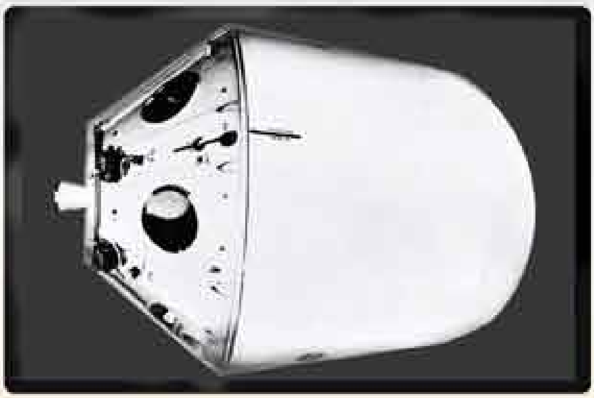
IN THE WORDS OF THOSE WHO SERVED



INTELLIGENCE REVOLUTION 1960:

RETRIEVING THE CORONA IMAGERY THAT HELPED WIN THE COLD WAR

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by Ingard Clausen & Edward A. Miller

Robert A. McDonald & Courtney V. Hastings, Editors

CENTER FOR THE STUDY OF NATIONAL RECONNAISSANCE

APRIL 2012

Center for the Study of National Reconnaissance

The Center for the Study of National Reconnaissance (CSNR) is an independent National Reconnaissance Office (NRO) research body reporting to the NRO Deputy Director, Business Plans and Operations. Its primary objective is to ensure that the NRO leadership has the analytic framework and historical context to make effective policy and programmatic decisions. The CSNR accomplishes its mission by promoting the study, dialogue, and understanding of the discipline, practice, and history of national reconnaissance. The CSNR studies the past, analyzes the present, and searches for lessons-learned.

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PREFACE FROM CSNR

Robert A. McDonald, Ph.D.

On 15 September 2005, I was walking down Pioneer Hall at the National Reconnaissance Office (NRO) headquarters in Chantilly, Virginia with newly inducted Pioneer of National Reconnaissance, Dr. Edward A. Miller. The then Director of the National Reconnaissance Office (DNRO), Dr. Donald M. Kerr, had just recognized Dr. Miller for pioneering the design, construction, deployment, and operation of the first man-made object to be recovered from earth orbit in 1960—the Corona Satellite Recovery Vehicle (SRV). The Corona SRV of August 1960 was going to be key to recovering photo satellite reconnaissance imagery that would provide critical intelligence during the Cold War. During that walk with Ed, he mentioned that, with the NRO having declassified the Corona program in 1995, he was interested in documenting the story of his contributions in a book. In fact, he told me he had done some preliminary writing.

On 20 September 2006, I had a similar encounter with Mr. Ingard M. Clausen, whom DNRO Kerr had just inducted into Pioneer Hall for Mr. Clausen's pioneering preliminary design and development of the Corona SRV. His contributions had laid the groundwork for the Corona system's ability to endure the harsh environment of space and withstand the heat of reentry into the earth's atmosphere. He had set the stage for Ed's later contribution to the Corona project. Independently Ed and Ingard had been talking about the earlier book idea, and Ingard told me he was willing to take the lead with the book project. I told the two of them that the Center for the Study of National Reconnaissance (CSNR) would have an interest in working with them on this project. The book would be consistent with the CSNR mission to advance the understanding of the discipline, practice, and history of national reconnaissance. In support of this mission, the CSNR is responsible for documenting the history of national reconnaissance, identifying lessons from that history for the future, and highlighting models of excellence in people and engineering as examples to emulate for future success. The book would help us do that. It is a collection of recollections and lessons from those who were national reconnaissance trailblazers.

When Ingard completed the manuscript, he took on the role of a CSNR Senior Scholar, and submitted it for publication. We accepted the manuscript, and the CSNR editorial staff has edited the manuscript and incorporated it into our publication style. However, we preserved the original first-person narratives and avoided the temptation to challenge recollections through documentary research. The recollections are from the perspective of the participants.

We are now pleased to publish this manuscript as the first book in a series known as, In the Words of Those who Served. This is a series of occasional CSNR publications that will collect the oral histories of those who served in the development and operation of various national reconnaissance activities, organize them into a collection of stories, and publish them to expand the understanding of national reconnaissance and provide insight that will offer lessons for future challenges in national reconnaissance.

I thank Ed for the inspiration for the book project, Ingard and Ed for their work on the book project, and the team of Corona trailblazers who contributed stories to the manuscript.

Robert A. McDonald, Ph.D.
Chantilly, Virginia
April 2012

PREFACE FROM INGARD CLAUSEN

Ingard Clausen

This book is a collection of first-person stories from the "Cold War warriors" who were in the "high-tech trenches" of space reconnaissance in the 1950's and 1960's. These are the people who developed the Corona film-return photoreconnaissance systems that brought back the secrets that helped win the Cold War. But they will tell you that they just were doing their jobs.

The first opportunity for any, unclassified acknowledgement and recognition of the Corona program was on 24 May 1995 when a joint Central Intelligence Agency (CIA)/U.S. Air Force (USAF)/ National Reconnaissance Office (NRO) planning committee, co-chaired by Joanne Isham (CIA), Col Phil Datema (USAF), and Dr. Robert A. McDonald (NRO), organized the 25th Anniversary Commemoration of the Corona program at CIA Headquarters to publicly honor the service and accomplishments of the Corona team. This unclassified event was possible because the Director of the National Reconnaissance Office and Director of Central Intelligence had approved the declassification of the program and its artifacts in late 1994 and early 1995, and President Bill Clinton had approved the declassification of Corona film in February 1995.

Shortly after the unclassified CIA event, and, by the grace of Ken Swimm (see his recollections in Chapter 21) and Joe Fanelli (Manger for Security for General Electric's Satellite Recovery Vehicle Corona Project)—and with some help from me—GE held a formal unclassified recognition ceremony for the SRV team. Other industry partners held similar recognition events for their Corona teams. Then in 2005, The National Academy of Engineering (NAE) presented a team of five engineers from across the Corona program (Minoru "Sam" Araki, Lockheed lead engineer for the Agena spacecraft; Francis J. Madden, Itek chief engineer of optical system's camera design; Don Schoessler, Kodak lead engineer for film design and production; Edward A. Miller, General Electric [GE] lead developer of the satellite recovery vehicle; and James W. Plummer, Lockheed program manager) from across the Corona program with The Charles Stark Draper Prize to recognize the Corona team's advancement of engineering.

The next occasion for even broader unclassified public recognition was with the start of this book when over fifty co-authors and helpers from the Corona project joined Ed Miller and me in getting involved. Now, the NRO's Center for the Study of National Reconnaissance (CSNR) has joined the project and agreed to publish this book. By doing so, broad public recognition is in sight. When the contributing authors of this book receive their copies, it will mark the first time that their children and grandchildren will see their fathers' and grandfathers' Cold War stories in print. And they will be able to share those stories with the general public.

Previous publications about Corona and early national reconnaissance have tended to focus on interviews with the top leadership in the organizations involved with the Corona project. This book is unique in that for the first time readers have an opportunity to hear directly from a wide range of those who were on the "high-tech firing line" of engineering, air recovery, and intelligence analysis. Corona was a very risky, "hush-hush" project. However, those involved were successful, and now they are telling their stories.

These "Cold War warriors" told their stories to our interviewers who recorded them and transcribed them. A few wrote down their stories. My collaborators and I edited the transcripts into a manuscript, which we submitted to the Center for the Study of National Reconnaissance (CSNR) at the National Reconnaissance Office (NRO) for publication. The CSNR was gracious enough to accept the manuscript and put it into their editorial process and publish it as a book as a part of their series, In the Words of Those who Served.

I was the first project manager for the Corona Satellite Recovery Vehicle (SRV) at General Electric (GE) Aerospace in Philadelphia, Pennsylvania. All of the recovery team members at GE owe thanks to Hilliard Paige, who was General Manager, GE Missile and Space Division. He persuaded the Air Force to adapt its technology in Intercontinental Ballistic Missile (ICBM) development flights to a film-capsule recovery system for the Corona satellite photoreconnaissance program. To do this, he showed photos that he recovered from his ICBM development flights of his three-axis stabilized Reentry Vehicles to shoot, reenter, and recovery photos of the earth to then President Eisenhower's Land Committee, which was exploring options for satellite photoreconnaissance and already was well on its way to making the decision to switch from radio transmission of images from orbit to the physical recovery of film from orbit. I believe Hilliard's presentation clinched the decision for a film-recovery system.

All of us in the Corona program owe special thanks to James W. Plummer (then Manager of Satellite Recovery Systems Development at Lockheed Missile & Space Company, and subsequently Lockheed's Program Manager for the Discover Space Program), M. Sam Araki (then a Systems Engineer at Lockheed Missile & Space who pioneered the development of the Agena Spacecraft), and then Col Lee Battle (who directed the government-contractor team that produced, launched, and operated Corona). These pioneering individuals overcame huge odds in attaining Corona successes. I say they snatched "victory from the jaws of defeat," and are some of the best examples of Corona heroes.

Closer to home, I must thank Ed Miller, the GE SRV Project Manager after me who first brought back film from orbit. I also thank him for initiating this book project and for his guidance, chapter contributions, and for his other numerous recollections woven into the body of the book.

My collaborators in preparing the manuscript have been Bob Kirby and Bob Peck, (both deceased at our publication) and at times, Jim Polski and Greg Williams, and, at all times, Dan Rossman. My remarkable interviewers were Raquel Hendrickson, an award-winning reporter and Managing Editor for Verde Valley Newspapers, and Elizabeth Goldman, who worked on a previous space reconnaissance book. Without their help, this book would have few oral histories. Two "high-tech guys" helped me with the manuscript—Richard Belcastro with Adobe Photoshop and Jere Hock with Adobe Illustrator. Finally, Doug Chamberlin, son of GE's own Bob Chamberlin who was the technical leader of the SRV and a contributor to this book. Doug volunteered to copyedit the manuscript as I was developing it. Like his father, he manages and integrates technical solutions and sometimes solves problems outside his specialty. He currently supports a team of epidemiologists, pursuing drug safety studies.

I thank Dr. Robert A. McDonald (Director of the CSNR) and his team at CSNR, who accepted our manuscript, put it into their editorial process, and made it possible for us to document—in a public way—the very important stories about how we were able to bring back from space secrets about the Cold War.

I particularly need to thank all forty-two of the "high-tech Cold War warriors" who contributed their stories to this book. It is hard for me to believe that Lt Col Harold Mitchell (Ret.), the pilot who flew the C-119 airplane that air-snatched the film capsule from Corona flight 14, a world's first, was available and volunteered to tell us how it was done. He provided us with an astonishing narrative of his adventure.

David Doyle was the National Photographic Interpretation Center (NPIC) officer who interpreted the film that Mitchell air-snatched, another world's first. It is easy to forget that this initial space imagery, compared with airborne reconnaissance imagery, had reduced resolution and expanded the footage by orders of magnitude. You will read about this challenge in processing and interpretation in Dave's chapter.

Dino Brugioni, another NPIC officer, shares his account of a meeting with President Dwight D. Eisenhower where the President is briefed on the intelligence of the Corona imagery. Dino was there when the President was able to conclude, "There was no missile gap." Then, suddenly, those who had the necessary security clearances knew that our cities and ICBM installations faced far less of a threat with the Soviets only having six operational ICBM systems.

Finally, I need to acknowledge my family's support. First, I thank my daughter, Kendra Clausen, who has been working full-time for me, writing, editing, and inserting photos and captions into the manuscript. If you want to know the truth, she is also my office manager. My lovely wife, Doris, has assisted my efforts since 2006, and we have been at it ever since. She is the one, in 1960, who wanted to build a bomb shelter as part of our basement in King of Prussia, Pennsylvania. Defying the GE Blue Book rules; I had to give her a direct order, an assertive, unsupported, "No." The successes of the storytellers in this book helped make it unnecessary to build that shelter.

Ingard Clausen
Paradise Valley, Arizona
April 2012

FOREWORD

The ballroom at the Crowne Plaza Hotel in King of Prussia, Pennsylvania was filled with some 450 alumni from General Electric (GE). It was the 10th of October in 2006. They were celebrating GE coming to the Delaware Valley back in October 1956 as GE's Missile and Ordnance Systems Department.[1] They called the celebration, "The Golden Anniversary of Space in the Delaware Valley." I had the honor of speaking to this impressive group of space trailblazers and their families.

Ed Miller, one of those alumni, had invited me to "give one of the keynote talks." Ingard Clausen was in the audience. These two distinguished GE space alumni were the forces behind creating this book. They collected and co-edited the recollections of those who served during the earliest years of space reconnaissance. (The other two co-editors to this book merely are observers and students of national reconnaissance from the National Reconnaissance Office's Center for the Study of National Reconnaissance.) Ingard and Ed personally know almost all of the contributors to the book.

Because of Ingard and Ed's GE association and involvement with the satellite recovery vehicle (SRV) that GE developed for the first photo reconnaissance satellite, Corona, a large number of the accounts in this book are by GE alumni who worked on the SRV. The Corona program, however, involved many other industry and government partners. The team was diverse. It included participation from such legacy industry partners as Lockheed Missiles & Space, Eastman Kodak, Itek Corporation, Fairchild Camera & Instrument, and Douglas Aircraft. And it was a government program managed by the Central Intelligence Agency (CIA) and the U.S. Air Force.

Ingard Clausen and Ed Miller, who drew from their personal experiences in the Corona program, were able to expand the scope of the book and collect recollections from non-GE participants in the Corona program—from both the government side and other industry partners. You will find recollections from CIA officers, uniformed Air Force personnel, and Lockheed.

Ingard and Ed, and their contributors to this book, lived during the pioneering days of space reconnaissance in the 1950s and 1960s. It was a time when many said it would be impossible for human kind to get into space; others admitted humans would be able to launch a rocket into space, but denied it would be possible to take pictures from space—too much radiation, no gravity, too far away from earth's surface, no way to get the pictures back to earth. Ingard, Ed, and the contributors to this book proved all that speculation to be wrong.

The GE alumni I addressed during the 2006 celebration were instrumental in developing the satellite recovery vehicle that brought back from space the intelligence secrets that Corona's on-orbit camera captured. Many of the GE contributors to this book were in the audience at the GE alumni Golden Anniversary celebration. This book is their opportunity to respond to my retrospective look

[1] James (Jim) R. Polski, one of the organizers of the Golden Anniversary reunion, shared his recollections of GE's organizational history in the first decade of GE space in the Delaware Valley. In 1956 GE appointed George Metcalf to head the Missile and Ordnance Systems Department (MOSD). In September 1958, GE renamed MOSD the Missile and Space Vehicle Department (MSVD) and appointed Hilliard W. Paige (a contributor to this book) as the General Manager. In June 1962, GE elevated MSVD to Division status, and designated it as GE's Missile and Space Division (MSD). In 1968 GE promoted H.W. Paige to Aerospace Group Executive and appointed Mark Morton (a contributor to this book) as the head of MSD. In June 1969, Mark Morton took over the Aerospace Group, and GE redesignated MSD as the Space Division (SD), and appointed Dan Fink to lead it. This first decade of GE Space in the Delaware Valley is the period that covers the events in most of the stories in this book.

at their contributions.

All those who contributed recollections to this book, both industry and government, were the trailblazers in national reconnaissance. They were responsible for making satellite imaging reconnaissance possible and for crafting the discipline and practice of national reconnaissance. Their stories document that journey.

By reading their stories, you will have an opportunity to relive the history of that time and learn the lessons that these trailblazers learned along the way. Those lessons are ones that you can use for space engineering challenges you might encounter today and in the future; they also are lessons that often are applicable to any life experience.

It was humbling for me to speak to that 2006 audience of GE space alumni. The GE alumni boast of four individuals who received the highest honor in the discipline of national reconnaissance—that of being designated a Pioneer of National Reconnaissance. Ingard Clausen and Ed Miller are two; Mark Morton and Edward Reese are two others. One of Lockheed's several pioneers of national reconnaissance, Sam Araki, also is a contributor to this book.

Pioneers of National Reconnaissance are a very select and distinguished group of individuals whom the Director of National Reconnaissance (DNRO) annually selects and honors with this designation. They are the ones who have created the discipline of national reconnaissance and over the years have made contributions that have changed the direction and scope of the discipline.[2] They were able to do it only because of the team that supported their projects. In this book, many of those team members tell their part of the story.

In the fall of 2011, five years after the GE alumni celebrated their Golden Anniversary in space, the National Reconnaissance Office (NRO) celebrated its 50th anniversary at a gala held at the Udvar-Hazy Center of the National Air and Space Museum. Many of those GE alumni from Valley Forge made the trip to Northern Virginia and attended the NRO Gala along with other national reconnaissance alumni—both Government and industry—from the earliest days of the discipline. All those early alumni at the Gala—and those who could not be there—were the foundation for the establishment of the discipline and the NRO. It was they who laid the foundation for the NRO's follow-on film-return photo satellite reconnaissance programs such as the Hexagon broad-area search and Gambit high-resolution satellites that the NRO operated during the 1960s through 1980s.

In this book you have an opportunity to read first-person narratives from a select group of those who were there at the start of national reconnaissance—those who were there to develop and operate the Corona program. If you were there, I offer you the opportunity to reminisce about those "golden years." If you were not there, I challenge you to relive the experiences of our story tellers, learn from their experiences, and blaze your own trails into the next revolutions in space and intelligence.

Robert A. McDonald, Ph.D.
Director/Center for the Study of National Reconnaissance
Business Plans and Operations
National Reconnaissance Office
Chantilly, Virginia
April 2012

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2 For a collection of the recollections of the first class of pioneers of national reconnaissance, see the NRO Center for the Study of National Reconnaissance's (CSNR's) book, *Beyond Expectations—Building an American National Reconnaissance Capability: Recollections of the Pioneers and Founders of National Reconnaissance* cooperatively published in 2002 with the American Society for Photogrammetry and Remote Sensing (ASPRS).

INTRODUCTION

Robert A. McDonald, Ph. D.

The recollections and stories in this book are about ground-breaking engineering contributions and technical intelligence operations from the 1960s—contributions and operations that may be the 20th century's most dramatic revolution for foreign intelligence—satellite reconnaissance. The engineers, pilots, and crews whose stories are in this book were trailblazers and pioneering contributors who made possible the collection and recovery of photographs acquired from orbit around the Earth. Their work ensured the availability of space-acquired reconnaissance photographs for analysis by intelligence officers on the ground. They all were involved with some aspect of the then highly classified Corona Satellite Photoreconnaissance program—one of several Cold War space reconnaissance programs. These programs, in their success, created an appetite and dependency on satellite photoreconnaissance in America. The success of the programs led to a desire for more, better quality, and more readily available imagery. This imagery, and in turn the space reconnaissance programs that provided it, helped win the Cold War for the U.S. and its Western Allies. The National Reconnaissance's Office (NRO's) Gambit high-resolution photographic system (that operated from July 1963 to April 1984) and its Hexagon broad-area search photographic system (that operated from June 1971 to April 1986) are examples of two other national reconnaissance platforms that provided intelligence that helped win the Cold War. The ground-breaking work of the story tellers in this book laid the foundation for developing those systems.

The Corona Satellite Photoreconnaissance Program

The Corona program was a 1960s era joint Central Intelligence Agency (CIA)-U.S. Air Force (USAF) intelligence project that involved taking space-based overhead photographs during the Cold War (McDonald, 1997). It acquired photographs on traditional film while on orbit, ejected the film from orbit for return to Earth, recovered the film as it re-entered the atmosphere, processed the film at ground-based processing facilities, and made the processed film available for photo interpretation by intelligence officers. Its main intelligence target was the then Soviet Union and other denied territories of the Cold War period. "Corona" was the classified program name for this project, and its space vehicles were the world's first space imaging satellites.[1]

How Did Corona Operate?

A Corona satellite, with its KH-1, 2, 3, or 4 camera payload, would orbit the earth at about 100 nm, take pictures of high-priority intelligence targets, store the exposed film in an on-board capsule, and periodically deorbit a capsule with the exposed film. The USAF would deploy recovery aircraft over the Pacific Ocean where the capsule would return to earth near Hawaii. The recovery aircraft (initially C-119s and later C-130s) would snatch the capsule as it was drifting to earth under the control of a parachute. The aircrew would send the exposed film to Kodak and USAF facilities for processing and then to the Central Intelligence Agency's National Photographic Interpretation Center for imagery analysis (which the military then called photo interpretation, and the Intelligence Community called

1 The CIA and the Air Force launched the first successful Corona mission on 18 August 1960. The Grab electronic intelligence (elint) satellite reconnaissance system, which the Naval Research Laboratory (NRL) launched two months earlier in June 1960 was the first space reconnaissance satellite.

"exploitation"). The imagery analysts would exploit the film by examining it through high-powered optics on light tables looking for intelligence about the Soviet and other Cold War threats to U.S. national security (McDonald, 1995).

The Corona project was one of the most guarded secrets and highest priority national security projects during the late 1950s and 1960s. It was President Dwight D. Eisenhower, a World War II military hero who understood the significance and necessity of accurate information in battle, who gave his personal endorsement for the program in 1958. The Corona project operated from 1960 to 1972, and the quality of its imagery improved significantly over the life of the program from the earliest KH-I camera to the later KH-4B camera. The KH-4B camera, offered the best quality imagery—somewhat better than 6 feet (2 meters) (McDonald, 1995).

The Corona project was a revolution for intelligence. It expanded imagery intelligence activities from airborne platforms at altitudes of hundreds to thousands of feet above the earth's surface to space-borne platforms at orbital altitudes around the earth. Corona, as the world's first operationally successful space-based imaging system, had a major impact on America's national security (McDonald, 1995).

Corona's Contributions to National Security

Corona made major contributions to America's national security. Its earliest operations had a surprising impact on the Cold War debate about a perceived missile gap—about whether the Soviets had an overwhelming number of intercontinental ballistic missiles. Contrary to conventional wisdom at the time, Corona imagery resolved the issue by making it clear there was no missile gap. The intelligence from the Corona program eventually gave U.S. policy makers confidence in the Intelligence Community's assessments and opened the door to monitoring nuclear proliferation and arms control from space and lent support to arms limitation treaties (McDonald, 1995).

Corona's vast contributions to helping protect American's national security are evident by looking at examples of the kinds of intelligence it provided over its operational life. Not only were early photo interpreters able to use Corona imagery to demonstrate that the Soviet Union did not have an overwhelming number of intercontinental ballistic missiles, but later photo interpreters used Corona imagery to monitor nuclear proliferation. There were additional unique contributions during the program's operational life. In December 1961, Mission 9029 provided the first satellite coverage of a Chinese nuclear test site, which was located near Lop Nor. By 1964, Corona imagery had confirmed that the Soviet Union was developing and deploying the SS-9 Intercontinental ballistic missiles. (The SS-9 was a "mammoth" ICBM, some 10 stories high, with an ability to carry a payload of nearly 9,000 pounds for a distance of 7,000 to 8,000 nautical miles.) This nuclear threat was a dominating part of the geopolitical backdrop of the period (McDonald, 1995; Missile Threat, 2011).

The 1950s—The Geopolitical and Societal Backdrop for Developing Corona

The 1950s were the formative years for the engineers, pilots, and crew members who developed and operated Corona during the following decade. They found themselves recovering from both World War II and the Korean War; they were exposed to what must have appeared to be an uncertain and potentially threatening Soviet Union. I believe it is important to know something about this geopolitical environment when you read their stories. Insight into their geopolitical environment will help you gain a sense of the time in which they were living. It will help you understand their motivations as engineers, pilots, and crew members. I will use this section to summarize some of the geopolitical realities of the 1950s.

Geopolitical Backdrop

The 1950's opened as a decade that was seeking normalcy and peace after the six years of world-wide conflict in the 1930s and 1940s. As the country moved from the 1940s post-war recovery of World War II into the 1950s, the international scene was becoming tense. Winston Churchill had alerted the world community in 1946 that an Iron Curtain had descended in Europe and separated the west from the east where the Soviet Union's influence and control was becoming absolute as Communism spread beyond the its borders. Bernard Baruch in 1947 had announced that a Cold War actually existed between the United States and the Soviet Union.[2] It became increasingly apparent to observers that there was a growing threat of nuclear annihilation.

World War II ended in 1945 when the U.S. used the atomic bomb in its raids on Hiroshima and Nagasaki. In 1949, the Soviets joined America as a nuclear power with its successful test of an atomic bomb. This influenced President Truman to direct U.S. development of a thermonuclear bomb—one powered by fusion, rather than fission. On November 1, 1952 the U.S. successfully detonated "Mike," the first hydrogen bomb, which exploded with a force 500 times greater than the atom bomb that destroyed Hiroshima, Japan in 1945. It vaporized the Pacific island of Elugelab (Evans, 1998; Glennon, 1999; Long, 2007).

Less than a year later, the Soviet Union detonated is own thermonuclear device on August 1953. By the end of 1954 both sides successfully had tested deliverable bombs. It was in the second half of 1957, in August, that the U.S. lost its sense of invulnerability to nuclear attack when the USSR successfully tested the world's first intercontinental ballistic missile (Evans, 1998; Glennon, 1999; Isaacs, J. & Downing T., 1998; and Long, 2007).

All of this made the image of worldwide nuclear destruction vivid and created a sense of doom that would influence how the Cold War would unfold. Americans prepared for the worst. Black and yellow Fallout Shelter signs began to appear in American cities and towns where areas in buildings were designated as fallout shelters for use during a nuclear attack. The U.S. Office of Civil Defense issued booklets on family fallout shelters, and the reality of devastating nuclear destruction made them popular in the U.S. (Glennon, 1999; Isaacs, J. & Downing T., 1998; and Isaacs & Taylor, 1998).

Communities conducted monthly tests of sirens and horns that would be used as warnings in the event of an attack. School children throughout the country practiced "Duck and Cover" drills where they would duck under their desks or move to the hallways and huddle on the floor with their hands over their heads to protect from nuclear attack (Glennon, 1999; Isaacs, J. & Downing T., 1998; Isaacs & Taylor, 1998).

Many analysts would describe the Cold War, as the defining experience of the second half of the twentieth century (Kort, 1998, p. 3). It grew out of the destruction of World War II and involved many nations, but it fundamentally was a power struggle between two military super powers—the United States and the Soviet Union—both of whom commanded massive nuclear arsenals that gave the

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2 On March 5, 1946 the former British prime minister, Winston Churchill introduced the phrase "Iron Curtain" into the international lexicon during a speech at Westminster College in Fulton, Missouri, when the college presented Churchill with an honorary degree. Churchill stated, "From Stettin in the Baltic to Trieste in the Adriatic an iron curtain has descended across the Continent. Behind that line lie all the capitals of the ancient states of Central and Eastern Europe. Warsaw, Berlin, Prague, Vienna, Budapest, Belgrade, Bucharest and Sofia; all these famous cities and the populations around them lie in what I must call the Soviet sphere, and all are subject, in one form or another, not only to Soviet influence but to a very high and in some cases increasing measure of control from Moscow" (Halsall, 2010).

On April 16, 1947, the financier and presidential advisor, Bernard Baruch, coined the term "Cold War" in a speech to the South Carolina House of Representatives on the occasion of the unveiling of his portrait. Baruch warned, "Let us not be deceived—we are today in the midst of a cold war. Our enemies are to be found abroad and at home (A&E, 2010).

Cold War its apocalyptic dimension (Kort, 1998).

It was out of this nuclear potential that information about adversaries—i.e., intelligence about the threat—became essential to national survival. Both nation state and personal survival were core concerns during the Cold War. Intelligence about threats to that survival were an integral part of the core ideological conflicts of the Cold War. That is why the stories in this book—stories that explain how the United States was able to create a photosatellite reconnaissance capability—are fundamental to understanding how this reconnaissance capability was a pivotal contribution to the U.S. winning the Cold War and preserving its society (Kort, 1998).

At times, the Cold War was more hot than cold, as in Korea and Indochina; at times it was covert, as in Iran; and at times it was reflected in popular uprisings and revolutions.

Korean War

The harsh realities of the Cold War became apparent early in the decade when American and "free-world" forces encountered Soviet and "Red Chinese" Communist forces in what Americans saw as remote lands. The first of these was the outbreak of the Korean War on June 25, 1950 when the Soviet-equipped North Korean Army crossed the 38th parallel from The Democratic People's Republic of Korea (North Korea) into the Republic of Korea (South Korea). President Truman ordered U.S. forces—under then 70-year-old World War II hero General Douglas MacArthur—to defend South Korea and support the United Nations "police action" on the Korean peninsula. His invasion of North Korea, which pushed Communist forces to the Chinese border, resulted in China deploying 180,000 of its troops into a counteroffensive. The war ended three years later on 27 July 1953 with the parties signing an armistice. The causalities were high with total American military deaths at just over 54,000 (over 33,000 on the battlefield). South Korean military deaths were at 47,000; North Korean at 215,000, and Chinese ranging from 401,000 to 3 million (Glennon, 1999; Evans, 1998).

IndoChina

The force of nationalism grew during the 1950s throughout the world as the populations in former colonies called for self-determination. The weakened European powers found it difficult to maintain control over existing colonies or regain control over their former colonies in Africa, South Asia, and Southeast Asia. The end of Japan's wartime occupation in Asia found this particularly strong in that region, especially in Southeast Asia (Glennon, 1999).

In Vietnam, the Viet Minh (a collation of mostly Communist forces organized by Ho Chi Minh who had declared the independence of the Democratic Republic of Vietnam in September of 1945) defeated the French on 7 May 1954 after an eight-year war. This French attempt to retain its influence and control over its former pre-WW II colony resulted in 95,000 French and 1.3 million Vietnamese deaths. The French agreed to a cease-fire and temporarily divided Ho Chi Minh's Democratic Republic of Vietnam at the 17th parallel with provisional Communist control of the north and a provisional French-backed government in the south (Glennon, 1999).

This 1954 Geneva Convention set the stage for the U.S.'s involvement in what became known as the Vietnam War. The agreed elections for a unified government failed to occur, and the south declared itself the independent Republic of Vietnam in October of 1955. In 1961 President Kennedy sent military advisers into the Republic of Vietnam (South Vietnam). In March 1965, President Johnson sent what is commonly acknowledged as the first U.S. combat forces into Vietnam. This was in response to a clash between U.S. and North Vietnam naval forces in the Gulf of Tokin on August 1964. In response to the clash, Congress passed the Tokin Gulf Resolution that gave President Johnson the authority to employ military force as he saw fit against the Vietnamese Communists. The U.S.

withdrew its forces after the 1973 Paris Peace accords, and evacuated Saigon in April 1975 when Communist forces captured Saigon and reunified the nation (Marolda, 2005; State, 2011).

Covert Action

The Cold War had U.S.-sponsored covert actions. The CIA's role in the overthrow of Iran's government in August 1953 is one example. After Irannian legislators, led by premier Muhammad Mussadegh nationalized British-owned Anglo-Iranian Oil company, and the situation in Iran appeared to be deterioting, President Eisenhower approved CIA covert action that included inciting unrest and promoting a military revolt. The end result was Muhammad Reza Shah Pahlevi taking over the government with absolute power as Shah of Iran (Evans, 1998; Glennon, 1999).

Popular Uprisings in Eastern Europe

The 1950s also saw pockets of unrest in Eastern Europe. The first popular revolt against Soviet influence was in June 1953 when some 3,000,000 East German workers walked off their jobs. What initially was a labor demonstration turned into a pro-democracy demonstration and riot. The Soviet Government sent tanks into East Berlin to squash the riots, and about 21 people were killed and over 6,000 were arrested (Glennon, 1999; CIA, 2008).

Cuban Revolution

The end of the decade found communism taking hold in the Western Hemisphere. In 1959 Fidel Castro's revolutionaries overthrew the Batista regime and took control of Cuba. Initially what Castro and his supporters called an "olive green" or nationalist revolution: "Cuba for Cubans," Castro eventually declared it to be Communist. By the early 1960s the U.S. severed diplomatic relations and imposed a trade embargo (Glennon, 1999).

Impact of Geopolitical Realities

The geopolitical developments of the post-World War II days of the 1940s and the evolving Cold War days of the 1950s demonstrated a clear need for timely and accurate intelligence about an emerging world-wide threat. There was a need for a capability to collect global intelligence. It was this sense of urgency that the actors in our stories found themselves thrust. The U.S. national security establishment knew that a new intelligence capability was essential if the U.S. was to acquire the intelligence it needed for its survival in the ideological and military hostilities of the Cold War. This created a sense of urgency to develop such a capability that would provide U.S. leadership with knowledge of the emerging Sino-Soviet threat—a capability that many saw as essential to American survival—a capability that would become the Corona space reconnaissance program.

The people who developed this revolutionary space reconnaissance capability were not only influenced by the geopolitical environment, but they also were products of mid-20th century American society—more specifically the decade of the 1950s. The 1950s was their preparatory decade when society formed who they would become, the decade that created the tools that they would have to work.

American Society in the 1950s

The post World War II period brought the 1950s an explosion in population and an expansion in the economy as ex-G.I.s returned home from World War II and the Korean War. National output had doubled between 1946 and 1956, and personal income almost tripled between 1940 and 1955. There was a new middle class that made up 60 percent of American families with a baby-boom birth rate rising from 15 per thousand in 1946 to a peak of 25 per thousand as the country moved into the 1950s. Home building exploded into new suburban communities like the Levittowns in New York and Pennsylvania. On Long Island, Bill Levitt built thousands of houses more quickly and cheaply than anyone had been built before to create his middle-class community in Long Island's Levittown, 20 miles from New York City. He sold a two-bedroom houses for $6,900 with no down payment for veterans. In four years he built 17,447 houses on 6,000 acres of potato fields. This is the offsetting in the 1950s (Evans, 1998; Glennon, 1999).

This American society of the 1950s formed the content of the stories and autobiographic reflections you will find documented in this book. Knowledge of that society will give you, the reader, insight into the nature of that society. This understanding will help you put the stories and story tellers into a context that should help you better appreciate what they have documented in their stories. What I have outlined in this section also will give any readers who lived through that decade, some prompts to reminisce about their very different world.

In the balance of this section I will highlight the dynamics of the 1950s domestic scene, the content of the popular culture, the activities of leisure time, and the limitations of the scientific and technological environment. It is out of this that you should better understand who Corona's trailblazing innovators were.

Dynamics of the Domestic Scene

The domestic scene saw a changing political landscape, Communist espionage, the "Red Scare," the emergence of a civil rights movement, and a growing presence of religion in society.

Politics. The decade's domestic political landscape opened with Democrat Harry Truman as president. But political control of the White House changed. With a promise to end the Korean War, retired World War II General Dwight D. Eisenhower won the 1952 presidential election and kept the White House for the Republicans for the rest of the decade. His vice president was former California senator, Richard M. Nixon, a politician with a reputation as a strong anti-Communist crusader (Glennon, 1999).

Espionage. As the 1950s began, Soviet spy cases were breaking in the U.S. and around the world. Donald Maclean, the former head of the Chancery at the British embassy in Washington, disappeared from London in 1951 when British authorities were about to arrest him as a top Soviet spy; he later showed up in Moscow in the mid 1950s. Also in 1951, a U.S. court convicted Ethel and Julius Rosenberg of espionage for the crime of giving the Soviet Union the design of the American atomic bomb. The trial judge Irving Kaufman remarked that when the Rosenbergs did that, they had encouraged communist aggression in Korea, and their crime was "worse than murder." He sentenced them to death (Glennon, 1999).

The "Red Scare." With Soviet espionage activities materializing and the communist influence expanding into Eastern Europe and Asia, the United States found itself in the midst of what was called a "red scare." Congress had passed the McCarran Act that required Communist and Communist front groups to register with the Attorney General; the Truman administration investigated federal employees for Communist tendencies; the House Committee on Un-American Activities investigated Communist influences; and individuals—especially those in the entertainment industry—and who had current or past Communist associations found themselves on black lists making it difficult to find employment. In 1950 Senator Joseph McCarthy announced that Communists had infiltrated the State Department. Later he accused the Army of harboring spies. McCarthy served as chair of the Senate Government Committee on Operations and a Senate investigatory subcommittee.

During a four-year period he conducted investigations (with publicly televised hearings) of alleged Communist infiltration. McCarthy's aggressive and public inquiries ended with the Senate censuring him (Glennon, 1999; U.S. Statute, 1950).

Civil Rights. The 1950s saw the beginning of a strong civil rights movement that set the stage for the landmark 1964 Civil Rights voting Act. Many students of history see the beginning of the movement being 1 December 1955 in Montgomery, Alabama, when a 43-year-old African-American seamstress, Rosa Parks, refused to give up her seat to a white man. A local ordinance barred African Americans from the front of the bus and required them to give up their seats in the middle of the bus to any white person standing on the bus. Her actions resulted in a year-long bus boycott, and subsequently the Supreme Court ruling that all bus segregation was unconstitutional. The leader of the boycott was then 26-year old Reverend Dr. Martin Luther King, Jr. (Evans, 1998; Glennon, 1999).

In 1954 the Supreme Court decreed an end to school desegregation. But integration did not come that easy. Toward the end of the decade in 1957 there was a confrontation at Central High school in Little Rock Arkansas. A federal judge ordered Arkansas Governor Orval Faubus to permit nine African-American students to enroll in the all-white high school. Faubus refused and directed the National Guard to seize the school and block the enrollment. The situation got out of control, and President Eisenhower nationalized the guard and deployed the 101st Airborne Division to calm the situation and protect the students. The result was a gradual peaceful desegregation of the school (Evans, 1998).

Religion. There were religious leaders who became popular and dominant forces in the 1950s. Baptist preacher Billy Graham began a weekly radio program, *Hour of Decision*, in 1950 and later televised his revival meetings. He went on to become one of the most influential evangelists during the latter half of the century becoming a visible religious adviser to Presidents. Norman Vincent Peale (a minister of the Reformed Church of America) published *The Power of Positive Thinking* in 1952, which became a bestselling book. Fulton J. Sheen, a Roman Catholic bishop, was the popular host of a TV program,"Life is Worth Living," a program where he preached to both Catholics and non-Catholics. The show drew some 10 million viewers each week, and in 1952 won an Emmy Award for most outstanding TV personality (Glennon, 1999).

The shadow of World War II and Nazism continued to haunt the religious thinking of Christians, especially Protestants. The debate into how the horrors of Nazism could take place in the basically Christian country of Germany became focused in 1951 with the posthumous publication of German Pastor Dietrich Bonhoeffer's book, *Prisoner of God: Letters and Papers From Prison.* Bonhoeffer had helped found an underground church that smuggled Jews out of Germany. When the Nazis linked Bonhoeffer to a plot to kill Hitler, they hanged him in 1945 (Glennon, 1999).

Content of the Popular Culture During the 1950s

Popular culture of the 1950s saw the emergence of fast food, the explosion of rock and roll music, and the influence of war themes in the popular culture.

Fast Food. The birth and growth of the nation's love of fast food is best symbolized by what would become the world's most famous hamburger. Midway through the decade Ray Kroc persuaded the owners of a California roadside restaurant, Richard and Maurice McDonald, to open a McDonald's franchise in a Chicago suburb and to license the roadside restaurant national wide. That he did and so grew McDonald's golden arches with its standardized hamburgers, fries, and milk shakes (Glennon, 1999).

Music. Rock 'n' Roll music—which had evolved out of rhythm-and-blues and country-and-western music—became popular by the mid 1950s with Elvis Presley leading the way as the most influential rock 'n' roller. He released "Heartbreak Hotel," his first number-one popular hit in 1956 (Glennon2, 1999). Harry Belafonte brought Caribbean-style calypso music onto the popular mainstream during the decade. His "The Banana Boat Song (Day-O)" was on the top of the musical charts for 31 weeks in the mid 1950s. The decade ended with a plane crash that took three lives from rock 'n' roll's first wave of creativity: Buddy Holly, J.P. "Big Bopper" Richardson, and Richie Valens. Valens was the first Mexican-American to enter into rock stardom with his "Donna" and "La Bamba" recordings (Glennon, 1999).

War Themes in Culture. The late 1950s saw the debut of Charles Schulz's *Peanuts* comic strip with insecure Charlie Brown and his daydreaming dog, Snoopy. Snoopy fantasized about fighter pilot dog fights with the World War I Red Barron. But the Cold War of the 1950s was becoming a growing theme in popular culture. Writer Ian Fleming introduced secret agent 007, James Bond, in his 1953 novel, *Casino Royale*. Fleming wrote a series of bestselling 007 novels, and the stories found themselves in a number of what became very popular movies. Even though Fleming had been a World War II British naval intelligence officer, his fictional Bond episodes were mostly fantasy stories of the personification of Good battling Evil, with 1950s sex appeal very much a part of the spy stories (Glennon, 1999).

Leisure Time Activities in the 1950s

Leisure time was becoming a part of everyday life, and Americans began to look to movies, sports, radio and television for diversion and relaxation—distractions from the Cold War and Communism.

Movies. The popular movies of the decade included: *High Noon* (Grace Kelly and Gary Cooper)—a western story about a marshal who risked his life to save the town on the day of his retirement and wedding; *The Bridge on the River Kwai*—a fictional World War II story of Japanese captors forcing British POWs to build a railroad bridge; and at the end of the decade: *Some Like It Hot*—a sex farce about two jazz musicians who are pursued by mobsters after witnessing Al Capone's St. Valentine's Day Massacre and dressing as women (Castro, 2002; Glennon, 1999).

Sports. Baseball was the popular sport of the decade, and the New York Yankees was the top team most of the 1950s. The decade opened with two stars joining two New York teams— African American, Willie Mays, joined the New York Giants; and Mickey Mantle (of English, Dutch and German heritage) joined the New York Yankees. Over their career these two players went on to hit a combined 1,196 home runs (Castro, 2002; Glennon, 1999).

Radio. Radio was in a transition between the 1950s and 1960s. It was becoming a source for playing and promoting popular music. The 1950s was the beginning of the farewell to the golden age of radio with its comedians like Jack Benny and dramatic presentations like, *The Shadow*, *The Lone Ranger,*and *Superman*. These kinds of programs were fading, and radio was becoming a common soundtrack for "rock and the pop, the deejays and the news, the all-night talkers and the FM fringe." For example, New York radio station WABC, broadcasting on 770 kHz, was the base for "Cousin Brucie" (Bruce Morrow), a highly popular deejay who promoted popular music on the 50,000 watt station that covered over 35 states on the East Coast (Fisher, 2007).

As radio was fading television was emerging, but radio still was a large part of how the generation of the 1950s got to be who it became. Radio was at its peak and had turned popular culture away from its tradition of writing and reading back to "the roots of human communication: voice and listening." In 1949 *Life* magazine asked "Is Radio Doomed?" With the advent of television, it seemed so at the time (Fisher, 2007).

Television. Television was coming to age as the decade began and was, in fact, replacing radio as the focus of home entertainment. In 1950 there were 3.9 million TVs in the U.S. The number of TV stations went from 97 in the 1940s to 550 by 1953. By 1955 there already were 30.5 million. By the end of the decade, TV was beginning to have a major influence American society. Television news was bringing the American public face to face with distant international events and the realities of the Cold War. Television also was raising the public's awareness of the emerging space age. Both are factors that came to reinforce interest and commitments to national reconnaissance from space (Evans, 1998; Fisher, 2007; Marling, 1994).

The decade opened with vaudeville and radio stars recycling into TV: Groucho Marx, Bob Hope, Jack Benny, George Burns & Gracie Allen, and Jimmy Durantee. Variety shows took the lead. *New York Daily News* columnist, Ed Sullivan emceed the *Toast of the Town* variety show; son of a circus clown, Red Skelton, hosted *The Red Skelton Show* comedy-variety show; Comedians Sid Caesar and Imogene Coca were the leads on *The Show of Shows.* The vaudeville star, Milton Berle, hosted the number one TV show, *Texaco Star Theatre*—70% of all viewers watched the show. "Uncle Miltie" and television had become so much a part of society that he and television were reflected in the humor of the day: Question: "Why is everybody putting a television set on their stove? Answer: To watch Milton Boil." (Edgerton, 2007; Fisher, M., 2007).

Radio stars and their shows easily made the transition to TV, as new and old shows joined the nightly line up: Arthur Godfrey with his *Talent Scouts* show (long before Fox TV's *American Idol* began searching for new recording artists in 2002); westerns, like *the Lone Ranger* and *Hopalong Cassidy*; children shows like, *Howdy Doody* (with kids screaming in the "peanut gallery" and Buffalo Bob Smith hosting the show with his puppet side kick) and *Kukla Fran, & Ollie* (another children's show with host Fran Allison and puppeteer, Burr Tillstrom); quiz shows like *What's My Line? a*nd *Twenty Questions*; and comedies like Jackie Gleason's *The Honeymooner's* and Lucille Ball's *I love Lucy*. Lucille Ball and her husband, Desi Arnaz, premiered their show in 1951, and it had more than 60% of the total television audience in its first season. The show ran through 1957 (American Idol 2011; Edgerton, 2007; Glennon, 1999).

By the mid 1950s, CBS launched a new adult-style TV western, *Gunsmoke*, which had a 20-year TV run. Children's shows became more sophisticated with Walt Disney's *Mickey Mouse Club*, featuring Annette Funnicello and the singing Mouseketeers. It was a time on TV when there were ethnic themes to many of the comedy shows: Irish in Los Angeles with *The Life of Riley*; Jewish in New York with *the Goldbergs*; and African-Americans in Harlem with *Amos 'n' Andy* (Edgerton, 2007).

As early as 1951 the Italian composer Gian Carlo Menotti brought opera to television when he composed *Amahl and the Night Visitors* for one of the first TV specials for NBC. *Amahl*, the story of a lame shepherd boy who crosses paths with the Three Wise Men, was the first opera written for television (Glennon, 1999).

Television of the 1950s established the template for much of the programming for the next 50 years. On 27 September 1954, personality Steve Allen premiered NBC's *Tonight Show* which became an institution as a late-night "sofa-and-desk" show with a large measure of comedy and where guests became involved in interviews, discussions, and performances. Earlier (1952) Dave Garroway premiered NBC's early morning *Today* show. The network broadcast the program from New York's Rockefeller Center on the first-floor of the RCA Exhibition Hall where people on the street could peer into the window, watch the show, and wave to the camera. It was a news-magazine-entertainment show and became the morning standard for broadcast and cable television (Edgerton, 2007; Glennon, 1999).

News also became a focus for evening television. The Korean War and the emerging Cold War became the basis for the growth of TV news. What started as fifteen-minute dinnertime news broadcasts would grow into the half-hour evening network news and later cable news network newscasts. The early newscasters—John Daly, Douglas Edwards, and Edward R. Murrow—soon became household names. The *Huntley-Brinkley Report*, with co-anchors Chet Huntley and David Brinkley, had a format that provided a model for future news programs. The news-interview TV talk show format began airing Sunday mornings beginning in the 1950s with NBC's *Meet the Press*. News shows and political talk shows suddenly brought distant wars and distant international threats into every home on a scheduled basis (Edgerton, 2007; Glennon, 1999).

Limitations of the Scientific and Technological Environment of the 1950s

Science and technology were becoming dominant forces in the 1950s. Medicine was making breakthroughs; computers were emerging as a foundation for the soon-to-be information age; nuclear energy was finding peaceful applications; and space was a new frontier.

Medicine. The 1950s saw dramatic scientific advances for medicine. James Watson and Francis Crick (1953) published a paper that explained the structure of DNA and revolutionized biology with great implications for medicine.[3] The 1950s saw a number of revolutionary advances in medical care, a number of them were breakthroughs that reduced the risk of cardiac death. Dr. John H. Gibbon developed the heart-lung bypass machine at Philadelphia's Jefferson Medical College Hospital. In 1953 Dr. Charles Hufnagel implanted the first artificial heart valve at Georgetown University Medical Center (Glennon, 1999).

