1964.

RELAY. First active repeater communications satellite. Solar powered. RELAY I launched December 13, 1962; RELAY II January 21, 1964. Exchanged live news between Europe, U.S., and Japan, including the assassination of President Kennedy.

San Marco. Italian-made satellite placed in equatorial orbit by a NASA Scout rocket. Launched from an Italian-operated platform in the Indian Ocean off the East Coast of Kenya in Africa.

SR-x Series. NRL Solar Radiation Satellite. Program to lead to continuous monitoring of the sun; to seek cause of radio blackouts during solar flares.

SURVEYOR. Unmanned lunar lander. Proved feasibility of soft landings on the moon; analyzed lunar surface material. SURVEYOR I launched May 30, 1966 returned 11,000 photos.

SYNCOM (Synchronous Orbit Communications Satellite). SYNCOM I was successfully launched February 13, 1963 into synchronous orbit but lost contact soon thereafter. SYNCOM II was placed over equatorial-Brazil in July of 1963 at an altitude of 22,300 miles. Three such satellites, spaced equidistant around the world.

TELSTAR I, II. Communication satellites designed and developed by AT&T, launched by NASA at AT&T's expense. TELSTAR I was used to achieve the first Trans-Atlantic television transmission via satellite; provided extensive data on radiation damage to electronic components. TELSTAR II launched May 7, 1963 stopped functioning after 450 orbits, reactivated a month later.

TIROS (Television Infra-Red Observation Satellite). World's first weather satellite: first launch April 1, 1960. Immensely successful. TIROS II launched November 23, 1960, III July of 61, IV February of 1962, V June of 1962, VI September of 1962, VII June of 1963, VIII December of 1963. The first ten launches were all successful, a very remarkable achievement.

TOS. TOS-C launch at WTR in April of 1967.

APPENDIX E

AMR Chronology

April 1960	ROS I orbited.
22 June 1960	NRL's SR-1 satellite launch aboard Thor-Able. Successful orbit.
Aug. 1960	ECHO I launch.
Sept. 1960	Atlas-Able failed to orbit; GSFC payload.
Nov. 1960	Explorer 8 orbited by Juno 2 vehicle.
Nov. 23, 1960	TIROS II
Feb. 1961	Explorer S-45/ Juno 2 failed to orbit.
March 1961	Explorer 10 orbited by a Thor-Delta.
April 1961	Atlas rocket failed in NASA's first attempt to orbit an unmanned Mercury capsule.
May 1961	Second S-45/Juno combo failed to orbit.
29 June 1961	Three satellites launched together on one Thor-Able: Transit, Injure, and SR-3. Injure and SR-3 failed to separate, orbited together, compromised experiments, but not total failure.
July 1961	TIROS III.
27 July, 3 Aug. 1961	Two successive Thor-Agena failures.
Mid-1961	A new PWM/FM telemetry station was installed in Hangar AE.
Aug. 1961	Explorer 12 orbit by Delta.
23 Aug. 1961	RANGER 1 launch, failed to leave parking orbit.
Sept. 1961	Mercury capsule successfully made one orbit.
Nov. 1961	RANGER 2 failure.
29 Nov. 1961	Mercury capsule achieved two orbits carrying Enos, a 4-year-old chimpanzee.

15 Jan. 1962	BIG SHOT (ECHO) launch at Cape. Attempt to inflate a rigidized 135-foot balloon in space and monitor inflation over live TV link. Balloon burst shortly after inflation.
24 Jan. 1962	BUCKSHOT launch, so called because it carried five separate satellites. U.S. Navy project—failed to orbit.
26 Jan. 1962	RANGER 3 aimed at moon, missed it by 23,000 miles.
Feb. 1962	First American astronaut in orbit in Friendship 7 capsule.
March 1962	OSO-1 orbited. PSL installed and operated Doppler station on Antigua Island to monitor third stage.
March 1962	AMR crew members began trigs to PMR to set up ground station.
April 1062	RANGER 4 impacted moon, but experiment failed.
26 April 1962	Ariel 1 orbited.
10 May 1962	ANNA launch supported by telemetry, Doppler and Minitrack. Failed to orbit.
June 1962	Received and installed first all-solid-state PCM telemetry ground station.
19 June 1962	TIROS 5 orbit.
June 1962	Cape crew built display unit, Doppler converters for PMR.
10 July 1962	TELSTAR I/Delta launch.
July 1962	Mariner 1 Venus probe failed to orbit.
July 1962	BIG SHOT 2 balloon launch.
Aug. 1962	Mariner 2 flew by Venus.
Sept. 1962	TIROS 6 in orbit.
2 Oct. 1962	Explorer 14/Delta.
Oct. 1962	Astronaut Schirra completed six Earth orbits in Mercury capsule.
19 Oct. 1962	Ranger 5 missed moon by 450 miles, went into solar orbit. One man to Antigua with Doppler station.
27 Oct. 1962	Explorer 15/Delta. PSL operated shipboard Doppler.