Poliomyelitis was at its peak in 1952 when it claimed 58,000 Americans. But on 12 April 1955, Dr. Jonas Salk announced a new killed-virus vaccine that was effective in preventing polio. It had been a paralyzing disease where the virus destroyed motor neurons that controlled muscles. It was a feared by the population and mostly a childhood disease[4] where many children with the disease ended up in iron lungs in order to breath (NMAH, 2011; Schmeck, 1995; WHO, 2010).

Computers. In 1950 the office supply company, Remington Rand, bought a business from John Eckert and John Mauchly who, in the mid 1940s, had built the first all-purpose, all-electronic digital computer for the U.S. Army. In 1951 Remington Rand subsequently delivered to the U.S. Census Bureau the UNIVAC, the Universal Automatic Computer—what was an innovative digital computer that used magnetic tape (not punch cards) and could read 7,200 digits per second (Glennon, 1999).

Nuclear Energy. Nuclear Energy was making its appearance as an energy source during the 1950s. On 20 December 1951, the National Reactor Testing Station in Idaho was the first station to generate electricity from nuclear power. It produced about 100kW(e), which was enough to power the equipment in the small reactor building. In January 1954, the U.S. Navy launched the *Nautilus*, the worlds' first nuclear-powered submarine. During its inaugural voyage from New London, CT to Puerto Rico, it logged 1,281 uninterrupted under water miles at an average speed of 16 knots. By the end of the decade, the sub established another record in a blind cruise under 35-feet of ice of the North Pole from Point Barrow, Alaska to the Greenland Sea. In 1957 the Shippingport Atomic Power

3 Watson and Crick were office mates at Britain's Cambridge and worked as a team. Like the Corona pioneers, they were not afraid to seek advice and make mistakes as they searched for solutions. By using X-ray diffraction photographs, they pieced together the structure of DNA and showed it to be a double helix, i.e., two intertwined, spiraling strands of polymers. Their findings explained how genes were replicated and revolutionized genetic science (Glennon 1999, Watson & Crick 1953).

4 Polio also could affect adults. President Franklin Roosevelt contracted polio as an adult in 1921 at the age of 39 (NMAH, 2011).

Station in Pennsylvania connected to the grid, and it could have an output of 60 MW(e). By the 1960s there were demonstration power reactors in operation in all leading industrial countries (IAEA, 2004; U.S. Navy, 1999).

Space. The space age began in 4 October 1957 when the Soviet Union successfully launched the first artificial Earth satellite, *Sputnik 1*. At first there was shock in U.S. when Americans saw that the USSR, which most Americans assumed to be technologically inferior, had beaten the U.S. into space. This was followed by a sense of panic because of the reality of how space technology easily could be applied to weaponry (Glennon, 1999).

More basically, a human presence in space marked a fundamental change in how humans would communicate, conduct war, collect intelligence, and interact with the universe. The railroad was fundamental to the 19th century; the automobile to the 20th century; and the space operations would become fundamental to the 21st century. But it was the ingenuity of engineers during the 1950s and second half of the 20th century that would set the stage for the space age of the 21st century—and space was where the actors of the stories in this book were looking (Evans, 1998).

Conclusion

The story tellers in this book and their families had lived through the hardships of the Great Depression during the 1930s and the horrors of World War II from 1938 to 1945. The post-war society of the 1950s was a new beginning of hope and prosperity, and they had first-hand appreciation for that new life. But they also were witnesses to the emergence of the Cold War and its threats to U.S. national security.

The early days of the Cold War in the 1950s were ones of growing fear of Soviet attack on the U.S.; the realities of the atomic blast at Hiroshima and Nagasaki had demonstrated the consequences of such an attack. The Soviets had that capability and were armed to use it. The pressure was on the Intelligence Community to collect information about that Soviet threat. The words of radio commentator H. V. Kaltenborn in 1945 anticipated what was to come after Hiroshima and Nagasaki:

> *"Anglo-Saxon science has developed a new explosive 2,000 times as destructive as any known before . . . . For all we know, we have created a Frankenstein! We must assume that with the passage of only a little time, an improved form of the new weapon we use today can be turned against us."*
>
> *–H. V. Kaltenborn, 1945*

These word made it clear what these trailblazers in space reconnaissance had to do; they had to ensure the U.S. had a reconnaissance capability that would give the U.S. information necessary to avoid those apocalyptic weapons being used against American society that they had been living in the 1950s.

Communist aggression and nuclear holocaust threatened the new way of life in the American society of the 1950s. As we have seen, that American way of life was a period of dynamic, multi-dimensional transitions—not only one emerging from the sacrifices and sufferings of the Great Depression and the Second World War, but also that of experiencing the beginning of the information revolution and the space age. There were opportunities for creativity; there was an imperative for action. The emerging technologies were opening the way to take advantage of the dimension of space; the realities of the Cold War were threats that could make it go hot and destroy post-war society.

I believe knowledge of these realities—and the experiences of the generation of engineers, military personnel, and intelligence officers whose stories are in this book—are what inspired them, motivated them, and gave them the psychic strength to accomplish the "Corona miracles" that Ingard Clausen talked about in his opening essay.

The narrators of the stories in the chapters knew from their life experience how dedication to the mission, imagination, perseverance, and teamwork could create miracles. They had a commitment to protect and preserve the good life of the 1950s—a life well-deserved after the prolonged depression and 4 years of war. Their narratives are the explanations of the miracles and the stories of how they contributed to winning the Cold War.

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PART I

THE CHALLENGES IN DEVELOPING THE CORONA SYSTEM AND ITS EARLY USE

The Air Force and CIA began the Corona program as a joint activity, following up on the success of the cooperative U-2 program. . . . The Corona schedule, from beginning to first launch, was one year.

A. Roy Burks, Corona Program Director
"Three Decades with the NRO," *Beyond Expectations–Building an American National Reconnaissance Capability, pp. 174, 180.*
American Society for Photogrammetry and Remote Sensing, 2002

[Corona was] developed in only 16 months to become the first photoreconnaissance satellite. The spy satellite filled in the gaping holes in the U.S. knowledge about Soviet nuclear armaments during the hottest part of the Cold War.

Lyndon B. Johnson, President of the United States
Remarks in Nashville, Tennessee
March 16, 1967

The imagery [from Corona] profoundly altered the course of the Cold War.

Jeffrey K. Harris, Director, National Reconnaissance Office
Correspondence
November 1995

The contributions of the Corona team cannot be overstated. Not only did their achievements help the U.S. win the Cold War, but they also led to the development of a wide variety of today's technologies.

Peter B. Teets, Director, National Reconnaissance Office
Remarks at Charles Stark Draper Prize Presentation
February 21, 2005

The Central Intelligence Agency (CIA) and the United States Air Force developed the Corona satellite to do something that never had been done before: take reconnaissance photographs from space. In Part I, those who participated in the development of the Corona system and its early use share stories about their experiences in facing and overcoming the challenges of working on a program that was ahead of its time.

Chapter 1

REFLECTIONS ON CORONA'S TOUGH CHALLENGES

Figure 1. Ingard Clausen. Photo courtesy of General Electric.

Ingard Clausen
First General Electric Project Manager,
Corona Satellite Recovery Vehicle

In his position as the first General Electric (GE) project manager on the Corona Satellite Recovery Vehicle (SRV), Ingard Clausen became intimately familiar with the project and its significance. In this chapter, Clausen recounts the major challenges the Corona program faced and the miracles the trailblazers of reconnaissance performed in order to make the project successful.

Almost all praise for Corona falls short of giving due credit for the system. The praise highlights the program's successes, but avoids the fact that the Corona team ran a "risky race" and overcame tough challenges through "miraculous saves," determination and innovation. The U.S. military provides the best example for bestowing praise. They learned long ago that in order to separate "heroes" from "superior performers," you must place "risk before result." The excerpt below from a military citation of mine exemplifies this lesson:

> *"… with utter disregard for his own safety from intense, close range, enemy mortar fire, (he) advanced in front of the (10th Armored division) … his action made possible … the advance by the (division) and reflects great credit upon himself and the military forces…"*

Like this example, the members of the Corona team faced significant risk in order to accomplish much. I was part of the team that won the "risky race" to successfully develop, launch, and operate the Corona system. The team deserves praise not only for the successes of the program, but also for dealing with the tough challenges and early failures of the program. Their story, and my story, is defined by winning the risky race by making the miraculous saves.

A Risky Race

First, let me define “risky race.” The race was to meet President Eisenhower’s edict to fly a photoreconnaissance satellite in one year and bring back film from space in two years. The risk arose because no one could have met Eisenhower’s one-year schedule and still conduct business as usual. If we had been compelled to follow Air Force specifications for qualifying designs and for accepting hardware for space flights, we would not have succeeded. The Air Force specifications or “laws” were, “thou shall not fly space mission components that have not been successfully operated in the space-like environment including tests of shock, temperature, vibration, acceleration, humidity, altitude, noise and life.”

At General Electric (GE) we had been following those “laws” for the four years preceding Corona. For example, I borrowed the Navy’s Line-of-Balance approach to track nuclear submarine components running through test facilities as if they were production lines. I suspect that all contractors on the Corona project set-up the required space environment tests program for components, and got as many of them as they could done before the first flight was made. We, too, qualified them all at GE, but not before the first flight.

Miraculous Saves and Tough Challenges

Next, to define “miraculous saves,” I draw upon a more recent example when the word “miracle” was introduced to discuss a new intelligence community imagery satellite system. At the final congressional hearings held to cancel the system called “Future Systems Architecture,” committee member, Representative Heather A. Wilson from New Mexico said, “We were promised two miracles by Boeing and received neither.” She concluded, “Congress should never again allow more than one miracle per intelligence contract.”

The trailblazers of the Corona program broke that rule many times. The difficult challenges Corona faced, over and over, required many miracles, not just one. The project was committed to meet nearly impossible mission requirements when the risk of failure was very high indeed. We used “saves” such as shortcuts, back doors, and appeals for higher authority. The “tough challenges” required us to stretch our thinking, to get outside of the box, and to make personal sacrifices. Accomplishing a miracle deserves a hero’s commendation, but the hero seldom gets one, especially when working on classified programs. That is the Corona story.

The three most important Corona challenges we overcame deserve special attention because there were a number of commendable miracles associated with the challenges. The three challenges are:

1. *Mission Profile:* This challenge included building the vehicles, properly sequencing the complex components, and other operations during an entire mission from the first launch to the first successful delivery of a returned object from space to the White House.

2. *Schedule:* This challenge arose from the incredibly short development time compared with Corona’s space predecessor, the Intercontinental Ballistic Missile (ICBM) reentry vehicle development schedule for example.

3. *Team Building:* This challenge developed from the necessity of identifying the right people and building an exceptional team during the Corona project.

Mission Profile Challenges

For its time, and even by early twenty-first century standards, Corona was a complex space photoreconnaissance system. The Corona program office launched the satellite into a low earth orbit where it imaged specific portions of the earth. After the satellite photographed targets on the earth's surface, it ejected a Satellite Recovery Vehicle (SRV) with the film; the SRV reentered the earth's atmosphere, and the Air Force retrieved the film package in mid-air for development and exploitation at ground facilities.

The complicated Corona mission is illustrated below. The circular, dashed line arching above the earth is the orbit path. Along this line of orbit, you see the Corona vehicle in mission sequence. The sequence begins with Douglas' Thor rocket boosting Corona to the required orbital path. Atop the Thor sat an Agena vehicle with the camera system, and the SRV at the tip. Lockheed's Agena finished boosting Corona into orbit. Once in proper orbit, the Agena stabilized in all three axis and controlled the camera and imaging through seventeen orbits. When imaging stopped, the Agena oriented in the opposite direction of the orbit path.

The "photo recovery" phase of the mission started as the Agena passed over the North Pole and the SRV headed south toward the recovery target zone over the Pacific Ocean. After entering the earth's atmosphere, a parachute would deploy. The descending recovery vehicle would then be snatched from mid-air by an Air Force C-119. The film would then be returned to the continental United States where Central Intelligence Agency (CIA) photo interpreters would review the film for photointelligence that informed the President and other senior U.S. government officials.

I have modified the mission profile graphic to summarize a "world's first" accomplishment for each point within the mission profile. There were several firsts that were miracles in their own right.

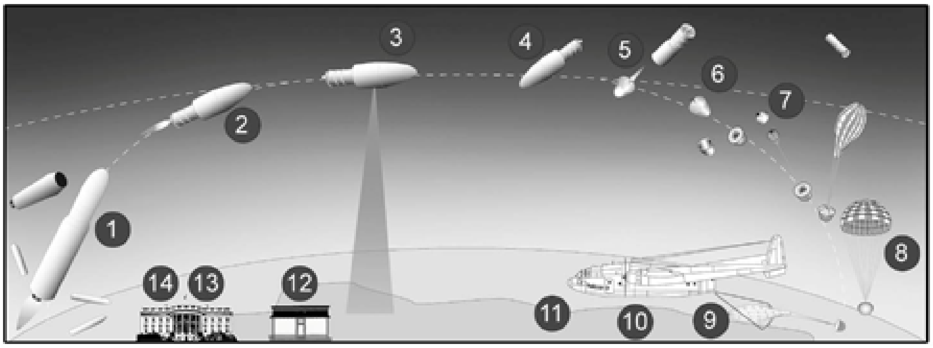
One of Corona's most important "firsts" was the completion of each of the steps in the mission profile. The failure of any single step would have terminated the entire mission. The odds were against this, but we beat those odds with Discoverer 13 when all segments of the mission profile succeeded. It was a genuine miracle.

The CIA pressed for camera changes on Corona that were critical for better interpretation. The CIA requested the changes during an operational flight series, another important first. Even at the start of the 21st century, making these critical changes during the course of an operational flight series is still considered very high risk. Itek deserves high commendation for getting it done against the high odds of failure.

The Agena's challenge was to hold Itek's reconnaissance camera straight, level, and without roll, while laying a virtual orbit-track on the earth below that included targets. The Agena's success in allowing Corona to lay a 500,000-mile track on the earth's surface in one mission is a first and another miracle.

Another of Agena's firsts was when it rotated to point backward, tilt down, and signaled the SRV to separate and to push-off. With the uncertainties introduced by seventeen orbits, the miracle comes from the nine C-119s finding and retrieving the SRV in a 200 by 600 mile target area after traveling 500,000 miles. By comparison, the ICBM reentry vehicles of the time targeted a 10-mile diameter circle after travelling only 5,000 miles. This is an impressive feat for Agena.

The SRV was a completely open-loop system, meaning it could only accept aiming as it pushed off from the Agena, hopefully with minimum disturbance. It then fired off its Jet Fuel Assisted Take Off (JATO) bottle with the faith that it will burn at the specified thrusts for the right duration, and with



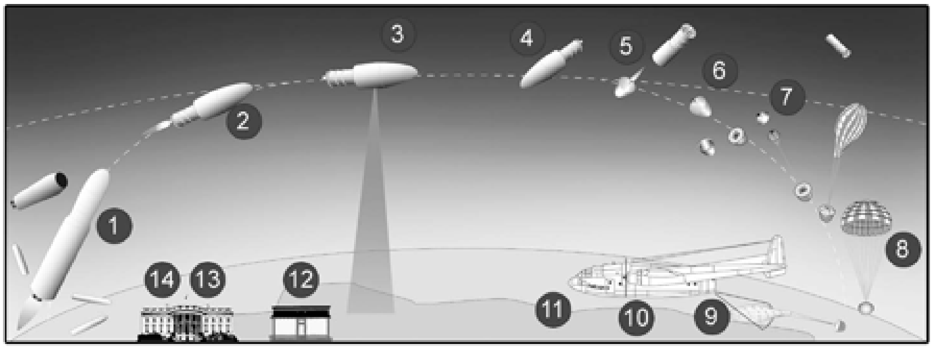
1. Thor boosts Agena and Satellite Recovery Vehicle (SRV) to near orbit. Three spent strap-on boosters drift away.
2. Agena boosts SRV into orbit, having separated from Thor, seen drifting off to the left.
3. Agena's 3-axis stability points camera along a longitude track. Camera shoots swaths across this track.
4. All film is exposed and reeled into SRV. Still in orbit, Agena rotates nose to the back and tilts down 30 degrees, thus aiming the SRV.
5. SRV blows bolts, springs out, spins up for stability, fires retro rocket, and starts down de-orbit and ballistic path.
6. SRV de-spins and Reentry Shell protects from reentry heat. SRV discards gear. Controls detect 1-g at 55,000 ft.
7. Reentry Shell pushed off. Capsule cover is released, pulling out drogue, pilot, and reefed main chute.
8. Reefs blown away, 24-ft chute inflates, and descent rate is 20 ft/sec as capsule reaches 20,000 ft.
9. Grappling hooks, suspended between two booms out from the C-119 aircraft, snag the 1,500-lb lines in chute.
10. Aircraft Commander tracks capsule beacon, often taking several passes for mid-air recovery.
11. To cover a 200- by 600-mile impact target area required nine C-119s, each assigned to a target zone.
12. First National Photographic Interpretation Center (NPIC) was an old auto sales building.
13. Head of NPIC presents 20- by 23-in photo boards and interpretation for President Eisenhower.
14. In 1961, President Eisenhower showed that 250 Soviet missile sites were a myth and we did not need to mobilize.

Figure 2. Corona Mission Profile Challenges.

the belief that it will hit within the required target area. There was no feedback and no mid-course corrections, no matter what. Weight restrictions killed any idea of closed loop mid-course corrections or of diagnostic telemetry on the SRV because any weight addition would rob the vehicle of film capacity. It was a tough challenge to meet, but the SRV was almost always within the range of some the C-119s, an important first for space programs.

The revered Theodore von Karman said that our toughest problem was survival of the SRV though

CORONA MIRACLE...
ALL 14 OF CORONA'S ESSENTIAL STEPS
ARE ALSO WORLD FIRSTS



1. THOR— First to boost 4000+ lbs into near orbit.
2. AGENA— First second stage boost of 4000+ lbs into orbit.
3. AGENA— First 3-axis stable base in orbit and orbit recon mission.
4. AGENA— First turn around and aiming of Satellite Recovery Vehicle (SRV).
5. SRV— First to cut loose, stabilize, ignite rocket, and de-orbit.
6. SRV— First Reentry Shell to survive de-orbit.
7. SRV— First third stage chute slows from hyper to sonic.
8. SRV— First delivery to 20,000 ft at 20 ft/sec.
9. CREW— First mid-air recovery of anything from orbit.
10. AF PILOT— First to position aircraft to snag film capsule.
11. AF TEAM— First deployment of nine C-119s to cover 200 by 600 miles.
12. CIA— First to identify Soviet intercontinental ballistic missiles from space films.
13. CIA— First to present orbit findings to President Eisenhower.
14. PRESIDENT EISENHOWER— First to declare "no missile gap."

Figure 3. Corona's Important "Firsts."

the searing heat of reentry. We initially solved that problem on the ICBM project. The Corona orbit reentry had three or four times the plasma duration of the simpler ballistic problem we had solved for ICBM reentry. My colleague, Rowe Chapman, ran computer programs many nights to keep up with our fellow colleague, Bob Chamberlin (see his account in chapter 15), who worked each day to assure the SRV's survivability. We were proved right on the second flight when the SRV landed on Spitsbergen (see chapter 14 for more information). Rowe Chapman and Bob Chamberlin were extrapolating with little time—a risky game on a critical program—but it worked.

People frequently see the C-119 mid-air recovery of the capsule as the most spectacular and daring of the Corona feats. To the credit of the Air Force, they and their forbearers had been preparing for this drill for decades including mid-air recovery of air mail in the 1930's, mid-air recovery of our secret agents in Europe during World War II, and mid-air recovery of the Genetrix 800-lb camera payloads floated by balloons over Soviet territory in the 1950's. The latter was the "jaw of defeat" from which a victorious Corona sprang. Taken altogether, consistently successful mid-air recovery was another miracle.

Analysts at the CIA's National Photographic Interpretation Center (NPIC) created three breakthroughs. First, they identified the ground signature of Soviet ICBM sites and vehicles given only 20-ft resolution. Second, NPIC analysts increased the "factory capacity" to handle ever increasing photographic images. Third, they handled, interpreted, cataloged, stored, and retrieved all those wonderful images. Their ability to meet three tough challenges in a row earns another miracle.

The Corona vehicular system (Thor, Agena, and SRV) was a single shot, unattended, automatic machine with a brain based on punched tape—the predecessor to punched cards. The only possible intervention from ground stations in the late 1950's and early 1960's was to "trim the sails" or slow the vehicle down. Despite the lack of control from earth, the Corona system brought back 1,700,000 square miles of photo coverage of Soviet territory—more film on the first shot than all of the manned and serviced U-2 missions combined. The Corona system was a robotic pioneer of pioneers, a miracle in its own right.

Most of the equipment on Corona was electromechanical or chemical-mechanical, the bane of reliability and long life in space. Electromechanical equipment failures caused most flight failures in military spacecraft during this period, Corona included. We met the tough challenge of increasing Corona's reliability over the life of the program, especially given the potential reliability problems with electromechanical components.

Mission Schedule Challenges

There were six critical elements that shaped the schedule challenges for a successful Corona program. First, as described above, the mission profile steps were all firsts and each introduced potential for schedule slippage. Second, President Eisenhower's edict that the system would fly in one year after initial development and return film in two was aggressive given our capabilities at the time, to say the least. Third, Corona program leaders Jim Plummer and Col Lee Battle committed to the schedule despite the risks. They employed a brilliant management tactic by telling program team members to be there on time or we fly without you. Nobody wanted to be left behind. Fourth, many system components flew without complete environmental testing, introducing risk of on orbit failure and further delay. Fifth, to maintain support of President Eisenhower, Corona program mangers indicated that earlier Corona failures were not due to the same causes. Sixth, the first operational flights provided a platform for testing system components and likely reduced the schedule by as much as a year.

To illustrate the aggressiveness of the Corona schedule, I have included a comparison of Corona's remarkable development schedule to GE's development of the world's first Intermediate Range Ballistic Missile (IRBM)/ ICBM reentry vehicles. Although I could not add the completion of system test dates and flight readiness dates, we can reach some startling conclusions on Corona's remarkable schedule. (Only the development flight tests were flown. In chapter 4, Hilliard Paige discusses those flights without mentioning dates, but with their contribution to Corona explained in some detail.) The ICBM reentry vehicle's component environmental tests took more than a year, even through the schedule shows a year. During that year we reduced the odds of flight failures during development flight tests by component, subsystem, and system environmental testing. We carried out the full spectrum of testing including Shock, Temperature, Vibration, and Acceleration (STVA) for development flight simulation. We followed with Humidity, Altitude, Noise, and Life Tests (HANL) for operational flight simulation.

We hedged a little on how long these tests took because sometimes a component would not pass and we would go ahead and fly it in a development flight test anyway. For example, one of our components, the arming and fusing component, never did pass its design, environmental, and qualification tests. Because of time pressures, we flew our first development flight test with it on board, and it worked perfectly through all of the development flight tests. In other words, we had proved that the design was qualified for operation by flight-testing it, the best simulation possible.

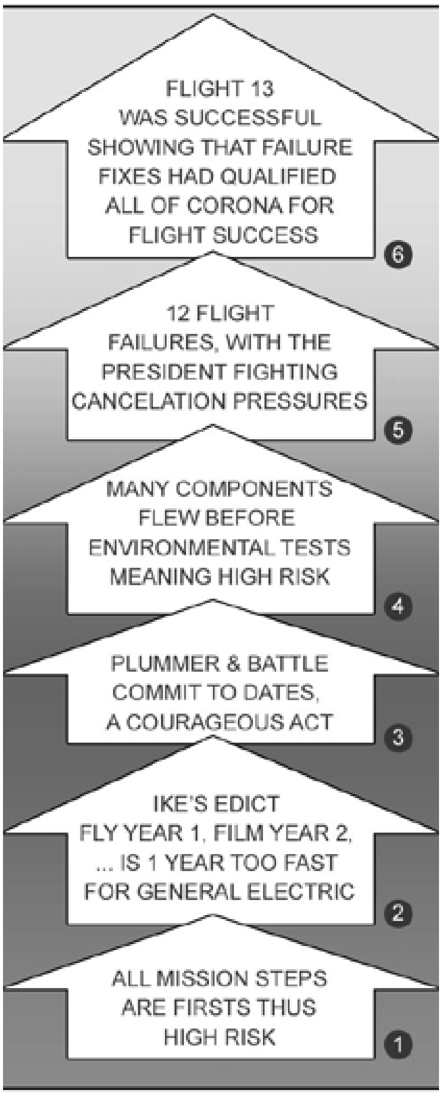


Figure 4. Corona's Challenges.

We used this same approach for Corona and it became the rule rather than the exception for the Lockheed/Air Force schedule. It shortened the Corona development by at least a year and proved critical to national security. In saving that one year, President Eisenhower was permitted to keep his Soviet information pipeline open after the Soviets downed Francis Gary Powers' U-2 in May 1960. Discoverer 14 was successful just three and a half months later, giving Eisenhower continued photointelligence of the Soviet Union.

The roadmap of schedule challenges was fine tuned to meet President Eisenhower's edict for photoreconnaissance from space in two years. The secret was to substitute expensive operational flights for cheap ground environmental tests and buy a year, at the very minimum, of schedule time.

Looking back, it is nearly unbelievable that the project was not cancelled after twelve flight failures in a row. Twelve failures are four times more than what seemed to be common practice at the time for development projects. Corona's flight failures generated extreme pressures on President Eisenhower to cancel the project. President Eisenhower could not tell most people why the project was so important. He faced another significant concern that NATO countries would balk at satellites capable of spying on them. Finally, every Corona launch was public knowledge, courtesy of Aviation Week, and failures could not be concealed.

If the program failed completely, it was entirely possible that Eisenhower could have to leave office with a tarnished legacy because he permitted so many flight failures. During a final term, when legacy is so important, that is a very big risk for a President to take. It took a very unusual President to ignore those pressures.

With respect to Plummer and Battle, if they had failed in their leadership of Corona, they would have failed to reveal one of the bigger hoaxes in the Cold War, the so-called missile gap. Also, they would have become the leaders who threw away one of the most important sources of intelligence for helping to win the Cold War by terminating Corona. They are to be commended for their extraordinary courage.

There were others who merited respect. For instance, I remember that the only people who could walk into a Corona briefing and receive a standing ovation were Kelly Johnson, developer of the U-2; Richard Bissell, the CIA's top Corona leader in the earlier years; and Bob Truax of steam rocket fame. The Eisenhower, Plummer, and Battle triumph may be an important miracle in our nation's history, but one that is not likely to be fully recognized.

CORONA'S MIRACULOUS DEVELOPMENT SCHEDULE			
EVENT	1958	1959	1960
Contract Signed	Feb		
Complete Design	Apr		
Build Prototype	Jul		
First Flight Failed		Jan	
First 12 Flights Failed		Feb	Jun
Flight 13 Successful (no film)			Aug
Flight 14 Successful (film)			Aug
U-2 Shot Down (with soviet images)			May

IRBM AND ICBM REENTRY VEHICLE DEVELOPMENT					
EVENT	1955	1956	1957	1958	1959
Letter of Intent	~May				
Design Completed		~May			
Component Environmental Tests			~May		
System Environmental Tests					
Development Flight Tests			CLASSIFIED		
Operating Capability Achieved (IRBM)					
Operating Capability Achieved (ICBM)					

Note: ~ = Approximate Date

Figure 5. Corona's Development Schedule Compared with the IRBM/ICBM Reentry Vehicle Schedule.

Team Building Challenge

The Corona project brought out the best professional behavior of those who joined the team. In a normal work environment, it is not unusual for a new engineer to take up to twenty-six months to get up to speed in a new job. In the Corona program, that same engineer would be owned by the project in thirteen weeks as he worked with all of the other team members in the same segregated area. When you assign that engineer to a black project with a mission from the President to save one hundred cities and all of our ICBM sites, he will be willing to do things that he would not have done in a normal work environment. He will be willing to sweep the floor and empty the trash, and do his own drafting (unheard of at GE). He will neglect his wife and family over an extended period. He will lie about what is he working on, or when he has to buy something for the project, or has to ship to a dummy address. He will go without a pay raise or promotion for an extended period because his real boss has no idea what he is doing.

This level of devotion to the project was the Corona miracle of team building. Ninety-nine percent of GE's Corona team members will admit that Corona was the high point of their lives. That is true, even surpassing for many their first real date, marriage, children, and current all-consuming passion of many former Corona team members, grandchildren.

Every engineer who designed some part of reentry vehicles was contributing to a critical line of defense by designing equipment to survive in space, the hard way, using engineering tools of the 1950's. Upon joining Corona, program leaders asked for complete devotion to this high-powered, crash project. No one turned down the request.

A black project that promises to reduce the threat to our cities and our defenses is a miraculous team builder. A team was built to complete a three or four year program in only two and one-half years. Sorry, Congresswoman Wilson, it took fourteen miracles to bring back the secrets that helped win the Cold War. One was not enough.

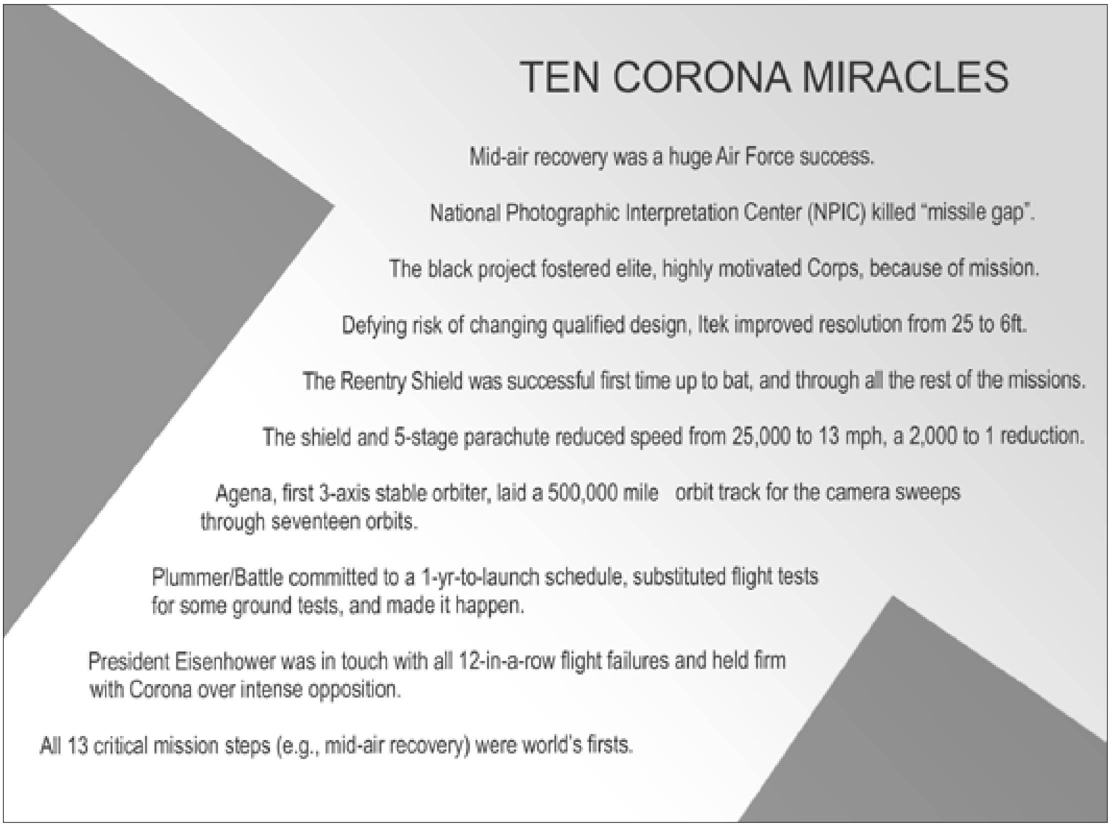


Figure 6. Corona's Ten Miracles.

Chapter 2

THOR BOOSTER CHALLENGE

Ingard Clausen
First General Electric Project Manager,
Corona Satellite Recovery Vehicle

Although the Thor Booster was not an immediate success, circumstances allowed for it to overcome several consecutive failures and become a space workhorse. In the account below, Ingard Clausen, the first General Electric (GE) project manager on Corona's Satellite Recovery Vehicle (SRV), recalls the history of Thor and its significance.

The History of Thor, First Stage Booster for Corona

The Thor booster was born as an Intermediate Range Ballistic Missile (IRBM). The Thor was not an instant success. The development program survived six consecutive failures, an impossible feat for a development project since the end of the Cold War. (The ICBM Atlas was running late, a contributing factor in the Douglas/Thor team being able to work through those six consecutive failures.)

Following successful qualification as the U.S. IRBM, and the delay in the Atlas Intercontinental Ballistic Missile (ICBM) resulting from budget constraints, Gen Schriever, head of Air Force Research and Development, successfully sold the idea to the Administration and the Department of Defense that the Thor, sited in Great Britain and Turkey, could reach large Soviet cities and industrial capabilities. This portrayed Thor as playing a part in the strategic role expected of the Atlas ICBM starting in 1959. After a bargain was struck between Khrushchev and Kennedy, the British and Turkish sites were to be disbanded starting in 1962. I have heard that the Air Force did not dismember those sites until much later, perhaps unbeknownst to Kennedy, if not to Khrushchev.

The Significance of Thor

Thanks to the Air Force and Douglas Aircraft, the Thor program went through at least six major improvements in thrust and became a military and civilian space workhorse.

Thor was a sure thing as Corona's first stage booster because that's all there was. The National Museum of the U.S. Air Force says that the Thor "proved to be one of the most successful U.S. satellite launch vehicles of the Cold War era."

But even that is not a strong enough commendation as Thor was to become even more valuable. Capitalizing on the lateness of Atlas, the next step for the Thor was to team up with the Agena on the Mariner series at Jet Propulsion Laboratories (JPL). Thanks to Thor, Mariner-4 photographed the backside of Mars in a very successful mission.

Figure 7. Thor Booster/Photo courtesy of United States Air Force.

Thor got a renewed life when the National Aeronautics and Space Administration (NASA) was forced down the small spacecraft route, with the so-called small interplanetaries, an economy move.

The following table provides more background information about the vital statistics for Thor, at the beginning of Corona.

Table 1. **Thor's Statistics**	
Range	1,750 miles
Length	65 ft
Diameter	8 ft
Gross takeoff weight	10,000 lbs
Empty weight	6,903 lbs
Fuel weight	103,100 lbs
Propulsion	Rocketdyne
Thrust	150,000 lbs
Inertial guidance	AC sparkplug
Accuracy	2 miles
Start date	December 1955

Chapter 3

THE AGENA BOOSTER PLATFORM CHALLENGES

Figure 8. Minoru S. "Sam" Araki. Photo courtesy of National Reconnaissance Office.

Minoru S. "Sam" Araki
Systems Engineer, Lockheed Martin
Missiles and Space

Starting his career at Lockheed Missile and Space Company in 1957 and eventually becoming president (1995 to 1997), Minoru S. "Sam" Araki pioneered the development of the Agena Spacecraft, the world's first stabilized platform for space. "His contributions resulted in a space platform that the National Reconnaissance Office used during the majority of its space-based Sigint and Imint systems, most notably for the highly successful Corona system. In this section, Araki discusses the history of Corona, outlining some of the important "Space Firsts," chronicling the stages of development, and highlighting several of its legacies.

Agena was the spacecraft used for Corona. In this chapter, I will discuss this spacecraft, which made the world's first orbital reconnaissance and film recovery system possible.

The Agena served several different purposes for Corona that I will address. Part of the Agena was the Upper Stage Booster for Corona during launch, engines to the left. As a reconnaissance space vehicle, it provided three-axis stabilization, steering, and pointing so that the camera payload could take quality photos of Soviet locations. As an orbiting spacecraft, it powered, commanded, controlled and environmentally-controlled, steered, and housed on-orbit operations. The Agena oriented and signaled the Satellite Recovery Vehicle (SRV) to separate and, in later operations, performed the deboost function from orbit of the SRV.

There were three configurations of Agena: Agena-A, Agena-B, and Agena-D (there was no Agena-C). See figure 10 for a comparison.

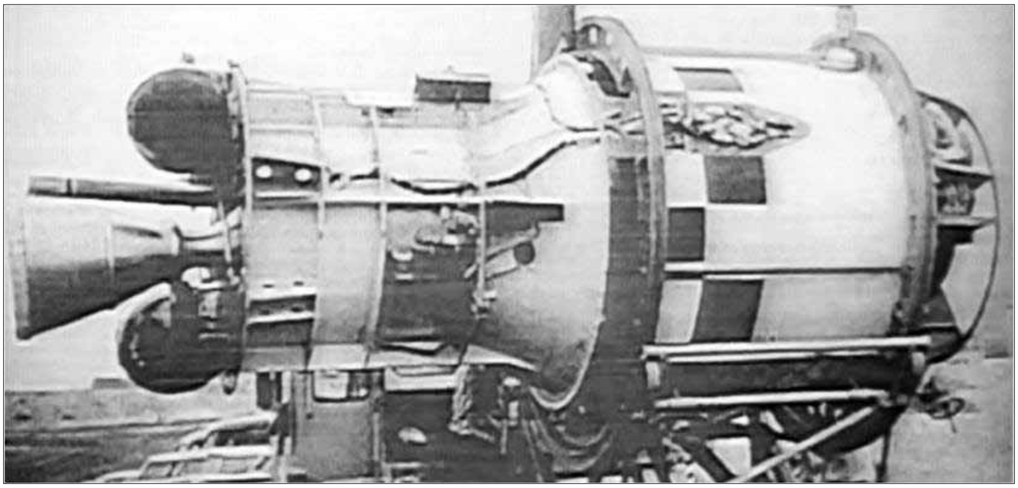


Figure 9. The Amazing Growth of the Agena, 1958-1962.

Agena-A. The left illustration of figure 10 displays the propulsion coming out of the rear of the Agena-A. It was an 8,000-lb thrust engine made by Bell Aircraft.

A battery provided the electric power. Later versions used solar power augmentation to provide up to nineteen days of orbit.

The guidance system consisted of three-axis gyros and Infrared (IR) sensors. These two IR sensors looked at the first space break point. Nitrogen cold gas jets acted as miniature rocket engines to drive the needed stabilization and pointing motion of the spacecraft and push the spacecraft as needed in no-gravity space.

The whole guidance system was a "dead man" system, meaning that when it failed to operate, the remainder of the spacecraft continued doing what it was doing.

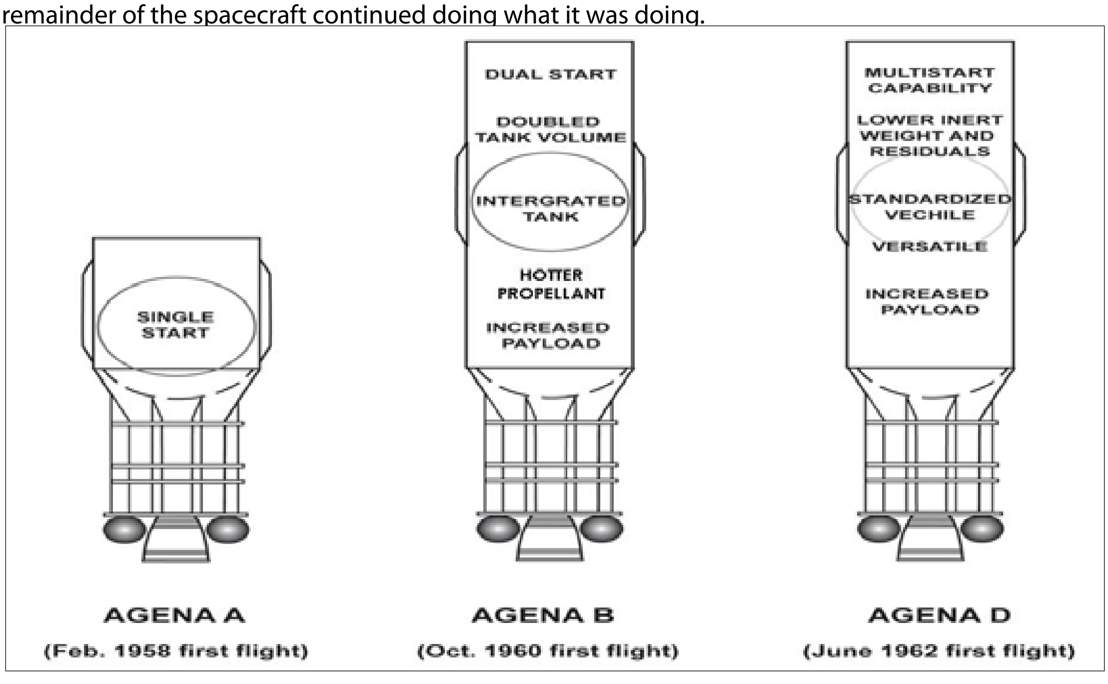


Figure 10. The Three Stages of Agena Development.

For command telemetry, we used a timer. The Agena also had an analog telemetry system. Later on, it transitioned to a Pulse Code Modulation (PCM) telemetry system, but the main command system was always on the ground.

Agena-B. Agena-B first flew in October 1960. It evolved in a short period and improved the Agena A. In the center sketch of figure 10, the Agena-B is shown as approximately doubling its propellant to 16,000-lbs. More propellant meant more film payload and more steering and orbit change capabilities.

Agena-D. The Agena-D first flew in June 1962. The right illustration of figure 10 illustrates Agena-D's additional capabilities.

Agena Successes

In an orderly and progressive manner, one or another of these three models of the Agena set world records that guided the future design of military spacecraft (see Table 2).

Table 2. **Agena's World's First Records**
First to achieve a polar orbit
First to reach a required orbit with good precision
First to enable earth recovery of its orbiting payload
First to adjust its own orbit
First major spacecraft to reorient itself
First spacecraft to achieve gravity gradient stabilization (thus, first passive stabilization)
First land-based, operational, command and control network for spacecraft
First three-axis stabilized spacecraft with attitude control
First spacecraft with engine restart
First spacecraft to rendezvous and dock with other vehicles

All of these records were important to the future of spacecraft design, but some were critical to our continuing leadership in space, both military and civilian. Here are the three that I see as having the most impact (1) command and control network, (2) three-axis stabilized spacecraft, and (3) rendezvous and docking.

First land-based, operational, command and control network for spacecraft. One of the key things I would like to highlight is the original tracking, command, and control network that became a very complex operational system as time progressed.

All space programs in this period, as well as into the 1970's and 1980's, used this global command and control system. It became one of the key workhorse tracking stations for the entire space program.

I have seen the displays on this network at the Smithsonian National Air and Space Museum Steven F. Udvar-Hazy Center and it is an unimpressive, even deceiving, representation of what this system was, let alone became. Perhaps that is why it has become too useful and classified to brag about.

First three-axis stabilized spacecraft with attitude control knowledge. "Three-axis capability" ranks high from a legacy point of view. In order to take high-resolution pictures, you have to have tremendous pointing capability and be able to be very stable during picture taking.

A recipient of this legacy would be the space telescope. In order to get its kind of resolution and its kind of picture taking of a star, 14 billion light years away, you would have to be able to point from Washington to New York and recognize a point the size of a dime. That is the kind of stability that became available because of Corona. Corona's capability was the forerunner of the technology that led to that kind of stabilization capability.

First Spacecraft to rendezvous and dock with other vehicles. This is a most interesting first. Agena participated in the very first rendezvous and docking mission of the Gemini program.

Later Agenas played a major role in the National Aeronautics and Space Administration's (NASA's) Small Spacecraft Missions.

A major Agena success as a boot-strapping spacecraft was best demonstrated on the Mariner-4 mission to Mars. At launch, it sat on top of an Atlas-D, the Intercontinental Ballistic Missile (ICBM) booster for the Air Force, providing the additional boost to achieve a parking orbit. Then its second burn put Mariner-4 into a Mars transfer orbit.

Later, Mariner-4 separated from the Agena-D and was captured by Mars gravity enough to swing by the planet on its backside. During transit, it took twenty photographs, which showed that Mars was barren and an unlikely place for life. Thus Agena was a partner in the "World's First Interplanetary Reconnaissance."

Corona's Challenges

As grand as these engineering firsts seem, developing the Corona was filled with challenges. On the way to our successes, we experienced some real heartbreak. One example of heartbreak was the first launch attempt. The program was started in February of 1958. The first launch was to be in the eleventh month and we were right on schedule for that first launch. But it turned out to be a disaster. It almost feels like it occurred for me yesterday.

I was hired into Lockheed in November 1958 and my first assignment was to be the Systems Integrator for the ascent timer. I worked quickly to get to know everybody and set-up the sequence for the ascent timer. There were only sixteen cams to trigger events and we ran out of contact switches, so we doubled-up all the commands on all sixteen micro-switches. Unbeknownst to me at that time, both the ullage multi-fire and the Agena engine hydraulic start were placed on the same contact point. *We forgot that we were going to run a ground test on the Agena engine gimbal hydraulic motor.*

Sixty minutes before blastoff, a technician initiated a planned Agena engine gimbal hydraulic motor test. But the timer was running and when the ullage rocket motor was fired on the test stand, (there were people on the test stand at that time) it burned a wire that started the ascent timer. The ascent timer started up and fired the separation rocket and then when it burned long enough, it burned the next wire that shut this timer off.

That was our aborted launch and miraculously the Agena stayed on top of the Thor. The only damage that occurred was the burning of some of the wires to the guidance system on the Thor. We had a major re-grouping. We literally worked twenty-four hours a day, seven days a week, to complete four corrective actions: (1) An in-depth review and integration of satellite and ground test equipment schematics; (2) A review of all engineering change orders and the setup of change control; (3) A complete review of launch base test sequence, ascent sequence, and orbit sequence; (4) A complete re-wire of the Agena. In one month, we made a successful launch and achieved orbit. The Corona system failed in orbit, but we did make it into orbit.

Of course, it was the first twelve flight failures that consumed the attention and concern from all Corona participants and especially President Eisenhower. Table 3 below shows the problem, going from 100 percent down in 1959 to 45 percent down in 1960.

Table 3. **Record of Failures During First Ten Years**

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Launches	9	11	17	14	12	10	10	8	6	4
Failures	9	6	9	5	3	2	2	0	1	0

In retrospect, the saving graces for the program were three factors: (1) it was Ritland, Bissell, and Eisenhower who got us through the first twelve in a row down, (2) it was the successful recovery on Discoverer 13 and the successful images on Discoverer 14 that steadied things up, and (3) it was the fact that our take convinced Eisenhower, just before leaving office in 1961, that there was no dreaded "missile gap." That put us on the road to success.

As the flight failures grew from one to twelve, serious consideration was given to scrapping the whole enterprise. The fact that President Eisenhower stayed with the project through twelve failed flights, spread over twenty months, is evidence of his concern about the Soviet space threat, his perseverance, and his desperation to replace the U-2. The success of Discoverer 13 and the examples of images from Discoverer 14 demonstrated the potential of Corona.

Richard M. Bissell, Central Intelligence Agency (CIA) Director for Plans, and Maj Gen Osmond J. Ritland, Vice Commander of the Air Force Ballistic Missile Division and Deputy Chief of the Corona Program, periodically suspended launch operations to give Jim Plummer, Corona Program Manager at Lockheed, and his subcontractors a chance to evaluate and fix the problems. More pre-flight testing was initiated in hopes of catching design and engineering mistakes before crippling another flight. All of this cost time and money. Bissell seemed acutely aware of the unusual circumstances in January 1960 and he appealed to Gen Cabell, Allen Dulles's deputy, for additional funds.

Dr. Albert D. "Bud" Wheelon, the first Director of the CIA's Directorate of Science and Technology, was responsible for U-2 overflights and development of Oxcart and three major satellite reconnaissance systems. Bud Wheelon said, "What is remarkable is that Bissell and Ritland pressed on despite these failures, and that Eisenhower continued to support them."

The Corona Legacies

Much later, when the Corona fires were put out and the smoke had cleared, we began to speak of the Corona legacy. What we accomplished cleared the way for proceeding generations of spacecraft.

I would like to conclude by discussing the legacies that perhaps we can pass on that might be important to future space projects and space reconnaissance projects—things we learned the hard way.

The legacies we can't pass on to the many programs that will follow in our footsteps are the national environment and the national level management that made all we did and learned possible. I am talking about a USA that felt it was so much at risk as its children were crawling under desks while the air raid sirens sound off in Menlo Park, California and Del Rio, Texas. This kind of crisis can unite the citizens, the President, and, sometimes, even the Congress.

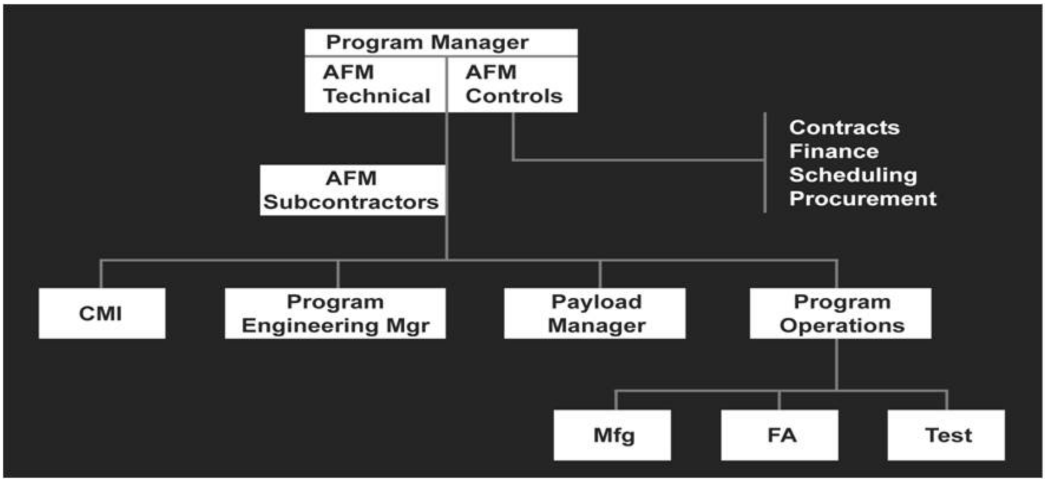
We also cannot pass on a wise, brave, informed, and vigorous president, such as President Eisenhower. Nor can we prescribe how to appoint a Gen Ritland or a Richard Bissell who took huge career risks to protect our program and, thus, the nation. Failing this, a future program manager is likely to find himself with more time, less money, and much less support than we did.

There are two aspects of the Corona project that I believe will leave a very long legacy to successful program operations into the future. One is tied to program management. The other is tied to the space environment.

Project Management Legacy. How we managed the program is key to this legacy. Two points to note are systems engineering and attention to cost and schedule.

All of our flight failures led to major changes in the way we managed the program. When Corona first started, it was put together as a group of subsystems almost like individual labs because it was highly Research and Development (R&D) oriented. We shortly realized that the system was not put together properly. The first very important thing to do was to put systems engineering together in a whole concept of having an end-to-end systems responsibility technically. The program office became very important criteria. The concept of having a technical systems program manager and a chief systems engineer who was held responsible for the entire operation technically became a "must" on Corona, as shown by the top box in table 4.

Table 4. **Project Management Structure**



Cost/Schedule Legacy. The other key element that came together was the cost/schedule. We ran a very tight schedule; cost and schedule had to be driven. In fact, the Controls Office under the Assistant Program Manager for Program Controls became our chief expediter because every milestone had to be driven to make sure we met both costs and schedule milestones. That is how we met every one of these milestones despite our many failures. Each milestone was driven by costs and schedule. The other part that became very clear is that every major subcontract with both Eastman Kodak and Recovery Vehicle had to be managed like the total program. We had to have a strong program management assigned together with each key element of the system. This whole organizational concept that we put together became the standard in aerospace management.

Space Environment Legacy. What we accomplished in encountering the space environment is another important legacy. Environmental testing that was a very key element. As you can understand, because we had gone into space with absolutely no understanding of the space environment, we had to write an environmental spec.

Not only did we need to know the physics of space, but we had to put an environmental spec together so that we could build environmental chambers such as the thermo-vacuum chambers, even vibration tables, and so on. All of these had to be built, put into place and test programmed together, as indicated in table 5.

Even though we did all the right things to the wiring on our first launch, we realized that of all the components we had built for all parts of the satellite from the Agena parts to the camera film to the recovery vehicle, **none** of them were built to survive space environments. Every one of them failed in one way or other because (1) they were not designed for a vacuum, or (2), they were not designed for zero-g operations. We had every, literally, every failure occurring in this very short period of time of the first twenty launches. This became the way in which we learned. Table 5 shows the time it took.

Table 5. **Evolution of Environmental Testing**

Type	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Manual Component		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Manual Subsystem	X	X	X	X	X	X	X								
Manual System	X	X	X	X	X	X	X	X	X						
Hot Firing	X	X	X	X	X	X									
Pyro Shock			X	X	X	X	X	X	X	X	X	X	X	X	X
Factory to Pad							X	X	X	X	X	X	X	X	X
Thermal Vac. System							X	X	X	X	X	X	X	X	X
Acoustic System								X	X	X	X	X	X	X	X
Programmed Testing						X	X	X	X	X	X	X	X	X	X
Module T/V										X	X	X	X	X	X
Automatic Module											X	X	X	X	X
Computerized System										X	X	X	X	X	X
Automatic Card													X	X	X
Box Burn-In													X	X	X
Dynamic Card												X	X	X	X
Controlled Part Line											X	X	X	X	X

During this time period from 1960 to around 1970, the Corona program mission success went from a miserably low number to 90 percent mission reliability success. Eventually this environmental test program methodology was integrated into a Department of Defense satellite test requirements document. As a result, if you look at NRO satellites, they operated beyond their design lives.

I tribute Jim Plummer with being one of the most influential individuals in the industry. Jim not only put the Corona program together as successfully as it was, but he was the father of this whole program management concept.

Conclusion

This is a very quick summary of the history of Corona starting from 1959 to 1972. It went through quite an evolution. We had about 145 launches, 105 successful missions, and covered all the 25 ICBM complexes in the Soviet Union. Using today's dollars, it would be 10 times the original amount. Even in today's numbers, I think this program was very successful.

Table 6. **Operation Overview: Corona Reconnaissance Program**

	KH-1	KH-2	KH-3	KH-4	KH-4A	KH-4B
Period of Operation	1959-60	1960-61	1961-62	1962-63	1963-69	1967-72
Number of RVs	1	1	1	1	2	2
Mission						
Series	9000	9000	9000	9000	1000	1100
Life	1 day	2-3 days	1-4 days	6-7 days	4-15 days	19 days
Alititude (nm)						
Perigee	103.5 (e)	136.0 (e)	117.0 (e)	114.0 (e)	u/a	u/a
Apogee	441.0 (e)	380.0 (e)	125.0 (e)	224.0 (e)		
Avg Ops	u/a	u/a	u/a	110 (e)	100 (e)	81 (e)
Missions						
Total	10	10	6	26	52	17
Successful	1	4	4	21	49	16
Targets	USSR	emphasis on USSR			worldwide/emphasis on denied areas	

*estimated
*unavailable
*Denied areas were generally considered to be Communist-controlled areas.

Many have asked me, "Can this be done today?" and my answer has been a very strong "yes," but there has to be a very strong urgency and need to succeed. It would require a very small team. A small team has to be driven by unreasonable demands and with a liberty to innovate and think outside the box. Teamwork and streamlined actions are very important in addition to a program managing style that allows for end-to-end responsibility and a very short schedule.

There is a reason why a short schedule succeeds: (1) you can have continuity of people, (2) you can have total commitment of those people that are dedicated to the program and most importantly, (3) budget stability. With today's program, when it lasts ten years, there is no such thing as continuity of people, you have lost total commitment, and you have lost budget stability.

For more information about Mr. Araki,
please refer to his autobiographical reflection in Appendix 2.

Chapter 4

PHYSICAL VS. RADIO FREQUENCY IMAGE RECOVERY

Figure 11. Hilliard W. Paige, Sr.
Photo courtesy of Hilliard Paige.

Hilliard W. Paige
General Manager,
GE Missile and Space Division

Hilliard W. Paige, Sr. worked for General Electric (GE) on its reentry vehicle program. It was through his team's successes that the concept for a physical film recovery idea was borne. Paige himself argued that the technology was available and worth pursuing, eventually convincing the White House to award GE the contract. In the following account, Paige recounts his experiences and role in developing an aerial photoreconnaissance system with physical film recovery capability.

The serendipity that led to GE's concept for recovering film from space started with my team: It was a little too good at what it did.

I was the Systems Engineer for the Intercontinental Ballistic Missile (ICBM) reentry vehicles in the early 1950's. We had twelve opportunities to send reentry test vehicles into space with telemetry backed up with a data recorder, to let us know the conditions of reentering into the atmosphere. After only half of the test flights, we had recovered a test vehicle from space.

At that point we had all the information needed, and we were looking for an encore.

Why Not a Camera?

Bob Haviland, a retired naval commander and a GE Project Engineer (see chapter 19 for his account), came to me and said, "Why don't we take out the data recorder and put in a camera?" There was another bit of serendipity in his suggestion. The data recorder's only purpose was to bring back flight data in case the vehicle was failing.

The reentry plasma flow around the vehicle prevented any telemetry transmission of failure data back to earth stations. The data capsule would capture the failure data and the capsule recovered at sea. But we never had a failure. So, the recorder was not really needed and might as well be replaced with a camera.

Here is another bit of serendipity—we needed to point, shoot, and recover film from space. Our reentry vehicles were already actively three-axis stabilized just in case they needed to control attitude upon separation and upon reentry.

We would need a few modifications to point the camera to the earth for picture taking, and I would have to convince the Air Force to permit the changes to the experimental flights.

I had built up a good reputation with the Air Force while managing GE jet engine projects earlier. I used that reputation to convince those in charge of the contract to allow the modifications for the camera experiment, subject to not disrupting other missile testing and not going over budget, of course.

The resulting photos demonstrated that it would be viable to take photos of the earth from 500 miles in space, return them to earth, and physically recover the film.

Convincing the White House

Our work took on a new meaning when President Eisenhower's Edwin Land Committee summoned me to tell them about my recovery-from-space experiences, including my camera-in-a-reentry-vehicle experiment.

At that meeting, I was informed that photo image radiofrequency transmission from satellite to earth station had proved to be too technologically ambitious at this time, and the Air Force and Lockheed were moving to physical recovery of the film. The Committee was leaning in that direction, also. However, it was worried about feasibility and asked for my experiences.

I explained my recovery work with very large, experimental reentry vehicles, the aforementioned data capsules I had recovered from space, and I showed them the photos we had taken of the eastern seaboard of the United States that we had recovered from the experimental flight I mentioned earlier.

I feel that the camera test in the ICBM was a big step in my career. It got GE invited to the table and, eventually, named prime contractor for the reentry and film recovery vehicle for Corona.

Another factor had to be that the Air Force's Ballistic Missile Division had invested over a billion dollars in solving the reentry problem and wanted that investment to not be needlessly repeated.

General Electric and Reentry Development

The ICBM work proved GE's reentry and recovery expertise with relatively heavy vehicles. It also showed our systems could recover reentry vehicles for study and enabled the concept of bringing film back from orbit.

When work on Corona began, the government named GE prime contractor for its portion with Lockheed as System Manager. As General Manager of Space Systems, I had oversight of Corona and other projects.

In 1956, GE was awarded the contract for the ICBM reentry vehicle and I moved to Philadelphia to take charge of that project. I rented an A&P warehouse to house our work (see figure 12).

Figure 12. GE's Missile and Space Division facility at 3198 Chestnut Street, Philadelphia, PA. Photo courtesy of Hilliard Paige.

My first contribution was to move my whole Corona team to the back of the fifth floor, well hidden from sight.

I was frustrated by administrative issues as well as the technological challenges and corporate rivalry. Due to the extreme secrecy of Corona, the fast-growing project could not quickly apply our manpower as needed. No one could start work until his clearance came through.

Early Days of the Corona Project

In recalling the early days of the reentry vehicles to the Corona project, I remember that the program had no development phase. Corona had a couple of development flights versus the twelve we had for our reentry vehicle programs. It could be that the difference between our two missions explains our different sensitivities to "test-before-fly:"

- In a reconnaissance mission, miss the target to be photographed by 10 miles, come back thirty-six hours later.
- In a ballistic reentry vehicle mission, miss a Soviet launch site by 10 miles and lose one of our cities.

In any event, pressure from the Air Force to fly was intense and tensions between Lockheed and GE ran high. I credit Lockheed's project manager, Jim Plummer, with restoring civility to the relationship and getting engineers from both sides to work together to fix key problems.

Finally, after many flight failures in a row, the Air Force gave permission for a telemetry flight. A team from GE went to Lockheed's California facilities for six weeks for an intensive requalification. The telemetry-equipped vehicle was put up on the launch pad, only to have the booster blow up.

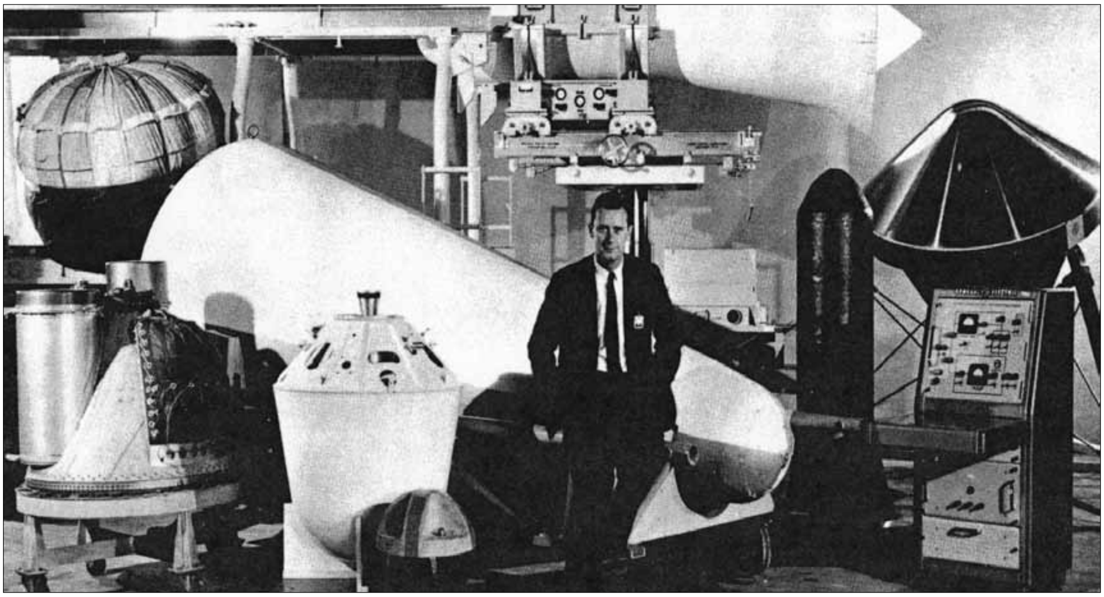


Figure 13. Hilliard W. Paige, Former Group Executive, GE Aerospace Group. The Corona capsule is directly to the left of Mr. Paige. The reentry vehicles shown were all developed under his leadership. Photo courtesy of Hilliard Paige.

Even without the data from that flight, the changes appeared to be the right ones because the next flight, Discoverer 13, successfully made it into orbit and back. That launched a string of successes that took the Corona program through the next decade before it was replaced by more advanced systems.

With much relief, I was able to reflect on Corona's accomplishments. I consider one of my major contributions to be "picking the right guys and backing them through all these troubles."

Conclusion

Now, with a little more time to reflect, I sum it up this way—after a long and varied career, the Corona project remains my most rewarding. Unlike our ICBM work, we didn't have to blow up the world to see that our work was successful. We had the tremendous satisfaction of knowing that the Corona pictures, by revealing that the Soviets had a very limited ICBM deployment, enabled the United States to take a tough stance against the USSR. That eventually led to the ending of the Cold War.

As the Corona image recovery decision was being considered, it was an important day for me when I was able to convince the President's Scientific Advisory Committee that physical recovery of film from orbit was doable now.

For more information about Mr. Paige,
please refer to his autobiographical reflection in Appendix 2.

Chapter 5

SATELLITE RECOVERY VEHICLE CHALLENGE

Edward A. Miller
Manager of GE's Satellite
Recovery Vehicle Program

Figure 14. Edward A. Miller.
Photo courtesy of Edward Miller.

With an extensive background in satellite recovery vehicles, Edward A. Miller began serving as Manager of the General Electric's (GE's) Discoverer/Corona Program on August 16, 1960. This was just after the recovery of Discoverer 13, the first man-made object ever recovered from earth orbit. In the following account, Miller explains the recovery sequence and satellite recovery vehicle used in the Discoverer/Corona system. Miller also shares some of his experiences and insight into the ground-breaking program.

On August 20, 1960, the *New York Mirror* carried an article about the United States recovering a "space cone"—a Discoverer 14 capsule—in mid air. The newspaper saw the story important enough to warrant 2-in tall type for it (see figure 15). But the interesting thing is how this New York newspaper also thought it was important that it happened on the same day that Francis Gary Powers was sentenced to 10 ten years in jail for his U-2 spy plane mission over Russia. Of course, that was a complete and total coincidence

Others have written about the overall Discoverer/Corona system. I'll write about the satellite recovery sequence and the Satellite Recovery Vehicle (SRV), itself.

The Recovery Sequence

To start the recovery sequence on ground command, the Agena satellite reversed direction by rotating in the yaw axis—in other words, flying backwards. The Agena pitched down 30 degrees below the horizon to enable a separation. What the recovery vehicle had to do first of all was to cut the film.


FINAL 5
WEATHER: Partly cloudy, a little warmer. Highest temperatures in 70s.
New York Mirror
SATURDAY, AUGUST 20, 1960
U. S. GRABS SPACE CONE IN MID-AIR
STORY ON PAGE 2

Figure 15. The *New York Mirror* headline on Saturday, August 20, 1960.

Then separation charges were fired that jumped the reentry vehicle off the Agena. This had to be done very accurately because the 30-degree down position below the horizon was a very critical angle. If the SRV came in too steeply, it burned up. If the SRV came in too flat, it would just bounce off the top of the atmosphere into an unpredictable decaying orbit and would be lost.

Following the jump off from the Agena, for ballistic stability during reentry, the SRV had spin rockets that spun up the SRV to about 6 rpm. The SRV then reentered the earth's atmosphere where it passed through a fierce 4,000 degrees F thermal environment and very, very high g-loads. After it survived the reentry, a barometric switch deployed the parachute at 55,000 ft and subsequently activated telemetry, chaff dispersions, strobe lights, and an omni-directional antenna to assist the aircraft in their search for the SRV. We at GE have never referred to the SRV as a bucket.

Here is an interesting story about Capt Harold Mitchell who recovered Discoverer 14 in mid-air.

During an earlier mission Capt Mitchell had been pursuing Discoverer 13 in its primary expected recovery area (where the vehicle actually came down.) There are various stories. Some say it was foggy. Some say there were layers of clouds. Some say it was a clear day and he just plain missed. I think the truth is there were cloud layers every 10,000 ft or so and he took a few passes at it and missed.

So Discoverer 13 actually landed in the ocean, and to the Air Force's embarrassment, was recovered by the Navy. A Navy frogman fished it out of the Pacific 600 miles southwest of Honolulu and the naval ship, *Sunnyvale*, came back to Honolulu proudly displaying their "clean sweep broom" on their top deck in accord with Navy tradition.

So for the Discoverer 14 mission, Capt Mitchell was "banished" to left field—the most unlikely splashdown area. He denies that he was banished to the southwestern sector and I will take his word for it.

But nevertheless he was flying in the most improbable part of the recovery zone and the SRV landed in his lap—instant promotion for Maj Mitchell. Many adventures later he was a lieutenant colonel and retired with honors and medals from the USAF.

The Satellite Recovery Vehicle

Figure 16 gives a fairly good idea of what the SRV looked like. The part with the GE logo on it is the heat shield. That small, shiny triangle atop the vehicle is the retro rocket nozzle. Everything on the right is payload contained inside of the SRV and accommodates the two rolls of film, and is the part of the SRV that is actually recovered.

The picture (see figure 17) was taken at the Pentagon on the occasion of the recovery of Discoverer 13, August 15, 1960. In this picture you can't see it, but the blade antenna is sticking up right under, Gen Schriever's nose. It annoyed him and he would rotate it away. Then you couldn't see the GE logo anymore and my marketing guys would say, "Hey, turn it back, turn it back." So I would turn it back under Schriever's nose and he would push it out of the way. That was the twelfth time the mock-up was taken to the Pentagon. It was a pretty sorry mock-up by that time, war weary at best.

Figure 16. Capt Harold E. Mitchell (left) and Dr. Ed Miller in Dr. Miller's office in Philadelphia. Photo courtesy of Edward Miller.

Figure 17. An early configuration mock-up of the SRV. From left to right, Ed Miller, USAF Gen Bernard Schriever, Brig Gen Richard Curtin, and Reginald R. Kearton, Vice President of Lockheed at the time. Photo courtesy of GE/U.S. Air Force.

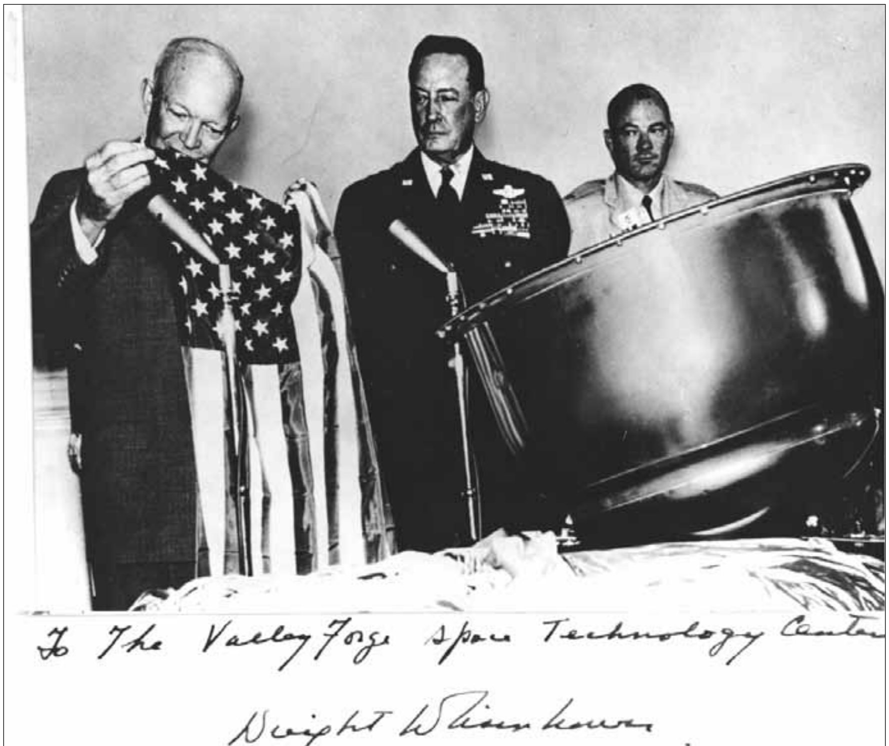


Figure 18. President Eisenhower (who always preferred to be referred to as General) and USAF Chief of Staff Gen Thomas D. White. Photo courtesy of the National Park Service and the Dwight D. Eisenhower Presidential Library.

Figure 19. A vintage *USA Today* picture, published on February 24, 2005, a day or two after the Charles Stark Draper prize was awarded to the leaders of the Corona Project by the National Academy of Engineering. I was one of five recipients. Photo courtesy of the National Academy of Engineering, 1960.

Air Force Gen Goodpaster was Eisenhower's personal military assistant at the White House. He told me a couple of years ago, "President Eisenhower was a staunch supporter." He was described as an "intelligence junkie" and always wanted to know "what was over the top of the next hill." So he was 1,000 percent supportive, in spite of repeated failures, and he kept telling General Goodpaster, "They'll get it right. They'll get it right." Between the President's confidence and the downing of Gary Powers' U-2, the intelligence agency kept the Corona project going. If that happened today, two or three failures, we'd be out of business.

The curious mishap is that when this picture, originally taken in 1960, was transmitted to the West Coast from the East Coast, the two people on the right side of the earlier version were cut out.

Lockheed has always said that they think that GE got them cut out of that photograph—not so! Believe me, anyone that has that much power over the press has not been born yet.

My Background in Reentry/Recovery Vehicles

How did I get into all this to begin with? I was transferred from our Aircraft Jet Engine Division in Cincinnati to Philadelphia in the GE Missile and Space Division towards the end of 1958. GE had a strong background in ballistic reentry/recovery vehicles. It had built a successful flight-proven copper-heat shield for the Thor Intermediate Range Ballistic Missile (IRBM). But copper is very heavy and was not suitable to a Corona type mission. After reentry, it remains very hot, and stays with the vehicle all the way in so it would probably bake the film into uselessness.

My earlier assignments were based in the Missile and Space Division as Project Engineer and Program Manager on GE's first two Intercontinental Ballistic Missile (ICBM) nose cones, the experimental RVX1 and RVX2. We developed the phenolic nylon, which is the material selected for the Corona heat shield. During the RVX1 and RVX2 periods, we made a choice from among phenolic nylon, phenolic glass, and phenolic refrasil. It turned out nylon worked best. Like Eastman Kodak's film, this was wound on in 7-in widths, a few thousandths of an inch thick. It was wound onto the structure to about the thickness of 1 in. The phenolic nylon "ablated" or charred, when exposed to the high temperatures of reentry. It also blew off, disposing of the heat it had absorbed and exposing fresh nylon. This was repeated over and over again and enabled a very lightweight heat shield as compared to copper heat sink designs.

Following that I was assigned as Project Engineer on the Mark III Research and Development (R&D) program for the Atlas ICBM reentry vehicle, which utilized the ablative phenolic heat shield. As a result, we were able to fly a reentry vehicle 9,000 miles successfully. This showed that reentry from orbit was not only feasible, but essentially proven.

Technical Challenges of the Program

And now, briefly, our technical challenges. The sole objective, simply put, was to preserve and recover the exposed reconnaissance film and return it safely to earth. This involved the development of the heat shield that I just discussed and the structure.

We had an aerodynamic problem. When you put this big 70-mm movie film in, we had to find a shape that would accommodate it. But the shape also needed to permit the vehicle to separate and reenter with what is called "laminar" flow, smooth flow over the heat shield. If too turbulent, it would excessively heat up the heat shield. It had to withstand 4,000-degree F temperatures, enormous g-loads and, also, acoustic noise.

The last is one thing often overlooked. The acceleration noise is from the acceleration loads on lift-off and it is the toughest one of those problems.

We had a tough acoustic noise vibration environment to withstand and keep all the pieces together on the way out. We had to develop the spin motors and the explosive bolts. The retro rocket was another tricky design since it had to have exactly the right number of pound-seconds of fuel in its casing and burn it to completion. No on-board computer meant you couldn't throttle it or turn it on and turn it off. Once ignited, that was it. It was going to burn to completion. And that made a fairly tricky design problem. Thiokol was our sub-contractor on that and did a great job.

I mentioned the sensitivity of the down pointing angle that probably couldn't exceed plus or minus two degrees for a successful recovery. As it was, the recovery zone was hundreds of miles wide and even longer.

We had to configure the film cover, design the parachute cover and parachute itself, the barometric switch, strobe lights, and antenna.

The heat shield got pretty hot and after the chutes deployed, a means of disposing of the heat shield had to be developed. And we also had to develop a means of jettisoning the heat shield after it had done its job.

We also had to assist in the development of the air-snatch scheme and the development of the multiple parachute systems to tolerate the shock of air-snatch.

The salt water sink plug was designed and installed so that the SRV would sink if it was in the water for more than twenty-four hours. Hopefully, that would keep Soviet ships and subs from getting it before we got there. All of this had to be done with programmers that provided precise event timing sequencing since there was no "real time on-board computer." Everything was hard-wired.

Operating Under Cost

Here are two stories that you will never read in the paper. We turned back half the money, (for the entire Mark III R&D program), to the government. We had a twenty-eight flight program and completed all engineering/development tests in fourteen flights. We turned the fourteen extra reentry vehicles over to the Operational Program and advanced the readiness of the Operational Program by a year. That you won't read in the New York Times.

Also, our official record for the SRV was as follows. During the period of June 1962 to January 1963, we had fifteen consecutive recoveries. Between June of 1964 and May of 1972, we went to bat sixty-five times. There were sixty-five opportunities to recover and we did so sixty-three times.

At one point in this "cost plus" program, GE gave back to the CIA funding from an underrun. Again, something you don't read about in the newspapers. The CIA was very grateful for that, as you can imagine. They promptly ordered some more SRVs from us at a favorable price. So, we both made out alright on that one. The CIA is, in this writer's opinion, the best government entity with which to do business. They kept a focus on the common objective—to succeed with the program. There were no pompous contracting officers trying to nickel and dime the contractors. They had all the technical skills in-house to make timely decisions and did so. As a contractor, you felt you were part of a team and not an adversary.

Conclusion

Corona was initially planned to be a temporary measure. Despite its "temporary" nature, Corona flew 145 times.

My job was manager of the Discoverer, Samos, and Midas programs at GE, also project engineer for the same programs. The Corona camera system did so well, I have a feeling that the Itek photographic fellows are owed much more credit than they received publicly. I have a hunch that the ground resolution they achieved at one point was less than 5 ft. Ground resolution means that you can discern something with the longest edge at least 5-ft long.

I want to thank all the GE people who worked with me, more than 300 strong, on Discoverer 13, the first man-made object ever recovered from earth's orbit. I want to thank those who made the world's first SRV a success.

I want to add my own accolade to Jim Plummer. Jim is always too modest about his important role. He ran a complex, multi-faceted, first-of-its-kind space program. He used to say "Well, they gave me a job and I did it." That's how he described it. He demonstrated not only technical leadership but also managerial and interpersonal skills in leading the major sub-contractors, GE, Eastman Kodak, and Itek, the camera developer. He also managed the CIA interface with considerable expertise. He guided from the beginning a novel satellite through crippling problems, booster, rocket, guidance system, film, and camera failures. He never gave up. He was fair-minded in distributions of roles and responsibilities. He gave the right roles to the right contractors with the best capabilities, regardless of who got the business. Actually there was very little profit made by the contractors who had standard cost plus fixed fee contracts with a 5 to 6 percent fee (before taxes). Overruns paid no fee.

I conclude by quoting President Lyndon B. Johnson who I think best summarizes the significance of the Corona program. He said,

"I wouldn't want to be quoted on this but we've spent 35 or 40 billion dollars on the space program. And if nothing else had come out of it except the knowledge we've gained from space photography, it would have been worth ten times what the space program has cost. Because tonight we know how many missiles the enemy has and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor.

> *"Because of satellites, I know how many missiles the enemy has and I can sleep comfortably at night."*

President Lyndon B. Johnson
Remarks to educators in Nashville, Tennessee
March 16, 1967

Chapter 6

MID-AIR RECOVERY CHALLENGE

Figure 20. Capt Harold E. Mitchell.
Photo courtesy of General Electric.

Lt Col Harold E. Mitchell (Ret)
Commander of C-119 that Recovered
First Reconnaissance Photos from Orbit

Capt Harold E. Mitchell was commander of the C-119 that recovered the Discoverer 14 capsule, the capsule containing the first reconnaissance photos ever recovered from orbit. After missing the recovery of the Discoverer 13, it was only through learning from their mistakes and being in the right place at the right time that Capt Mitchell and his crew successfully recovered the Discoverer 14 capsule. In the account below, Mitchell recounts not only the conceptual history but also his experience with the Corona midair recovery.

At first, no one believed me when I reported that I made the midair recovery of an object returning from space on August 19, 1960. Eight other planes spread across hundreds of miles of the Pacific were tracking the signal of what they thought was the still-falling recovery capsule of the Corona satellite. But the capsule had reentered at a point farther south than programmed. On my third try, I snagged its parachute with a hook and winch system out the back beaver tail doors of my C-119 aircraft, call sign Pelican 9.

We called in to the command post that we were reeling it in and coming back home. They told us to stay off the air because they were working the target. Twenty minutes later, my crew observed another plane that was still trying to catch the prize. Eventually the rest of the team figured it out and joined Pelican 9 for our triumphant trip back to Hickam Air Force Base (AFB) in Hawaii. That momentous catch was Discoverer 14, the first successful mission of a reconnaissance satellite that would transform American intelligence gathering.

Recovering High-Altitude Balloons: The Genetrix Program

The Corona catch followed successful efforts in the mid-1950's to snag high-altitude balloons as part of the Genetrix Program. Genetrix balloons were designed to fly as high as 65,000 ft in order to

Figure 21. The United States Air Force C-119J #037 responsible for "hooking" the parachute lowering the Discoverer 14 satellite. Photo courtesy of the U.S. Air Force.

conduct reconnaissance missions over the Soviet Union. Most of the balloons were lost over Soviet territory, but I caught one of the rehearsal systems off the west coast of the United States and tracked another to a successful ground recovery in North Dakota.

Although Genetrix was a largely unsuccessful attempt at pilotless reconnaissance, the techniques developed to capture objects hanging from airborne balloons or parachutes would prove to solve a problematic question on the Corona project—how to bring the film capsules safely back to earth from orbit.

The Recovery Concept

The process, largely the same for Genetrix and Corona, started with a C-119G aircraft that had been modified to a beaver tail system so the cargo doors and tail lifted up hydraulically over the rear of the airplane, rather opening like a clamshell. This allowed for free movement of a system of poles, nylon line, hooks and winch that would snag the parachute and allow it to be reeled into the cargo bay of the aircraft.

I remember first seeing the modified plane. All of us agonized and wondered what we were going to use the plane for. There were two hydraulic actuators, each located at the rear edge of the cargo floor on both sides of the plane. When they started bringing in 36-ft telescopic poles with rolls of nylon line and bronze hooks, we had no idea what we would be doing but we knew it would be something new and different. A powerful electric winch with a 3/8 in steel cable rolled on the drum was located about half way back to the rear of the aircraft and just to the rear of two enclosed 500 gallon fuel tanks.

The steel cable was attached to a loop made from approximately 100 ft of nylon line and had three bronze hooks attached at specific distances at one end of the loop. The loop was then attached with spring clips to the end of the poles. The other ends of the nylon line, forming the loop, were attached by wedges to the winch cable. The 36-ft poles, run through the hydraulic actuators, were extended into the slipstream and lowered to a 45-degree angle below and to the rear of the airplane forming a loop. Snatching a capsule involved getting the parachute to pass beneath the airplane, between the poles and into the loop where it would be snared. The nylon loop attached to the winch cable would be pulled from the clips attaching it to the ends of the poles and like a fishing reel pay out the cable. The winch operator would slowly apply brakes to the drum, bringing it to a stop.

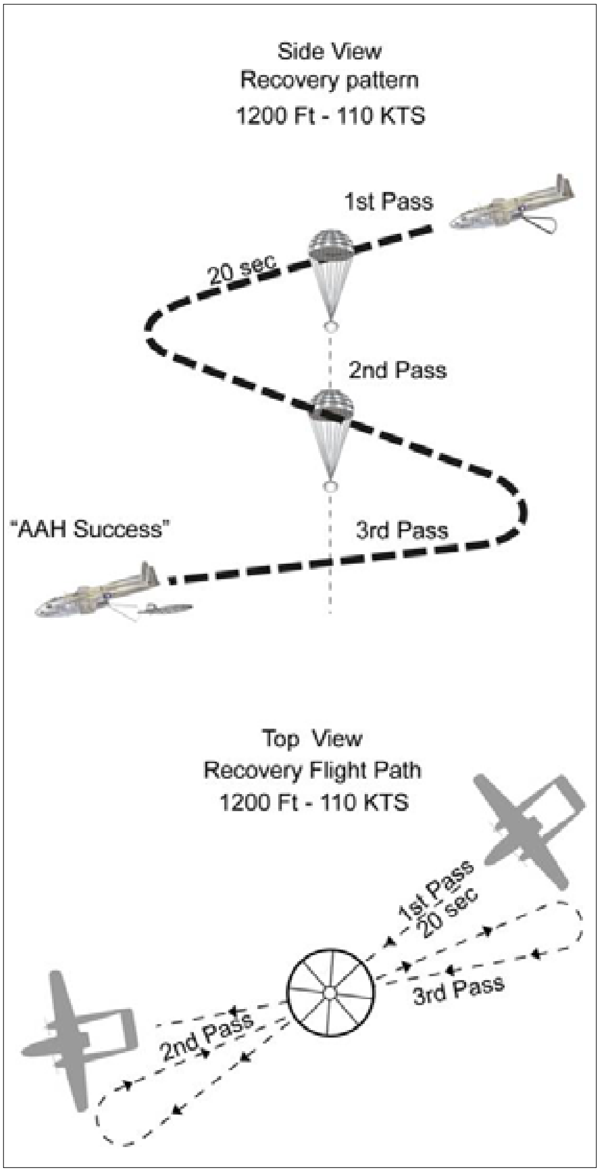


Figure 22. Recovery flight pattern and path.
Figure courtesy of Ingard Clausen.

Editor's Note

Early acquisition of the beacon's capsule is not shown in the sketch. In order to increase the odds of recovery, the pilot would issue the crew oxygen bottles and take the aircraft up to 18,000 ft for early beacon acquisition. Mitchell did not do this because his orders said he must not.

In Mitchell's recovery, when he was at 1,200 ft, he missed on two passes, catching the Discoverer/Corona capsule 13 on his third pass.

In the top view, the aircraft is still at approximately 1,200 ft, flying at 110 knots, and painting the petals of a sunflower. In the figure, three petals are painted as Mitchell sets the world record for mid-air recovery of a man-made object from orbit. Note that this capsule contained film.

He would then reverse the rotation, reel in the cable, nylon and the recovered package to the rear of the plane and into the cargo compartment.

The Weight Issue

The major difference between catching the Genetrix and Corona systems was the weight. The Genetrix system weighed 800 to 1,000 lbs and Discoverer systems weighed approximately 100 lbs. This necessitated an alteration to the winch system by replacing the steel cable with nylon line. The Genetrix gondola was suspended from four large 24-ft chutes with a 15-ft drogue chute tethered on a line above them, which was used to recover the system. Corona was suspended from a single 24-ft reinforced parachute (larger chutes were used on the later and larger Corona payloads). The Corona parachutes were more stable and much easier to work.

To give the same weight effect as the actual system to recovery training missions, concrete blocks weighing 100 lbs were fabricated and suspended from modified 24-ft personnel parachutes.

Constant Fine-Tuning

I commend Lockheed and General Electric (GE) on their work to make the concept viable as well as their response to suggestions by pilots and recovery crewmembers. The entire operation required a total team effort by all of the individuals involved. The result was a system that met all of the rigorous requirements needed to successfully complete an aerial recovery mission—ease of visual and electronic identification, desirable stability, and rate of descent, as well as survivability with low g-loads.

We were constantly fine-tuning the system to make a safe, successful operation. For example, while working on Genetrix and training for Corona, I had developed my perspective on flying and aerial recovery. I liked to have my seat at the same height and distance from the yoke on each recovery. I liked to fly with the parachute rather close to the belly of the plane on my approach. That could cause an inversion, which prevented deflation of the chute. This allowed the parachute to pull the rigging from the poles and loss of the capsule.

After discussing this with my crew, they decided to raise the poles to a more in-trail position and not down to full 45-degree angle. Using this method on our practice missions proved successful for us and reduced the number of bent poles that could result from a pole receiving the full force of a fully air inflated parachute.

Even with constant re-evaluation of systems and techniques, we would encounter situations we had not experienced in the development and mission phases.

Discoverer 13–Recovery Failure

On Discoverer 13, we were flying in the primary recovery position, Pelican 1. As the capsule descended, it was directly over our orbiting position. We were so close and the beacon reception so strong that the navigator could not determine a heading on the oscilloscope. As we orbited our position, we received a vector of 285 degrees to a suspected target by an RC 121 radar control aircraft.

After a period of minutes on this heading, my navigator requested a 360-degree turn to check for an oscilloscope reading. We had completed turning 180 degrees when the navigator advised me the target was dead ahead. The RC-121 radar had mistakenly given us a reciprocal heading.

Continuing on the new heading, we arrived back where we had started in time to see the parachute and Discoverer 13 capsule floating in the water with Pelican 3 circling over it. It was soon recovered by a Navy ship, much to the disappointment of the Pelican 1 crew.

The following week my crew and I flew our plane 037 on several missions testing radios, electronic equipment, and receivers to duplicate the problem encountered on the Discoverer 13 mission. The nearest thing that could be determined was that from directly overhead the beacon could saturate the oscilloscope tracking capability.

Discoverer 14–Successful Recovery

Discoverer 14 was launched on August 18, 1960, and when the satellite went into orbit, all was not rosy for my crew.

After the fiasco of the previous mission and the following week test flying the electronic equipment, our aircraft 037 had developed an intake on the left engine. This would require a new

Figure 23. The Discoverer/Corona 13 capsule in the Pacific Ocean, eventually recovered by the United States Navy.
Photo courtesy of GE/U.S. Navy, August 11, 1960.

cylinder being flown in from the States to Hawaii. Nevertheless, that evening at dinner, I jokingly told my wife Nancy to pack my bags to go back to the States tomorrow night.

I arrived at Hickam AFB, Hawaii at 6:00 am and found my plane and crew ready. After briefing, we gathered at the plane knowing we would be flying the Pelican 9 position, several hundred miles from the programmed reentry area. By noon we were orbiting on position, 300 miles southwest of Hickam AFB at 17,000 ft, awaiting the notification of separation and reentry of Discoverer 14. Successful separation was confirmed over Kodiak, Alaska and reentry at 12:46 PST by the Command

Post. Pelican 9 continued to orbit at 17,000 ft until 12:53 PST when the navigator reported he had beacon identification at a heading of 255 degrees. Rolling out on the desired heading, I started 037 on a gradual descent, expending excess altitude and gaining airspeed toward the target.

The navigator requested a 360-degree turn to reaffirm the heading and commented, "I'll bet my life it is dead ahead, 255 degrees!" A couple of minutes later, the orange and silver parachute appeared with the golden capsule suspended from it. It was 4,000 ft above and ahead of the aircraft. Rick, the co-pilot, called the Command Post to make the coded report that the capsule had been sighted and Pelican 9 was proceeding with recovery preparations. The Command Post advised, "Stay off the air!" because they were vectoring another plane to a suspected target in the primary recovery area. So Pelican 9 proceeded with recovery preparations without further Command Post communications.

The initial recovery pass was started at 12,000 ft as the target descended through our altitude. The first two attempts for recovery were near misses and the third could be the last, as there was an under cast of clouds with tops at approximately 7,000 to 8,000 ft.

After a shortened outbound leg on the recovery pattern, Pelican 9 started the third and successful pass. As we rolled in on the inbound heading, the parachute was slightly bobbing and moving left of the aircraft's flight path. I edged the plane only slightly with the rudder pedals and as the parachute flashed down the belly of the fuselage, I felt a slight tug as the parachute made contact with the right pole and pulled the loop from the spring clips. The safety Non-Commissioned Officer (NCO) called over the intercom, "Good hit Captain. We've got her in tow." We successfully "hooked" Discoverer 14 on August 19, 1960, at an altitude of 8,000 ft, 360 miles southwest of Honolulu, Hawaii.

When the Command Post was called to report a successful recovery, Pelican 9 was told to stay off the air and not interfere with a recovery attempt in progress. Discoverer 14 was safely on board and stowed in the gray metal security canister and the gear was stowed when the Command Post radioed requesting "Pelican 9." Pelican 9 reported Discoverer 14 was safely on board and stowed and gave an estimated time of arrival to Hickam AFB.

Celebrating the Success

Arriving back at Hickam, the celebration began. All of the members of the Recovery Squadron as well as family members and, yes, my wife, Nancy, had my bags packed and ready for my trip back to the States.

Gen Emmett O'Donnell, Pacific Air Force (PACAF) Commander, had called Gen White, Air Force Chief of Staff, to report the successful recovery. Gen White's reply was, "I don't know these men but give them a medal." Gen O'Donnell awarded me the Distinguished Flying Cross and the other crewmembers the Air Medal on the spot.

I attended a press conference with my navigator, Lt Counts, and winch operator, Tech Sgt Bannick, in the hanger. Afterward we joined the rest of our members at the beer keg to celebrate the success that eluded us the week before. Poetic justice? Maybe.

Upon arriving back and parking in the place of honor and immediately after shutting down engines, those waiting for us transferred the grey metal canister holding the precious capsule securely locked inside to another plane for its trip back to anxiously waiting hands and eyes in the States. The next morning, after twenty-four hours with no sleep, the weary but jubilant navigator, winch operator, and I arrived at Los Angeles International Airport. Maj O. J. Ritland and the Air Force Captain who launched the Thor/Agena system, which put Discoverer 14 into orbit, met us.

Figure 24. Maj Harold E. Mitchell being congratulated by Edward A. Miller, Manager, Discoverer Project, General Electric, at Valley Forge for his successful efforts in the recovery of Discoverer 14. Photo courtesy of GE/U.S. Air Force.

Following a press conference at the airport and a greeting by the staff at Air Force, Ballistic Missile Division and other well-wishers, we retired to a motel for some needed rest. The coming days were full for the recovery crew with personal appearances on the Dave Garroway show and other places as well as press conferences in New York. Then it was on to Washington, D.C. and Headquarters Air Force Research and Development to meet with our Commander, Lt Gen Bernard Schriever to brief his staff. This was followed by a trip to Sunnyvale, California and a tour of the Palo Alto Lockheed facilities for the Discoverer project.

Though the Corona Program continued on into the mid-1970's, Discoverer 14 would be my only air recovery of a satellite capsule.

Conclusion

Looking back at the successes and failures of the Genetrix and Corona aerial recovery programs, both have a significant place in aviation history. A Corona capsule and the C-119J Recovery Aircraft 037, Pelican 9, share their place at the Air Force Museum, Wright-Patterson AFB, Ohio.

For more information about Lt Col Mitchell, please refer to his autobiographical reflection in Appendix 2.

Chapter 7

MID-AIR RETRIEVAL CHALLENGE

Figure 25. Lt Robert Counts.
Photo courtesy of GE/U.S. Air Force.

Lt Robert Counts
Navigator and Director of
Mid-Air Recovery Operations

A secret team which was training to recover satellites from space out of Edwards Air Force Base (AFB) recruited Lt Robert Counts to join them. Joining Capt Mitchell's crew (see the previous chapter for Mitchell's account), he served as navigator on the C-119, which recovered the Discoverer 14 capsule, the first ever successful midair recovery of an object from space. In the following recollection, Counts recalls his preparation to join the Discoverer Recovery team, the recovery concept, and his experiences in attempting to recover the Discoverer capsule.

Capturing the first Discoverer capsule to reenter the atmosphere successfully was bound to be a point of honor for any flight crew. As it turned out, no one but the Pacific Ocean had the glory when Discoverer 13 returned. However, the thrill of snagging capsules was felt by several aboard the C-119s, including me as the navigator.

Preparing for a Midair Recovery

As a navigator, I served with the Military Air Transport Service (MATS) at Travis AFB in California for two years, September 1956 to 1958. Then a cryptic assignment came my way.

I was selected through some mysterious mechanism to go to this super-secret outfit, which was training at Edwards AFB to recover satellites. I never knew exactly why I was chosen; being a bachelor was in my favor though.