31 Oct. 1962	ANNA 1-B achieved orbit. Doppler support only.
13 Dec. 1962	Relay I launched into orbit; first active communications satellite. One tech to Antigua with Doppler station.
16 Dec. 1962	Cape and Antigua Doppler stations monitored launch of GSFC's Explorer 16 aboard a Scout rocket from Wallops Island, Va. Good orbit.
Feb. 1963	Cape got PAM/FM station, another PCM station on way.
14 Feb. 1963	SYNCOM I launch. First use of new Arnoux telemetry station.
3 April 1963	Explorer 17/Delta.
April 1963	Russian Lunik 4 moon probe missed moon by 5,000+ miles.
April 1963	Cape crew assembled a complete Doppler station to be used downrange at PMR, to get 4th stage data.
May 1963	Telstar 2 into orbit but circuits failed after 60 days.
June 1963	Russians put first woman in space. Valentina Tereshkova made 49 orbits.
June 1963	TIROS 7 orbited.
25 July 1963	SYNCOM II at Cape. Successful.
Aug. 1963	Bob Gray asking for 3 data reduction types permanently at Cape. K. Hennigh not interested in having people at Cape.
Oct. 1963	Heavy work on Centaur.
16 Oct. 1963	TRS 5 radiation sat orbited by Atlas-Agena.
26 Nov. 1963	IMP I launch. Two technicians to Antigua.
27 Nov. 1963	Atlas-Centaur vehicle test launch.
21 Dec. 1963	TIROS 8 success.
21 Jan. 1964	Relay 2. Linked Japan and France.
30 Jan. 1964	Ranger 6 landed on moon but television system failed. No pictures.
Feb. 1964	Now have seven PAM/FM stations. Takes eight people.
19 March 1964	S-66 (Explorer 20) launch. Third stage failed, first failure in 23 Delta shots. Jimenez and Fitzpatrick to Antigua with Doppler station.

March 1964	AMR station recorded telemetry and Doppler from a Scout launched from Wallops. Willis and Matlock to Bermuda.
14 April 1964	Project FIRE launch.
April 1964	Delta solid propellant stage ignited in hangar, killed 2 people. No Delta launches for two months. 5/64 Saturn launch. Tm, Doppler. Guyse and Fitzpatrick to Antigua.
30 June 1964	Atlas-Centaur AC-3 vehicle test flight. Used 8 telemetry stations.
22 July 1964	ASSET launch.
28 July 1964	Ranger 7 launch. Impacted moon.
Summer 1964	Began sending one person with Doppler station on downrange ship for launches, including Syncom in August covered by co-op student Bruner.
Aug. 1964	Stations secured twice for hurricanes nearby.
4 Sept. 1964	POGO 1 launch. Apogee 93,000 miles. Bruner and Bachman to Antigua station.
18 Sept. 1964	Saturn SA-7 launch. Gilcrease to Antigua.
Sept. 1964	Hurricane Dora hit Cape with 60 mph winds.
3 Oct. 1964	IMP 2 orbited by a Delta rocket. Sullivan and Bruner to Antigua. Dozens of pre-launch tests on other craft required over 500 Sanborn records in one month.
5 Nov. 1964	Mariner III launch. Shroud failure killed experiment. Bruner on ship.
6 Nov. 1964	Scout launch at Wallops put Explorer 23 in orbit. Three Cape people to Antigua for Doppler and spacecraft command.
28 Nov. 1964	Mariner IV success.
21 Dec. 1964	Explorer 26 launch.
18 Jan. 1965	TIROS launch. Bruner to Peru.
3 Feb. 1965	OSO Cape, perfect orbit achieved.
Feb. 1965	Big computer for telemetry station is coming soon. PSL asked to furnish two people with digital capability to install and maintain equipment for a new launch director center.