Usually it was required that the Air Force give an officer a thirty-day notice that he was to be assigned to a different area so he could get his life and responsibilities together. In this instance, with these secret orders, I was expected to be at Edwards AFB in six days.

Figure 26. Photograph of Aircraft JC-119 #037, August 19, 1960, taken after landing at Hickam AFB, Hawaii. In the center, in canister, is Discoverer 14, ready to be lifted off the tailgate of the airplane (note the keyless padlock on the right side of the canister). The recovery crew, identified left to right: TSgt. Louis Bannick, Winch Operator, A2C Lester Beale, Loadmaster, A1C George Donohue, Loadmaster, SSgt Arthur Hurst, Flight Engineer, A2C Daniel Hill, Loadmaster, SSgt Algaene Harmon, Loadmaster (face not seen), and SSgt Wendell King, Photographer (note the overhead camera mount, just above Daniel Hill's forehead). Photo courtesy of GE/Air Force.

There were nine airplanes and nine crews for those airplanes. That meant nine aircraft commanders (Lt Col Harold Mitchell was my commander) and nine pilots. The pilots were all captains, all married, and all with experience in air recovery through other programs. The co-pilots and the navigators were all first lieutenants and were all single. The navigators, like me, were right out of MATS.

We came from bases across the country. Those on the East Coast flew the missions over Europe and South America. The West Coast crews flew over the South Pacific and Asia. We would meet up halfway around the world in Pakistan. Only recently did I discover that one of the navigators, a fellow no one really knew, was actually a CIA "mole."

I also later discovered that the lovely secretary for the squadron in Hawaii also worked for the CIA, as did an adventurous civilian named Harry Conway, who was a company tech rep.

We trained at Edwards AFB for six months, learning aerial recovery and refining the equipment. We then deployed to Hickam Field in Hawaii.

We were all briefed early on about the purpose of the program and the importance of what we were doing.

It was a super-secret thing, but the secrecy of this program kind of ebbed and flowed. I have newspaper clippings openly covering our activities in Hawaii. But after the first successful recovery, the Discoverer program again cracked down on secrecy. There was a difference between what the officers knew about the reconnaissance film and what the enlisted men were told.

How a Recovery is Supposed to Work

As the navigator, I directed the aircraft any time we were out over water and operated the homing equipment to pick up the satellite's radio beacon. Once I guided the crew to the capsule, however, my task was done and I became a safety officer as the crew went into recovery mode.

In recovery mode the back door of the aircraft is open and the equipment is deployed. There are a couple of poles that swing out and then down. A winch inside the airplane has a line on it and a rope that goes out into a Y to the tips of the two poles. Then there are a couple of ropes that go from pole to pole. There is an array of hooks on the end of each pole, and hooks in the middle of the lines that go pole to pole.

The pilot was to maneuver the aircraft to fly over the top of the parachute carrying the capsule to the surface. The parachute would then be impaled in the network of trailing lines. The lines would let out and then a brake on the winch would slowly apply, "much like the star drag on a fishing reel," to accelerate the parachute up to aircraft speed—an envelope of 115 to 120 kts, depending on the aircraft. Some aircraft could not fly as slowly as others could.

Finally, the crew would slowly reel in the parachute and get it on board. The 0.5-in nylon rope alone, with all the other activity and equipment, created plenty of opportunities for hazards. That was where the safety officers came in. My job at that point was to be alert to any dangers around the working men. My crew, in fact, did have one adventure during practice that could have been fatal to more than one of them.

Figure 27. A C-119 #037 making an operational recovery. This is not Discoverer 14, as no other aircraft were present. Photo courtesy of GE/U.S. Air Force.

A Recovery Mishap in Practice

During the training sessions, we used three aircraft.

Figures 28, 29, and 30, in sequence, depict a practice/test recovery in the Pacific Ocean near Hickam AFB, Hawaii. The photos were captured by an overhead high-speed camera looking out of the backdoor of the C-119 aircraft. The sequence shows the gradual pay out of the line by slowly applying the brake to the line so that the force is held below its safety limit, resulting in a constant, tolerable, capsule acceleration. Figure 28 is showing the parachute engagement on the right pole. Note at the bottom of the picture is the upper portion of the parachute. Figure 29 is showing the parachute and the loop paying out. Note the pole tips at the bottom of the picture are flexed into frame. Figure 30 is showing the loop payout continue.

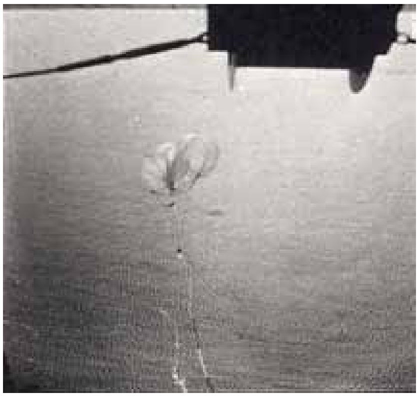


Figure 28. Parachute Engagement/Photo courtesy of GE/U.S. Air Force.

Figure 29. Parachute and Loop Paying Out/ Photo courtesy of GE/U.S. Air Force.

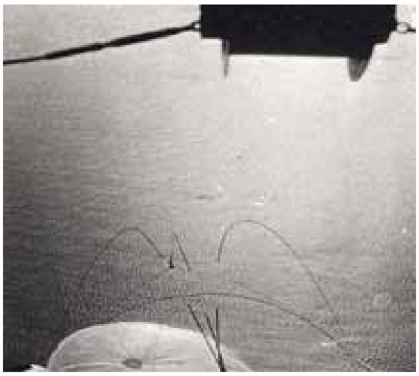


Figure 30. Loop Pay Out Continues/ Photo courtesy of GE/U.S. Air Force.

One of the aircraft dropped a parachute, one was the primary recovery aircraft and one was a backup. That day my crew was the drop airplane. After we executed the drop and the other aircraft went after it, our duties were over. That gave us the opportunity to go off and perform a drop to ourselves. A drop to ourselves meant pushing out the practice weight and then executing a dramatic drop in altitude to recover the falling parachute. That required plenty of preparation to have the poles ready to push out after the drop.

The loadmaster was right on the edge of the open door. Usually he would sit on his butt and then just kick (the practice weight) with his feet. It was a hundred and some pounds and would topple over the edge and fall to the end of the static line and open.

On this day, for reasons still unknown, loadmaster Al Harmon stood up and pushed it with his hands, thereby saving his life because when it fell out, for some reason, it opened immediately. It opened up right in the back of the airplane. It grabbed one of the hooks and fell away already "recovered" and took the line out with it.

Harmon, wearing a safety harness and tether, was standing with all the recovery equipment, grapple hooks, etc., behind him.

It shot out across the floor and whacked him at the feet. It knocked his feet right out from under him and he went up in the air. The whole recovery rig went under him and was gone when he fell back against the deck. So he was ok, but if he'd been sitting, he would not have been ok.

I was well inside the airplane standing to one side. I didn't have a safety harness on but I was wearing a parachute.

Suddenly I was grabbed around the right leg by the snaking rope and was snatched out into the air. The rope whipped me out past the actuator that held the pole on the ramp just outside the aircraft. As the rope pulled me out, I grabbed hold of it.

I don't know how I reacted that fast, but I did and I hung on! It stretched me out pretty tight, but then it came off my foot and I was ok. I had a badly torn ankle but I was still aboard the airplane.

Discoverer 13 Disappointment

My crew, under Mitchell, was on Discoverer 13, the first successful Corona recovery, in August 1960. We were Pelican 1, meaning the primary recovery aircraft with eight other planes spanning south from us as the capsule reentered. But it hit the water and we were the crew that didn't get to it in time. It was a great disappointment. It's hard to say what happened. We were never debriefed on what was found out. It appeared to me that the capsule had pretty much come down right on top of us.

The tracking equipment was pretty primitive. We read signals from both the left and the right antennae. One signal would be stronger than the other, and the pilot would turn to the right and then to the left until the signals were equal. But there was ambiguity in judging a source that was straight ahead or straight behind.

In the early days, we were flying C-119s, which had no radar. But we had backup from C-121s with more sophisticated equipment. The parachutes were radar-reflective and there was also chaff to show up on radar.

When the Discoverer 13 capsule was reentering, we were contacted immediately from one of the C-121s informing us of where it was and vectored us in. However, I soon realized that something was wrong. The signal was getting weaker and we turned around. We flew over the capsule just as it splashed down. We actually contemplated somehow recovering it from the water but decided the difficulty was too great. Years later I would help design a method for doing just that.

Discoverer 14 Success

A week or two later, our crew rotated to the end of the line of the nine-plane array and our call sign became Pelican 9 as they anticipated the Discoverer 14 capsule. Seemingly, we would have been the least likely aircraft to make the recovery.

But lo and behold, in the erratic force of the universe, it came right down on us again. Not right on us, but pretty close. This time we were able to pick up the signal (without help from the Navy tracking), home in on it, arrive on time, and pick it up.

After the first one, the failure, we were very discouraged, a lot of long faces. Here had been the big opportunity and we muffed it. Then nature made it up to us and we were highly elated.

As they reeled the capsule into the airplane, Harmon, the senior loadmaster, reached out and grabbed it. He then quickly let go because it was still so hot. I think he's probably the first human on the planet to feel the heat of reentry.

We did pull it in, tied it into an anti-magnetic and anti-radiation mylar bag and locked it into a canister. We landed at Hickam and were greeted by the press and dignitaries. Mitchell, the winch operator, and I were told to go home, take a shower, and be back in an hour because we were going to Washington, D.C. to meet President Eisenhower. The rest of the crew joined us there for a public relations tour. We could talk about the recovery but could not go into the actual description of how we recovered the capsule. That led to much imaginative speculation in the press as to how the recovery was completed.

Figure 31. A practice recovery test over the Pacific Ocean near Hickam AFB, Hawaii. The first part of the loop is being reeled on board by the crew. Photo courtesy of GE/U.S. Air Force.

Conclusion

Those in the Air Force never knew the program as Corona. In fact, years later when reunions were organized calling on everyone involved in Corona, many others and I didn't show up because we did not think the invitation referred to us.

Looking back, I appreciate the importance of the Corona project in ending the Cold War. I hope I made a contribution. While I was still in the service, I received validation of that when visiting my sister. She had the World Book 1960 Year Book and showed me my name in a recap of the satellite recovery.

That changed my life. Up until that time, I had been kind of driven. What am I going to do in life? Is my life going to be meaningful? Why am I put here? All these questions. But when I saw my name in the encyclopedia, I thought, that's enough. I can relax and do what I want to do and not worry about my place in history.

For more information about Lt Counts,
please refer to his autobiographical reflection in Appendix 2.

Figure 32. A practice/recovery test where the crewmembers are erecting the recovery poles to reel in the capsule. Photo courtesy of GE/U.S. Air Force.

Figure 33. The recovery of Discoverer 14. The capsule and chute are nearing the rear of the aircraft. Note the charcoal black top of the capsule, soot from reentry, and clean center where the parachute cover door has been ejected. Photo courtesy of GE/U.S. Air Force.

Chapter 8

PHOTO INTERPRETER CHALLENGE

David S. Doyle,
Photo Interpreter, National
Photographic Interpretation Center

Figure 34. David Doyle, right, is accepting the Distinguished Intelligence Medal from Leo Hazelwood, left, upon Mr. Doyle's retirement in1994. Photo courtesy of NPIC.

David Doyle became interested in aerial observations while serving as a pilot in the Korean War. He began working for National Photographic Interpretation Center (NPIC) only six months before the first successful Corona recovery and was heavily involved with learning how to interpret and use the unprecedented amount of imagery recovered from Discoverer 14. In the following account, Doyle shares his experiences learning how to interpret and use the new data made available with the success of Corona. Doyle shares the value of the data and its effect on the Cuban Missile Crisis.

Before the first successful Corona mission in August 1960, the country's nascent photo interpretation agency suffered from not only a lack of film evidence of Soviet weapons building, but also a lack of core knowledge about Soviet territory itself. Working with outdated and inaccurate maps, the few spools of film returned by the dangerous, manned U-2 missions over Soviet territory were not enough to give interpreters and intelligence agents a true sense of how big a threat the Soviet Union posed.

Learning to Interpret a New Kind of Film

Discoverer 14, the second successful Corona mission and the first to carry film, changed all of that. After a successful midair snatch of the recovery capsule on August 19, 1960, film traveled to Eastman Kodak in New York for processing before arriving at the newly formed NPIC. I had been at NPIC for less than a year and was one of forty or so photo interpreters who started to pore through the film acquired from eight orbits over the USSR.

Interpreters had been preparing for the onslaught of data, should a Corona mission be successful, but no one knew exactly what it would look like. I knew it was coming down the pike. I didn't realize this until much later, but I found it really impressive that Corona actually brought us back more imagery than all the U-2 missions combined. That was from a one-day mission with eight passes over the Soviet Union.

My first day at NPIC was only six months earlier. I ended up in Washington, D.C. due to a fortuitous connection between one of my professors at the University of California and Arthur Lundahl, who founded the photo interpretation center for the CIA.

Upon arriving at my new position, I was assigned to follow Soviet missile activity. I had the chance to practice my skills a few times on U-2 missions before Francis Gary Powers was shot down over Soviet territory in May 1960. That led to the cessation of U-2 flights and a gap in new photographic evidence until the Corona flight in August.

At this time our photo-derived understanding of Soviet missile systems was limited to what could be gleaned from coverage of test facilities at Tyuratam and Kapustin Yar.

I remember that at first, training was nonexistent. Later, when NPIC was better established, new hires went through some courses. When I came on board, however, interpreters relied on whatever experiences they might have gleaned from studying for degrees in fields like forestry and geology or from working as photo interpreters in the military. The training was all on the job, working with the more experienced types. I was thrown right into it.

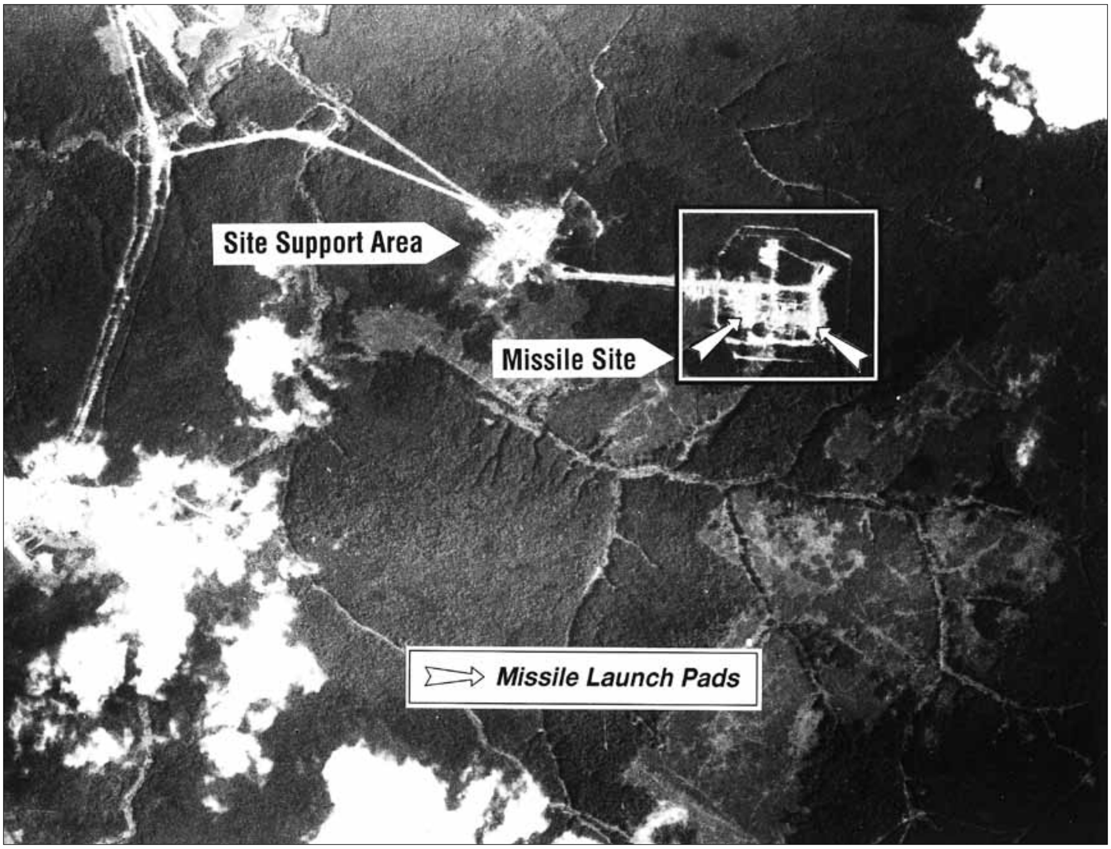


Figure 35. ICBM Complex, Yura, Russia, 1962. Photo courtesy of NPIC.

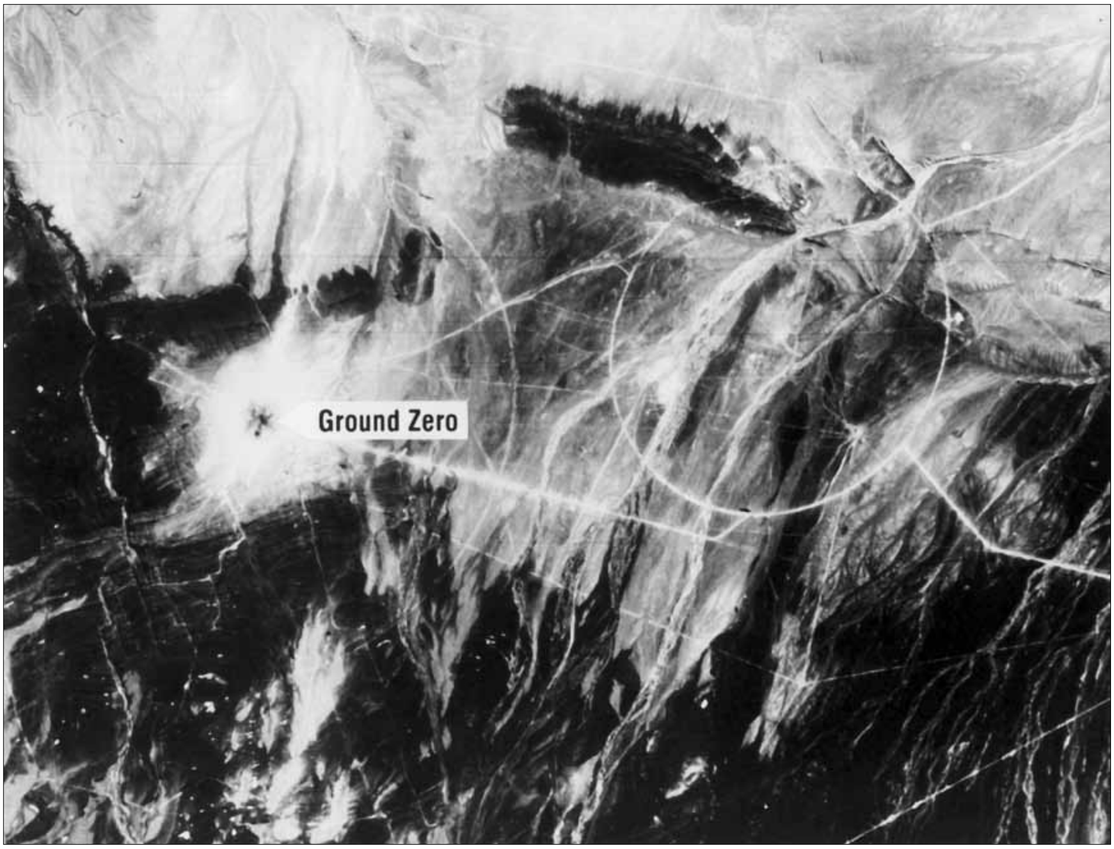


Figure 36. Nuclear Test Site, China, October 20, 1964. Photo courtesy of NPIC.

On my first job, a U-2 flight, I worked in a support role gathering supplemental materials and just learning the ropes. By the time Corona brought back film six months later, I had gained considerable experience.

The Challenges and Value of Corona's Early Data

Although Discoverer 14 brought back significantly more film than the U-2 missions had, the resolution was much lower. The resolution of those early missions was not all that good. Luckily, the kinds of questions they were asking were not very detailed. The CIA was looking for the locations of major airfields and military installations, which analysts could easily find on the film. Aircraft could be identified by type but not by number. While the first mission had its limitations due to resolution and cloud cover, it gave the interpreters enough material to develop signatures for what Soviet installations looked like. These would guide identifications in future missions.

After the August 1960 mission, NPIC received film from missions in December 1960 and June 1961. It was the third mission that really transformed intelligence in the United States. We had clear imagery over the Western Soviet Union for the first time. We saw the first Intercontinental Ballistic Missile (ICBM) and medium-range missile bases and started to catalog them. It was obvious that the Soviets had started building bases and production facilities but that almost no missiles were operational. By June of 1961, we had put to rest the whole missile gap argument.

Interpreting and Storing Corona's Film

On a typical mission, I remember, film would arrive at NPIC at an inconvenient time like 2 or 3 am. That was after having been rushed thousands of miles from the recovery zone in the Pacific Ocean to Lockheed's facilities in California and Eastman Kodak's in New York.

Along with knowledge brought from study and experience, interpreters had access to coordinates and other key information from past missions. They would make notes in longhand, comparing the growth of facilities or identifying new ones. The notes were then transferred to punch cards for storage in an IBM computer, which allowed for quick retrieval the next time around. Key data stored on punch cards included the time, altitude, and scale for each frame of film. The automated system proved invaluable. In fact, the punch cards could get interpreters started with a mission before they received the film. NPIC would receive coordinates for the predicted path of film exposure, and old missions on that track would be called up on the computer.

Early flights returned less than a thousand frames, but later, when more film was added to each spool, a second camera was added and Corona moved into the realm of stereo photography.

My background in forestry proved useful for interpretation. Because the Soviets liked to build their facilities uniformly, a certain pattern in the trees or snow was easy to read. When the Soviets would prepare for a new missile silo, the first thing to appear was a new rail complex with lots of sidings. Flattened snow and pegs in a pattern marked survey work, and fences cutting through the forest always surrounded launch sites. It allowed us to know where the silo would be before they ever dug a shovel of dirt.

Figure 37. Dave Doyle and Dino Brugioni, 1994/Photo courtesy of NPIC.

Corona and the Cuban Missile Crisis

Because of the length of missions and delay in getting the film back, Corona proved less useful for observing sudden events like the Cuban Missile Crisis. The U-2, although it never again flew over Soviet territory after 1960, frequently came into play for situations such as these.

Nevertheless, Corona planted the seeds for a thorough understanding of the Cuban Missile Crisis. During the first few years of Corona flights, photo interpreters developed signatures specific to each type of Soviet missile. For example, surface-to-air missile sites had different designs than launch areas for ICBMs. When U-2 missions brought back imagery of Soviet installations on Cuba, interpreters used the knowledge gained from Corona. It was instrumental in knowing what was going on in Cuba.

Over the years, the technology used in Corona and follow-on satellite programs advanced. So did the information photo interpreters could find.

Conclusion

The experience of being a key player in the developing field of photo interpretation is one I wouldn't trade. Corona made the difference between guesses and certainty, between a United States unsure of its world position and one that knew where it stood.

I remember back in the early days we were in a briefing with Sherman Kent, the head of estimates for the CIA. After reading and seeing input coming in from the community as a whole, his statement was that this wasn't an estimate. It was a fact book.

For more information about Mr. Doyle,
please refer to his autobiographical reflection in Appendix 2.

Chapter 9

EISENHOWER BRIEFING CHALLENGE

Dino A. Brugioni
Founding Member of National
Photographic Interpretation Center

Figure 38. Dino A. Brugioni/Photo courtesy of NPIC.

Dino A. Brugioni, a senior Central Intelligence Agency (CIA) officer, began his career in aerial photoreconnaissance with an interest in photography. Arthur C. Lundahl, the first director of CIA's National Photographic Interpretation Center (NPIC), recruited Mr. Brugioni to be a founding member of NPIC. During his career, Mr. Brugioni made major contributions to the discipline and practice of photoreconnaissance, including briefing President Eisenhower on some of Corona's first images. In this chapter Mr. Brugioni shares his early experiences at NPIC and his exploitation of Corona photography.

The period August 1960 through June 1961 was a highpoint for the NPIC and in my life and the life of Arthur Lundahl, as we helped found NPIC. To see why, we will look in on our briefings to President Eisenhower on the Corona Project.

Briefing President Eisenhower

I was the leader in preparing the presidential briefing boards using the photos taken by Corona and then blown up to 20 by 22-in images after the original images had been interpreted by the NPIC staff at the light tables. We focused on images with strategic implications, but we had learned that if we did not have a ready answer for the conspicuous, but extraneous, images in the photos, some of the important "Eisenhower Time" resource would be lost.

On a morning in December in 1960, we were ready. Lundahl, the representative, and me, as back up, proceeded to the presidential briefing.

The President knew that he had in his hand an "enormous search light that had been turned on in a darkened warehouse," to quote a metaphor of Dr. Albert "Bud" Wheelon.

Disproving the Myth of the Missile Gap

Lundahl showed the President his first pictures of three missile launch sites "under construction" at Plesetsk, a city located in the northwest of the Soviet Union. We emphasized those very words, "under construction." In January 1961, before leaving office, Eisenhower knew that he was almost home free, there was no missile gap, there never had been, and there might never be one.

The National Intelligence Estimate for February 1960 indicated that the Soviet Intercontinental Ballistic Missile (ICBM) program would have 140 to 200 ICBMs on launchers in mid-1961. The June Corona mission had exploded the "missile gap."

The first three missions to return film came in August and December 1960 and June 1961. On the first film, no missile sites were evident. The December pass revealed footage of the facility at Plesetsk, and the June material included several more locations. The photos revealed all of the missile production facilities to be under construction, with almost no missiles completed. It just blew the whole missile gap away. Estimates predicted that the Soviet Union contained 250 ICBM launch sites, when instead there were only about a dozen. The estimate of 500 bombers turned into a reality of less than 100 bombs.

A new estimate published in September 1961 indicated, "New information, providing a much firmer base for estimates on the Soviet long range ballistic missiles, has caused a sharp downward revision of our estimate of Soviet ICBM strength." The new estimate "is now in the range of ten to twenty-five launchers from which missiles can be fired at the United States and that force level will not increase markedly during the months immediately ahead."

An Interest in Aerial Photoreconnaissance

Always interested in photography, my introduction to aerial photoreconnaissance came during World War II. I served as a radio operator. During missions in Northern Africa and Italy of the 66th Bombardment with the 12th Air Force, I was assigned to planes that received some new cameras. No one was having luck getting good photography out of them until I, a hobbyist, used a cheap light meter I had on hand to dramatically improve the results.

Reconnaissance missions were as dangerous as any other wartime flight but lacked the glamour of bombing missions. Still, the experience became central to my long career in the reconnaissance field as one of the creators of the first NPIC, the organization responsible for interpreting film returned by U-2 spy planes, Corona satellites, and other reconnaissance vehicles.

Photoreconnaissance during World War II was an underdeveloped field. As the Cold War heated up after the war, the need for strategic reconnaissance required a number of new techniques. I became very acquainted with what was needed to delineate targets.

Establishing the National Photographic Interpretation Center

In the 1950's, I met Arthur Lundahl, the man who created modern photo interpretation in the United States. Lundahl, too, had developed his skills while serving in World War II as a Navy photo interpreter. After the war, he continued to work on interpretation for the Navy. We met while I was already at the CIA and he was still with the Navy.

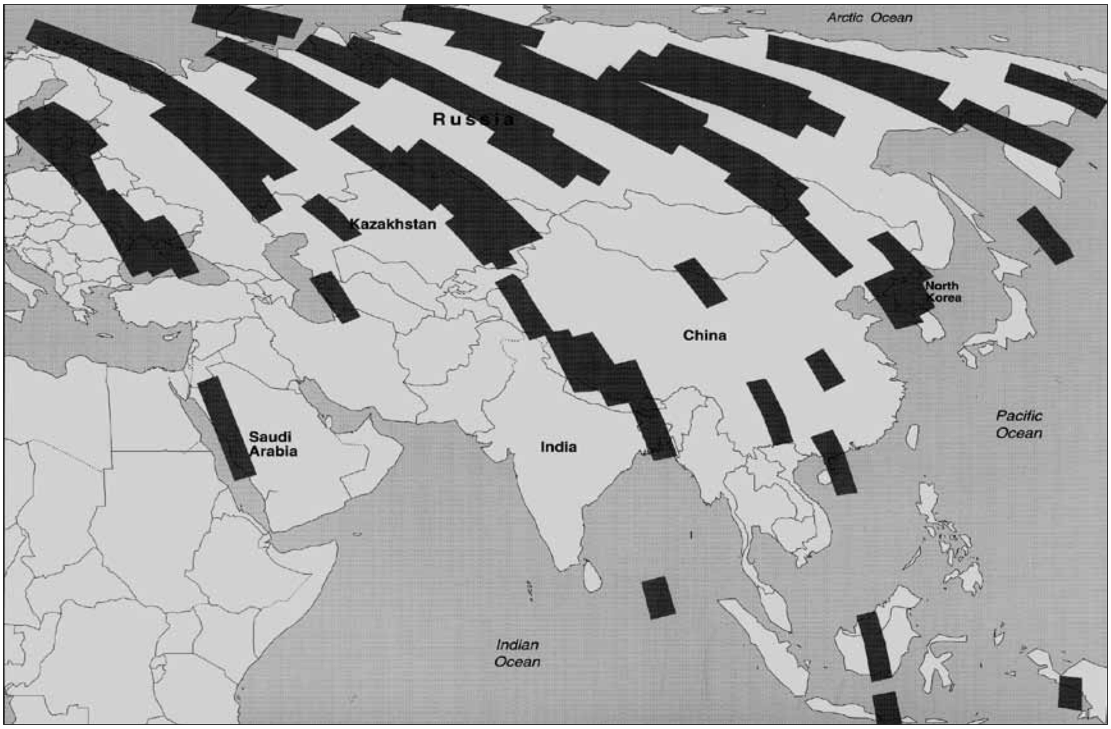


Figure 39. A depiction of Eurasian Missile coverage plotted from photoreconnaissance taken by Corona/Figure courtesy of NPIC.

Figure 40. The director of the NPIC, Arthur C. Lundahl (center), and his Executive Director, Charles Camp (right), being briefed by a photo interpreter using a briefing board/Photo courtesy of NPIC.

Figure 41. Dino A. Brugioni (center) and Ben Gable (left) are demonstrating the value of aerial photography in preparing target charts for Allen Dulles, CIA's director from 1953 to 1961, and younger brother to John Foster Dulles, Secretary of State from 1953 to 1959. Both served under President Eisenhower. Photo courtesy of NPIC.

During this time I got to appreciate his abilities and he appreciated mine. When he was selected to head up a new photo intelligence center, he said, "I want you." So I went into a darkened room and was told I had a new job.

Arthur Lundahl and I were two of twelve employees who made up the initial staff of the NPIC. I was the resident Soviet expert thanks to my years of work on the Industrial Register. I also drew on my wartime experience, where I saw how important it was for interpreters to have supporting documentation to aid in their understanding. I realized that we were going to need vast systems to handle the photography and report it, so I leapt into the young world of computers and invested in an automated system whereby information from reconnaissance missions was cataloged on punch cards and could later be retrieved quickly as background for later missions. Among the machines used at NPIC was the UNIVAC, a vacuum tube model that "you had to warm up in the morning stage by stage to get it going."

The Work of NPIC

NPIC opened in 1955, not long before the first U-2 missions flew over Soviet territory the following year. As principal intelligence officer under Lundahl, my responsibilities included making briefing boards and notes for presentations to government and military leaders.

With no shortage of resources at my hands, I set-up an all-source collateral system for the photo interpreters. I created editorial, graphic, photo development, and reference support for my staff and a vast library of maps, charts, and other reference material. The U-2 brought in high-quality imagery of small areas and under dangerous circumstances. In addition to flights over the Soviet Union, it surveyed crises and skirmishes including the Suez Crisis in 1956 and Chinese incursions into Tibet.

Of primary importance, however, was Soviet military strength, namely how many bombers and missiles the republic had built. On a mission to determine such information, Francis Gary Powers and his U-2 were shot down over Soviet territory on May 1, 1960. The ensuing crisis was largely political, but at NPIC, no one knew when we might get the next imagery to interpret. Although the Corona satellite was in testing, it had not yet achieved orbit, much less brought film back from space. The center's staff was preparing for the new technology, which would dramatically alter operations.

NPIC and Corona

When the U-2 missions ended abruptly in May, NPIC staffers caught up with other work. We knew when they were launching Corona and every time there was a failure. Our spirits were down. The atmosphere changed to elation in August 1960 when Corona had its first success, followed shortly by the first successful flight to bring back film. The NPIC was back in business.

The film returned by Corona had a much lower resolution than then U-2 imagery, which was taken only 68,000 ft up, but Corona also brought back many, many times more data. In one Corona mission we obtained more coverage than from all the U-2 missions over the Soviet Union.

Impatient staffers took the coordinates of the passes the satellite made over Soviet territory and waited for the film to travel from the recovery site over the Pacific Ocean to Hawaii, on to Lockheed's Northern California facility and then to Eastman Kodak in New York to be developed before heading south to NPIC's facility in a dilapidated Washington, D.C. warehouse. NPIC was jammed full of people. This was something new. We were going to see things and solve some of the current problems. Indeed, despite the low resolution of the first Corona film, it answered conclusively the missile gap question: The Soviet Union was far behind the United States in weapons production. You can't imagine the joy we had from this one little can of film.

Figure 42. The Steuart Motor Car building, a dilapidated Washington, D.C. warehouse and the facility for NPIC from 1956 to 1963. Note Dino Brugioni is standing directly in front of the glass door entrance. . Photo courtesy of NPIC.

Conclusion

Lockheed, GE, Kodak, and other contractors working on Corona continually made improvements. These resulted in better and better resolutions, the addition of stereoscopic imagery, and later, longer flights and more film. Staffers at NPIC augmented their skills and equipment and reveled in what they were now able to see from high above the earth.

The era of technological reconnaissance had arrived, and those involved knew they were part of something special. There was no doubt about it. We were making the biggest contribution to intelligence, bigger than communications, covert operations, everything else. The crowning achievement of the Corona program was best stated by Sherman Kent, Director of the Office of National Estimates who, while pointing at a book of National Intelligence Estimates, once told Eisenhower, "This is not an Estimate Book any longer. It is a Fact Book!"

When the Corona program started, less than 25 percent of the world had been photographed or mapped. By the time of its last mission, Corona had helped to photograph 75 to 80 percent of the world.

Figure 43. Arthur C. Lundahl, Director of the NPIC, awarding Dino A. Brugioni a promotion.
Photo courtesy of NPIC.

For more information about Mr. Brugioni, please refer to his autobiographical reflection in Appendix 2.

PART II

CORONA'S COVER, DISCOVERER

Almost all of the people involved in the government side were more interested in getting the job done than in claiming credit or gaining control.

Richard Bissell, Corona Program Director
"Corona: Honoring Corona Pioneers"
May 24, 1995

This dedication to mission and purpose resulted in unparalleled insights into the Cold War realities and data on the earth's landscape features.

Brian Latell, Director,CIA's Center for the Study of Intelligence
"Piercing the Curtain: Corona and the Revolution in Intelligence"
George Washington University, May 23-24, 1995

It didn't take a rocket scientist to realize that satellite photography was going to become a core of our intelligence portfolio ... it changed the entire intelligence community to the point where at no time would we want to do with anything less.

John McMahon, Deputy Director of Central Intelligence
"Corona: Honoring Corona Pioneers"
May 24, 1995

The Program was its own reward. It was damned exciting. It was the highlight of my life.

Lee Battle, Col, USAF, Corona Program Manager
"Corona: Honoring Corona Pioneers"
May 1995

During program development and operations, the fact of the existence of the Corona program was classified. To protect development and provide a security screen for its activities, the Central Intelligence Agency (CIA) and United States Air Force created a cover story under the name, "Discoverer." The Government described Discoverer as a scientific space program with a focus on biological research. The cover story was that the returning space capsules would contain animals such as mice, not reconnaissance film. In Part II, several of those who worked on the cover program, Discoverer, share their stories.

Chapter 10

OBJECTIVE OF DISCOVERER

Figure 44. Ingard Clausen, Project Manager of General Electric's (GE's) team, which constructed and instrumented the life capsule, examines four mice, cousins and exact duplicates of those in orbit aboard Discoverer 3. Photo courtesy of GE/U.S. Air Force.

Ingard Clausen
First Project Manager of Discoverer
Life Support Capsule and the
Corona Satellite Recovery Vehicle

Ingard Clausen, as the first project manager of the Discoverer Life Support Capsule, was intimately familiar with the Discoverer Project. Looking back now, and using his first-hand experience on the program, he explains how Discoverer worked and its effectiveness as a cover story in the account below.

Acquiring a realistic perspective on the Discoverer cover story is important because there may be lessons we can learn about concealing future efforts to overcome new threats to our country. To acquire such a perspective, we need to know Discoverer's weaknesses and its strengths as a concealment project.

How Discoverer Worked

Here is how the Discoverer concealment plan worked.

GE designed a "mouse house" and a "monkey mansion" in cooperation with the Air Force School of Aviation Medicine (AFSAM) and the Air Force Aeromedical Field Laboratory. It was a remarkable piece of work representing the best of talents from each of the contributing organizations. The startling news is that it was fully qualified for flight in a space simulation chamber. After the test, the primate emerged unhappy but unscathed.

The life support system fit within a space defined by Lockheed inside the Satellite Recovery Vehicle (SRV) that had been set aside for the reconnaissance film cassettes. Naturally, none of these life-support people had any notion of the reconnaissance film that was to take the place of the life support system after the first few flights.

The life support system was to take care of all of the usual life-support needs including food, oxygen, urination, and etc. for seventeen orbits—roughly twenty-five hours plus logistics time. Being a scientific program, it also had to obtain design information during the space simulation tests.

As George Christopher (see chapter 16 for his account) will attest, it took superhuman will to force the operators of the space simulation chamber to complete the tests throughout the mission, apparently because they knew that the mission was fake. In my opinion, that is just one of the tragedies of this program.

How Effective Was the Cover?

Edward A. Miller (see chapter 5 for his account) put me on the right track several years ago when he noted that Discoverer was not a very good cover story for concealing our reconnaissance mission from the Soviets. Since then I think I have pieced together the rest of the story.

The strongest circumstantial information we have demonstrating the ineffectiveness of the cover is the fact that Discoverer/Corona was launched from Vandenberg Air Force Base (AFB) on the west coast where any nearby sailor or spy could see from the highway that the launches headed south. Therein lies the weakness.

Launching southward loses all of the earth's rotational speed to the east. For a purely scientific mission, there never will come a time when boosters will have so much thrust that anybody can afford to lose the momentum you get from an eastward launch. Why then were the launches to the south instead of the east?

That reason comes from the fact that the most efficient way to scan large areas of the earth's

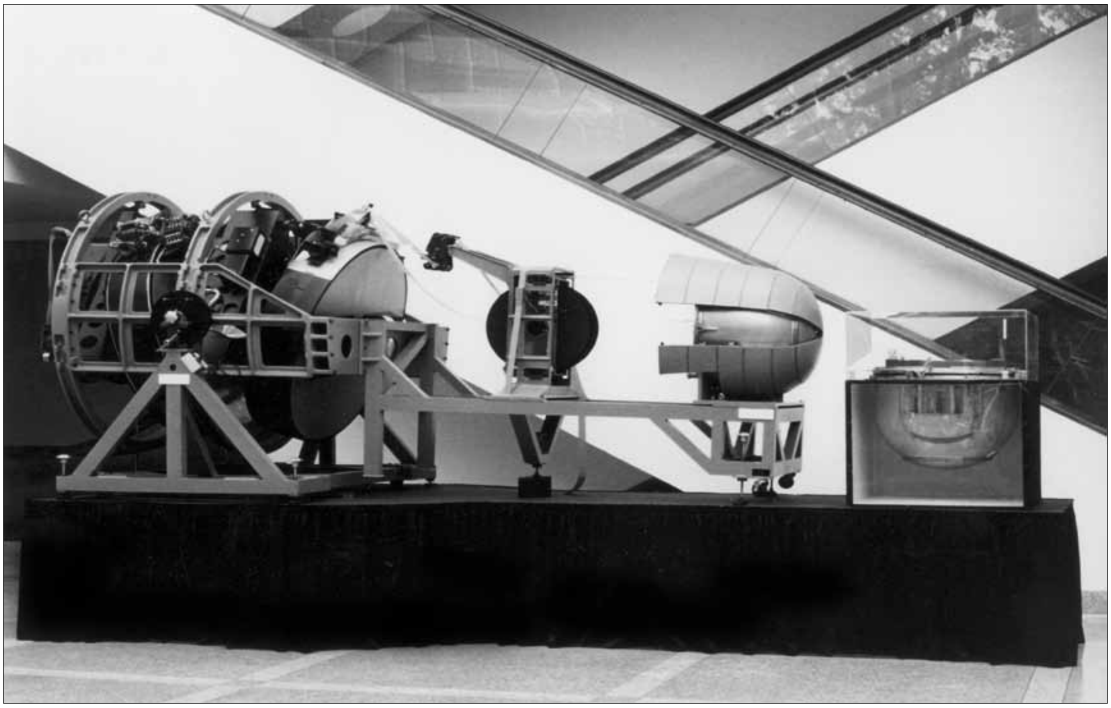


Figure 45. An expanded view of Corona. On display at the Smithsonian Institute, 1995.

surface is to use the earth's rotation to expose every surface nook and cranny at no extra cost in fuel. There never will come a time when satellites will have enough fuel left over after getting into orbit to scan more effectively than resulting from a southward launch. So a southward launch implies a reconnaissance mission.

Another important clue is that the Agena satellite was always over important film targets at high noon. That is a clue that Soviet space observers could not have missed. Case closed for smart leaders and populations knowing a reconnaissance satellite from other kinds. But the case is not closed for all of the other leaders and populations on earth, of which there are many.

President Eisenhower's Goals

President Eisenhower has given us a few points to connect and see what his intentions were for the Discoverer cover story.

The first is that as a certified intelligence aficionado, as described in Edward A. Miller's chapter 5, and with a battery of experts and advisors, Eisenhower knew that the Soviets would see through the polar orbit giveaway of reconnaissance.

In addition, we know that when Nehru, the premier of India, called Eisenhower to request that the Rhesus monkey not be sent in orbit because of its sacred place in their religion, Eisenhower buckled and agreed. The effect of this was that a completely new cadre of primates of a different species would have to be restraint-trained, a difficult assignment. (The only way one can get a primate to live through a mission in space is to teach him, over extended periods of time, to tolerate being restrained by a full set of feet, hand, and shoulder "seat belts." Without this, the primate goes into an extended frenzied state, which is dangerous for his survival.)

In fact, during the initial all-ups systems tests, the main bone of contention between GE and the Air Force experts was, "Whose fault was it when a monkey expired—the equipment made by GE or the restraint training performed by the Air Force?" One officer once told me that it was everything he could do not to kick in the face of his GE TV in his motel every evening over this issue. (Later, with the problems behind us, all was forgiven, especially after passing the space simulation test.)

For a space-literate world leader, the edict on the Rhesus monkey was evidence that Eisenhower did not place prime importance on the cover story. This leads to a conclusion that I have seen in the literature—namely that the real purpose of the Discoverer story was to conceal from his friends in the NATO countries that he had the ability to compare their competitiveness with the United States every month or so.

One last lead—at this point in time the arguments on who owns the space rights over any country were raging. An innocent Discoverer was a far better vehicle for establishing, by example, that space was free to all.

Some say that Eisenhower's termination of the U-2 flights was really motivated by his concern for European sensitivities.

As a cover story for the majority of the population, the Discoverer cover story was extremely successful, as every Coronian knows personally. He had only to look at his family and neighbors to see that none had any notion of a reconnaissance mission underway until the project was declassified in 1995.

Chapter 11

CREATING THE SATELLITE AEROMEDICAL RECOVERY VEHICLE PROGRAM

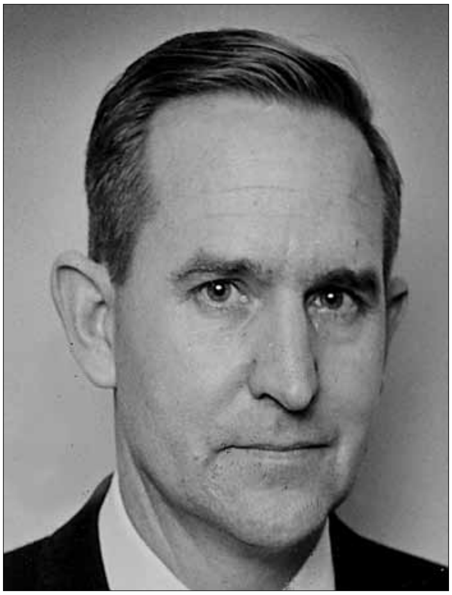


Figure 46. Marvin Clarke.
Photo courtesy of Hazel Clarke.

Marvin Clarke
Project Manager,
Discoverer Life Support

Corona's cover project, Discoverer, worked to get animals, specifically mice and a monkey, into space. Marvin Clarke, as manager of General Electric's (GE's) Aeromedical Recovery Equipment Engineering Operation, was involved with the experiments from the beginning. The Discoverer program yielded significant research results that paved the way for manned space flight. In the account below, Clarke shares his experiences, and challenges, in getting the Satellite Aeromedical Recovery Vehicle (SARV) project up and running. Clarke also speaks about the GE/Lockheed contract battle over the program.

As I saw it, thoughts of putting man in space were becoming concrete in the late 1950's.

After the Soviets launched the first satellite on October 4, 1957, they proceeded to launch a much bigger satellite into orbit on November 3, 1957. This payload was over 1,000 lbs in orbit and carried a dog as the primary experiment.

In 1958, I proposed to the Air Force a system for flying animal experiments in space with the use of mice and a monkey. I soon became manager of GE's Aeromedical Recovery Equipment Engineering Operation. The plan would not come to complete fruition, but Discoverer was a perfect cover for the Corona project. In the end, the biomedical research proved indispensable in space studies.

Paving the Way for Manned Spaceflight

In 1957, we knew that it would be some time before we could launch anything that big, and even longer before we could even consider putting a man in space, but there were a lot of other things that we could do to start getting ready for that manned flight.

The Air Force had already been studying the medical problems of manned flight in the atmosphere for fifty years and they were just beginning to study the possible medical effects on man of flights out beyond the atmosphere.

In 1957, Col David G. Simons had spent thirty-two hours in the gondola of a balloon at an altitude of more than 100,000 ft. The human factors involved in these kinds of flights had been under study at the Aeromedical Laboratory at Wright-Patterson Air Force Base (AFB) in Dayton, Ohio, for several years. The Space Biology Branch of the Air Force Aeromedical Field Laboratory (AFL), at Holloman AFB in New Mexico and the Air Force School of Aviation Medicine (AFSAM) at San Antonio, Texas, had also been involved in such studies. In fact, the AFSAM had set up a Department of Space Medicine in 1949.

Beginning with Animal Experiments

Bob Haviland (see his recollection in chapter 19) introduced me to Col Dave Simons in late 1957, after his remarkable balloon flight. Col Simons was very interested in the possibilities for manned flight in space and had a number of ideas as to what could be done to get ready for that kind of activity. We had a number of interesting conversations on the subject and I had picked up a lot of ideas from him. Sometime in early 1958, I decided to make a proposal for flying some animal experiments in space. There were no biologists at the GE Missile and Ordnance Systems Department in Philadelphia, but that didn't stop us. I drafted the help of the GE company doctor, Stanley Gottlieb, and we wrote a proposal for flying mice and monkey experiments in a satellite and to recover them alive in a Satellite Recovery Vehicle (SRV). We presented our proposal to the Air Force Ballistic Missile Division at Los Angeles, California, on March 9, 1958.

The aeromedical people were interested. They were anxious to fly experiments in space, and the possibility of recovering the animals alive after orbital flights was exciting.

I don't remember exactly when it happened, but I remember taking a flight from San Francisco to Los Angeles on a return trip from one of those rush visits to Lockheed with an Air Force colonel. I remember trying to convince him that GE needed the animal experiments contract as a cover story for the actual reconnaissance recovery vehicle that we were already designing for Lockheed. I remember following him all the way out to his plane at the Los Angeles airport, still talking. I don't remember the colonel's name or whether or not he had anything to do with GE getting the experiments contract, but shortly after that, we were committed to building the animal experiments.

The Lockheed versus GE Contract Battle

This was not good news to Lockheed. They were already designing animal payloads for the recovery vehicle on their own money without any help from GE. In addition, the AFSAM also wanted to build the animal payloads for the recovery vehicle.

On March 16, 1958 Lockheed sent GE a "stop-work order" on the original oral go-ahead for the recovery vehicle. On March 23, Lockheed gave GE an oral contract redirecting the work on aeromedical payloads; the new work statement was received by GE on March 26. On the same day, Lockheed presented their aeromedical payloads without any participation by GE. On March 27, GE gave Lockheed a formal proposal to do all of the aeromedical payloads. On April 1, at a meeting of Lockheed, AFSAM, and GE, Lockheed and AFSAM raised the question as to why GE was even invited to the meeting since Lockheed and AFSAM were going to make the aeromedical payloads.

Meanwhile, GE had made a presentation on the small primate payload to Gen Ritland on March 30 and repeated the presentation to Gen Flickinger on April 6 and to Col Dave Simons on April 13.

On April 17, Lockheed notified GE that GE would not make the aeromedical payloads.

That same day, the Air Force reaffirmed that GE would make the aeromedical payloads.

The next day, Lockheed said that they were going to make the aeromedical payloads.

On April 19, Lockheed notified GE that the work statement of March 26 did not include the recovery program. On April 20, there was a joint presentation on the subsystem integrity made to Col Oder of the Air Force Ballistic Missile Division. On April 23, GE agreed to work with Lockheed as a subcontractor on the job. GE made a presentation on the aeromedical payloads to Lockheed and the Air Force Ballistic Missile Division on April 27.

That was the Program Manager's nightmare in the spring of 1958. I was closely involved in most of the presentations. As the key interface between the Program Office and the engineers who were implementing the work statements, I was also intimately affected by all the oral and formal work statements changes. But I also had other eggs to fry in that time period.

Getting the Aeromedical Recovery Operation Up and Running

In April 1958, GE appointed me the manager of the newly established aeromedical recovery equipment engineering operation. The operation provided for fifty-one employees, divided among engineers, technicians, and draftsmen, plus a couple of secretaries. I kept the small nucleus of men who had been working with me and hired the rest of the people to fill the empty positions. These positions included all of the life support and animal experiments people, the electrical system for the recovery vehicle and for the payloads including the mice, monkey and the photographic film cassettes, the recovery vehicle and its heat shield and all of its parachutes, location aids, de-orbit and spin rockets, etc.

In April, May, and June, we were still building the small 20-in Orbit Determination (OD) recovery vehicle with a weight allowance that started at approximately 120 lbs and went up to about 170 lbs by June 20, 1958, when the small SARV was cancelled. Although the payload work continued, it wasn't until July 21, 1958, that we received the letter contract from Lockheed that specified the interfaces with the satellite and the approximate weight and size of the SARV that we were to eventually fly.

During the period of April to July 1958, I hired twenty-nine people, established a life support and animal experiments capability at GE, and started an animal laboratory. Edward S. Miller was put in charge of the life support work and the animal experiments from day one, and he helped find and staff the empty positions. The group continued the design and development of the 20-in OD SARV and the integration of the payloads into the vehicle, plus the heat shield, location aids, parachutes, spin and de-orbit rockets, and the aft structure for the SARV and its heat protection, etc.

On May 11, we received the design control specification from Lockheed, and it was on that day that Lockheed finally conceded that GE was to be the aeromedical payload supplier. GE received the official work statement from Lockheed defining GE's aeromedical payload responsibilities on May 17, 1958.

I was involved with helping to set up the Bioastronautics Operation at GE and the hiring of Dr. Richard Lawton, who had been a flight surgeon and who brought an extensive knowledge of the effects of G-loads on man and animals to the GE capabilities. Lawton's background experience and technical training was of immeasurable assistance in the work we were trying to do then and for many years to come.

By August 6, 1958, we were able to demonstrate the life support and mice experiments payload to the Air Force Aeromedical Laboratory and to deliver the Mark I mice experiment and life support module to Lockheed. On August 19, we demonstrated the life support and mice experiment payload to Hilliard Page (see chapter 4 for his account) at GE. On August 20, at a meeting of GE, AFSAM, and Lockheed, a general consensus was reached on the respective activities of the three relative to the aeromedical payloads.

We also demonstrated the life support and payloads to Mr. Phillips and Mr. Paxton of GE and to Gen Funk and Gen Flickinger of the Air Force some time that month.

On September 16, the Mark I mice payload development model and the Mark II monkey experimental models were critiqued by Lockheed, GE, AFSAM, and AFL. On September 28, 1958, delivery was made to Lockheed of the prototype SRV, the Mark I mice payload, and drop test hardware.

Sometime in October, I assisted in the formulation of a new bio-pack specification for SARV with AFL/AFSAM. On October 29, the Biomed Criteria Agreement was signed by GE, Lockheed, and Air Force AFL/AFSAM.

Conclusion

I left the SARV program in late 1958 and took an engineering job for a Global Surveillance Study for GE. Like many in the "black" program of Corona, my work appraisals were sorely lacking for my thirty months of work. When a supervisor noted in my last appraisal that I had only "partially met" my job requirements, I took the initiative of writing a self-appraisal.

Knowing that I had had a major part in putting the department into the space business, and that I had developed a whole new aeromedical capability within the department, which they had never had before, and knowing that what we did on the SARV job was a major advance in the state of the art in several technical areas, I felt that my manager's appraisal was seriously lacking specifics and completely wrong as to what I had really done while working under his authority. The appraisal dispute was a major factor in my decision to leave GE in 1959.

Editor's Note: Since providing this account, Marvin Clarke has passed away.

Chapter 12

DESIGN OF DISCOVERER'S PRIMATE LIFE SUPPORT SYSTEM

Figure 47. John Hoffnagle.
Photo courtesy of GE/U.S. Air Force.

John Hoffnagle
Life-Support Systems Designer

John Hoffnagle worked as a Life-Support Systems Designer. He helped design the Mark I and II life cells to house mice and a monkey in space for the Discoverer Program, Corona's cover program. In the following account, Hoffnagle shares his recollection of designing, testing, qualifying, and seeing the success of the life cells.

I joined General Electric's (GE's) Discoverer/Corona project at its beginning, in April 1958, reporting to Edward S. Miller (not to be confused with Edward A. Miller, a contributor to this book). Ed S. Miller was in charge of our new unit called, "Biomedical Engineering" and I was his lead engineer.

Our job was to develop life-sustaining compartments, within which small animals could travel to earth orbit and, after the mission was complete, return safely to earth. Only later did I find out the mission of Discoverer was to conceal the real mission of Corona.

The first of two designs was the Mark I life cell for four Bar Harbor mice. The second was a Mark II life-support compartment for a young Rhesus Macaque monkey. Physiologists of the Air Force School of Aviation Medicine (AFSAM) at Austin, San Antonio, and Holloman Air Force Base (AFB), New Mexico supplied, trained, and handled the animals used for Mark I and Mark II life cells. There was a large animal research and training operation at Holloman run by the University of Texas, under AFSAM contract.

Designing the Mark I Life Cell

I began on a concept for the Mark I "mouse house" for four black Bar Harbor strain mice. Foremost in this was zero-G operation of the automatic feeder. About this time, May 1958, we also began an animal lab. I had decided on four 6 by 6-inch compartments in a square, with a centered feed tube common to the four compartments, having its vertical axis on the axis of the nose cone and missile symmetry.

Ed S. Miller and I began a search for the three basic components of a life cell atmosphere control system—a gas reservoir, a regulator, and a fan. These formed the Gas Management Assembly (GMA).

We went to the Air Reduction Company's Research & Development center, Fairfield, New Jersey, and they agreed to design a special oxygen (O2) regulator to our requirements. We used their air reduction regulator on our life cells.

The Air Reduction Company also agreed to develop a three-in diameter spherical O2 tank to hold 3,000-psi pure dry oxygen gas.

We needed a fan or blower to maintain O2 circulation through the life cells. The engineering department of the Franklin Institute in Philadelphia found a test fan after looking at some eighteen available fans. They picked one and tested it extensively to prove the bushings would hold up and motor heat rejection would be adequate.

By the end of July 1958, I had a design layout of Mark I and the animal lab was in operation.

Designing the Mark II Monkey Life Cell

As early as March 1958, Ed S. Miller and I began concept talks on the Mark II monkey cell. We decided the most difficult aspect of it was the photography requirement. The Russians had put a small dog into orbit briefly and had put a backup dog cell on display in the Coliseum in New York City. Ed S. Miller and I had studied it but it had no photo capability. It had been stripped of all lighting, instrumentation, GMA, etc., and was some 50 percent larger than our nose cone could accept. Also, it was quite sturdy looking, as if they did not have the weight limitations we had. Further, our Rhesus monkey was stronger than a small dog.

I had worked on portrait photography as a hobby during the 1940's while I worked at the National Advisory Committee on Aeronautics (NACA) and I knew there was no camera in the world that had 200 ft of 16-mm film capacity that would come close to fitting into Mark II life cell.

Nevertheless, in order to justify designing my own camera to meet requirements, I reviewed some three dozen cameras on the market. None could be adapted, so I devised the smallest camera possible that could run 200 ft of 16-mm black-and-white film. GE subcontracts put us in touch with the photographic division of the Bulova Watch Company who accepted my preliminary design.

By the middle of July 1958, I turned the Mark I over to others and concentrated on Mark II. The AFSAM asked us for a "couch" design for the monkey. I prepared a final design and center of gravity of the nose cone capsule. The AFSAM approved the design and we had one built in our shop and sent it to Holloman AFB. They liked it and ordered a number for training use in October 1958.

During July and August of 1958, I developed the life cell configurations and finalized the structure and GMA circulating pattern. During this period we set up the electrical and gas absorption systems. I had located most major items of these systems on my master layout and, by September of 1958, we had completed the Mark II sufficiently so I could make fabrication drawings of the life cell platform and housing, or cover.

The GE subcontracts put me in touch with Chalmers & Kubeck (C&K) in Brookhaven, Pennsylvania. The choice of C&K resulted from the fact that the use of magnesium was necessary to get it as light as possible. The C&K was a first-class fabrication shop and had a master welder—possibly the only welder within hundreds of miles of us who could have put the life cell structure together.

When C&K finished the first life cell structure, Chalmers called and I drove out to Brookhaven to pick it up. Kubeck saw me drive into their parking lot and brought the cell assembly out to meet me.

When I got close to him, he set the cell down on the pavement, got up, and stood on top of the housing! My heart skipped a beat. I told him to get off because it was designed for distributed pressure loading, not point loads. Kubeck was a large man, probably about 270 lbs and about 6 ft and 3 in tall. We examined the housing—not a single dent. I delivered this first unit to Quality Control (QC), and it became our engineering test unit. After re-inspection, the unit passed these tests without incident. We then shipped it out to Lockheed for temperature-altitude testing.

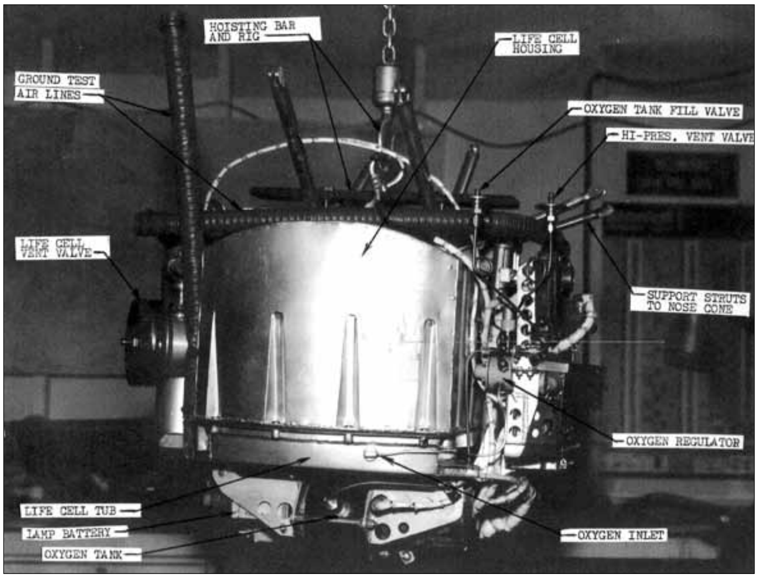


Figure 48. Head-end view of life cell assembly for Rhesus primate.
Photo courtesy of GE/U.S. Air Force.

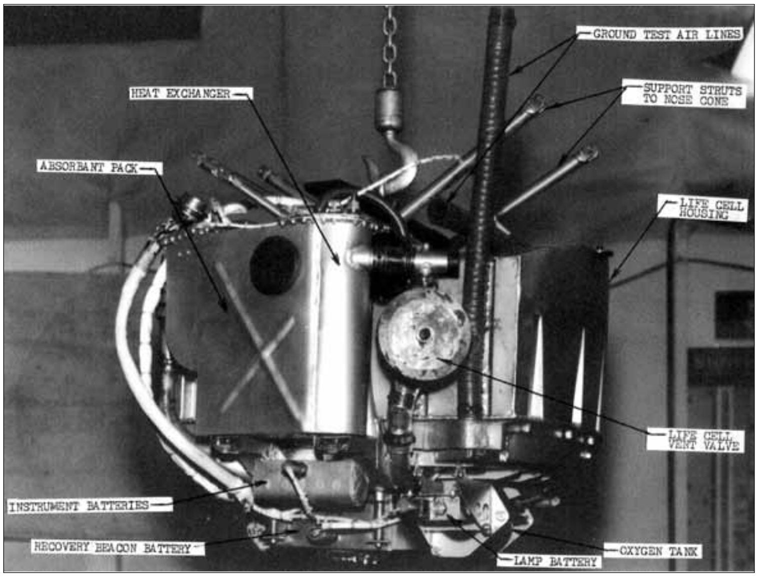


Figure 49. Right side view, foot end, showing LL OH canister.
Photo courtesy of GE/U.S. Air Force.

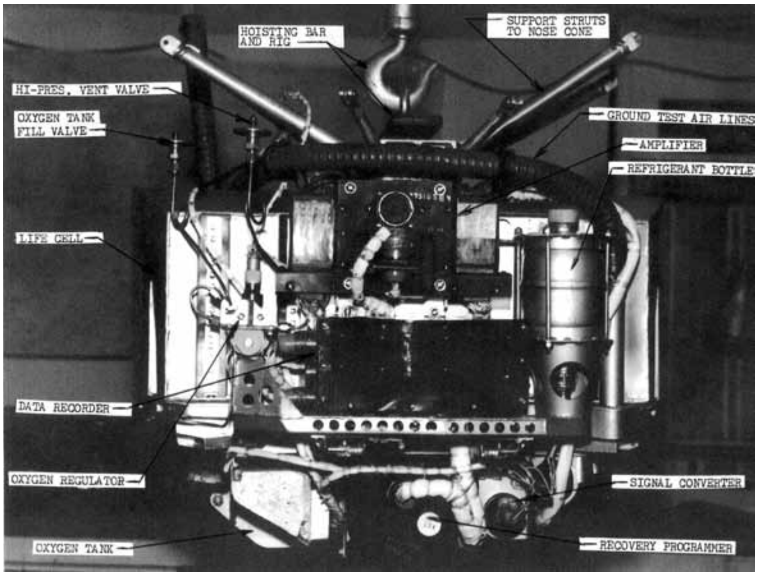


Figure 50. Left side view of life cell showing equipment cluster.
Photo courtesy of GE/U.S. Air Force.

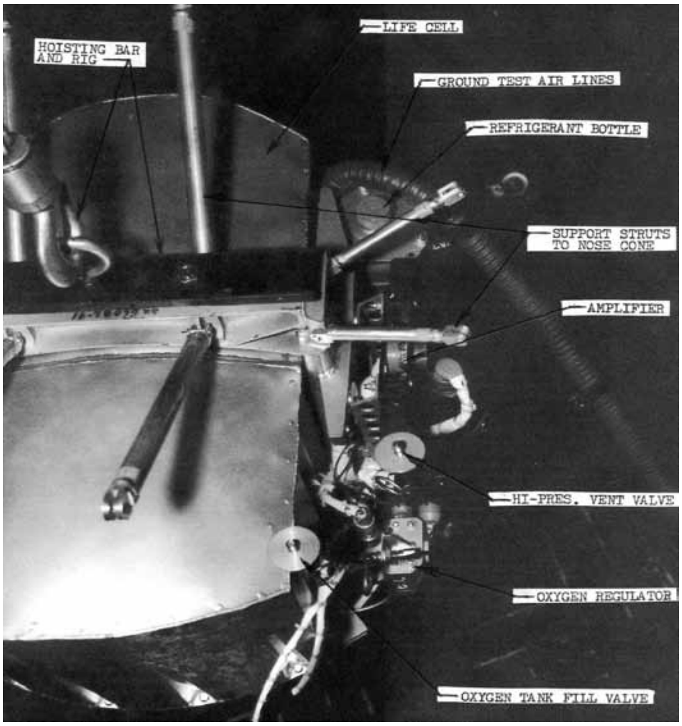


Figure 51. Top view of assembly, left side showing hoisting bar and stabilizing struts that attach to nose cone frame. Photo courtesy of GE/U.S. Air Force.

With the mil-spec tests passed, the last item of concern was a lens for the camera. The Bulova photo division on Long Island searched and found just the right one in France, a Kern-Paillard "Switar" made in Switzerland—focal length 16 mm, f1.8, focusable from 8 in to infinity and depth of field larger than we needed.

With this matter settled, the Mark II was clear to complete.

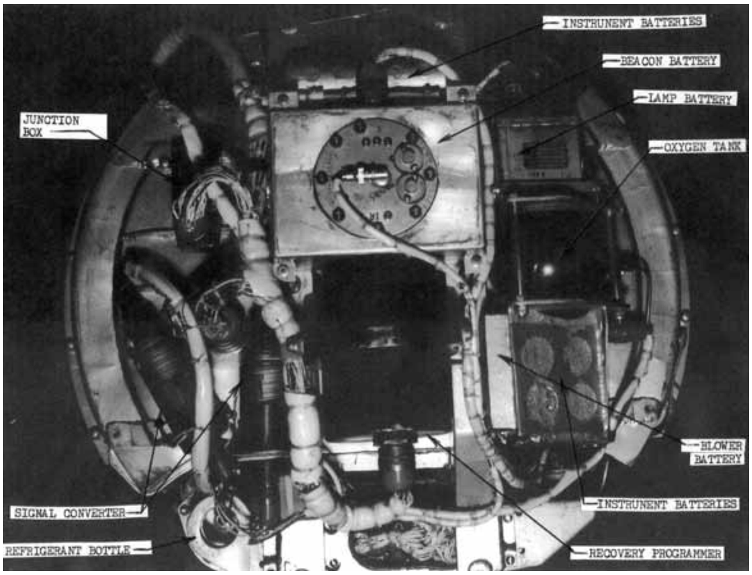


Figure 52. Bottom view of assembly showing recorders, ball, O^2 tank and harnessing.
Photo courtesy of GE/U.S. Air Force.

The team continued putting together all of the components. A pressure regulator with a high-pressure ratio was added because the O2 regulator could not handle the tank pressure. A pressure relief valve was added to ensure the life cell would not be over-pressurized. Pressure and temperature sensors were added. Cabling and connectors were added and routing worked out.

Testing the Mark II Life Cell

The plan was to check out the life cell, load it, put in the monkey, and take it with us to the Bemco altitude chamber at Lockheed Martin Space Division (LMSD). There we would test it at high altitude pressure, about 250,000 to 360,000 ft, bring it out and remove the monkey, in order to complete the ground-test simulation of the proposed orbital mission.

We had sent the Mark II to Holloman AFB so the AFSAM-University of Texas trainers could help a Rhesus monkey acclimate to the life cell. The full mission test ran, and then we sent the unit to Vandenberg for the mission simulation. I believe Holloman lost one Rhesus monkey in an earlier test, and we were not going to risk losing another specimen. I know that QC did a lot of testing on components (e.g., cameras, O2 regulators, and etc.).

Later, I flew to Vandenberg and went through a preliminary assembly and leak test named "use 15." Ed S. Miller and his team had instrumented it in Philadelphia during the first week of August 1959, had given me a set of schematic drawings, and shipped it to Lockheed at Vandenberg AFB. During the latter part of August, I reviewed the Bemco chamber interface for use 15 test. Lt Pinc had called from Los Angeles saying the Air Force group there did not have any information concerning our Mountain View activities and asked for a quick review.

The field team assembled at Vandenberg and began the dry run on September 21, 1959, in the Lockheed biomedical mobile home building. We were able to get a good seal on the life cell housing and we moved it out to the C-47, secured it on power, donned parachutes and flew up to Moffet Federal Airfield in Santa Clara County, California, wheeled it onto an LMSD truck, drove to the Bemco chamber, closed up and took it up to about 200,000 ft altitude pressure. It was a very good dry test (no animal). We put it back aboard the C-47 and returned to Vandenberg. At the follow-up meeting with the Air Force and LMSD, it was agreed to proceed with the full test.

The First Live Test—An Issue with Oxygen

Accordingly, we began preparing for the live test. On September 25, 1959, we started the usual 15 countdown at Vandenberg. The AFSAM people inserted their monkey in the pallet, laced up the jacket, put the respiration sensor in place, and connected the monkey to the life cell electronic system. We had a tight life cell. We moved it out to the C-47, secured and powered it, flew up to Moffet (no parachutes this time), and trucked it into the Bemco. Lockheed took it up to test altitude vacuum. All went well for about ten hours when AFSAM called to tell me the monkey was showing signs of distressed breathing and needed oxygen.

I had no direct control over the O2 regulator, so I tripped the life cell over-pressure vent valve, which lowered the pressure enough to activate the regulator. I had designed the oxygen inlet into the life cell to spray oxygen directly under the monkey's head. I held the vent valve open for five seconds, and AFSAM called over to say they "did not know what I did but do it some more." So I held the vent open for twenty seconds, which satisfied AFSAM. After a few hours, the same thing occurred again, so after I introduced oxygen, we aborted the test, brought the life cell out of the Bemco, removed the monkey and began looking for the problem. The CO^2 rise occurred because the vent valve froze shut because of the monkey's respiration moisture. When I powered it to activate the oxygen regulator, the ice that had formed was overcome, and it opened.

Throughout this long live test period of about thirty hours, the team members and several other technicians took naps in the cafeteria (I believe), but I stayed with the test because I could not risk losing the monkey. Since the monkey was completely restrained and had a tight diaper, we did not have the serious particulate and gas chemistry problems that plagued later biosatellite life cells housing a Macaque Nemistrina, a larger monkey.

Qualifying the Cell

Sometime in October 1959, Lt Col Harris conducted an acceptance demonstration in which he completely disassembled and re-assembled a Mark II life cell mounted in a GE nose cone on a ground support dolly. He did this on a stage with a group of observers in the auditorium seats. I positioned myself in the stage wing in case he had a problem. He completed the demonstration to the point of reconnecting the life cell harness to the nose cone harness but could not quite bring the two connectors close enough to mate. I suggested that the nose cone harness had drifted down a little in its tie supports and that if he could gently pull the harness up he could complete the connection. He agreed and successfully completed the demonstration. He then stepped back a bit, looked at the life cell a few seconds, then said—and I quote him exactly—"I like it; I'll buy it, and I'll fly it."

This meant life cell qualification and Air Force acceptance to fly. When he made that statement, I felt my time and effort spent that summer with the Field Development Engineering team had been worthwhile.

Conclusion

In the meantime, Ed S. Miller had built his group from just himself to a very competent engineering team that conceived and developed a complete life-support system for extended earth orbit missions. This complex assembly involved combining engineering knowledge in the areas of mechanical, chemical, electrical, life functions and dynamic relationships expertise. Maintaining the pressure differential of life cell to space, life cell to sea level pressure, and life cell to oxygen regulator supply was a challenge. Furthermore, considering that pressure control problem, controlling the monkey's atmosphere in the life cell was a delicate balancing of oxygen, respiration products, and moisture.

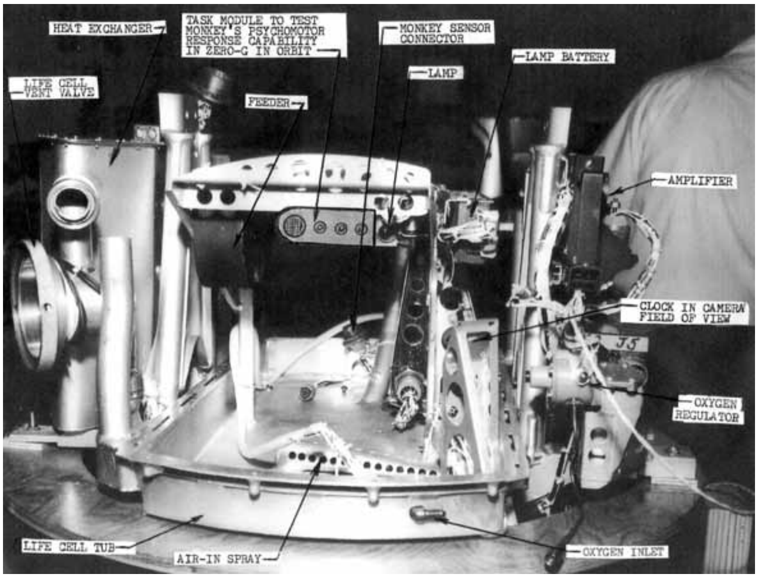


Figure 53. Partial life cell assembly, housing removed, looking into head end.
Photo courtesy of GE/U.S. Air Force.

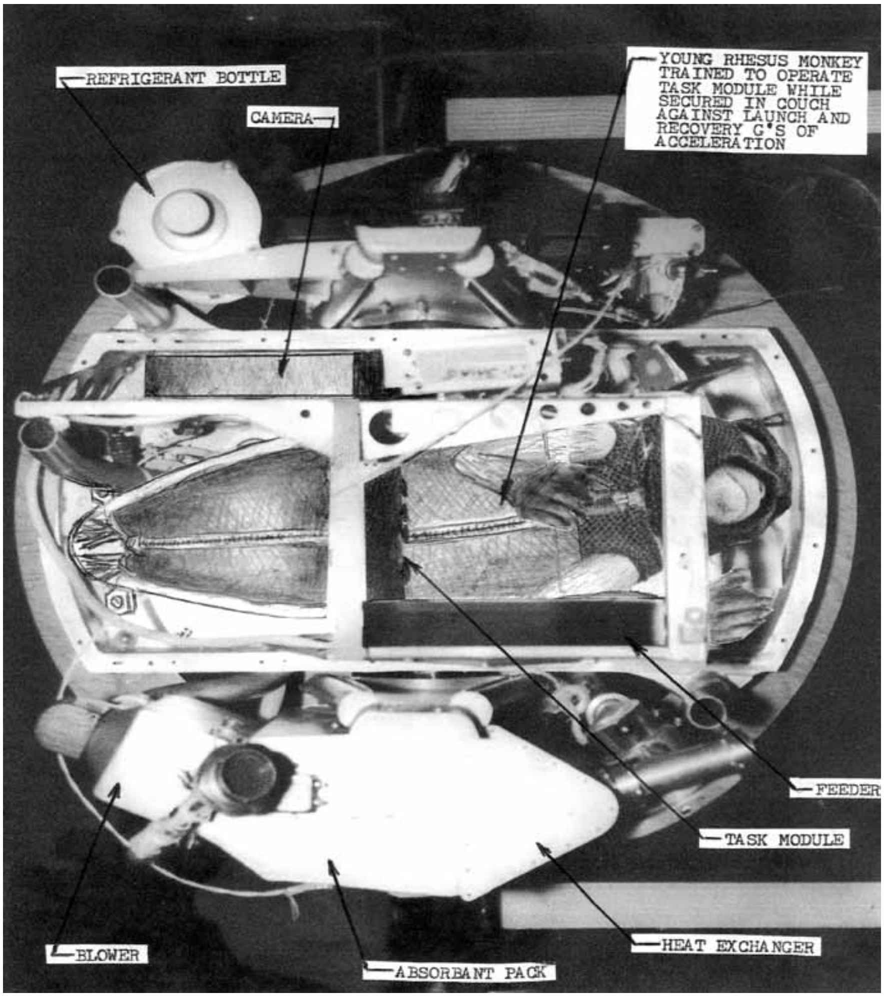


Figure 54. Looking down on life cell tub, housing removed, monkey faked in by sketch, Bulova photo. Photo courtesy of GE/U.S. Air Force.

The GE Biomedical laboratories investigated gas products of monkey respiration and particulate production so we could provide specific control of the life cell atmosphere. Primary to this control is removal of CO^2, accomplished by a canister of lithium hydroxide, which readily absorbs CO^2 in the presence of moisture, to form stable lithium carbonate with a release of water. This adds to the moisture removal requirement, which was done through a system of permeable membranes exiting to space. Carbon monoxide from the monkey was oxidized to CO2 by hopcalite in the main canister. A small amount of metabolic ammonia was absorbed by a little amberlyst resin. A small canister of activated charcoal absorbed large molecule odors. Thermal load created a problem during ground and Bemco chamber operations, requiring some cooling, but heat rejection during orbit was sufficient according to heat transfer estimates.

However, the cooling system was automatically operated. The Air Force planned to recover the life support capsule, with life cell, after reentry by an air snatch of the parachute lines prior to landing, or by water recovery. Air snatch tests were successful but tricky, as I understand it.

Chapter 13

SPACE ENVIRONMENTAL QUALIFICATION TEST OF THE RECOVERY CAPSULE INCLUDING PRIMATE

Figure 55. George Christopher.
Photo courtesy of GE/U.S. Air Force.

George Christopher
Project Engineer
Discoverer Life Support System

George Christopher (see chapter 16 for further recollections by Christopher on his time as a Systems Engineer for Corona) was involved with the Discoverer program for only short period of time, but in that time he helped lead the qualification testing of the Mark II capsule. In the following account, Christopher shares his experiences, although brief, working on the simulation tests for Discoverer.

Primates first entered my career in Sunnyvale, California. Previously I had been the Systems Engineer for the Mark II and for the modification of the Corona recovery of reconnaissance film, not Rhesus monkeys. I lead the engineering team for qualification testing of the Mark II Biomed version. This was to include a live Rhesus monkey in a pressurized recoverable capsule. I managed six engineers during tests over thirty-one days at Lockheed I was also responsible for the technical direction of the team and was the official spokesman with Lockheed and the Air Force colonel monitoring the tests.

The Simulation Tests

We placed the monkey in a clone of the data capsule, which we then put in simulated orbit in Lockheed's high-altitude vacuum chamber. This test imitated a five-day flight. We gave the monkey an apple for nourishment during the test period. The vacuum chamber was a "spherical thing" with plenty of room for such a small item as the capsule.

The simulation tests themselves went rather smoothly. The monkey's vital signs, which we constantly monitored, always registered "satisfactory." But I had external battles with those who were observing the qualification testing.

Lockheed wanted to stop it. I have no earthly idea why. The working atmosphere was contentious, with Lockheed being uncooperative and the monitoring Air Force colonel exhibiting an obvious dislike for General Electric (GE). Lockheed's veterinarian, also, continually urged me to stop the test (and return to sea level/earth). Because the monkey's vital signs were satisfactory, I always refused and directed the test to continue for the planned five-day period.

After the simulated orbit, we returned the capsule to ground level with the simian pilot intact.

I must say that this was the most satisfying moment. We recovered the "first" monkey from simulated space orbit. The monkey had survived, although very hungry, because he did not take bites from the apples we supplied to him in the capsule.

When we moved testing to an actual launch site to simulate takeoff procedures, Lockheed continued to object. We went through a ritual, the order in which you would count down and count up. We didn't bother with a monkey; he was inside all the time.

Aside from what I considered an unhelpful attitude from those my team worked with, I was also bothered by a lack of real security.

Although no one ever told me that all the work I was performing was a decoy for Corona, the lack of heightened secretiveness made me suspect there was a cover-up program in the works. I didn't think they were concerned with security the way they were with the other mission.

Conclusion

Shortly after the completion of that thirty-one day qualification testing, I moved on from Discoverer to other "less political" GE projects. I stayed with GE for thirty-nine years.

I look back on Discoverer as a good experience, though as only a decoy. I felt the monkey tests had been a waste of money. If they ever had used a monkey in space, those tests would have been useful. Furthermore, my experience is that the cover story was working because of the reality of the biomedical work.

Figure 56. George Christopher receiving the GE Ground Systems Program General Managers Award from Bill Phucas. Photo courtesy of GE/U.S. Air Force.

Chapter 14

THE SPITSBERGEN INCIDENT, LOSS OF THE DISCOVERER II LIFE SUPPORT CAPSULE

Two Recollections and Speculations
Edward A. Miller and George Christopher Recall the Spitsbergen Incident—The Mission Where a Discoverer Capsule Landed on Spitsbergen Island, West of Norway

Edward A. Miller's[1] Recollection
Manager of GE's Satellite Recovery Vehicle Program at the Time of its Recovery of Discoverer 13

Discoverer 2 reached a successful earth orbit and, after seventeen passes, was commanded to return to earth in the Pacific Ocean southwest of Hawaii. For some as yet unknown reason, the satellite came out of orbit way too early, thousands of miles short of the planned impact area. To the best of our knowledge, it landed on Spitsbergen Island, west of Norway.

Why this happened could most likely be attributed to a mistake in the timing of the de-boost command or possibly intervention of others that reset a previously correct de-boost command. We will probably never know the answer for sure.

The Air Force used a creative and imaginative approach to investigate whether or not, in fact, Discoverer 2 came down on Spitsbergen. They sent a team headed by USAF Col Richard Philbrick to Spitsbergen.

The team interviewed local people separately, one at a time, and gave them a dozen different colored crayons. They asked them to draw what they saw. All observers, independently of each other, pictured a gold bucket and light colored shrouds leading to an international orange and silver parachute—exactly right. Rumor has it that Russians from a nearby mining camp retrieved the capsule.

Discoverer 2 had only engineering instrumentation, no camera or film. But it did have a "mechanical mouse" that weighed roughly what a real mouse would weigh and emitted heat appropriate to a live mouse. Although no one has admitted doing so, someone in final assembly of that capsule threw in some real mouse droppings.

I would have liked to have seen the look on the faces of the Soviet scientists who examined the capsule—real droppings but no live mouse. Years later at the invitation of Itek Corporation, the camera contractor, Sergei Khrushchev, son of Nikita Khrushchev, visited the Itek Labs in Lexington, Massachusetts. When asked directly whether the Russians had gotten the capsule, he said "No." Hard to believe.

1 See Chapter 5 for Edward A. Miller's full account of his time on Discoverer/Corona.

George Christopher's[2] Recollection

I once heard a report that the Spitsbergen accident may not have been an accident after all. I will retell the story as I have heard it.

Maybe it was Discoverer 2 that included what we called a "mouse house," a life support system that Discoverer/Corona was to put in orbit and recover as though it were a reconnaissance payload. It is said that a wag in our laboratory, just before he buttoned up the life support system and energized the atmosphere and feeding systems, put a number of mouse droppings in the life support system.

Assuming this is true, Discoverer 2 took off and landed in Spitsbergen, either by accident or error.

Spitsbergen is a series of islands that, by treaty, are occupied by the Russians and Norwegians. In this incident, the capsule parachuted to land on an island that had a Russian manufacturing plant nearby.

Judging from the tracks in the snow going in and coming out, the evidence is that the capsule was taken by the Russians. We can imagine the Russian excitement when they opened it in their space laboratories and the mouse housing cover was removed. Did they not assume from the droppings that several mice had escaped in the lab? Did they not look for them without success?

At this point, I have heard that the landing was intentional in order to provide the USSR with all the information that they would ever need that those crazy Americans were so stupid as to waste their Air Force funds on "mouse in-space." In other words, the cover story was now Gospel.

Now for my conjecture, based on this story, it explains why the black (the term "black" is defined in Robert Chamberlin's account in chapter 15) program powers that be were confident enough that the cover was bullet proof that they stopped all flights of the Rhesus monkey.

Another shot in the dark: It is said that Nehru, the premier of India, called Eisenhower early in the program and got his assurances that the United States would never fly Hindu's sacred monkey, the Rhesus.

For more information about Mr. Christopher,
please refer to his autobiographical reflection in Appendix 2.

2 See Chapters 13 and 16 for George Christopher's full account of his time on Discoverer/Corona.

PART III

THE FIVE "FIRSTS" OF CORONA

An historic first for U.S. Science.

The Washington Evening Star
August 12, 1960

Developed over only sixteen months to become the first photo reconnaissance satellite, Corona's systems pioneered spacecraft stabilization with gyroscopes, space photography and mid-air capture of reentry vehicles from earth orbit ... the spy satellites filled gaping holes in U.S. knowledge about Soviet nuclear armaments during the hottest part of the Cold War....

USA Today
"Spy Satellite Developers Win Draper Prize"
February 24, 2005

The Corona Project is notable not only for its many engineering breakthroughs, but because its technical achievements impacted world peace

William A. Wulf, Ph.D., President National Academy of Engineering
Remarks at Charles Stark Draper Prize Presentation
May 24, 1995

Corona's first successful mission marked the beginning of a revolution in acquiring foreign intelligence.

Robert A. McDonald, Ph.D.
Corona Between the Sun & the Earth–
The First NRO Reconnaissance Eye in Space, p. 212.
American Society for Photogrammetry and Remote Sensing, 1997

Corona was ground-breaking technology. It accomplished things no other program had ever done. Part III is divided into five chapters, one for each of the five "firsts" of Corona. In these chapters, those who developed the Satellite Recovery Vehicle (SRV) tell their stories.

Chapter15

SYSTEMS DESIGN OF A SATELLITE RECOVERY VEHICLE (SRV)

Figure 57. Robert Chamberlin.
Photo courtesy of Doug Chamberlin.

Robert Chamberlin,
Chief Systems Engineer, Corona, SRV

As Systems Manager of the systems engineers on the Project Hermes Intercontinental Ballistic Missile (ICBM) project, Robert Chamberlin was exposed to several projects with ties to Corona. Chamberlin was then recruited to work on developing Corona's Satellite Recovery Vehicle (SRV). In the following recollection, Chamberlin shares some of the projects he was exposed to as he managed the systems engineers, his experiences in building the SRV project, and the challenges they faced in designing the Corona project to be successful.

For as far back as I can remember, I have been interested in airplanes and fishing; and if you had asked me what I wanted to do when I grew up, I probably would have said trout fishing. I didn't have the least notion that I would wind up as a spacecraft engineer, least of all the Chief Systems Engineer on a SRV that would bring back the first man-made object from space.

Managing the Systems Engineers

After working in the Heavy Military Department successfully conducting wind tunnel tests, I found that the Project Hermes ICBM Nose Cone proposal had been successful and saw my chance to rejoin the team. Here is the big news—I was appointed the Systems Manager of the systems engineers, each assigned to a separate nose cone project. The challenge here was to protect a strategic defense weapon as it entered space, as it rises along a ballistic path as high as 450 miles. That's the easy part. Now comes the hard part—that had never been done before. We had to protect that strategic weapon from the highly destructive heat generated by its hypersonic reentry through the atmosphere. If it failed, we had to provide a means of finding out why, without the luxury of a radio beam telling us why because of the searing plasma surrounding the nose cone as it comes back to earth. In those days, we also had to incorporate in the systems the means for recovering the heat shield at sea in order to see firsthand how well it had done.

George Christopher (see chapters 13 and 16 for his accounts) was working on the aerodynamic design of a reentry vehicle called "Discoverer," a developing Air Force experiment, as well as other projects. In fact, the Discoverer was to bring a Rhesus monkey back from orbit. But in actual fact, that was the cover story for Corona.

Jack Rogers developed a computer program that was an excellent "command and control system." It simplified the operation of a spacecraft project that is still classified. On the first countdown utilizing that program, the Air Force checked throughout the countdown thoroughly, questioning every aspect of the flight. The Air Force reported back to me later that this was "the best first flight ever run," due to Jack's system.

I found that Rowe Chapman, with input from Fousto Gravelos, had been developing a complicated computer program, which provided data showing 6 degrees of freedom of motion analysis. (If you only know about 3 degrees of freedom, just add a few rotations.) I briefly looked over his shoulder, and sat in on many discussions. This completed computer program became a major tool in reentry configuration design, and Discoverer/Corona was one of these vehicles.

Rowe's program was a vital tool of value for me. Using it, I was able to calculate six coefficients of aerodynamics data providing aerodynamic behavior of a vehicle from reentry into the atmosphere as it fell to the ground. Putting the object into space, it calculated the fall of a ballistic missile reentering the atmosphere at the same altitude and rate of speed. The data was valuable with any reentry vehicle, permitting vision of the motions of a vehicle during overhead flight as well as reentry.

Introduction to the Corona Program

During these months managing the engineers and learning from the work of each of the projects, I was attending a NASA conference on ballistic missiles in Sunnyvale, California. I received a phone call from Ingard Clausen requesting my immediate return to Philly. I was happy to return to my family, having learned of a major easterly storm from the news on TV, but of course, I was extremely curious to meet with Ingard. I went directly to the General Electric (GE) building at 32nd Street to see him. As usual, on a Saturday, the building was very quiet.

I let my family know I would be home soon and then gave my full attention to Ingard. His message came from Hilly Paige (see chapter 4 for his account) and he wanted to know if I would shift my work to a project of great secrecy: moving my focus entirely to the development of a reentry vehicle with the label, not of "top secret," but a "black" program, meaning that to all but those eventually to join this project, there "was no such project."

The challenge was to design a reentry vehicle to receive the film from a complex camera, designed by Itek, to provide the least disturbance to its reconnaissance spacecraft. The film would be exposed in orbit as it passed over Soviet potential targets. The Agena spacecraft was designed to sweep the Soviet continent. It was stabilized and timed to capture images of their strategic capabilities in north to south swaths. My SRV's job was to boost itself out of orbit and to survive hypersonic reentry atmosphere successfully, both world's firsts. Then it must eject a series of parachutes starting at 60,000 ft and, finally, to present itself at a descent rate of 20 ft per second, such that it could be mid-air recovered by a circling C-119 Air Force aircraft, another world's first.

Accepting this challenge, Ingard and I made plans to return to Los Angeles for work on Monday. I arrived home to find electricity was out at our house. Rowe Chapman's home had electricity turned on again and Nancy had accepted their invitation for shelter. We packed and moved carefully, because many wires were down and no travelling was advised. On the next day, Jim Vitale, directly across from our home, agreed to let us hook up extension cords for electricity from their home to ours, thus enabling our family to return home. This was of immense relief to Nancy and to me as I left for the airport to meet Ingard.

Preparing For the Project

Arriving at Lockheed in Palo Alto, we were shown to our future office in the "skunk works." There were two rooms with desks and a drafting table which were still in their packing cases. The Lockheed man who had shown us to our quarters said, "Assemble everything." I said, "Have you got a screw driver?" It was an auspicious beginning.

I proceeded to unpack and assemble the drafting table, the drafting machine, and the paper while Ingard setup a desk in the next room and started making plans over the phone with our GE counterparts in Philly. With Ingard next door in our secure rooms, we discussed the work ahead.

New staff was soon to be joining our project. We agreed there were specific abilities necessary—crucial was the ability to keep any aspect of this project unknown, actually to not acknowledge there was a project at all. Over the phone at night, your wife would ask, "How was your day?" And you had to answer something like, "Same old stuff."

With my tools in order, I set to work to design the nose cone. By dinner time, I felt comfortable with my work and we left to eat, securing the rooms appropriately for a "black" program.

The Challenges of Working on Corona

Our first challenge was to ensure the stability of this vehicle, to keep it from tumbling. The location of the supply reel was crucial. I knew this weight had to be located carefully to assure that the center of gravity was kept forward towards the center of pressure. Other equipment would include motors, a data capsule, and a command system. When the command system activated the filming, the motors pulled the film forward, rolling it off the supply reel and continuing through the camera. The rotating drum then collected the exposed film on to the take-up reel. The command system therefore controlled the starting and completion of the filming.

Explosive, spring-loaded bolts separated the reentry vehicle from Agena after the filming was completed. Velocities would be varied. At the instantaneous separation of the Agena, Corona would continue on its ballistic trajectory. The heat shield would be made out of plastic ablation to enable Corona to survive the tremendous temperatures. I determined that the shell of the vehicle should be a 10-degree curve. We continued our work in Palo Alto for two weeks.

Now these two weeks were not peaceful times. Jim Plummer was the Lockheed man in charge of the total Corona System: the Spacecraft, its camera and space-keeping functions, and the SRV. He kept stirring our pot, as he should. He defined the requirements we had to meet and checked our work to see that we were meeting them.

The thing of it is that he had a large team of experts in various disciplines that assisted him with his daily reviews of total systems progress, including our work. And some of the meetings became very contentious. We weren't always on the winning side. Throughout several discussions regarding the 10-degree conical angle, it was explained that 10 degrees would not be an easy fit to the Agena without changes. I was confident that the 10-degree curve was crucial, and held to my design. Holding to this was tough so it was a relief for us to prevail.

These two weeks of work got us far enough along that we could return home, occasionally traveling to several secret locations for conferences. When Nancy asked how to locate me should there be a crisis, my response was, "You can get a message to me, just phone my secretary." It worked. Thus, she was the on-duty parent, a demanding job with four children from one- to seven-years-old. Yet our life settled down with these changed dynamics; and in 1960 we moved into a larger home in Wayne and our children attended Radnor Schools. Life returned to merely "abnormal."

Conclusion

Throughout the months that I secretly worked on "the bird," I continued to manage the systems engineers and their projects in the Aerodynamics department under Otto Kilma. Although I was not very pleased with the role of "management," it afforded me the ability to work on a number of nose cones, the kind of work I truly loved.

During this time, I was assigned to assess the calculations of the reliability and effectiveness of a large satellite that required the conversion of the Atlas booster. I eventually reported to the Air Force that the mission effectiveness could be improved without manned flight. With the cancellation of the Atlas program, GE laid-off many of its staff, including me. Sometimes that's the way it is with systems engineering. New England beckoned. As I look back over the years, I have never lost the satisfaction of utilizing my technical knowledge in designing aircraft, from airplane models to airplanes to the Corona reentry vehicle. All of my work has been exciting, yet Corona topped them all. I will always be grateful for the opportunity to serve on the Corona team.

For more information about Mr. Chamberlin, please refer to his autobiographical reflection in Appendix 2.

Figure 58. Robert Chamberlin, first from left, and Ed A. Miller, sixth from left, are shown in this group photo at Johnston Island in the South Pacific. Photo courtesy of U.S. Air Force.

Chapter 16

FIRST MAN-MADE OBJECT TO EJECT, STABILIZE, AND PROPEL ITSELF TO DE-ORBIT A PAYLOAD

This chapter includes two recollections by General Electric (GE) employees who worked on Corona's Satellite Recovery Vehicle (SRV): (1) Max Dienemann and (2) George Christopher. They share their engineering perspectives on ejecting, stabilizing, and propelling a payload from orbit.

Figure 59. Max Dienemann.
Photo courtesy of Max Dienemann.