16 Feb. 1965	Pegasus 1 launch.
17 Feb. 1965	Ranger 8 fired at moon, hit it.
21 March 1965	Ranger 9 fired.
March 1965	Centaur blew up, Noda and co. ran playbacks all weekend.
March 1965	Syncom. Fitzpatrick on ship.
9 April 1965	Comsat. Perfect orbit.
April 1965	Gray's group now a Division - no longer under Mazur.
May 1965	Fuller to Antigua for Delta shot.
June 1965	First American space walk.
1 July 1965	Delta shot.
Aug. 1965	Bottey and Fuller to Grand Turk for Gemini shot.
25 Aug. 1965	Delta failed to orbit.
Sept. 1965	Hurricane Betsy narrowly missed Cape.
Sept. 1965	New Mission Control Center operative. Pace working in there.
1 Oct. 1965	GSFC groups at Cape and PMR placed under control of newly established Kennedy Space Center. Gray to be an assistant director to Debus.
6 Nov. 1965	GEOS launch. NASA's Rosenberg to Rick: PSL saved my life with good data from shipboard and the San Marco stations: Arellano and Hankamer on the ship.
Dec. 1965	Helfrich to Ascension, Jimenez on ship for launch. Last trip downrange, per KSC.
Jan. 1966	GEOS-A launch.
27 Jan. 1966	Bottey and Brush to Key West Naval Air Station for Delta 36.
3 Feb. 1966	TIROS OT-3 Cape. NOTE: Lemon and crew tracked first pass over WSMR.
4 Feb. 1966	RSC lifted ban on downrange travel. Asset launch Cape. Sabin, Barnett, and Lindsay on Ascension for shot.

March 1966	OAO and Centaur both misfired at Cape.
5 April 1966	OAO misfired again!
27 May 1966	Delta 38. Wallops telemetry station recorded for about six minutes.
6 June 1966	OGO III on Delta.
12 Aug. 1966	Aldridge to Ascension to cover Pioneer launch scheduled for 17 Aug.
Sept.-Oct. 1966	Jimenez to Rio de Janeiro to install station on a United States ship. He served as interpreter between the USAF, Pan American Airways, and the Brazilians.
Dec. 1966	ATS launch Cape. Good orbit.
11 Jan. 1967	Comsat launch, good orbit.
Jan. 1967	NASA announced would fire no more Agenas. Will use Centaur instead.
Feb. 1967	Tragic Apollo fire.
31 March 1967	Prepping ATS and Surveyor.
13 Aug. 1967	Joe Matlock of Cape crew departed for Australia to cover Sept 7 BIOS re-entry.
27 Sept. 1967	Intelsat launch.
7 March 1968	Final Agena fired at Cape.
18 Dec. 1968	Intelsat launch.
6 Feb. 1969	Intelsat III (F-3).
25 Feb. 1969	Mariner-Mars 6. Success.
26 Feb. 1969	TOSG/Delta launch.
26 Feb. 1969	ESSA 9 launch.
27 March 1969	Mariner Mars 7.
22 May 1969	OV-5.
21 July 1969	Apollo 11 landed on moon. PSL crew got holiday.
9 Aug. 1969	OSO-6 successful.

Sept. 1969	5,000 people laid off at Cape.
Sept. 1969	Noda to Titan/Centaur school - shots coming up. To employ PCM telemetry.
31 Dec. 1969	Two Intelsats on schedule for Jan 70!

APPENDIX F

PMR Chronology

June 1962	Joe Schwartz of NASA placed in charge of GSFC group at PMR.
Aug. 1962	Wong PSL supervisor at PMR, Lemon at Wallops, Noda at Cape.
11 Sept. 1962	The FM/FM telemetry and Doppler ground stations were pronounced ready for business. Tests on the Alouette spacecraft (Canadian satellite) began the very next day!
29 Sept. 1962	Alouette launched into polar orbit by a Thor-Agena. This spacecraft utilized a unique antenna system consisting of a pair of crossed dipoles with one dipole 150 feet from tip to tip.
5 Nov. 1962	FM/FM station supported a Thor-Agena launch of a classified DOD satellite.
13 Dec. 1962	Injun 3 satellite (NRL/SUI). First few orbital passes were tracked and recorded.
Feb. 1963	Recorded telemetry and Doppler for an Air Force classified launch.
5 April 1963	Supported another Air Force shot.
April 1963	NASA is asking PSL for two men to operate Doppler station near San Diego to get fourth stage data during launch. We assembled a portable Doppler station in a van for this purpose.
9 May 1963	TRS 2, TRS 3 launched piggyback aboard Atlas-Agena. TRW study of radiation damage to solar cells.
May 1963	Tracked several passes of TELSTAR launched from AMR.
June 1963	NRL's SR 5 achieved orbit, first in series to succeed. Carried aloft by a BUCKSHOT piggy-back system which also launched NRL's LOFTI satellite.
July 1963	TRS 4 radiation satellite orbited.
Sept. 1963	Shaw to San Diego.
Oct. 1963	Recorded Doppler signal on a couple of DOD satellite shots.
Jan. 1964	PMR plans one Agena per month.

15 Jan. 1964	“NRL payload” launched, A-12 in preparation.
25 Jan. 1964	ECHO II launched into polar orbit.
April 1964	Group supervisor Frank along transferred to Cape.
May 1964	Jerry Cooper placed in charge of PMR group.
May 1964	PSL now operating hilltop van. Complete Doppler station, relay equipment, some telemetry. Joe Matlock in charge.
May 1964	Installation of Doppler station in San Diego van completed.
4 June 1964	Scout launch, DOD payload, good orbit, good data. Jerry Cooper’s first shot as supervisor. Charles Watkins to San Diego van.
June 1964	NASA plans to move Atlas and Titan launches to PMR in 1965.
July 1964	Supported two DOD Thor launches.
Aug. 1964	NIMBUS 1 and Explorer 20 (Scout) launches.
21 Nov. 1964	Two Scout launches on same day; Explorer 25 (Injun 4) radiation monitor and Explorer 24 air density satellite.
March 1965	Two launches, both in orbit. NASA lost track of one of them, PSL station found it for them!
Spring 1965	PMR added a 30-ft dish antenna to hilltop Doppler station.
Summer 1965	Labor unions at PMR found out PSL people were installing cables for the ground station. The union threatened to strike the whole base if we did any more of it.
2 Sept. 1965	Thor-Agena blew up over the base.
Fall 1965	PMR group very busy on POGO satellite and STL.
Sept. 1965	PMR group received first PCM/FM station - full of gremlins, no manual.
Oct. 1965	Agena launch. Agena had problems but good orbit. Good telemetry data.
Nov. 1965	Bendix G-15 computer added to ground station at PMR. PSL programmed, operated, and maintained it.

Nov. 1965	ISIS-X launch. First use of new PCM/FM station, good data.
Nov. 1965	Alouette and DMEA satellites launched. Tracked all passes of DMEA.
1 Jan. 1966	Gilcrease took over group from Cooper.
25 March 1966	Scout PMR, good shot.
April 1966	PSL crew now has full responsibility for microwave link and command transmitter.
21 April 1966	OV3 on Scout.
18 May 1966	Scout PMR, good shot.
2 June 1966	Begin checkouts on PAGEOS, a 100-ft. balloon.
24 June 1966	PAGEOS launch. Good orbit.
4 Sept. 1966	Townsend on ship for 3 to 6 weeks.
29 Oct. 1966	Delta 41. Good orbit. Townsend on ship, got good data.
Oct. 1966	PMR crew helped Air Force with telemetry recording on short notice. General very grateful (they'd been having problems with base telemetry stations).
20 Jan. 1967	Townsend on ship.
26 Jan. 1967	Delta 45. Good shot. Station tracked first pass.
20 April 1967	TOS-C launch.
24 April 1967	Townsend off on another cruise of 30 to 60 days.
5 May 1967	UK-E/Scout. Good orbit. PSL group commanded spacecraft "on" for first time.
Mid-1967	PMR group has both telemetry and Doppler stations, doing operation and maintenance on command transmitter, microwave link. PMR computer is a GE Mod 235 using Fortran language. It computed look angles for telemetry antenna tracking, orbital parameters, vehicle performance, winds, and debris fallout.
24 May 1967	IMP-F shot.

29 May 1967	ESRO II/Scout launch. Scout third stage exploded, no orbit.
28 July 1967	OGO launch. PSL crew tracked and commanded this satellite through 4 or 5 passes per day for two months.
24 Sept. 1967	Scout launch. NASA/PSL station backed up APL telemetry station - they lost it, we recorded for 800 seconds.
4 Dec. 1967	Scout.
Dec. 1967	NASA/PMR schedule for 1968 listed 12 major launches:
Jan. 1968	Townsend on ship again (Sampan Hitch) to cover a GEOS. The ship developed mechanical problems, returned to port for repairs, and headed out again. Another ship was also sent out from the Cape with Chowning aboard. But the GEOS launch was moved up a day, meaning that neither ship could reach the assigned location for receiving data. The two co-ops had a nice ocean cruise for naught.
11 Jan. 1968	GEOS-B.
4 May 1968	Townsend departed on Sampan Hitch to cover ESRO scheduled 10 May. Shot delayed, Sampan Hitch returned; Marvin Nuce went out on another ship.
13 May 1968	NIMBUS launch. Off course, had to blow it. 50 million bucks into the sea. PSL crew made dozens of telemetry playbacks to trace cause.
16 May 1968	ESRO. Good shot.
4 July 1968	RAE/Delta. Perfect orbit.
4 Oct. 1968	Scout launch.
15 Dec. 1968	TOS-F. Good shot.
26 Jan. 1969	Flood – 2 ft. of water in hangar where ground station housed; 3-4 ft. in NASA building.
13 April 1969	NIMBUS III launch.
June 1969	OGO shot.
21 June 1969	IMP-G success.

3 Oct. 1969	ESRO-1B. Low orbit.
7 Nov. 1969	Azur (GRS-A) shot. Good one.
Nov. 1969	Station got new computer.
5 Dec. 1969	TIROS-M arrived WTR. Scheduled for January.