Max Dienemann
Chief Engineer
SRV De-Orbit Systems

Max Dienemann's long career at General Electric (GE) involved important work on Corona's Satellite Recovery Vehicle (SRV). It was his design of the de-orbit control system that allowed for the data capsule to be successfully recovered. While Dienemann didn't know the true goal of the Corona project, he worked through the challenges of the program and saw the project through to success. In the following account, Dienemann explains the SRV mission, design, and challenges, followed by his experiences working on the Corona Project.

I spent the late 1950's consumed by the intricacies of how to position a SRV exactly right for its return trip to earth. As a project engineer for the Corona satellite program, I designed the de-orbit control system for the reentry vehicle, ensuring the safe capture of the satellite's data capsule containing film from reconnaissance missions over the Soviet Union.

My entree to the Corona project came when I was asked to design a reaction control system for what was described as a biomedical mission to bring animals back from space. While I had suspicions as to the true purpose of the satellite, I didn't concern myself too much with that. I had my responsibilities. Lockheed's involvement was one hint that the program might be bigger than sending mice to space.

The Design and Challenges of the SRV

The first question usually asked is, Why was this so difficult? Here is an explanation concerning the mission of the SRV and the challenges I faced.

The sequence goes as follows—cut the film, separate the SRV from the mother ship, the Agena, push them apart, spin up the SRV, fire a rocket, de-spin the SRV and throw away the thrust cone that holds the spin assembly and rockets. On the ground, admittedly it would be simpler stuff. In orbit, it is not as simple as saying goodbye and walking out the front door.

The Agena, with the SRV as its nose, points forward as it flies along the orbit track. After the last pictures are taken and the Agena follows along the orbit track to the precise point that it should part company with the SRV, it rotates 180 degrees so that the SRV is pointed backwards. Why backwards?

Contrary to conventional wisdom, the purpose of the rocket engine on the SRV is to slow the SRV down, not to speed it up. To get a given object into orbit, the object must reach a velocity that balances the centripetal force pulling it up into orbit with the gravity forces pulling it down. The Agena and the SRV had achieved that balance, maybe seventeen orbits ago. To recover the SRV, we want to lower its speed so that gravity wins.

Before separation the Agena must tilt down, say 30 degrees from the horizontal, so that when separated, the SRV moves out of the orbital path it was on.

That done, the SRV, now completely on its own, might drift away from this preferred ballistic path if we do not hold it steady to its planned alignment. Thus, weight limited as we are, we must stabilize it like a top. We spin it up with little spin nozzles around the thrust cone.

Finally: the big event. The solid propellant rocket is fired and the SRV slows down enough to get on a ballistic path, which means it will impact the earth somewhere in the 600-mile target area.

Note that at this point the SRV is still spinning, and still pointed at that 30-degree angle, meaning it is coming into the reentry zone with its side presented to the dangers of reentry. The SRV, by virtue of its shape and mass distribution, is aerodynamically stable, so accordingly, we de-spin the assembly allowing the ever-increasing dense atmospheric forces to align the heat shield to point forward into the raging heat of reentry.

Finally, the last task is to get the SRV to jettison its thrust cone, the conical structure that held the spin assembly and the rocket, allowing parachute deployment.

One of my challenges was to time all the rockets and releases properly. In the 1950's, no one yet knew how the low temperatures in space might affect the thrust, and engineers worked without any solid data. This continued even after flight testing started because of several failures in a row before the first successful flights in 1960. After a string of failures, I joined a team of GE engineers that traveled to Lockheed's northern California facilities to solve problems. I worked with Lockheed engineers on a change to the de-orbit and separation process that involved bottles of freon and explosive valves that created the spin and de-spin torques.

Lockheed's Management of Corona

I found working on-site at Lockheed interesting in part because of the different approach the company took to projects such as Corona.

You can overwhelm a project with hundreds of people all going off in different directions and Lockheed tended to overwhelm a job in just this way. They will come to a successful conclusion,

Figure 60. Max Dienemann on the job at GE. Photo courtesy of GE/U.S. Air Force.

but it can be very painful. In the case of Corona, redesign work at GE and Lockheed individually and as a team turned around the satellite project. It was a good process. It was effective at solving the problems. Everybody was focused on trying to do the right thing.

From my perspective, the issue came down to achieving "repetitive reliability." The engineers ran many, many firing tests and paid close attention to whether the rockets worked in the correct sequence and at the proper thrust. Reliability problems were the key. There was nothing there that was overly technically daunting. There were just repetitive reliability questions. You only get one chance on each launch.

Failures and Successes

The failures affected morale, I recall, primarily because without telemetry data from the test launches, it was nearly impossible to isolate where exactly the problems lay. The commands were simply sent and either nothing happened or it happened prematurely.

However, we identified the problems and solved them so the team felt they were making some progress. For example, at one point, an engineer discovered that the accelerometer that ejected the parachute could be put in backwards so a new mounting plate had to be manufactured to prevent the error.

In August 1960, the project had its first success, followed by many years of successful launches. I don't remember much about the announcement of the first success, but I do know the engineers felt relieved.

Conclusion

As signified by the Corona reentry vehicle, I spent my whole life working on things that were pretty much advances to the state of the art. That's one of the most appealing things I found at GE.

Corona, I realize, played a "tremendous role" in photoreconnaissance. I am pained at the lack of publicity to the program even today. I don't think people want to hear about the first capsules and photographs from space, but it's an object lesson that the more information you have, the better your decisions can be.

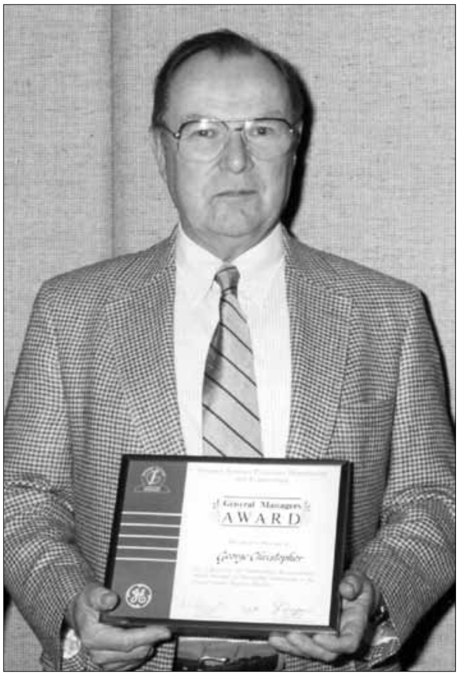


Figure 61. George Christopher receiving the General Manager's Award. Photo courtesy of GE/U.S.Air Force

George Christopher
Biomed System Test Leader

Without knowing of the Corona program, George Christopher (see chapter 13 for further reflections by Christopher and chapter 14 for Christopher's account of the Spitsbergen incident) was involved with the Reentry Vehicle program as Systems Engineer. Christopher's contributions to the Satellite Recovery Vehicle (SRV) and subsequent testing contributed to the overall success of the Corona program (see chapter 13 for a separate account by Christopher of his time qualification testing the recovery capsule on Corona's SRV including a primate). In this account, Christopher shares his recollection of working on the Reentry Vehicle Program along with the design and challenges of the program.

I had the engineering bug since high school, studied aeronautics in college, and had come to General Electric (GE) quite early in my career. It was a natural choice to be part of GE's Discoverer program. Little did I know that I would become a Systems Engineer on the first man-made vehicle to be recovered from orbit.

Work on the Reentry Vehicle Program

When Ingard Clausen asked me to consider a new assignment reporting to Rowe Chapman, I agreed to be Systems Engineer for the Corona Mark III Reentry Vehicle program, which met its activation date as the first operational ablation cooled reentry vehicle.

Back in those days, a Systems Engineer was the technical leader of a program. I would read everything and make all the technical decisions to make everything work together—that role persisted for quite a while.

While I was caught up in the technical advancement of heat shields, I knew nothing of the Corona program.

The Discoverer program was having trouble. After twelve flight failures in a row, systems engineer Charles Robinson had to spend all of his time in the field. To fulfill duties back at the factory in Robinson's absence, I became East Coast Systems Engineer for the Discoverer/Corona Mark II Reentry Vehicle and Modifications, including the version that provided a capsule/cabin for a rhesus monkey (ostensibly to be the first animal in space).

The Agena and Reentry and Recovery Vehicle Design

The Agena was one of the early three axis stabilized platforms in orbit. After the photographic mission was over, and it was at the correct distance from the recovery-targeted site, the Agena's nose (which had been pointing forward along the orbit) was rotated 180 degrees to the rear and pitched at 30 degrees below the horizon.

This position was the launch direction for the Reentry and Recovery Vehicle (R/RV) since it was necessary to reduce the R/RV's speed along the orbital path just enough so that the earth's gravity would overcome the centripetal forces on the R/RV, breaking it out of the orbit into the planned ballistic path.

At that time, the Agena signaled the R/RV to cut the film, to separate, and to forcibly push off, nudging it up from its ongoing path. The R/RV cut the film, an essential step, released cold gas into four nozzles on the thrust cone, and so aligned as to cause the R/RV to spin stabilized, like a top. Then the Jet-Fuel Assisted Take Off (JATO) solid propellant rocket was fired, being steered by the spin, providing sufficient velocity to break loose from the bonds of orbit, and accepting those of earth gravity.

When the JATO was exhausted, the R/RV was still spinning, thus keeping the askew attitude of the R/RV. Then the mid R/RV was de-spun so that as the atmosphere increased density, it would present its reentry shell forward.

The Problem of Tumbling

The way the SRV worked is that it was attached to the Agena vehicle and the Agena controlled the attitude prior to separation and reentry of the nose cone of the vehicle. That worked for a few flights.

Then we converted to the system where we first separated from the Agena. The very first one of those didn't separate properly. It separated but didn't control itself. It was tumbling all over the place.

I was the Systems Engineer in the control station up at Sunnyvale, California. After the first experiment where the vehicle tumbled when it separated from the Agena, it looked like something was driving it, causing it to tumble.

After that mission was aborted, Alex Kaplan and I examined assembly drawings in which it appeared that gas venting from the pressurized tank could produce the torque causing the satellite to tumble.

Later we determined that a Schrader valve had not been installed. Thus, when the squid was blown to energize the control nozzles, gas blew out of the fill vale, producing a torque, which caused the tumbling. It was a costly error, although a simple fix.

Conclusion: Success

My only connection to the ultimately successful Discoverer 13 was conducting an intensive review, which found no flaws or weaknesses in the engineering design/analysis. I do remember the jubilation when the vehicle was recovered.

Two flights after Discoverer 13, I was an observer with two Air Force colonels at Lockheed in Sunnyvale, California.

We were in the observation booth looking down into the control area where the Lockheed and Air Force staff was monitoring telemetry. After a successful separation, de-orbit, and reentry, the telemetry data indicated that the film cutter hatch had not closed, which means hot reentry gas could get into the capsule. This was disturbing, and I was asked whether this was a problem to be concerned with. I recall that I stated that I was not worried. The capsule volume was small, and the thermal capacitance of the film payload was large. Therefore, there would not be any effect on the film. The biggest worry should be for the chase planes failing to capture the parachute before the capsule fell into the ocean.

For more information about Mr. Dienemann and Mr. Christopher, please refer to their autobiographical reflections in Appendix 2.

Chapter 17

FIRST MAN-MADE OBJECT TO REENTER FROM ORBIT

This chapter includes five recollections by General Electric (GE) employees who worked on Corona's Satellite Recovery Vehicle (SRV): (1) Walter J. Schafer, (2) Florian Brent, (3) John Segletes, (4) George Sutton, and (5) Harold Bloom. They offer their perspectives on space vehicle engineering, thermodynamics, ablation material, and systems engineering.

Figure 62. Walter Schafer. Photo courtesy of Walter Schafer.

Walter J. Schafer
Manager, Space Vehicle Engineering

Walter J. Schafer helped design the heat shield and structure for General Electric's (GE's) Satellite Recovery Vehicle (SRV) to survive the searing heat of orbit reentry (2500 degrees F), a world's first. Many observers have suggested that Corona brought the United States back from the brink of nuclear holocaust. In the following account, Schafer shares his experiences working on the Corona project and the impact it had on his life.

Working on the Corona Project

While working for GE, I became Manager of Space Vehicle Engineering, working on the recovery capsule for Corona. The challenge for our department was to solve the severe nose cone atmospheric problem of finding a process and materials that would survive the severe heat of reentry. In addition, I had the major responsibility of handling the interfaces with Lockheed Missile and Space Company (LMSC), making certain the capsule was compatible with the satellite and booster. It was a unique situation never experienced before!

We invented a new way to make a recovery vehicle. Former designs relied on a metal substructure to support the external ablating heat protection system. We developed an integrated plastic substrate to support the heat shield and substantially reduced the weight and complexity of earlier entry designs.

It made Corona very efficient.

Figure 63. Walter and Irene Schafer.
Photo courtesy of Walter Schafer.

Corona's atmospheric path was along a shallow entry trajectory, resulting in a long glide path requiring very careful balancing. This resulted in my spending a good deal of time at Vandenberg Air Force Base (AFB) balancing the capsule's inertial characteristics when mated to the satellite. I spent a good deal of time with LMSC personnel establishing excellent relationships that carried through future business in other areas.

Conclusion

I look back on my years working on the Corona project as a pivotal time in my life. It gave me a groundbreaking project of which I still am immensely proud and taught me how to work with reliable, cooperative people willing to go outside the norm. It was incredibly important to my career. I learned how important it was to look for creative people who were self-motivated.

Florian Brent
Chief Space Capsule Engineer

Florian Brent (see chapter 18 for further information), as Chief Space Capsule Engineer, spent several years at General Electric (GE) designing a durable reentry shield and data capsule for Corona. His work was vital to understanding the physics of reentry. In this account, Brent relates some of the challenges of designing a durable reentry shield and capsule.

Long before Corona, when work on a data capsule began in 1956 in the Campbell Avenue plant of GE, Schenectady, New York, I was a vehicle design engineer on the Mark I nose cone that was being developed as a weapons carrier for Intercontinental Ballistic Missiles (ICBMs). One of the critical design issues was, "What if the first nose cones don't survive the incredible heat of reentry? How are we going to know what to do to make them work?" Everyone agreed that there was no way to transmit measurements of the failures through the reentry plasma surrounding the nose cone. The answer was the recovery of the nose cone itself.

The Instrumentation Group was renamed the Instrumentation and Recovery Group and the recovery design was assigned to me. I began to investigate how to bring the critical failure data back on a recorder. The idea was that a "data capsule" containing the recorder would be shot out of the back of the nose cone and recovered at sea. That is the challenge that was put into my hands and, as you will see, it occupied my time for a number of years.

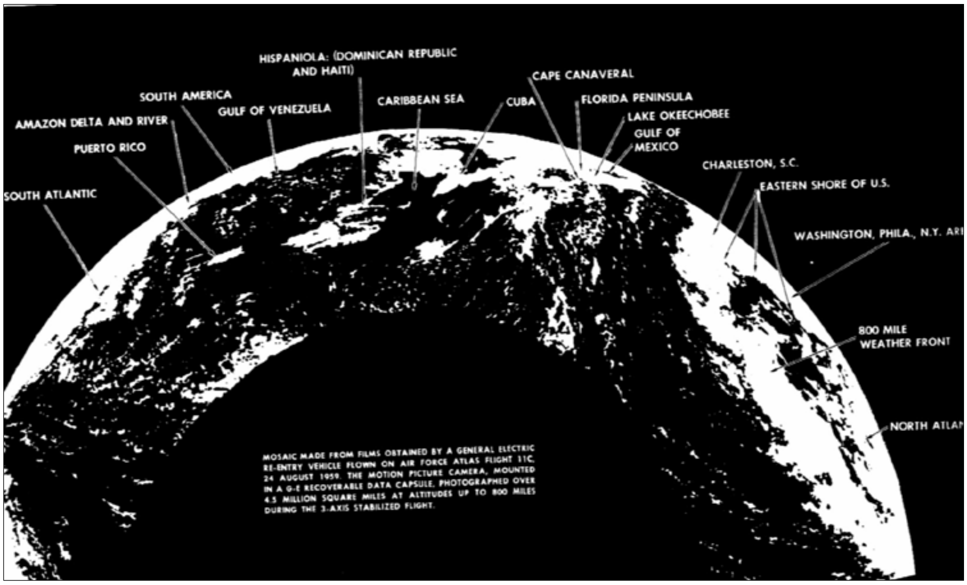


Figure 64. World view from the data capsule. Photo courtesy of GE/U.S. Air Force.

Mark I—Creating a Durable Reentry Shield and Data Capsule

The Mark I, my first project at GE, reflected an important step toward understanding the physics of reentry. At the time, no one knew what shield material would melt and what would hold up while traveling back into the atmosphere. Despite numerous temperature sensors, atmospheric conditions and turbulence caused a transmission blackout at certain elevations and the data could not be transmitted. Yet, if the shield should be breached during blackouts, the instrumentation data was imperative to retrieve. I devised the data capsule, a durable 18-in sphere containing foam, a recorder, batteries, a flashing light for observation, a small, 0.5-watt transmitter, and dye markers to locate the capsule. The data capsule was shot out of the back end of the nose cone, falling into the ocean with incredible force, but floating back to the surface. There the recovery aids, mentioned above, would signal its location so that recovery ships with frogmen could recover it from the ocean's surface.

During the course of the next year and a half, I tested and made changes to the data capsule, first measuring its impact load at a facility on Assateague Island off the coast of Maryland and later from a plane over the South Atlantic. The spheres worked and, covered in a 1-in glass shield, would be protected during reentry. But as it turned out, the data capsule's parent, the Satellite Recovery Vehicle (SRV), never failed and the data capsule became "surplus."

Figure 65. The data capsule, left object in photo, and Earth. Photo courtesy of GE/U.S. Air Force.

Figure 66. The data capsule segmented. Photo courtesy of GE/U.S. Air Force.

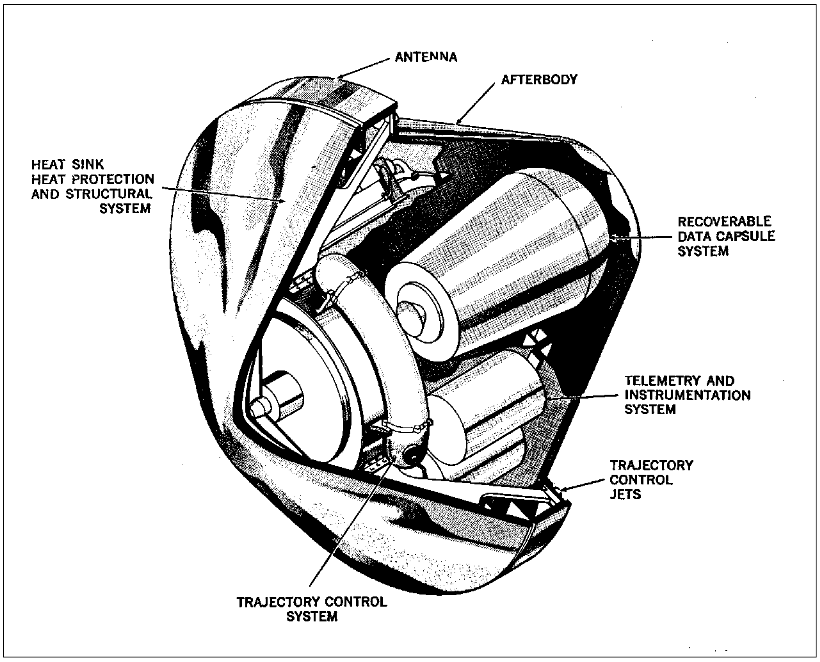


Figure 67. MK2 Atlas/Thor Reentry Vehicle and Recoverable Data Capsule. Photo courtesy of GE/U.S. Air Force.

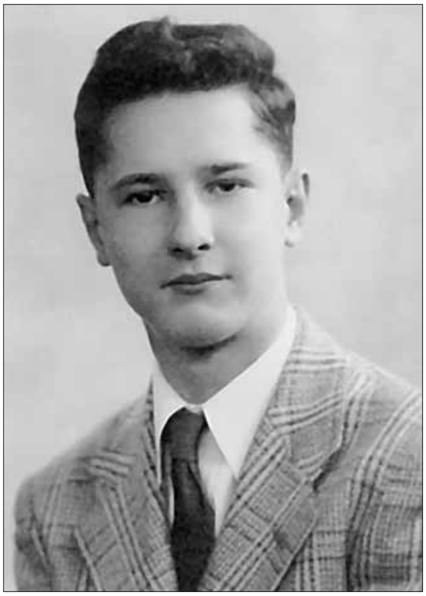


Figure 68. John Segletes.
Photo courtesy of John Segletes.

John Segletes
Aerothermodynamics Lead Engineer,
SRV Reentry System

Without knowing the true purpose of the Discoverer project, John Segletes' work on developing a durable heat shield directly contributed to the overall success of Corona. Segletes spent four years at General Electric (GE) as an aerothermodynamics engineer and was able to see the heat shield for a reentry vehicle through to success. In the following recollection, Segletes shares the challenges, failures, and successes of working on the Discoverer Program and evaluates the impact the program had on his life.

A year after graduating from college, and several false career starts, I started work at GE. I found what I had been seeking: an energetic and cutting-edge environment. GE had just moved from Schenectady, New York, to Philadelphia and was hiring engineers for several of its aerospace groups. The company was taking advantage of the emerging space race between the United States and the Soviet Union, propelled by the launch of Sputnik in the fall of 1957. Generous contracts were about to be handed out to companies like GE that could unravel the mysteries of how to bring an object safely back from space, a key step in developing Intercontinental Ballistic Missiles (ICBMs).

Engineering Challenges for ICBMs

The real engineering challenge at that time was designing ICBMs that could reenter the earth's atmosphere at very high speeds. It was really state-of-the-art work. As we were designing the missiles, others were developing the theory to predict what was going to happen. It was a real rush to produce something before we really had the technology to confidently do it.

My initial position at GE was in a group called configurational analysis where engineers attempted to calculate the temperature and ablation of the Reentry Vehicle (RV) when it entered the earth's atmosphere. I developed models to predict how RV's protective heat shield would respond to the intense temperatures it would be exposed to while traveling through the earth's atmosphere.

The major questions were how hot would it get and how much of it would burn away during the reentry process. I worked with a computer programmer and spent a good deal of time on these problems. Although I didn't know it at the time, my work was also directly relevant to Corona.

An Introduction to Discoverer

Six months after starting, GE pulled me off the ICBM project and sent me to do thermal analysis for Discoverer, the cover program for Corona that involved sending mice and later monkeys into space and bringing them safely back home. Although I had a security clearance, it did not allow me access to information about the true purpose of Discoverer. There were a lot of cover stories. They actually wanted us to believe they were going to put a monkey in the capsule and collect data on the monkey.

In fact, during my four years at GE, I was never told the true purpose of the program. During Corona flight tests, when the program managers encountered a seemingly endless number of problems, they would pull aside individual engineers who had expertise in the problem area and brief them on the nature of the photoreconnaissance program. I did not fall into this category but was able to make an educated guess as to the real mission. As it turned out, after a while, many of my colleagues knew. From their conversations I could pretty much surmise what was going on even though I was never officially briefed.

Engineering Challenges for Discoverer

In any case, the mission of the program was not necessarily as interesting to the engineers as the engineering problems they faced. My colleagues and I focused on trying to understand what would occur when a man-made object came back into the atmosphere from space, something that no one had previously experienced.

I worked largely with an engineer who did analysis of the aerodynamics, predicting at what angles and speeds the RV would come in. I took that information and used it to predict what the heat shield's temperature would be during reentry and how much of the material would burn away. Although they felt the reentry process could occur in "an infinite number of ways," they eventually devised a design trajectory based on the most severe situation that was likely to occur. This allowed for a speedy prediction of the thickness of the heat shield that protected the payload from burning during reentry.

The atmosphere at GE during this time was anything but calm, given the government's push to get an object into orbit, the initial string of failures during Discoverer flight tests, and later the downing of the U-2 spy plane in May 1960, which left the United States without a means for obtaining aerial reconnaissance of the Soviet Union. Everything was rush, rush. We typically had group meetings two or three times a week where all the engineers working on the heat shield would get together and everybody would report whether they were meeting the schedule and the weight specifications. Those meetings became pretty hot and wild.

Discoverer Fails and Finally Succeeds

Once the first in a series of a dozen unsuccessful Discoverer launches started, information about the failures trickled down to engineers at my level through several layers of management at Lockheed, the systems contractor, and at GE. It became apparent from the start that we were putting too much faith in our analyses and not enough in actual telemetry instrumentation that could provide hard data on each flight and give clues to the reasons for failure. The problems seemed to start while the satellite was still in space and continue through the attempted reentry.

Finally, in August 1960, the program had its first success, Discoverer 13, the capsule of which was the first object ever recovered from space. Even that was kind of a fluke. Only the payload—a bucket containing rolls of exposed film—was meant to be recovered, but the heat shield did not separate properly, so it came back with the payload. For me, this was a great treat.

I was pleased with that recovery because I was able to see what the heat shield that I worked on actually looked like after reentry. They sent it back to Philadelphia, and people who worked on the program were invited to go down and take a look at it—from a distance.

Working on a Covert Program

While I was not involved in GE's relationship with primary contractor Lockheed and other subcontractors, I heard stories about some of the situations that can come up while working on a highly classified program. In one instance, GE employees traveled to Rochester, New York, to speak with people at Kodak who were building the camera. Kodak required all visitors to sign in, which could have blown the cover of the program, so the visitors supposedly went around back and climbed through a window. I don't know about that one. To me, that sounds somewhat farfetched.

Another rumor went around that Congress was going to investigate the program because of the long string of failed flights. No hearings ever occurred. In fact, President Eisenhower made sure the Corona program had the support it needed to achieve success.

Conclusion

The four years I spent at GE from 1958 to 1962 shaped the rest of my career, which lasted more than thirty-five years. I didn't stay with GE all that long, but I did stay with them during a very critical period. It was an exciting time. While the Cold War heated up, the country turned to engineers to stay ahead in the space race and find solutions to complex problems. I thought it was really a great time to be an engineer.

Figure 69. Dr. George Sutton.
Photo courtesy of GE/U.S. Air Force.

Dr. George Sutton
Research Scientist,
GE Space Sciences Laboratory

As a research scientist at General Electric (GE), Dr. George Sutton developed the material durable enough to survive the heat of reentry and allow for the successful recovery of Corona. Dr. Sutton's recollections highlight some of the basic research that was necessary to accomplish the Corona mission. Dr. Sutton is also a good example of a key contributor who was not aware of the true nature of the mission.

I invented the material and the mixing process for the material that was used in the heat shield of the Corona Reentry and Recovery Vehicle and became, on Discoverer 13, the first Satellite Recovery Vehicle (SRV) to survive reentry from orbit. Back in those days that problem was called the "long heat soak" to distinguish it from the nose cones ballistic reentry.

The Need for a Durable Reentry Material

I was offered a job at GE. It was an opportunity to work on a hypersonic reentry vehicle. It's exactly what I wanted to do in order to solve the "long heat soak" problem.

Over the next few years at GE, I developed the material that would protect the Corona satellite's precious payload of film as the Reentry Vehicle came back to earth. The capsule had to be shielded from the intense heat created as it came back through the atmosphere and no material currently in existence was quite up to the task.

Shortly after starting at GE, my supervisor, frustrated over how to solve the reentry problem, took me to lunch and informed me about the project to recover a data capsule from space. Current nose cone designs had only a thick sheet of copper to reabsorb the heat of reentry. Engineers were concerned that this would not be sufficient to protect the contents of the data capsule. There was some concern that it would overheat, which was a correct concern.

The data had to be protected and brought back to earth in part because there was no way to get telemetry from the capsule during reentry because of the superheated air around the nose cone. This air acted as a reflector that would not allow for data transmission.

Designing a Durable Reentry Material

I went to work to find the appropriate material, first by considering what had already been tried. Ceramics, I knew, would crack, while graphite, a promising alternative, proved to be too brittle.

I researched GE's Hermes rocket program, which was protected with laminated plastic, made from layers of glass cloth alternated with resin and built up to an inch thickness. Under heat and pressure, the layers become a composite material. Unfortunately, when exposed to the heat of rocket exhaust, the panels of this material tended to come apart in layers.

Doing some research on plastics, I found that the ideal type of plastic to use was thermosetting plastic that would not melt. For reinforcement, I developed the idea of using glass and other fibers. These could not be laminated together, I knew, so I conceived a system that involved chopping up the glass fiber and mixing it in a blender so the fibers were oriented in different directions and could hold together without lamination. I made a whole bunch of these specimens with the help of GE engineers in Schenectady, New York. We tested about fourteen of them in the exhaust of a rocket. During the tests, the glass would melt but the plastic would paralyze the flow. These things were just immensely resistant to hypersonic heating.

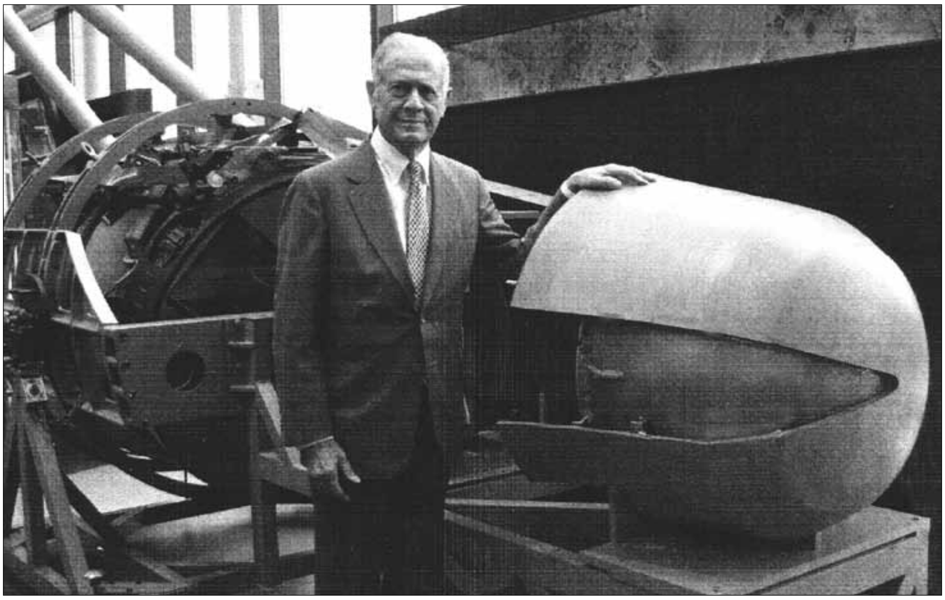


Figure 70. Dr. George Sutton standing next to the Corona SRV, Smithsonian Institute. Photo courtesy of George Sutton.

The fabrication of the heat shields was an intricate process. The resin and fibers were put into a giant mixing bowl until it was uniformly mixed up. The material was put into matched metal moldings and squeezed together under heat and pressure. It is very difficult to make.

I presented my findings to great acclaim at a June 1957 ballistic missile technology symposium. Then Flo Brent (see his section earlier in this chapter as well as chapter 18 for his accounts) took the material and incorporated it into the data capsules that would go on the Corona satellite.

Conclusion

My involvement in Corona did not extend beyond the development of the thermal material, and I did not find out for sure until many years later that the data capsule in fact was designed to bring film back from space with reconnaissance photographs of Soviet missile installations and other sensitive sites. I only knew the Discoverer biomedical satellite cover story. It was clearly aimed at getting some kind of reconnaissance satellite. I knew this was going on. I was just not contributing to the program as a fully knowledgeable participant.

Because of security on Corona, I did not get to see any of the few heat shields that were recovered after satellite missions. The only one I have seen is at the Smithsonian Institute.

Figure 71. Harold Bloom.
Photo courtesy of GE/U.S. Air Force.

Harold Bloom
Advanced Aerospace
Systems Engineer

Harold Bloom worked for General Electric (GE) on a contract designing nose cones for missile reentry. Like many others who made significant contributions to Corona, Bloom did not know the true purpose of the Discoverer/ Corona mission. Despite that, his design of the blunt nose cone made reentry possible and Corona a success. In the following reflection, Bloom shares his experience of the debate and early development of the blunt nose cone for Corona.

The Nose Cone Shape Debate

When I came into the debate about the shape of nose cones in 1954, many of my colleagues and superiors were convinced a design with a pointed end would offer the best chances for successful reentry. I disagreed. Based on a combination of intuition and my previous experience in basic aerodynamics research at the National Advisory Committee for Aeronautics (NACA), the precursor to the National Aeronautics and Space Administration (NASA), I proposed a blunt nose, the design that eventually made it onto the Corona satellite.

Tours and tests at NACA facilities in Ohio and California helped make the case for the blunt nose cone. I was new to GE after nearly five years at NACA, I would spend many years perfecting the design without ever knowing the true purpose of the Corona project. I dedicated my time to the biological

Figure 72. Soviet Academician Leonid Sedov, Hal Bloom, and Bill Lovely discussing the Discoverer model.
Photo courtesy of Hal Bloom, date unknown.

cover story for the Corona project, a mission to send a live monkey to space and return it successfully. I now know it was essentially an intelligence mission, and it went under the code name for thirty years before we were informed and received awards. It was a real surprise to us.

From the perspective of nose cone engineers, however, the true contents of the satellite payload made little difference. The challenge remained the same: to bring an object successfully back from space while protecting its contents.

Proving the Value of a Blunt Nose Cone

I recall the work of intensive mathematical calculations in a time before computers were commonplace—as almost comically complex. We had to do all the stuff with big desk calculators that went to twelve places. I was given one assistant to work on that calculator. I would make big spreadsheets and he would grind them out on the calculator. It has to be one of the most primitive ways to get things done.

My design for a blunt nose cone went through many stages.

Things sped up when the GE engineers got access to a computer program at Ramo-Wooldridge, another engineering firm. The computer processed 250,000 variations on the exact parameters of the nose cone design and finally came out with one that looked like it would do the job.

In the meantime, GE's space projects had moved to a new site in Philadelphia where work on the Corona project would soon be underway. I continued to refine the nose cone design and materials.

For more information about Mr. Schafer, Mr. Brent, Mr. Segletes, Mr. Sutton, and Mr. Bloom, please refer to their autobiographical reflections in Appendix 2.

Figure 73. Hal Bloom in what his compatriots called "Fink's Bloom Closet."
Photo courtesy of GE/U.S. Air Force.

Chapter 18

FIRST SATELLITE RECOVERY VEHICLE TO BE RECOVERED FROM ORBIT

This chapter includes six recollections by General Electric (GE) employees who worked on Corona's Satellite Recovery Vehicle (SRV): (1) Florian Brent, (2) Robert Lowe, (3) Anthony M. Smith, (4) Bernard Mirowsky, (5) William Woebkenberg, and (6) Borge Andersen. They discuss a variety of engineering topics that include design and test, backflow, electrical design, drop testing, and satellite recovery.

Florian Brent
Chief Engineer
Corona SRV Recovery System

Despite security and engineering obstacles, Florian Brent successfully led the Corona Satellite Recovery Vehicle (SRV) System as chief engineer. His greatest challenge was designing a durable parachute that met specific requirements to allow for a mid-air recovery. In the following account, Brent shares his experiences working on Corona, particularly his recollection of designing, testing, and using a parachute for the Corona SRV System.

Figure 74. The Corona SRV Recovery Team at the 1995 GE Aerospace Discoverer Recognition Celebration. From left to right, Bernard Mirowsky, Robert Lowe, Edward Spangler, Florian Brent and Marvin Clark. Photo courtesy of GE/U.S. Air Force.

As mentioned in my other chapter (see chapter 17 for Brent's experience as the Chief Space Capsule Engineer), back in 1957 I had devised the first man-made object to be recovered from space. Subsequently, somebody had an idea of putting a small camera in there. As this data capsule separated from the booster, it started to take 16-mm pictures. It took pictures from the New England coast all the way to halfway down South America.

That experiment, as I recall, gave General Electric's (GE's) Bob Haviland (see chapter 19 for his account) the idea to use a similar design for spy satellite recovery. The particular capsule, devised by my fellow engineers and me, was too small for those purposes but nevertheless laid the basis for the later Corona/Discover design.

Managing the Early Corona System

As Chief Engineer of Recovery Systems, I was the first person locked into the secure facility where I had top-to-bottom responsibilities ranging from recovery vehicle design to payload retrieval. Given permission to handpick my staff, I got right to work.

My obstacles came not just in the form of engineering challenges but also working on a project very few people knew existed. In fact, my security introduction to Corona involved being introduced to one person at a time to ensure only those who truly had the appropriate clearance knew the nature of the project. The only way you got introduced was to be referred by somebody else. They introduced you to somebody, and that person introduced you to another, and so on down the line.

We were trying to do this program when nobody outside our group was cleared. This caused us to have to handle tasks that would otherwise be completed by others. I did the budgeting, scheduling, and other administrative tasks related to my part of the project. Many managers didn't like that.

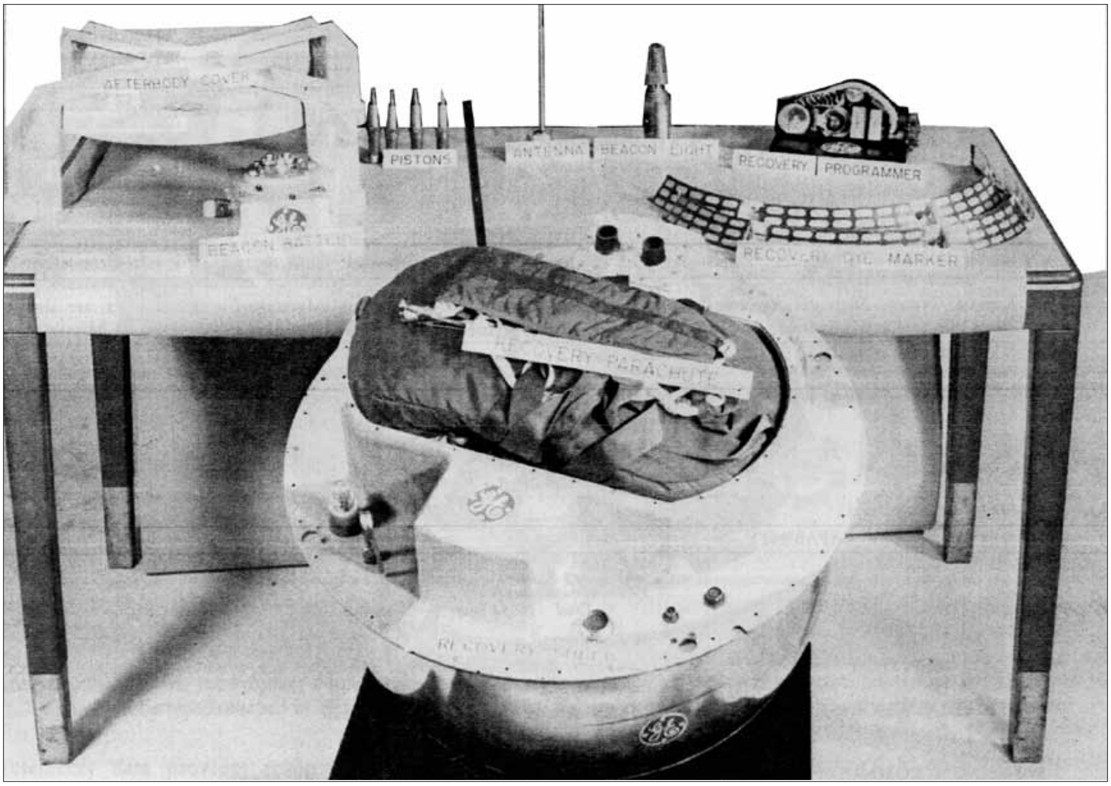


Figure 75. The Corona SRV RecoveryComponents. Photo courtesy of GE/U.S. Air Force.

Our self-sufficiency extended to procurement. The work area lacked an overhead crane to put pieces together and was very small. I had to get a letter from the head of projects saying, "Flo Brent can buy anything, any time, any place. Don't bother him."

Design and Early Testing of a Recovery Parachute

One of my tasks was to make a parachute strong enough to withstand being deployed at high speeds and high elevations. The requirement was to deploy a parachute at Mach 1 at 60,000 ft that didn't weigh more than 8 lbs. That was tough. It was very fragile.

Tests of parachutes initially occurred at Wallops Naval Station near Chincoteague, Virginia. During the first two tests, the parachutes popped out and went right back into the capsule. It was determined that the nose cone wake pressure was too great and that the deployment force had to be increased to assure parachute opening at 10 calibers from the nose cone.

The Discoverer program was for a satellite with a biomedical payload (first mice and later monkeys) that would be sent to space and returned unharmed as a lead up to the first human orbit. Some of the early test runs carried mice. Many mice failed to make it during testing—they were left to become little gray carpets. One test landed near a chicken coop and the other near a woman hanging up clothes, both on the nearby island of Chincoteague.

The Parachute Design

Because of the stringent requirements in terms of size and weight and the delicate mechanisms that had to work in concert, the recovery device had many complications. For temperature control, the capsule carrying the film back to earth ended up gold-plated.

Tiny manufacturing marks affected its ability to reflect heat properly. A machine such as a lathe bent the metal into shape. That tool left little V-marks. When they did thermal tests on that surface, it wasn't any good because even microscopic discontinuities meant it didn't reflect sufficient heat. The solution involved coating the metal with a layer of plastic to fill in the grooves, followed by gold plating.

The parachute itself was held into place by a reinforced fiberglass cover with four legs. Four pistons and bolts held that cover to the outer shell and also separated the inner capsule from the fiberglass outer cone. The system was designed so that when the pistons were blown, the parachute pulled out and opened part way. After the package had slowed further, pyrotechnic cutters severed the nylon rope holding the pieces together, the parachute opened fully, and the recovery capsule drifted toward earth.

Further Tests of the Recovery Parachute

After the testing on the east coast and some adjustments to the cover, the system was tested further at Edwards Air Force Base (AFB) and other locations, by both GE and Lockheed. Lockheed considered the GE tests inadequate, as I recall, and determined to take the vehicle up to 100,000 ft to test the parachute system further.

The test failed and I was off to Lockheed to check out what might have gone wrong. In examining likely causes for the failure, I found that Lockheed had not reinforced the corners of the cover properly and had used a fiberglass material that was not fine enough and therefore had relatively large pores that filled with the protective resin. Tests at GE had determined the ratio of fiberglass material to the resin. Lockheed's resistance to my findings meant the two systems had to be tested side by to determine which worked.

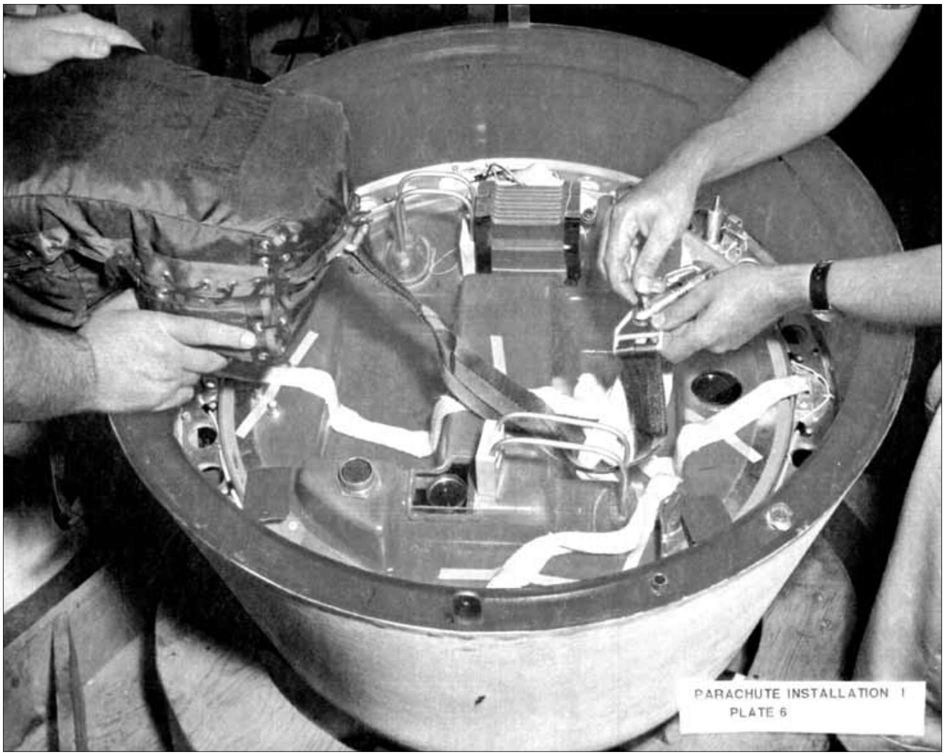


Figure 76. Parachute installation on the Corona SRV. The parachute was held into place by a reinforced fiberglass cover with four legs. Photo courtesy of GE/Air Force, date unknown.

Only GE's worked. If you watched the Lockheed cover, it was flopping all over the place. We fired one of ours, and it didn't fail. We proved to Lockheed and the Air Force representatives that you could not obtain the correct magnitude of force to eject the protective cover. That solved that problem.

Parachute Retrieval

The next step was the recovery of the parachute, a process involving a flyby by an Air Force pilot who had a hook attached to his plane to snag the parachute in midair. The parachute was designed with alternating panels of orange and silver, the silver being silver nitrate that would create a radar target and aluminum chaff for the airplanes trying to locate the recovery capsule for a catch.

During testing of the retrieval process, I witnessed pilots at Edwards AFB missing time and again and, occasionally, getting into dangerous situations as with one instance when the pilot hit the parachute with his right engine. The engine died, and the pilot was forced to drop down to 4,000 ft before he recovered. I remember jokingly giving the pilots a hard time, but the Air Force people had a lot of guts. Snagging a parachute in midair as it falls up to 20 ft per second is an activity I liken to pulling letters out of a mailbox while driving by at 20 miles an hour.

Conclusion

I remember my colleagues at GE as hard working and committed. We were a dedicated bunch. Somebody put the monkey on our back to do something in a relatively short time, and we were darned if we weren't going to get it done! We put in a lot of hours for free. It was an honor among engineers to get a job done on time.

Figure 77. Robert Lowe.
Photo courtesy of GE/U.S. Air Force.

Bob Lowe
Lead Engineer, Corona Satellite Recovery Vehicle Equipment

Robert "Bob" Lowe worked as a lead engineer on the Corona Satellite Recovery Vehicle (SRV) equipment. He joined the project in time to help complete the design of the data capsule, participated in drop testing for Discoverer, and stayed with the project through its success in 1960. In the following account, Lowe chronicles his time on Corona, sharing experiences from his time engineering the data capsule, designing and testing the recovery system, and finally seeing Corona through to success.

As an Engineer, I was intensely involved in the early design and testing of the recovery vehicle for the Discoverer program. I was a key player in the first data capsule group, followed the drop-testing program around the country, and survived the pressure of the early failures that contributed to ultimate success.

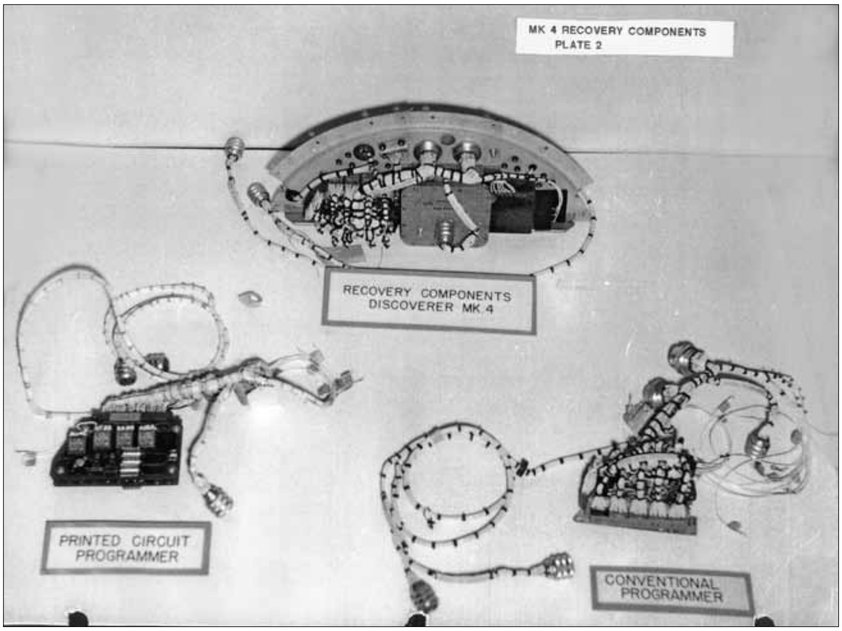


Figure 78. Discoverer Recovery Components. Photo courtesy of GE/Air Force, date unknown.

Engineering the Data Capsule

I came to General Electric (GE) as a design engineer in February 1957. The first project I worked on was the data capsule. Flo Brent (see his earlier account, also in this chapter) and Paul Aller were the two key engineers on the job. I had known Aller previously during his work with the Navy.

They had done 90 percent of the work by the time I joined them but I went to work on various component parts of the data capsule, such as the Sound Fixing and Ranging (SOFAR) bomb, dye marker, and explosives switch module. I was also responsible for turning the engineering unit into a production unit, making sure the drawings would replicate what they had built in the engineering lab.

Flo Brent led that whole effort. He had designed the capsule, the capsule shell, and the component parts that went in there. They were still having test failures when I joined them, but the problems all got worked out.

Joining the Satellite Aeromedical Recovery Vehicle Team

I came to work on Monday morning, April 10, 1958, and was informed that I was being transferred to a new group. It was the Satellite Aeromedical Recovery Vehicle (SARV) project on the Discoverer program. Marvin Clarke (see his account in chapter 11), Florian Brent and Bernie Mirowsky (see his account later in this chapter) came in at the same time.

They understood they were going to fly and return a monkey and mice. Initially, only Flo Brent had clearance for the black part of the program—the reconnaissance film—and SARV was just a cover project. Within a few months, however, I too received "black" clearance. Nevertheless, I never heard the term Corona until after I had left GE.

Of course, I could never tell my wife or family about the work. For the next few years, when I was regularly leaving them, I could say nothing about it. I would go on trips and I couldn't even tell my wife where I was going. I couldn't tell her what city I was going to. I'd say, "If you need to get in touch with me, here's the contact at work." She'd say, "Where are you going?" And I'd say, "I can't tell you."

Designing the Recovery System

My major responsibilities included the design of the recovery system for the payload, which encompassed design of the capsules, the covers, the parachutes, the recovery aids, and worrying about the ascent being able to exhaust the vehicle and the descent being able to allow air to pass into the vehicle.

In earlier development, the data capsule was an 18-in sphere. The idea may have floated around about using that as the payload, but I don't think that concept lasted very long. However, the data capsule led us into the Corona program because the kind of things that involved the data capsule, which is basically recovery at sea, were applicable to the film payload.

The 20-in diameter nose cone was not in the picture very long either, I recall. At the time, the thought was that they would recover the entire recovery vehicle with a payload of mice. They built a prototype of it, and that was the concept that was presented to Lockheed on June 2, 1958. At that time, the little group under Marv Clarke was responsible for the whole project.

Then the 33-in nose cone quickly came into play. Vehicle Engineering took over for the SARV group. I personally saw that as a big loss of control.

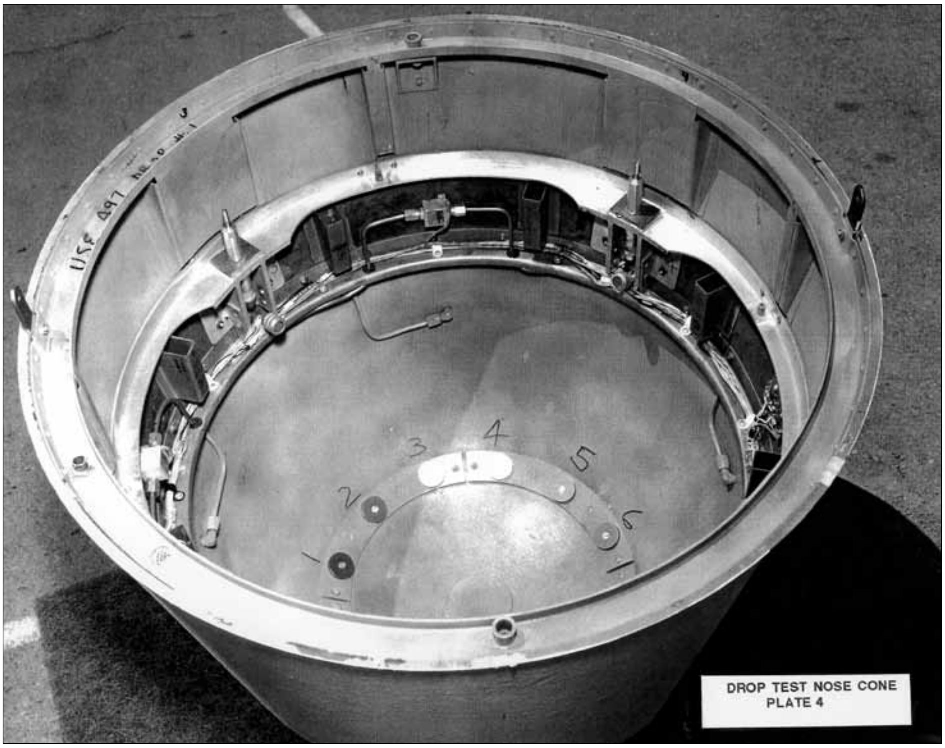


Figure 79. Drop Test Nose Cone. Photo courtesy of GE/Air Force, date unknown.

To circumvent the decision to have their subsystem components integrated into the vehicle, lead designer Elwood Richards and I came up with another key concept. Richards and I worked out the idea that their total subsystem would have only a single component interface with the reentry shield.

I always thought I was original in that idea because I remember coming back and telling the guys, "This is what we're going to do." And they said, "What are you going to do again? You're going to pull everything apart?" I said, "Yeah, that's the way we're going to do it." And our interface with Vehicle Engineering is going to be very simple, makes life easy for us.

But I was not the only one with this idea. Much later I found out that Systems Engineer Bob Chamberlin (see his account in chapter 15) presented that very concept to the customer because it was most efficient with its improved thermal environment for the payload and reduced weight.

I was doing it for selfish, political reasons. He was doing it for technical reasons. The end result was we got a good vehicle out of it.

Drop Testing the Project

The drop tests were a major part of my responsibilities. We did parachute tests in California, drop tests at Wallops Naval Station and high-altitude balloon drops at Holloman Air Force Base (AFB).

The test vehicle we had was much more complicated than our flight vehicle because on board we had telemetry systems, recorders, and cameras that were looking at our cover ejection so that we could see how everything separated. We ran a series of those tests. We also ran a series of cover-ejection tests.

Figure 80. Drop Test of Recovery Parachute System at Holloman AFB. Photo courtesy of GE/Air Force.

Every decision they made on every aspect of design involved weight restriction. That was especially true of the parachute and parachute deployment.

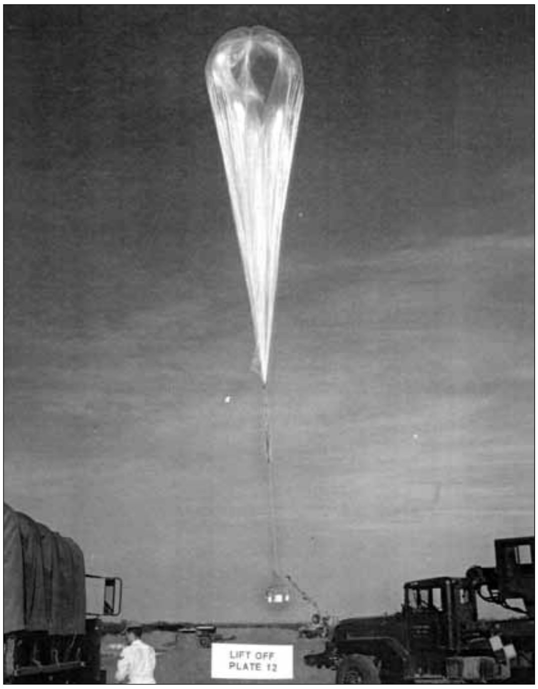


Figure 81. Lift-Off of Recovery Parachute System at Holloman AFB. Photo courtesy of GE/U.S. Air Force.

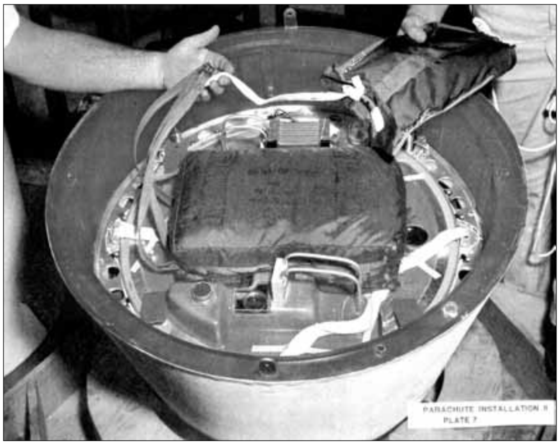


Figure 82. Nose Cone Parachute Installation. Photo courtesy of GE/U.S. Air Force.

The group decided that the "least weighty way to do that" was to have the thermal cover ejected to act as drag to pull out the drogue parachute, which pulled out the main parachute, which in turn pulled the capsule out of the recovery vehicle. The tests were all designed to validate that.

One of the Mark I drop tests at Wallops with a payload of live mice was a particularly memorable failure. The parachute failed to deploy so the nose cone and data capsule hit the ocean at 60 to 70 mph, which was like hitting concrete. I remember calling it a horrendous impact. We had measured deceleration forces on the capsule of 40,000 to 60,000 G's with water impact.

We were able to track and, with a veterinarian in tow, recover the capsule. He wanted to see what was inside very quickly, so we took a screwdriver and punched a hole in the housing so he could look in.

Looking through the hole we had shoved in there like opening a can of beer, all he could see with his little flashlight was the eye of a mouse. And he said, "My God, Bob, I think it may be alive. Let's get that cover off." And I said, "I don't think so. We'll get the cover off, but I don't think you'll see anything in there." Well, we got the cover off, and the mouse had been strained through its quarter-inch mesh life-cell structure.

GE's tests at Holloman AFB were all successful. At the same time other tests were being conducted. At Lockheed, the Air Force was using GE-built Recovery Aid Capsules for training and conducting air-snatch tests. The Navy, with GE techs in support, was using another GE vehicle at Point Mugu for training to sight, track, and recover from sea if necessary.

I recall that the Mark IV capsule designed by Vehicle Engineering was much superior to the Mark II. There was a little more weight allocated to the design, and Bob Smevog did a great job of utilizing that allocation to provide a far superior capsule cover and ejectable after-body cover.

Finally, Success

Every flight of the satellite recovery vehicle was an excitement. Though the design group was not let in on every detail of what was happening, we knew there were failures. However, we did not necessarily know how or what happened. In fact there were a lot of failures and we had a lot of people on our backs reviewing what we had done to be sure that our design was accurate. So I remember a lot of pressure because things weren't working so well.

But I do remember the uplift of Discoverer 2 on April 13, 1959, when it successfully de-orbited and survived reentry. Carrying a "false" payload, it came down near Spitsbergen, Norway, and was believed to have been recovered by the Soviets.

Discoverer 13 was a disappointment for me personally because I was not there to see it. They had a giant celebration while I was on vacation so I missed that great, spontaneous victory party. I just felt like I'd missed an awful lot because while I had been there for every failure, I ended up missing the success. Instead, I heard of the success on the radio.

Conclusion

I worked on Discoverer until 1960 while I was working on other programs. By then the engineering design work was completed, and I was assigned elsewhere. Discoverer/Corona was a relatively short span that was probably the most memorable three or four years of my career. The dedication, the work that we did, what we accomplished—we knew we were working on a red-hot program that was essential to the security of this country. The people that I worked with were extremely dedicated, and we bonded to some extent like people who serve in combat situations. It certainly was an important time in all of our lives.

Anthony M. "Mac" Smith
Consultant on Critical Failure Identification and Resolution

While working for General Electric (GE), Anthony M. "Mac" Smith discovered the reverse wake phenomenon, which led to his involvement in the nose cone parachute recovery system. Beyond that, Anthony has had an exciting and varied career working on everything from space projects to reactor power plants. In the following account, Smith shares his experience in discovering the reverse wake phenomenon and managing its implications.

Figure 83. Anthony M. (Mac) Smith. Photo courtesy of Anthony Smith.

I joined GE in late 1956 at their missile and space business in Philadelphia. There I did a variety of free flight aerodynamics tests (ballistic ranges, drop tests, rockets tests) on the Intercontinental Ballistic Missile (ICBM) Mark II, Mark III, RVX1, two nose cones, and the reentry vehicle for the Discoverer program.

One of my ballistic test projects at the Army Ballistics Research Lab (BRL) involved small-scale experiments of a data capsule ejection from a Mark II nose cone. Basically, it had been assumed that the capsule ejection velocity need only be enough to initially overcome the deceleration of the reentering nose cone—after which the trailing wake flow would provide enough drag force to complete ejection into the free stream airflow.

As the shadowgraph of a model test in figure 84 illustrates, the spherical capsule, which was ejected with a velocity sufficient to overcome nose cone deceleration, actually returned to the nose cone base and then bounced off the afterbody into the free stream. The challenge was here and I was the first to discover the phenomenon of a reverse wake behind blunt shaped nose cones.

This work then led to my involvement with the test of nose cone parachute recovery systems (both small scale ballistic range tests and full scale aircraft drop tests), and ultimately my involvement with the problem of successful deployment of the parachute recovery system for the Discoverer/ Corona SRV.

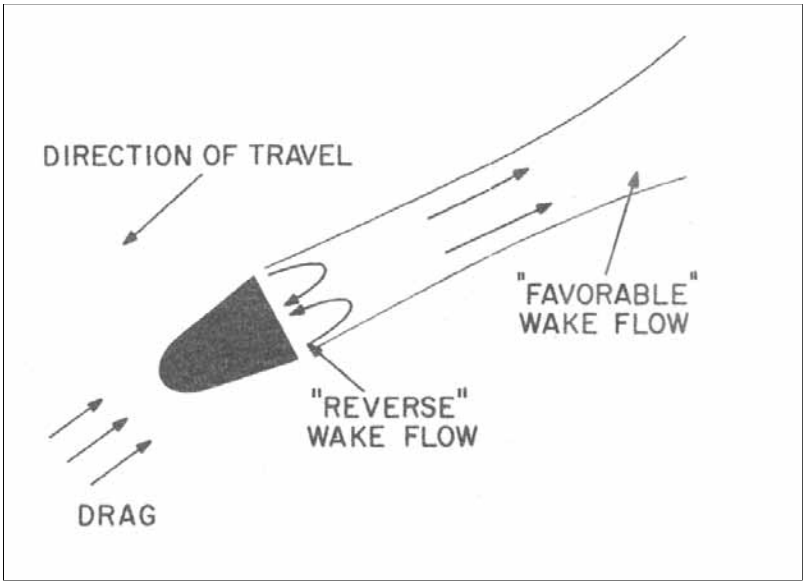


Figure 84. Reverse wake phenomenon. Figure courtesy of Anthony Smith. On Corona, the data obtained on various ballistic ranges, wind tunnel, and high altitude drop tests defined the reverse wake conditions more precisely. This information provided the input to the hardware design team (Bob Lowe [see his account also in this chapter] et al) on the required ejection velocity for the aft cover, which in turn then provided the drag force needed to deploy the drogue and main parachute system.

Presenting the Findings

As a result of these efforts, I presented a (then classified Secret) paper on the recovery systems for the RVX1 and two research nose cones and the Discoverer Satellite Recovery Vehicle (SRV). I presented this paper in Los Angeles in 1960. My particular session was chaired by Dr. Roy Smelt, then the Chief Scientist for Lockheed. Before the session, Roy introduced me to Jim Plummer, Lockheed's Program Manager for Discoverer/Corona, who told me that his people were warned not to "harass" me with questions during the presentation. As I recall, there had been some bad feelings at Lockheed that GE had been the one to solve the reverse wake problem.

Figure 85. Anthony Smith demonstrates his Dynamic Mission Equivalent technique to Corona management, Jack Katzen, Ingard Clausen, and Bob Hatch, 1967.
Photo courtesy of GE/U.S. Air Force.

Shortly before I presented this paper, the Discoverer team recovered the first Discoverer capsule from space (after twelve consecutive program failures) and I was honored to have this Discoverer capsule on stage with me when I delivered the paper.

Conclusion

I feel that my engineering career of more than fifty years has been exciting and rewarding to me personally. I believe that my technical contributions in the fields of aerodynamics, reliability and maintenance engineering have been significant to the betterment of my country and my profession. Corona, of course, is one of the most important and satisfying achievements with which one could ever wish to be associated.

Bernard Mirowsky
Supervising Engineer, SRV Electrical Systems
and GE Test Conductor for Recovery Drop Tests

Bernard Mirowsky put in long hours and was determined to see the success of the Corona drop tests. His innovations and continual improvements helped contribute to the overall success of the program. In the following account, Mirowsky shares his recollections of working on the early drop tests of Corona and some of the challenges they overcame.

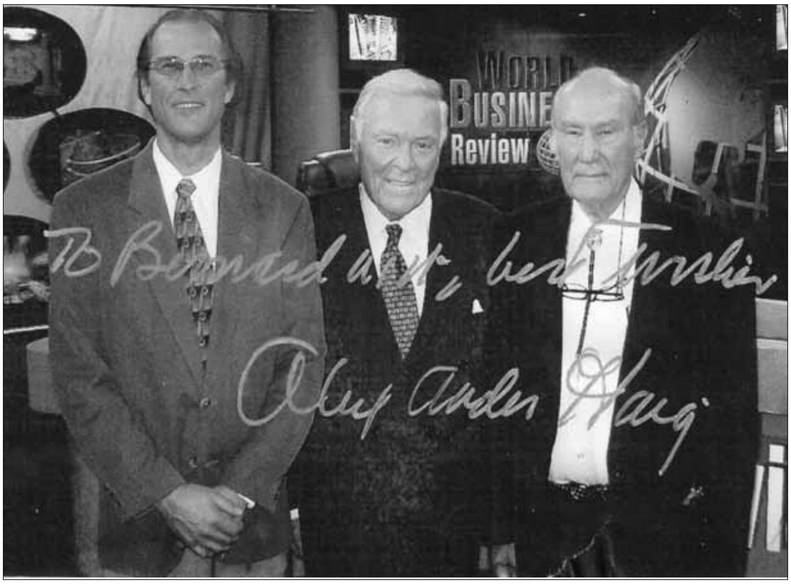


Figure 86. Bernard Mirowsky, right, his son, Paul Mirowsky, left, and General Alexander Haig, center. Photo courtesy of Bernard Mirowsky,

In the late 1950's, both General Electric (GE) and Lockheed were working on a wide range of drop tests in a variety of locations. I signed on as an Electrical Engineer for GE's Discoverer /Corona program and stayed with it all the way to the end. My changes to the reentry control system helped convince the right guys to let us do the recovery system. Then we got the job. It led to the film payload of the first satellite reconnaissance flight returned to earth from orbit.

Early Changes

Upon joining the Discoverer/Corona program, I immediately changed the reentry control system from non-redundant electromechanical timer-based sequencing to quad redundant high-impedance crossover electronic programmer with dual circuit redundancy out to the vehicle pyrotechnic charges. Engineer Milt Smith accommodated this concept with dual igniting elements in pyrotechnic charges used to deploy the parachute and free the payload recovery capsule from the ultra-hot ablative reentry shield. My electronic programmers were used in Discoverer/Corona and other reentry vehicles for years.

Challenges with Early Drop Tests

I was assigned as a drop test conductor in 1958, starting at Wallops Naval Station. There, I got off on the wrong foot with the techs when I expressed my concerns about the flimsiness of the release telephone jack activator and the construction of the drop vehicle. Charles Rabolli, vehicle engineering manager, told me to leave the technicians alone and "kindly stick with the design of the flight hardware."

But soon Rabolli called me in on a Sunday and informed me that all my concerns had proved correct. Two chutes deployed from vibration, simply being in an airplane still sitting on the ground revving its engines. I was put to work redesigning the drop electrical circuits and designing a release activator "that could almost withstand an atomic bomb" and then convinced the pilots to fly it.

Bob Lowe and Florian Brent (see their accounts also in this chapter), supported by excellent technicians, prepared "white" (unclassified) and "black" (classified) drop test articles (SRV drop vehicles) that flew both animal (monkey or mouse) and film cassette payloads.

I was at Wallops for two weeks for my first drops, which were at about 40,000 ft. I found it slow going developing a rapport with the techs now working under me. I remember the technicians were not too friendly with the new test conductor and even refused to bring some items back to Philadelphia for me.

Figure 87. Corona nose cone, August 1959. Note the handle on the right and the drop-aircraft mounting lugs on the left. This nose cone was used to test recovery system effectiveness. Photo courtesy of GE/U.S. Air Force.

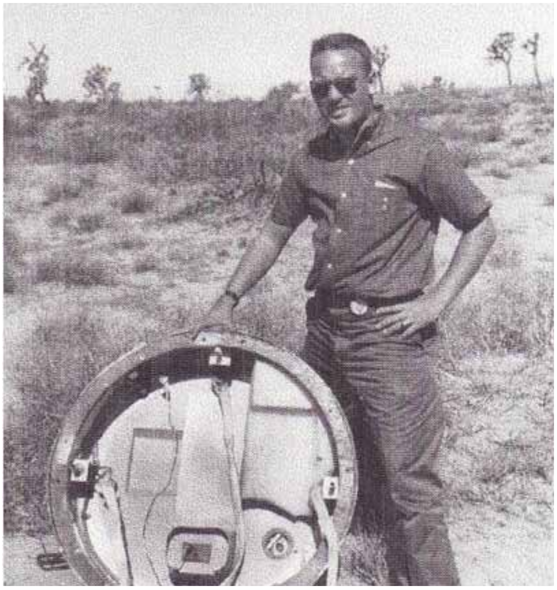


Figure 88. A drop-test capsule after recovery, Edwards Dry Lake, 1959. Photo courtesy of GE/U.S. Air Force.

Taking Over GE's Drop Test Program

When the trials moved to California, I received the news that I was in charge of GE's drop test program. Irene Tisch, an electrical engineer who was fairly familiar with Point Mugu naval operations, was assigned to assist me to make sure I had access to whatever I needed.

I was then put at the head of the table in a conference room in Point Mugu with at least twenty attendees. I saw more "brass" in one day than I had seen on the J. F. Kennedy, Jr. destroyer in my Navy days. They included Navy and Air Force base officers, personnel from Lockheed, Eglin, Edwards, Oxnard, San Nicholas Island, King County Recovery Ship and more.

They all looked at me and asked me for a plan and a schedule. For my own benefit, I had them all explain who they were and what they needed to know. I felt the pressure and expectations. I remember that I worked around the clock for two or three days straight. On schedule I passed out our GE operating plan for the first drop test at a second meeting. It included a list of times, the actions required and collation "X" columns for those having action, involved and effected.

With so many agencies and bases put to use, there was the inevitable red tape during the drop test program. When an airplane from Edwards Air Force Base (AFB) got a flat tire at Oxnard AFB before a drop, they were not allowed to get a tire from the Strategic Air Command (SAC) Base, Oxnard, inventory and had to wait until a tire was flown in from Edwards. However, we did get the drop off.

Being merely a civilian, I worked side by side with Point Mugu Test Conductor, Olly Kalp, who had authority over the military operations. After two successful drops in a row at Mugu, we attempted our very first payload drop. For unknown reasons the F101 pilot released the vehicle early. The chute did not deploy and it was lost near the Pacific shelf. A three-day search yielded nothing.

But during the California operation, my relationship with the techs apparently warmed. They were magnificent. I sometimes thought that they were telepathic. While I was involved in briefings on the drop, they would get the vehicle ready and attach it to the aircraft at Oxnard.

A Rush to Share "Black" Equipment

To conduct a drop test, the airplane would go up to San Francisco, climbing to 50,000 or 60,000 ft, and then fly down the West Coast to get back to the theodolites over Point Mugu.

The drop test team and I usually stayed at the Wagon Wheel Motel on Route 101 in Oxnard. One evening, the phone in my room rang. Col Johnson spoke, "Don't pack your suitcase. Just get in your car and as fast as you can get to the Los Angeles airport." I called Borge Andersen (see his account also in this chapter), "Come on, get in the car!" Borge refers to it as his "white knuckle ride."

We were intercepted by a station wagon before the car rental entrance. We got out of the car and into the station wagon. We were driven out to a passenger jet stopped partway down the runway. Borge and I climbed up a portable stair, we were seated and on our way to Philadelphia. We drove to the Chestnut Street plant where we went to the "black" assembly room, which contained the "black" ground support equipment that I had designed. We tested it and placed a Quality Control (QC) stamp. It was packaged and rushed to Vandenberg, where they were waiting to check out a "black" Satellite Recovery Vehicle (SRV).

Later Drop Tests

I was test conductor in a balloon launch from Truth or Consequences, New Mexico. The balloon was released at 80,000 ft so as to reach proper terminal velocity over White Sands theodolites. There were also recoveries at Edwards AFB and early drops at Holloman AFB in 1960 as we attempted to perfect the recovery subsystem. I still remember a White Sands rocket sled test story with a monkey in the sled. The restless monkey was pacified with a banana for which he was going to take the first bite when the sled rocket was ignited. They said the monkey wouldn't eat another banana for several weeks!

The drop tests were confirmation that GE's reentry hardware could meet mission requirements. The reentry shield (now at the Smithsonian) was discarded to the earth or water. Then the deployed parachute floated the payload capsule down from about 60,000 ft, to be air-snatched or gently settled in the water or onto the ground. The parachute was radar reflective, and the half-pound X, Y, and C band chaff was deployed in the air so recovery aircraft could snatch the vehicle before it reached the surface.

Each chaff piece was slip coated and about half of them were dipped with a small epoxy tip so that some floated horizontally and others floated vertically to match horizontal and vertically polarized radars. If the capsule reached the surface, a light flashed continuously, a Radiofrequency (RF) signal beeped, and dye marker was deployed to support a water or land recovery. Almost all the flights were recovered by air snatch.

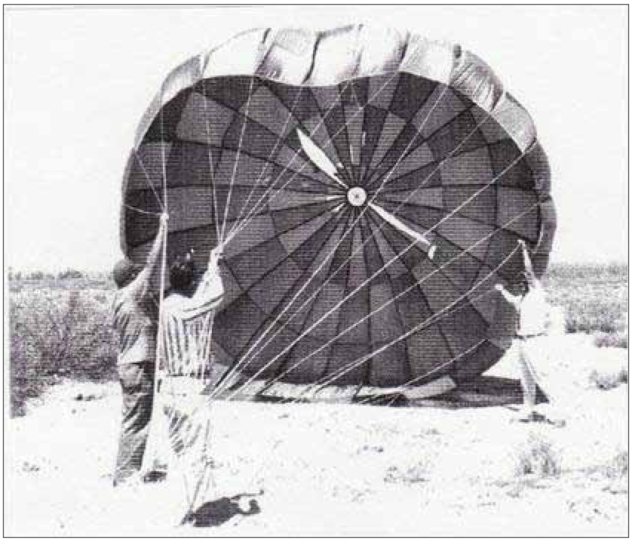


Figure 89. Drop Test, Edwards Dry Lake, August 1959.
Photo courtesy of GE/U.S. Air Force.

Further Endeavors

When I was sporadically home in Philadelphia, I designed the electrical system, the programmer, the chaff package, and the three-bay checkout complex for the black program and other boxes. I also created the mission sequence for the recovery system.

Milt Smith and I developed dual loop igniters for redundancy. Milt Smith also designed the explosive charge for the drogue that fired through the reentry wake, pulling the parachute cover and the pilot chute that deployed the main chute. Milt needed to test the drogue charge. He fired a drogue into a horizontal barrel filled with sawdust. The drogue went through the sawdust, the bottom of the barrel, through the open doors of a garage, and lodged in the rear cement block wall of the garage. I was delighted Milt took the time for the test as he then downsized the flight drogue charge.

I remember tests on the centrifuge, with varying temperatures, trying to get the G switches in tolerance. After 3G, I believe we timed out 720 seconds, fired thermal batteries for pyrotechnic chute deployment of drogue and then main chute between 50,000 and 60,000 ft. No pyrotechnic event could occur unless the preceding event had occurred. As one event occurred, it armed the next event.

Conclusion

I just never stopped. It had to be done. My GE superiors were not cleared and did not know the importance of what I was doing and my reviews could not reflect my accomplishments. I rarely received pay for overtime or weekend work. I made less pay per hour than the techs.

Interestingly enough, the Air Force customer, the Navy, and others involved with proving performance in the field were well aware of my knowledge, competence, and ability to schedule and task multi-agency participants (Air, Navy, Ground Support, theodolites personnel, pilots, crews, etc.) and make on-the-spot decisions and field adjustments. I never let go. I worked the program all the way through.

William H. Woebkenberg Jr.
Engineer, System Experimental Engineering

William Woebkenberg, Jr. was involved with the balloon drop tests for the Corona program. He saw the program through the early tests and development of the Mark IV/V parachute system. In the following account, Woebkenberg shares his experiences, challenges, and early solutions discovered during drop testing of Discoverer. Woebkenberg also illustrates and discusses how the Mark IV/V parachute system works.

Figure 90. William H. Woebkenberg Jr., far left, at the Discoverer high altitude drop test, Holloman AFB, White Sands, New Mexico, 1960. The other test crew members from left to right: Bob Driscoll, Telemetry and Instrumentation Technician, Lex Devlin, Mechanical Technician, and Bill Root, Electrical Technician. Photo courtesy of U.S. Air Force.

In March 1960, I went to Holloman Air Force Base (AFB) as a test conductor on General Electric's (GE's) balloon drop tests for what was publicly being called the Discoverer project. The high altitude drop test series was performed to develop the recovery subsystem of the capsule.

There were three series of balloon drop tests performed on the Discoverer program.

The initial tests were performed at Wallops Naval Station near Chincoteague Island, Virginia. A second series was performed at Edwards AFB and Pacific Missile Range, Lancaster, California, from a U-2 aircraft.

Bernie Mirowsky (see his earlier account in this chapter) participated in the Wallops and Edwards AFB tests. He also aided in preparing range documentation for the White Sands/Holloman AFB tests but did not participate in the actual balloon tests.

The third series of about eight tests was performed at Holloman AFB in 1960 to 1961.

Initial Challenges and Solutions

The first tests of the recovery project used flat circular parachutes that were unsuccessful, and I felt the frustration panels were blown out or torn. In addition, the flat circular canopy was unstable at air recovery altitude and caused problems for air recovery pilots.

The chute needed a velocity of 25 ft per second for the program's planned recovery altitude of 10,000 ft. The early test chutes were not stable enough for that plan.

We tried some interesting fixes to improve the situation and prevent damage when the parachute deployed. We made panels in double nylon thickness. We changed the cloth cut from square-cut to bias-cut. The deployment damage continued.

The Mark IV/V Parachute System

Ultimately, a more imaginative solution saved the day. The team developed the Mark IV/V system and described it as "a two parachute, three-stage system." It required minutely timed deployment of a deceleration chute seconds before allowing the deployment of the main, ring-slot parachute. To the engineers' pleasure, the ring-slot parachute provided the appropriate velocity and altitude. The ring-slot parachute was very stable for air recovery. All tests of the Mark IV/V parachute system were successful. The following four figures show the design of the Mark IV/V parachute system and illustrate its operation. I recall that the test program was in progress when Discoverer 13 was sea-recovered and Discoverer 14 was air-recovered.

For more information about Mr. Lowe, Mr. Smith, Mr. Mirowsky, and Mr. Woebkenberg, please refer to their autobiographical reflections in Appendix 2.

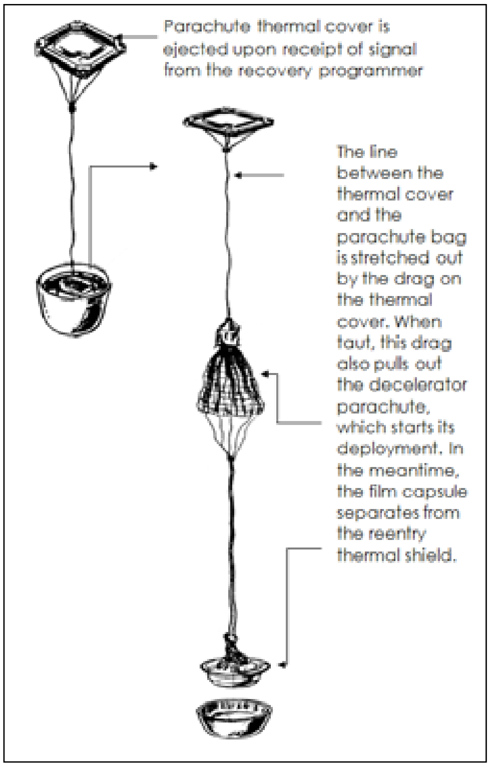


Figure 91. Parachute thermal cover is ejected upon receipt of signal from the recovery programmer. Figure courtesy of William Woebkenberg.

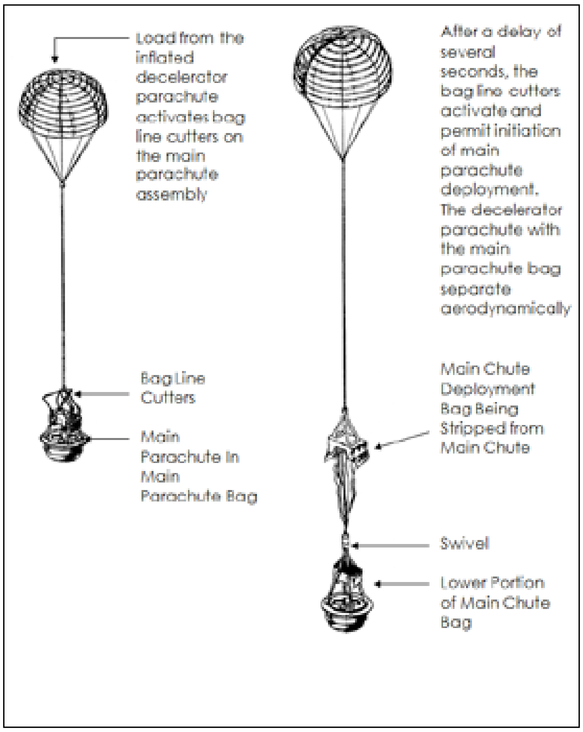


Figure 92. Load from the inflated decelerator parachute activates bag line cutters on the main parachute assembly. Figure courtesy of William Woebkenberg.

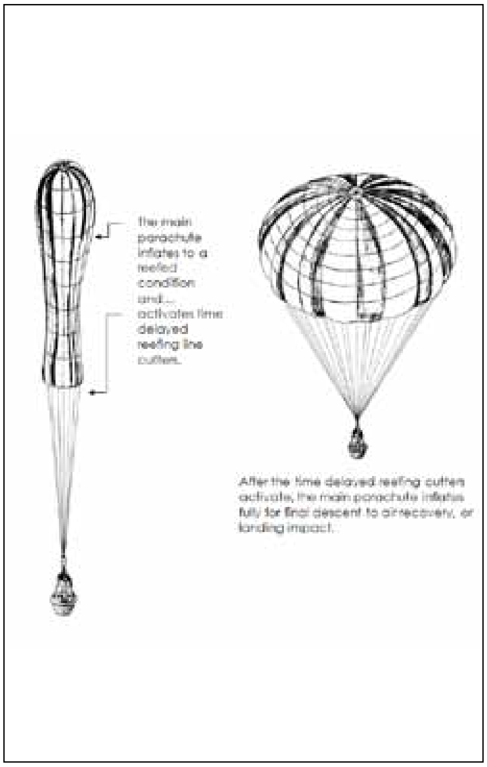


Figure 93. The main parachute inflates to a reefed condition and activates time-delayed reefing line cutters. Figure courtesy of William Woebkenberg.

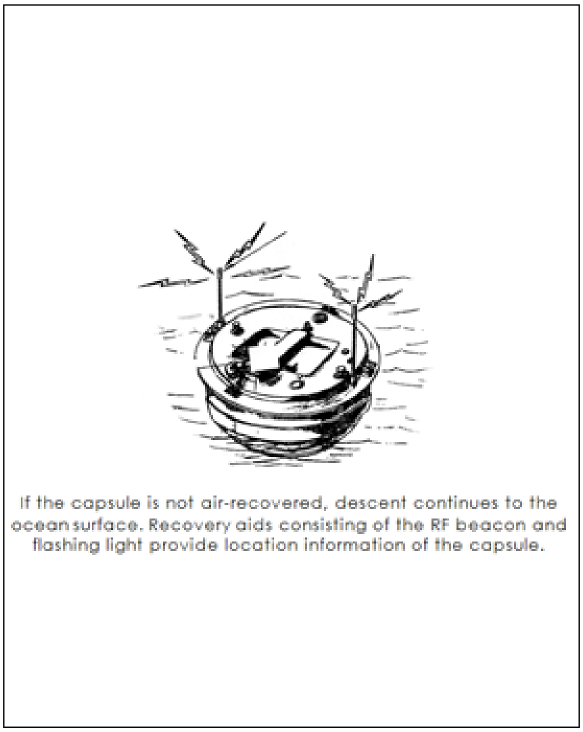


Figure 94. If the capsule is not air-recovered, descent continues to the ocean surface. Recovery aids consisting of the Radiofrequency (RF) beacon and flashing light provide location information of the capsule. Figure courtesy of William Woebkenberg.

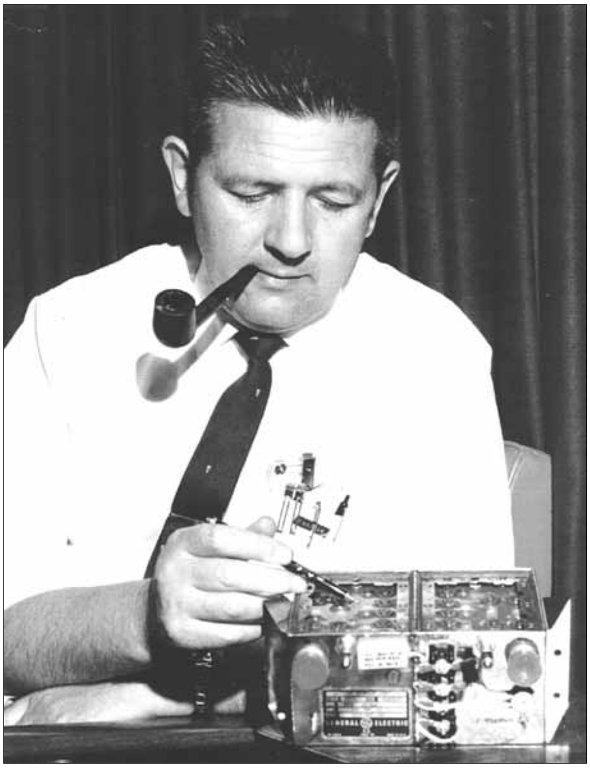


Figure 95. Borge Andersen.
Photo courtesy of GE/U.S. Air Force.

Borge Andersen
Lead Technician
SRV Recovery Equipment

An immigrant to the United States, Borge Andersen joined the Air Force before getting his U.S. citizenship. Andersen was brought on board the Corona program in 1958 as a technician for the Satellite Aeromedical Recovery Vehicle (SARV) program. In the following account, Andersen discusses working on the Corona drop tests—the disappointment accompanying failure and the excitement of success.

In 1958, while working for General Electric (GE), I was transferred to the SARV program. This section needed a technician that was familiar with electrical schematics for wiring breadboard systems and harness assemblies for the Aeromedical Systems Group. This was part of GE's contract to build support systems on the reentry vehicle to carry mice or a monkey into space and back.

My function was to build the electrical programmable systems on a breadboard, perform component testing, and assemble interconnecting harnesses for engineering drop test program evaluation.

The first drop tests were in September 1958 at the Wallops Naval Station near Chincoteague, Virginia. We had many failures before success. Those included a parachute becoming wrapped around the recovery vessel screw, a splash-down without deployment of the parachute, which caused the vehicle to directly sink to the bottom of the ocean, two released heat shields being blown into the backyards of residences miles away, and premature parachute cover deployment during engine start-up.

While these drop tests were ongoing, the GE biomedical group was busy with animal testing in Philadelphia in the sixth floor laboratory. They were working on a life-support package to send the aforementioned mice or monkey into space. The group built a small payload mockup and its recovery vehicle on June 1, 1958, and they were presented to Lockheed at GE the next day. I had just finished testing the system programmer that was then installed in the capsule, which was a bucket.

The project began in the early afternoon and, by working through the entire night, the job was finished in the early morning of the following day. Some said it could never have been done—well, this group knew better. The impressive results were a model of teamwork, with everyone in the biomedical lab providing vital enterprise. Presentation was dramatic, with the vehicle (made of salvage hardware) rolled into the presentation with strobe light flashing. GE got the contract and Corona began.

Drop Test Challenges

During drop tests at Wallops, I helped prepare the vehicle and loaded it under the wings of the B66. Walter Roman (see Appendix 3 for a tribute to him) and I also helped the U.S. Navy retrieve the capsule from the sea. The hardware performances brought good results, but that could not be said for the mice payload. I then went with the team to California for more drop tests originating from Oxnard Air Force Base (AFB). Again, either Walt Roman or I performed the activation and retrieval of the drop test vehicle hardware. And again, the failures were adventurous. Film used in the cameras hung up or broke; parachutes did not fully deploy, twice resulting in the vehicles sinking to the ocean floor, never to be found; and parachutes became waterlogged on splashdown and turned the capsule over, thus putting the strobe light underwater where it could not be seen. As fixes were tried, I was put in a PT boat with the naval search crew in order to measure the longest distance of an obtainable signal from the beacon and the strobe light. I also recorded data of the capsule's behavior in heavy sea conditions.

Five Discoverer launches in 1959 were filled with mishaps and the drop test program at Holloman AFB near Alamogordo, New Mexico, began in November. I was on the technical staff. We soon discovered that the parachute cover material built by GE was superior to those of Lockheed, and future assemblies used the GE covers.

During the first set of drop tests at Holloman, I was in a search helicopter and had the unenviable task of locating the second launched capsule, which went wildly awry on landing. The pilot and I finally retrieved it from the mountains and returned it to the base with little damage.

The fourth vehicle launched turned out to be rather special. It was first launched successfully near Elephant Butte Lake, New Mexico. However, on descent, it landed in the treetop of a Ponderosa pine on the Mescalero Apache Reservation near Cloudcroft. Members of the tribe retrieved the vehicle from the trees and loaded it on an Air Force truck. I recall the tribal leader was paid $2 for their efforts. The vehicle was in such good condition, it was reloaded and retested. I spent the night before the new test visiting all the technical groups to be assured everything was ready. It again launched smoothly from Elephant Butte Lake, after which I drove the truck back to Holloman, stopping for breakfast in Truth or Consequences.

When crossing the top of the trail of the Organ Mountains, New Mexico, I stopped at one of the view sites. My eyes caught the balloon drifting smoothly at a high altitude with the hardware reflecting from the sun. I stood there and watched the balloon and looked at the desert terrain towards Holloman AFB, which was approximately 50 miles ahead of me. I experienced a magnificent view of the beautiful surroundings. It was so impressive that it was beyond description, and a certain stillness came over me.

Finally Success

In the midst of this beautiful creation and by the stillness surrounding me, I was assured that this mission would have a successful recovery. When I arrived at the base and went to the hangar, the capsule was sitting there with the entire crew around it, and as I approached the capsule, one of the members turned toward me and said, "Borge, we did it!" I answered him by saying, "Yes, fellows, I already know; and please accept my deepest gratitude for a job well done, and let us jointly close this shop so we can head for home."

The high-altitude reentry drop test program was completed in February 1960. Looking back, it is almost unbelievable the ingenuity shown by a small group of men that were able to bring this reentry system to reality.

Figure 96. Borge and the helicopter pilot recovering drop test number 2 near Holloman AFB, New Mexico.
Photo courtesy of GE/U.S. Air Force, 1959.

Figure 97. Close-up picture of drop test number 2; note the parachute is not opened.
Photo courtesy of GE/U.S. Air Force, 1959.

Chapter 19

FIRST PHOTOGRAPHS RECOVERED FROM SPACE FROM A 3-AXIS STABILIZED PLATFORM

Robert. P. Haviland, Cdr., USNR (Ret)
General Electric Project Engineer

Figure 98. Robert P. Haviland, Cdr., USNR (Ret).
Photo courtesy of Robert Haviland

In setting the stage for the Corona effort, it was key to pull together the early experiments in rocketry and recovery. Robert Haviland was involved with the early experiments and concepts that led to the successful development of the U.S. spaceborne reconnaissance program. In the following account, Haviland traces the beginnings of that program, also highlighting the push the United States received from the success of Sputnik.

The article, "CORONA: Success for Space Reconnaissance, A Look into the Cold War, and a Revolution for Intelligence," by Robert A. McDonald, in the June 1995 issue of *Photogrammetric and Engineering Remote Sensing* presented a vivid description of the success of reconnaissance with physical recovery of the gathered data. However, the article covers only the events that occurred after the decision to establish the program had been made. The following material is intended to complete another part of the total history of the program, covering the elements that led to the concept of and ability to execute recoverable photographic data.

The Beginnings of a Spaceborne Reconnaissance Program

The real start of these concepts was in 1946 when reports and captured German V-2 archives became available in the United States. On duty in the Navy Bureau of Aeronautics at the time, I started a study of possible extensions of rocket techniques, which led to an internal proposal for satellite and space studies, which included satellites, communications, ocean surveillance and mapping, but not in any detail. Capt Berkner and Capt Fahrney and ADM Stevens were instrumental in getting this accepted as a program. I remained on active duty, instituting a series of study contracts with Martin (Baltimore), Cal Tech, North American Aviation, and, through the BuAer propulsion section, with Aerojet. A contract was proposed with Douglas, but did not develop since they had just established

Project Rand for the Air Force and had been asked to study future possibilities. These events, plus some additional important ones from the scientific community, and much maneuvering over the following years, eventually led to the establishment of the U.S. space program.

Using Cameras from Space on the Hermes Project

During this period, there were several important inputs to reconnaissance concepts from various sources. The first came from the U.S. test of the V-2 rockets, under the Army Ordinance Hermes project at General Electric (GE). Cameras were installed for several purposes—the detail and resolution of these at vertical incidence was striking, even at heights far above airplane capabilities. There was another V-2 input also—as the war-end scarcities developed in Germany, it was no longer possible to obtain graphite to make the steering vanes immersed in the rocket jet. By experiment, it was found that green oak made an acceptable substitute. That marked the start of ablation protection of high temperature gas flow.

The military budget cutbacks of 1947 prevented further work. I returned to inactive duty and joined the Hermes program. I received an early assignment there as project engineer on the Bumper two-stage test, a cooperative program with Jet Propulsion Laboratory (JPL), Douglas, and Army Ordinance (Aberdeen).

Developing a Durable Nose Cone

Aerodynamicists were seeking supersonic data at high pressures, so two vehicles were modified to fly horizontally at 50,000 ft. To withstand the high temperatures while permitting good radio transmission, I proposed a Teflon jacket for the glass-resin nose cone. The molded form of this was developed and designed by Charles Botkin of GE. Douglas worked out an alternate using multiple coats of Teflon spray, but this was not used. This was the first ablating nose cone, incidentally being used on the first missile launching from the Joint Long Range Proving Ground, Cape Canaveral.

The next input came from the reentry vehicle work at GE for the Air Force. One problem that appeared was proving that a nose cone would not reenter backward and be destroyed. As flight test planning engineer, I proposed installation of an ablation-insulated sphere with an internal motion picture camera in the warhead space. The developed system was first demonstrated by a Thor flight test at Cape Canaveral on May 12, 1959.

Recovering Photographic Packages

An almost incidental input came a little earlier, from the Nuclear Emulsion Recovery Vehicle (NERV) package developed by GE for the Naval Research Laboratory (NRL). This ablation-protected vehicle was to recover a large package of nuclear track photographic emulsion. I had little contact with the program, beyond arranging for the initial contacts between NRL and GE.

The Push from Sputnik

The 1957 launching of the first Sputnik had a profound impact. I was in London, en route to the Barcelona meeting of the International Astronautical Federation (IAF), at the time. I remember the comment of the newsstand vendor when I asked for a copy of the announcing newspaper, "I say, old chap, they beat you to it, you know." Actually, a few weeks before leaving on this trip, I had warned the senior personnel of the GE reentry program that there was a very real possibility that the USSR would have the first satellite, a conclusion based on U.S. delays, open accounts, and the information in the USSR magazine "RADIO," the location of the first announcement of USSR work and schedule.

Returning to the United States, Hal Bloom (orbit and trajectories [see his account in chapter 17]), Hal Crane (cameras) and I (system design) started in November 1957 to work on a concept we called "The Recon Satellite." In essence, this was built entirely on past programs, the Bumper/Recovery Sphere/NERV reentry and recovery techniques, and the V2/sphere camera systems. We did have the benefit of consultation with Capt Aslaxon, one of the pioneers of aerial photography.

In December, we started to make proposal presentations. Our records are not complete, but they show that these were made to Rand, BMD, WKDC, ARDC and IBM.

There was another contributing event in this series. Air Force Col Dave Simons had been pushing for expanded research preparation for man in space programs. He, Marvin Clarke (see his account in chapter 11), and I met one Saturday on such possibilities. We blocked out a set of experiments, essentially expanding the data recovery sphere technique. Clarke and Simons carried on the program informally for a time.

Deciding the Future of the Program

We team members were not privy to the debates going on regarding physical recovery versus TV techniques, nor were we aware of the steps, which combined the recovery and life experiment programs. My only contact with this activity was a trip to Boston with GE Reentry Systems General Manager Hilliard Paige (see chapter 4 for his account) to a meeting with Edwin Land of Polaroid and the committee he headed. I sat outside the meeting, but from initial and ending comments, I developed the idea that a decision to proceed with physical recovery had been made and that the purpose of the meeting was to confirm that the decision was sound.

This was the end of the contacts of the initial conceptual team. Completely new and expanded activity ensued, with very tight security. Beyond answering occasional questions, the original team went on to other work; Clarke continued on the life system work, now officially the Discoverer program. The program was real but served as a mask for the reconnaissance activity.

Editor's Note: After providing this account, Robert Haviland passed away in March 2010.

PART IV

RECOVERY OPERATIONAL CHALLENGES, 1960–1973

... [W]e've spent 35 or 40 billion dollars on the space program. And if nothing else had come out of it except the knowledge we've gained from space photography, it would have been worth 10 times what the space program has cost.

Lyndon B. Johnson, President of the United States
Remarks in Nashville, Tennessee
March 16, 1967

It just blew the whole missile gap away ....

Dino Brugioni, Senior CIA Officer
National Photographic Interpretation Center
"Eisenhower Briefing Challenge" Chapter 9,
INTELLIGENCE REVOLUTION 1960: Retrieving the Corona Imagery That Helped Win the Cold War, 2011

... Because tonight we know how many missiles the enemy has and, it turned out, our guesses were way off ... Because of satellites, I know how many missiles the enemy has and I can sleep comfortably at night.

Lyndon B. Johnson, President of the United States
Remarks in Nashville, Tennessee
March 16, 1967

Corona was another technological space marvel that [they]developed beyond expectations and made unprecedented contributions to national security.

Robert A. McDonald, Ph.D.
Beyond Expectations–Building an American National Reconnaissance Capability, p. xxix,
American Society for Photogrammetry and Remote Sensing, 2002

After the Corona team built and designed the satellite recovery vehicle, it had to go on to test and operate the Satellite Recovery Vehicle (SRV). Following the first successful mission and recovery in August 1960, the program went on to experience 104 successful missions between 1960 and 1972. Part IV includes two chapters with stories about SRV testing and recovery operations.

Chapter 20

REQUALIFICATION TESTING THE SRV AT LOCKHEED

This chapter includes four recollections by individuals who worked for General Electric (GE) on the Satellite Recovery Vehicle (SRV): (1) Charles Robinson, (2) Alfred Gross, (3) Henry Bried, and (4) Walter Overstreet. These accounts provide varied perspectives on the challenges of requalification testing the SRV at Lockheed.

Charles L. Robinson
Requalification Project Manager

Charles Robinson was appointed Requalification Project Manager following Discoverer's string of failures. By pushing the Satellite Recovery Vehicle (SRV) through every test possible and solving problems as they arose, Robinson saw the Discoverer through to success. In the following account, Robinson outlines his history with Intercontinental Ballistic Missiles (ICBMs) and reentry vehicles followed by his experience on Corona. In Robinson's recollection of his time on Corona, he chronicles the challenges faced and problems solved leading to the successful requalification of the vehicle.

Figure 99. Charles L. Robinson, right. Included in the photo are Lee Farnham, left, and Dan Fink, center. Photo courtesy of GE/U.S. Air Force.

I led the fifteen-man, General Electric (GE) team of engineers and technicians who requalified the SRV, after the flight of Discoverer 11. The team was to conduct these tests in Palo Alto, California, under the eyes of Lockheed.

The Mission

Qualifying a design means subjecting it to as many as eight rigid space environmental stresses to see if the design is adequate for the flight mission. Acceptance testing is similar to qualification testing but its purpose is to certify that the fabrication, as well as design for this particular vehicle, is ready to fly.

I was to requalify the GE SRV. My orders were:

Charles, do whatever you can to torture this spacecraft. See if it can survive. We must be successful.

Early Work on ICBMs and Reentry Vehicles

At GE, I first designed the structure of an ICBM. I was then asked to join a new systems engineering group to knit together all of the parts into a functioning spacecraft. In this group I found people with other areas of expertise from whom I could learn a lot—not just machines that flew in the sky but missiles that touched space and then had to make it safely back to the ground. It was on-the-job training. At the time my only experience was in structures and I worked with guys in aeronautics, thermodynamics, telecommunications and other specialties. We sort of rubbed off on one another.

The group was assigned a project, Thor-Able, to provide a reentry vehicle for an ICBM. The vehicle was the Air Force's opportunity to get into ablation technology, as opposed to the ongoing copper heat-sink business. This was in competition with the Army's intermediate range, Intermediate Range Ballistic Missile (IRBM) project, where Wernher von Braun (a former WWII German rocket scientist who worked for the National Aeronautics and Space Administration [NASA]) was championing ablation. I worked with his team on making a structure that could withstand the heat of reentry into the atmosphere without harming the payload inside. GE's success in designing the reentry vehicle made it a leader in the field and brought more government contracts.

An Introduction to Corona

One of the next contracts had less explosive potential but became the dominant force in winning the Cold War—Discoverer/Corona. In Corona, there was no need to recover the satellite itself, but the film inside was wound into a capsule that had to be brought to earth unharmed. Then the Central Intelligence Agency (CIA) had to develop the film and interpret it before the intelligence lost its value. The first successful reconnaissance mission brought back photos of more than a million and a half square miles of the Russian continent, more than all of the flights of Lockheed's U-2 aircraft combined.

I was asked to join the Discoverer/Corona project while waiting for assignment to a new team after the Thor-Able reentry vehicle was completed. GE's Bob Chamberlin, the manager of the systems engineering group, recruited me one morning for Discoverer. I was bored so I asked, "Would this afternoon be soon enough?" The next morning I was there! The group worked with Logan Cowles, the director of engineering, known as "straight arrow."

I took the role of Systems Engineer for Discoverer, GE's term for chief engineer within any one-project group. At the time, the reconnaissance program was experiencing a long string of failures. With the failure of ten consecutive missions (with maybe one or two failures attributed to GE), I was initially expecting to manage GE's system redesign for later flights. Chamberlin said for me not to pay attention to the current design.

Requalifying the System

Two weeks later, the job description changed. Discoverer 11 had just been added to the list of failures so I found myself on a flight to the West Coast to do an immediate and fast system "requalification" with Lockheed. The requalification required putting the system through all its paces, as in, "Do whatever you can do to torture this spacecraft and see if it will survive."

The assignment was intense, with the Air Force breathing down Lockheed's neck to get a satellite into orbit fast and Lockheed calling its contractors in for thorough evaluations and solutions. I had quickly come to know that my country's near-term intelligence future lay in my hands.

At the time, I knew very little about how the Corona satellite was put together, having only started on GE's SRV a few weeks earlier. I hadn't even looked at the prints on the thing, and I was the head of twelve engineers going to do the system requalifications.

Developing a Plan

I landed in California at night. The next morning, I was summoned into the Lockheed offices. They wanted to know my plan, and I said I didn't have one. They said, "When will you have one?" I said tomorrow morning. That launched several days of nearly nonstop work, with my engineering team and I working until 4 am three nights in a row.

I was asked to bring the plans, alone, to the meetings with Lockheed's project manager, Jim Plummer and his thirty associates. At these meetings the Lockheed team would comment that the plan was too complicated or not quite what they were looking for. I would retreat to the local GE office and assemble my team for second, third, and fourth attempts. At this point, no one had slept more than a few hours for several nights, and tempers were short.

By the fourth day of working on a plan I was getting pretty tired and dopey. Lockheed had a hatchet man who said, "How can you justify your plan when you take 32 days and ours only takes 15?" I responded, "Let me talk to the man who made these timelines." As it turned out, there were two men, each doing a timeline and they hadn't talked to each other. Better rationalized, the timelines were shortened to 16 days for one and 19 for the other.

Nonetheless, at the following meeting, the hatchet man berated me with a laundry list of our past sins. I responded simply, "My father can lick your father!" Suddenly all the Lockheed guys started laughing, one even falling out of his chair and beating the floor with his feet. "They had never seen this guy put down so well." Jim Plummer chose some features of my GE plan and some from the Lockheed version and we proceeded.

Satellite Reentry and Recovery

One part of the requalification focused on the satellite reentry, where, once sufficiently through the atmosphere, a parachute released behind the capsule to slow its descent. The design called for an airplane to snag the parachute while the capsule floated toward earth or, if that failed, for the capsule to land safely in the water for retrieval by ship.

Now the latest obstacle to the launch was Lockheed's new analysis showing the "snatch" loads on the capsule, when the chute was snagged by the trolling line behind the airplane, to be half, again, larger than previously thought. My background in structural analysis and my in-depth reviews of the analyses of other GE engineers led me to unilaterally authorize Lockheed to run the big centrifuge to the newly defined loads on the capsule. The test showed that capsule was not damaged by this higher load.

Behind the scenes, however, my unilateral decision without the approvals of upper management resulted in the Manager of Engineering, Logan Cowles, to come to the scene of the event. I met him at the airport and took him to the assembled Plummer-and-thirty man meeting. Logan started to make a warning speech, but was interrupted by congratulations to GE for making it possible to launch on schedule. Later Cowles told me, "I came here to fire you. I leave saying keep up the good work."

Failure and then Success

After a battery of tests was completed on the SRV, it turned out the launch failed one last time when Discoverer 12's booster blew up on the launch pad. At one point, Lockheed asked the GE team to make a few wiring changes to the telemetry to the spacecraft, which was being prepared for launch at Vandenberg Air Force Base (AFB) in Southern California. I sent a trusted team member, Al Gross (see his account later on in this chapter). Lockheed had previously not properly wired the telemetry system, which sends performance data from the satellite back to controllers and is the key in helping engineers understand why a launch succeeds or fails. Gross was the expert in the wiring and was working feverishly to get things done right. It's worth mentioning that while Gross was doing this in a preparation building, the satellite was sitting on its booster rockets on the launch pad, ready to go. He was using a soldering iron on live wiring with the GE's retro-rocket hot and ready to go. If he had been wrong, that retro would have lit up and taken him into the ocean with it. Gross succeeded in completing his task safely, but the launch in question, Discoverer 12, again failed because of a booster explosion.

Nevertheless, Discoverer 13 sailed smoothly into orbit, demonstrated successful reentry and was recovered from the ocean. It was then flown to California to Charles "Moose" Mathison's care.

Figure 100. Charles "Moose" Mathison, on the right in the cockpit, flying with Discoverer 13 to California from Hawaii. Photo courtesy of GE/U.S.Air Force.

Upon the news of Discoverer 13's successful flight, there was a joint GE/Lockheed celebration at a hotel near Palo Alto. I found myself soaking wet after being thrown into the pool in celebration. By my side were fellow teammates from GE and Lockheed, including Jim Plummer.

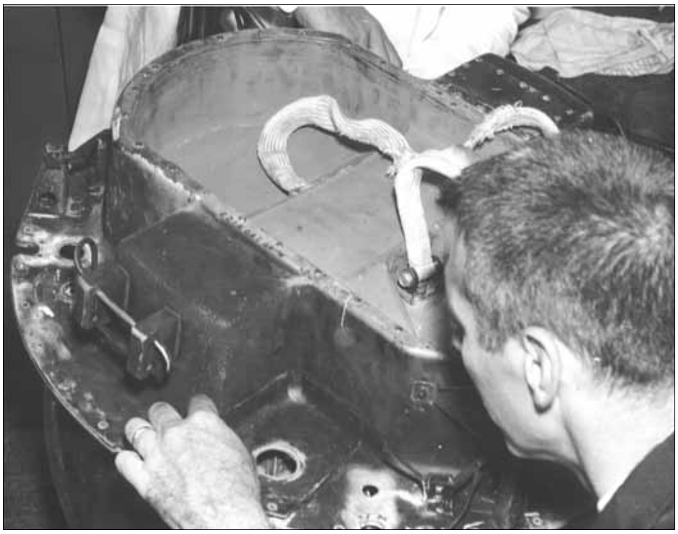


Figure 101. Charles Robinson inspecting the Discoverer 13 capsule.
Photo courtesy of GE/U.S.Air Force.

I was particularly grateful to the team to which I credit most of my success. Al Gross and the others of the gang of twelve were equally wet. Al Gross is one very smart guy. In fact I was surrounded by very smart people.

These guys had specialties and I could only listen to them and make a decision whether they knew what they were talking about. My philosophy was, "Just let a guy talk, and he'll let you know pretty soon what he knows."

Conclusion

During this requalification effort, I believe four possible problems were solved—the film cutter, replacing spin rockets with pressurized gas thrusters, restraining the in-flight disconnect to prevent "snagging" the capsule at separation, and the overall timing.

The requalification lasted five weeks at Lockheed's facilities in Sunnyvale, California, with GE and Lockheed engineers occasionally continuing to find themselves in competition with each other. As I grew to know the Corona system intimately, I gained confidence in meetings with Lockheed. I also developed a great respect for Jim Plummer who tried to recruit me away from GE. I declined because my wife did not want to move our family. I regretted not being able to take the job because Plummer was a good man. I liked a lot of GE people, too, but this guy really impressed me.

Reflecting on my career, I remember the thrill of solving a tough problem, whether ensuring a clear broadcast of channels on a Japanese television satellite or bringing film safely back to earth on Corona. Although I worked for only a short, intense period on the Corona project, it put me in contact with the kind of smart, knowledgeable engineers I relished working with throughout my career. There were so many challenging things where I didn't know the answer. I wasn't always successful but I always enjoyed the challenge.

Figure 102. Alfred M. Gross.
Photo courtesy of GE/U.S. Air Force.

Alfred Gross, Project Manager, Requalification Electrical Systems

With experience in telemetry and reentry vehicles, Alfred M. Gross was brought on board the Discoverer Project to bring a new perspective. Gross helped solve several problems plaguing the project, including a last-minute rewiring of the hot rocket. In this account, Gross outlines several of the major challenges facing the requalification of the Discoverer reentry vehicle.

I climbed up the launch stand for Discoverer 12, looked askance at the armed retro-rocket on the Satellite Recovery Vehicle (SRV), and coolly fixed an electrical short induced by a last minute telemetry installation. Happy to see that the retro didn't fire, I climbed down.

Later I will tell what happened sequentially. In the meantime, here is how I worked my way into that predicament.

Early Work on Reentry Vehicles

I initially worked on the telemetry system for the Intercontinental Ballistic Missile (ICBM) Mark II, a reentry vehicle designed to bring a warhead back into the atmosphere safely. At the time, the heat shield was little more than a cone of pure copper, known as the "coolie hat" by the engineers. Through estimations and testing, my team and I found that the telemetry was more complicated than necessary and helped redesign the system. I then moved on to create a transmitter for a radar system that was designed to go up 200 miles via rocket and then make an image of the ground. The system was designed to give the company an idea of what radar pictures from space might look like. At the time, I didn't understand how the radar might be transported over the Soviet Union to make the photos relevant.

Both projects involved hardware design, not developing commands for the telemetry systems. After spending some time on the radar system, I convinced my supervisors to let me transfer to the telemetry systems group, where I felt my skills would be better used. I was there four or five months, when all of a sudden they stuck a bunch of security papers in front of me. About a month later, they called me into my boss's office and said we want you to work on the Discoverer program. Discoverer was described by its cover story, an effort to safely send a monkey into orbit and bring it back home.

An Introduction to Corona

The progress of Discoverer thus far was described to me as pretty badly screwed up and I was told my role was to give a fresh perspective on the overall configuration of the system from my area of expertise in telemetry. I agreed but found myself stymied. I couldn't do very much because almost everything was being done in closed areas. Every time I asked a question, I was told, "I can't tell you about this."

After four frustrating months, I got called into a superior's office and, without introduction, was briefed on Corona and two other spy satellite projects, Lanyard and Argon. I really had no idea what was going on and I recall halfway through the briefing I stopped the captain and said, "Sir, what are you talking about?"

In response, I learned the United States had plans to build a satellite carrying a camera, with General Electric's (GE's) role being to build the recovery vehicle that would bring the film safely back to earth. I soon learned that I should only speak about the project to people whom I personally knew had the appropriate security clearances. I also discovered the "black" area of GE, an engineering room on the fifth floor that most employees had no idea existed. Exposed to the actual workings of the project, I finally felt I was able to contribute.

Challenges in the Discoverer Program

The flaws in the Discoverer vehicle primarily stemmed from the project being so secret. That's the whole problem with black programs. It's done so secretly that there's nobody from the outside to do a design review. They just did what they wanted to do. My assignment was to see whether the redesigned vehicle, the Mark IV, would be more reliable. In addition to stirring up the status quo at GE, I had to deal with a resentful Lockheed as the companies competed over how to handle various aspects of the project.

One problem was that the reentry vehicle was so heavy that it contained no telemetry system. So when a launch failed, engineers suffered from a lack of data to offer clues as to what had caused the problem. That left them nearly blind as they tried fixes and alterations.

I was young and carried a lot of responsibility for the redesigned vehicle. I turned to a friend, Jim Barney, who I had worked with in the telemetry systems group but who did not have a clearance for the Discoverer project. He was about 5 years older than I was, and I had the utmost respect for him. He was one of the best engineers I ever came into contact with. I would describe the problems I encountered—without giving away the purpose of the project—and Barney helped me work through the obstacles.

Barney suggested we use a lanyard disconnect connector to cut the wires that ran from the satellite vehicle to the reentry capsule as the two pieces broke away from each other. This replaced a complicated guillotine-like system that cut the wires while the parachute pulled the capsule out of the vehicle, eliminating the need for several small pyrotechnics.

In addition to the conflicts with Lockheed, I found some resistance within GE where my telemetry systems group competed with the vehicle engineering group, which was considered the main manager of the Discoverer vehicle. They looked at me as an intruder. It got to be sticky but I forced my way through.

I eventually found an ally within vehicle engineering, Bob Smevog, who joined the project at the same time I did with the assignment of working on a mechanical redesign. We both agreed the program was awful. We would talk about how we could do this and how we could do that. It was a very profitable redesign activity.

In 1960, Discoverer 11 failed when the reentry capsule failed to come back to earth. That was a really bad scene, and at first no one could understand what had gone wrong. As it turned out, GE had shipped the vehicle with no telemetry system and Lockheed, unbeknownst to the GE engineers, modified it on site by adding a four-channel telemetry system. Lockheed finally admitted that telemetry data was available and gave GE the data. With that data, the engineers and I were able to determine that one spin/de-spin rocket had fired while the other failed. That sent the reentry vehicle in the wrong direction.

The Question of How to Spin the Rockets

Soon after the Discoverer 11 failure, I met Charles Robinson, whom GE brought in to give the vehicle a thorough going-over and solve any remaining problems. Charlie Robinson came in and said, "My name is Charlie Robinson, and I'm in charge here." He left no bones that henceforth he was the boss of all the engineering activity on the project. After a briefing from Smevog and myself, Robinson brought me out on his trip to Lockheed's Northern California facilities to do a system requalification. Heated meetings ensued related to the timing of the ejection and the use of rockets vs. cold gas to spin the vehicle properly.

Demonstrating the company's access to immense resources, Lockheed set up a program to design an alternate system to the spin rockets. When Lockheed goes through a crash program, they sure know how to do it. They got a guy. They told him to pick who he wanted in the whole organization. A hot gas spin system failed to work, but a cold gas system seemed reliable. Still, GE representatives insisted on sticking with the rockets. It was a nasty fight. The cold gas system ended up on the satellite, which I admit was really the right thing to do because it was a more reliable system.

The Challenge of Timing

My next assignment to tackle related to timing. Specifically, the spin rockets were going off too soon. Again, Lockheed was resistant to the GE engineer's analysis that faulted the interface between the Agena rocket and the recovery vehicle. I was sent by Lockheed manager Jim Plummer to meet with Val Peline who was in charge of attitude control for the Agena at Lockheed. He told me to get out of there. I told Robinson, he told Plummer, Plummer told Peline, and Peline called me back in. About halfway through, Peline said, "Is this right?" Then he took me seriously. A change in the timers allowed more time for the vehicles to move apart before starting the spin/de-spin process.

The Final Fix

Finally, the requalified satellite system was ready for launch at Vandenberg Air Force Base (AFB) in Southern California. Word came in from GE engineers in Philadelphia that Lockheed needed to make a small modification to the wiring, involving nothing more than removing a few connectors and disconnecting two wires. I saw the order off to Vandenberg and prepared for a much-needed dose of rest and relaxation in San Francisco. But Robinson told me I had to go to Vandenberg along with an engineer from Lockheed to supervise the field technicians.

We hopped in the car at 1 pm or so the day before the launch. We got there and the guards escorted us in their vehicles right into the shack—where they were doing covert work. Where the technicians were waiting to complete the task, a row of sandbags stacked chest high created a barrier around the satellite vehicle. My Lockheed counterpart, Julian Kaplan, and I felt awkward, as if we were "smartass engineers" there to "put in this simple modification." Then we noticed a more major wiring flaw that apparently hadn't been caught in tests. The Lockheed manager on site, Chuck Gedecke, ordered Kaplan and me to fix the problem.

I said, "We don't know what's wrong with this!" He said, "Fix it." I said, "Chuck, it's a hot rocket here." He said, "Fix it." So they got everybody out. With two technicians, we engineers started poking and prodding to figure out where the problem was. We completed the rewiring using heat guns while sitting with a rocket ready for launch.

The launch went off the next morning but failed to make it to orbit. Not wanting to repeat the dangerous situation, we later checked the rockets at Sunnyvale before we shipped them.

Conclusion

In August 1960, Discoverer 13 brought back the first images taken from outer space and marked the first successful mission of the program. With others from Lockheed and GE, I celebrated at a hotel in Palo Alto, getting thrown into the swimming pool with Robinson and Jim Plummer from Lockheed. Robinson and I returned to the East Coast and completed the Corona vehicle redesign, the Mark IV.

I remember my time on Discoverer/Corona as being a highlight of my career for its significance in world history. A few months before the first successful flight of the satellite, the U-2 spy plane went down over the Soviet Union. That's when it really hit me how important what we were doing really was. I've always said that this is one of the few times I worked on a program where I felt what I was doing really made a difference.

Figure 103. Henry W. Bried, standing in front of the Stevens Institute of Technology, Johnsonburg, New Jersey. Photo courtesy of Hank Bried.

Henry W. Bried
Project Engineer,
SRV Systems Improvement

As a project engineer, Henry Bried helped fix some of the problems facing Corona and saw it through to success. In this chapter, he chronicles not only the challenges and eventual success of the project, but also the frustration caused by the strict security rules around the highly classified Corona project.

I am a determined man. I believe it was this quality that led Ed Miller (see chapter 5 for his account) to pick me for his reconfigured Corona team when the project was beset by failures in 1959. I was so focused on getting it done. My job was to improve communication, scheduling, and efficiency on the project. They knew if one person said no, I'd go up to the next level until we got it done.

In my opinion, many of the project's problems were rooted in the intricate nature of its high security. Because of the extremely high-level, need-to-know security, General Electric (GE) had not identified Corona as a priority program in its early years. This meant difficulty getting access to materials, machine shops, and other resources. When I joined the project, I worked doggedly with Miller to work within the fact that, while security is important, it also can be a major hindrance to getting things done. It's a double-edged sword.

Early Challenges and Fixes for Corona

I came onto the Corona project at a time when it was mired in a string of failures, with the prime contractor, Lockheed, questioning the abilities of GE engineers. With Ed Miller in the lead, I brought in a fresh perspective, sorted out the problems, and got fixes into place. One problem I noticed right away was that because of the extremely high level of security, Corona did not get treated as a priority program by the larger GE organization. To make it a priority could expose that the satellite's mission was more significant than simply flying mice and monkeys into space.

The urgency just wasn't conveyed. We had to get people focused on the program within every department. Ed had to get certain management people briefed and knowledgeable so they could get behind it.

Over time, the Discover/Corona team succeeded without risking secrecy and moved out of the true research mode, into development mode. GE management gave the project the resources it needed and was quicker to respond to requests. For instance, the reconfigured Corona team eventually included someone who managed purchasing, which eliminated the need for such requests to go through a general purchasing department. Another responsibility involved creating a program schedule that consisted of all the tasks that had to be completed with timelines.

Once delineated, I coordinated among the necessary parties to set up meetings, tests, and production schedules. I spent time with engineers and on the production floor itself, overseeing and smoothing the interaction of the many players.

I have nothing but respect for my supervisor. Ed Miller was a tremendous leader. Miller had people who would follow him to the ends of the earth. He had that kind of charisma and loyalty. Among Miller's key triumphs was bringing in the new team and opening the program up to better communication. If people are brought on board and they know what they're doing, it makes a difference. Secrecy is important, but you can't keep it so secret that nobody knows what's going on.

The Success of Corona

In 1960, the team prepped and launched Discoverer 12, a flight I sensed would be yet another failure. But I informed a Lockheed representative that most of the problems were resolved. Discoverer 12 represented a reconfigured satellite that included a great deal of testing equipment. It exploded on the launch pad due to a booster failure. The next reentry vehicle could be ready to go with almost no delay and went up on August 18, 1960, to great fanfare. This time, I knew it was going to work.

After the success of Discoverer 13, the program had almost a perfect record. Every one after that was successful. That was an amazing thing. It always amazed me that once you got it to go, everything turned out smooth.

Once you become successful, that attitude permeates an entire organization. I believe that after such a series of losses when there is a significant success there is a positive energy/attitude shift, which occurs. This happened on Corona and the result was that there were a significant number of subsequent flight successes that today has many people wondering "How?"

There were solid design changes that contributed greatly to the initial success on Discoverer 13 after that but without the major stress environment, good things happened.

Conclusion

Although the intense nature of the space race made the satellite work thrilling, the security requirements came at a high price.

Figure 104. Hank Bried, left, and Ken Swimm, the host for the 1995 GE Aerospace Discoverer, at the Recognition Celebration. Gold-plated Corona Recovery Capsule featured in the foreground. Photo courtesy of Hank Bried.

Security was paramount. This program probably cost me significantly—the hours, the travel. My family very frequently did not know where I was. The engineering feats may not have come with the rewards of money or fame but they offered the satisfaction of solving cutting-edge engineering problems. This effort also provided immense satisfaction in that we all knew the value of the data collected and that it contributed significantly to the security of our country.

The Corona project sticks out for its leading edge expansion of technological possibilities and its major contribution to keeping America safe during the Cold War period. Significant emotional events are things that people never forget—things that cause change in your life. This was a significant emotional event for me, and I think it was for a lot of people.

Figure 105. Hank Bried, left, with Ingard Clausen at the 1995 GE Aerospace Discoverer Recognition Celebration. Photo courtesy of Hank Bried.

Figure 106. Walter Overstreet.
Photo courtesy of GE/U.S. Air Force.

Walter Overstreet
Test Engineer and Leader,
GE SRV West Coast Support Operations

Walter Overstreet worked for General Electric (GE) for the bulk of his career, highlighted by his time on Corona. Working as a manager, Overstreet was intimately familiar with the relationship between GE and Lockheed. In the following account, Overstreet chronicles his experience with some of the challenges of working on the program along with the contracting relationship and its affect on the Corona project.

Preparation for Work on Corona

While working for GE in Philadelphia, I performed a variety of roles in areas like scheduling, training, and logistics before being transferred to Florida as the test engineer responsible for GE's portion of the Intermediate Range Ballistic Missile (IRBM) known as Thor. These tests launched high over the earth and provided time in space, twenty-five minutes for the Atlas and ten minutes for the Thor. This time became a laboratory in space for experiments that led to the idea and technology used for the reconnaissance satellites.

The testing at Cape Canaveral provided several firsts in engineering as the United States entered the space age. Radiation measurements were made, which showed the need for protection of the film. Shock measurements during reentry defined the design needs for reentry. Cape Canaveral had the first 3 axis stabilized vehicle in space using Infrared (IR) sensors to sense the earth-space interface, and a sun sensor for roll control. Gas jets controlled the vehicle attitude. A camera was installed in a recoverable data capsule to obtain photos of the earth and cloud cover. The data capsule was the first object recovered from space that allowed viewing of the film.

During 1958, the RVX-1 recoverable vehicle flight test program successfully solved the fundamental problems of supersonic reentry by proving feasibility of an ablation type heat shield. A secondary objective was the recovery of the reentry vehicle. By proving the feasibility of the ablation type heat shield and developing the reentry vehicle recovery techniques to a high degree of efficiency, the way was paved for use on the reconnaissance satellite.

An Introduction to Discoverer

In 1958, the Thor test wound down and I got a call from Charlie Bryant, then managing West Coast operations for GE. We had previously crossed paths and he requested I get myself out to California in a hurry.

My wife and I drove cross-country as the year turned to 1959, catching a big fireworks show in El Paso, Texas, at the end of the Sun Bowl college football game. When we arrived in the Bay Area, I learned about Discoverer.

Although I was not originally told the true mission of Corona, I eventually learned. Security was high and I remember using code names for experts in photography that were based on TV actors in shows like "Have Gun Will Travel."

Lockheed and GE Relations

Relations between Lockheed and GE were at times tense, leading to difficulties such as the GE engineers being denied access to Lockheed facilities, even though the Lockheed satellite vehicle had to work seamlessly with GE's reentry vehicle. GE hardware manufactured in Philadelphia was shipped across the country, but once in California, GE engineers on site could not check it or make alterations.

Bryant reacted simply by handing the small group of engineers the specs and telling them to memorize the vehicle from the paper drawings. The knowledge was a great asset for redesign for the diagnostic vehicle. The Air Force finally stepped in to gain access to Lockheed, but GE lacked its own equipment. At one point, I recall sitting in a meeting with GE manager Hilliard Paige to discuss the issue of testing. He said the West Coast team would need a certain large instrument system currently located in California. "They flew this van—it was a huge 18-wheeler type of truck – across the country," he said. "We moved it into the Lockheed plant."

Challenges as Manager

Shortly thereafter, I was named manager of field operations for the West Coast, supervising workers in California as well as at Holloman Air Force Base (AFB) in New Mexico where some tests were run. After getting out of that meeting with Paige, I realized I was being interviewed for the job. I guess I gave him all the right answers.

My challenges as manager continued. Despite access to Lockheed's facilities, GE chose to use a third-party plant for testing for additional security. Vehicles shipped from Philadelphia and, after completing tests in the Bay Area, were sent to Vandenberg AFB for the launch. Some significant tests were of the electronics system, which coordinated the separation and firing of the return rocket and the air jet system.

Despite the testing, Discoverer launches failed time after time. I remember the group from Philadelphia coming in for several weeks of intense rethinking of the program. Lockheed provided the group with a conference room but no desks; I used my Navy connections to obtain desks and chairs, and with my group's expertise from studying the system's specifications, the team was able to provide Lockheed and the visiting GE team with detailed answers that led to the building and testing of a diagnostic vehicle that could give more specific data on failures, if they occurred.

The Final Push and Success

When U-2 spy plane pilot Gary Powers was shot down over the Soviet Union in May 1960, the job went into overtime. We went from a regular work week to twenty-four hours, seven days a week. Our project became the prime project in the whole country. While I was not manned to handle the twenty-four -hour schedule, I look back at it as one of the most pleasing jobs I had.

Many problems were related to issues with the interface between the Lockheed and GE portions of the satellite, but there were many more minor problems with the structure that may have occurred because of concerns about the weight of the vehicle.

The original vehicle was built very, very light because the booster wouldn't lift it off the pad otherwise. So you ended up cutting a lot of corners. That was probably a major part of the cause of the failure of the vehicle. I also worked with Lockheed engineers to solve a timing problem related to the pieces disconnecting before reentry.

In August 1960, Discoverer 13 became the first successful satellite in the program and brought back the first object recovered from orbit. I was there when the capsule returned to California, having fallen in the ocean. It was late at night, and we took it apart to see what it looked like. Everything was in pretty good shape. Everything worked very well—a relief at the end of a long, trying test program.

I remember my time on Corona as special for the intensity as well as the quality of colleagues. We worked together so well, and we had fun. We looked forward to going to work each day. We worked hard, and we managed to get things done. The result was a successful flight, which made it even more enjoyable.

Figure 107. From left to right, William Crispin, GE Manager, an unidentified reporter from the *Orlando Sentinel*, and Walt Overstreet during a press meeting examining an Atlas 3C data capsule used to record data during reentry, which proved helpful in developing the Discoverer program and subsequent success with Discoverer 13.
Photo courtesy of GE/U.S. Air Force.

For more information about Mr. Robinson, Mr. Gross, Mr. Bried, and Mr. Overstreet, please refer to their autobiographical reflections in Appendix 2.

Chapter 21

"104 SUCCESSFUL MISSIONS" FOR THE SRV

This chapter includes eleven recollections by individuals who worked for General Electric (GE) and saw the Satellite Recovery Vehicle (SRV) through its "104 Successful Missions:" (1) Walter D. Smith, (2) Daniel Rossman, (3) Alfred Little II, (4) Myron Peterson, (5) Robert Gross, (6) William T. Weir, (7) Edmond J. Bryce, Sr., (8) Clifford E. Barr, (9) Richard Lasher, (10) Edwin Hearn, and (11) Bruce Waechter. Their varied accounts provide perspectives on the years of successful operations for this ground-breaking national reconnaissance program.

Figure 108. Walter D. Smith, left.
Photo courtesy of GE/U.S. Air Force.

Walter D. Smith
General Manager,
Space Reentry Systems Programs

Walter D. Smith joined the Corona program in 1968, after Corona was successfully flying missions. He served as General Manager of the Space Reentry Systems Programs and saw the program achieve success after success. In the following recollection, Smith shares his insights into the program from a management perspective, particularly highlighting the effects of being in a "black" program and keeping the workforce motivated.

I assumed the position of General Manger for General Electric's (GE's) Space Reentry Systems Programs in September 1968. I remember "this group of professionals" garnered an outstanding record of performance—and we could not talk about it! By providing the "reentry phase of these programs, we were able to successfully recover more objects from space than the rest of the free world combined!" One of those programs was Corona, whose record of over one hundred consecutive successful recoveries made a major contribution to this achievement.

An Introduction to Corona

After twenty-two years with Martin Marietta, I resigned in September 1968 and joined GE as General Manager of Space Reentry System Programs in Philadelphia.

When I took over, Corona was a pretty mature program. It was flying very successfully and had a well-knit team. To the best of my recollection, we never had a failure with Corona. I'm not sure the Air Force always caught every parachute, but from our standpoint, the program was 100 percent successful.

I compare the first time I saw film of a Corona satellite captured by aircraft over the Pacific to the first time I defused a German artillery round—exciting and ending safely.

Because Corona was running so smoothly by 1968, and in fact was nearing the end of its run, I had no briefing on the problems that beset the early launches. Not knowing what caused the problems, I think if they had had a little more quality assurance in the initial design phases, they might have done better.

The Effects of Being a "Black" Program

What I did see immediately was the difference between how the Gemini program ran and how the "black" Corona program was running. They were at two ends of an extreme.

The Gemini program was all over the newspapers, television, radio—everywhere. When we selected our team of people to work on it, we kind of made them a blue-ribbon team. We gave them all kinds of publicity. Everybody got interested in it. The astronauts came to the plant and talked to the people, got to know them, shook their hands, and made them substantial people in their neighborhoods. We then dropped the kind of subtle message that if anything happened to the astronauts, they'd get blamed for it. They had a lot of reasons to be motivated, and they were, and these people did a great job.

Now let me go to the other extreme—Corona. No publicity. No outside contact. People had no one they could talk to but themselves and their customer. They fully understood the importance of what they were doing. They absolutely understood that, but they could only talk about it amongst themselves. They got to be a very well-knit team, well motivated—just as well motivated as the people were at Gemini, but from an entirely different standpoint. Black programs have something in favor of them—you don't get any outside interference. You could run the program, just you and your program officer and the customer, and you could do what had to be done without justifying it to the last guy in Congress or somebody. I think that's one of the reasons it was so successful.

Motivation and "Truth Sites"

Motivating people to be conscientious in their jobs is not as simple as it sounds, and the lack of it is usually a contributing factor to things that go wrong.

As one form of motivation, the customer brought in "product," or photographs, taken by Corona. It was never photos of the target but instead footage of a "truth site."

When you put a camera up in space and you subject it to all the force of the launch and the environment in space and everything, you know it's going to work. You know it's going to work well. But you're really not sure it calibrated the same way you had it on the ground.

So you establish what you call a truth site—something on the ground in your own country—and on this truth site you know exactly the size, the north-south-east-west orientation, the shapes and everything. And you take a picture of them. And as you go around in your various orbits you keep on taking pictures of your truth site. Then when you get your product back, you have some place you can go to and you know exactly what it is you're looking at—so then you know exactly the calibration of the camera and the film.

The customer, on occasion, would bring in some of this truth site information and show it to us. Obviously they never showed us anything they took of the final product that the analysts were looking at, but they showed us this. It does something when you see the product that you're working on.

I specifically remember being shown a picture that was not a truth site but was instead the city of Los Angeles. The customer pointed out a flat rooftop where a young lady was sunbathing. While the film manufacturer might have been constantly working to improve the film grain even more, they could tell it was a female.

The quality of the footage was always remarkable. While American intelligence had other sources of information, overhead surveillance was a key to winning the Cold War.

Conclusion

During the few years I spent at the end of the Corona program, there were no modifications and I recall no pressure to improve the product. I believe the film manufacturer was under pressure to get a better granularity, but I know of nothing else.

I've had a very interesting, challenging career. Everything I was tangled up with was on the cutting edge of technology. As some people used to say, sometimes we didn't know the answers to the questions. Well, sometimes we didn't know the questions. We had to find out the questions before we could get the answers.

Figure 109. Daniel Rossman.
Photo courtesy of GE/U.S. Air Force.

Daniel Rossman
Manager, Product and
Resource Management

Daniel Rossman enjoyed a varied career, highlighted by his time working on General Electric (GE) reentry vehicles, Corona in particular. In the following account, Rossman shares his experience becoming involved with Corona.

An Introduction to Corona

Ingard Clausen gave me an early introduction to Discoverer/Corona by taking me on a trip to Lockheed. Until we were on our way, I didn't even know Lockheed was "on" the program or what Discoverer was. I thought I was along to discuss schedule planning, measurement, and analysis systems.

Rather than meeting with program planning people, I was suddenly in a management meeting. The atmosphere was vitriolic. Language was proper but body language and tone of voice were caustic. What I didn't realize at the time was that a struggle was under way regarding GE's role—prime contractor, sub-contractor, or none at all. And I had walked right into the middle of it.

I didn't ask Ingard any questions. He went off to other meetings I was not privy to.

After that I learned more about Discoverer/Corona as the program advanced to successful retrieval of photos from space. My time on Discoverer included writing progress reports for top management and I fully appreciated the jubilation over Discoverer 13. I even suggested numbering all other program first flight vehicles "13."

Working on GE Reentry Vehicles

I came to GE in July 1956 with a clearance that allowed me immediate access to the still young nose cone program. Since then, I worked on every GE reentry vehicle program from Thor and Atlas through the Minuteman III and Mark XIIA as well as being on Discoverer from its start.

My assignment as a Development Engineer was to put together a schedule system as I had done at Piasecki (see Rossman's biographical reflection for more information on his time at Piasecki). Again, it was a ground-floor opportunity in an unstructured environment to which I thrived.

The objective of a development program is not to produce hardware. It is to find the right drawing and specifications. The schedules come together by a lot of interviewing and a lot of thinking. What drawings do we need to build this? When are we going to release those drawings? It's a detailed, rigorous process.

The last thing in the world the people actually doing the design want to be asked is what are you trying to get done and when are you going to get it done.

The GE Discoverer/Corona Program

During the development of the Mark I and Mark II nose cones in 1957, I noticed that Ingard would disappear from time to time. But I knew better than to ask. Eventually Ingard took me aside and told me about a "technology transfer" from the reentry vehicle program to Discoverer (meaning the data capsule). Ingard's new position with Discoverer meant he would have to leave his management position and he had the option to choose his replacement.

As a result I became the Manager of Progress Analysis Operation and wound up also personally doing work for Ingard's new group without fully understanding what the work was for.

Through the subsequent years and after the Discoverer assignment, I continued to work with Ingard on an ad hoc basis on a number of management systems very instrumental in gaining the GE reentry vehicle organizations an excellent reputation in the management systems area. Some of those efforts include the incentive fee contract formula to be applied in the ballistic missile program (1959), the Program Appraisal and Review System providing top management briefings in a structured consistent format (1962), and most importantly the GE Cost of Work System, which was the first industry developed, coupled cost/schedule system validated by the Department of Defense (DoD).

Conclusion

Looking back on my Air Force and GE careers, it was an honor and privilege to serve. My Dad said, "Give more than you get." I tried!

Figure 110. Alfred Little II.
Photo courtesy of Nancy Little.

Alfred Little II
Project Engineer,
Corona Satellite Recovery Vehicle

Alfred Little II was involved with the Discoverer/Corona project from its very beginning and for the bulk of his career. His work on the program varies from engineer to project manager. In the account below, Little discusses some of his experiences in getting the developing program started and the challenges and failures of the program along with the impact of working on a "black" program.

I came aboard the Discoverer project in its infancy. I was a novice project engineer for the Mark II nose cones and eventually became project engineer on various aspects of the Corona program. I knew first-hand the pressure, panic, and struggles the team had to work through for months to keep the project alive and then succeed.

Getting the GE Missile and Space Vehicle Department off the Ground

I joined the General Electric (GE) Missile and Space Vehicle Department in September 1956 as an engineer in the structure laboratory under a true gentleman named Bill Campbell.

The entire effort was getting started in the former A&P grocery warehouse at 3198 Chestnut Street in Philadelphia. Recruiting, moving in, designing, and facilitating were all proceeding simultaneously.

The structures laboratory consisted of an allocated area on the building layout drawing. At this time, I was assigned to help define, cost, specify, and generally "push" for equipment for the structure lab. This was largely "by guess and by gosh" since the needs were so little understood. For example, one tentative equipment list contained structural fatigue machines but, not seeing a need for multiple fatigue machines beyond the usual material specimen machines, they converted the item to an "acoustic fatigue machine" anticipating high acoustic levels of atmospheric reentry.

This saved paperwork and time and, right or wrong, preserved the outstanding funding request. However, I soon perceived that the structure lab played a much smaller role than for aircraft. There was a limited future for me.

The Next Opportunity: Project Engineer

I looked around for another opening and was reassigned as a project engineer in early 1957. I had little understanding of the project engineer role or of how the various activities (design, test, qualification, production, etc.) phased and meshed.

Luckily some individuals who understood this area, most notably my boss during part of this time, Stan Sadin, spent time to introduce me to the project engineer concept and to chalk talk phasing and schedules. This all fell quickly into place in my mind. I was a "natural" for the work.

I cut my teeth on a number of assignments including initial operation capability of the Mark II (copper heat shield version) Atlas/Thor ballistic missile nose cones. That title was later upgraded to reentry vehicle. These were to carry nuclear devices through the heat of reentry and to arm and fuse them. This was a panic, Cold War program to get something on the launch pads even before adequate development was completed.

Other assignments included a proposal for Minuteman, a new nose cone design, and the Discoverer Satellite Aeromedical Recovery Vehicle (SARV) in June 1958 through January 1959.

During 1957 to 1958 my manager was Frank Rand, a very creative and independent soul who got tangled in internal politics and left for Lockheed at the beginning of 1959. Initially Discoverer's SARV was to be an off-the-shelf nose cone, the Mark II developmental, plastic data capsule "basketball." When my Discoverer assignment started (without "black" clearance) the "basketball" had pretty much been abandoned and a 20-in diameter tapered aerodynamic design was about to be abandoned for a 33-in diameter version.

It was all in the face of Lockheed's refusal to recognize a GE role despite Air Force Ballistic Missile Division support. When a GE role was established, it was as a directed subcontractor to Lockheed. This was an awkward arrangement since Lockheed did not want us and much of our relationship was directly with the government.

From Discoverer to Corona

I started to work with the core group of engineers working on Discoverer SARV including Marv Clarke, Flo Brent, and Bob Lowe. It was soon evident to me that the Discoverer SARV crew was extremely small for the magnitude of the work. This dearth of manpower resulted not only in excessive workload and work hours, but also in individuals making technical decisions/choices beyond their strengths and with no one to help, review or critique. I was puzzled and frustrated by not being allowed in some engineering rooms with the explanation that the work in there was "proprietary."

However, I was soon briefed on Corona. Until that time I had only the faintest perception that there might be things so classified that they were not in the normal Secret/Top Secret classifications. The Central Intelligence Agency (CIA) designation "black" was used and even the term "black" was black!

I soon learned the ropes. Knowledge of who was cleared came only by personal introduction and handshake. There was a blanket denial to all outsiders that the program even existed.

I also learned that Corona was a joint Air Force/CIA program led by Richard Bissell, CIA head of covert operations.

In January 1959, I was named Discoverer engineering Project Engineer and, later, Systems Engineer, reporting sometimes to Jack Katzen but mostly to Program Manager Ingard Clausen. On one occasion, before I was briefed on Corona, Katzen told me I would not be recommended for a raise because Katzen was not allowed to know what I was doing.

Early Challenges and Failures

By the time our routine work week ended, we were often so "wired" that we couldn't slow down. Periodically we would go to Cavanaugh's Railroad Bar on 31st and Market for a drink (or many more).

On Monday morning we would arrive at work already exhausted and unable to "get up to speed" for many hours.

Despite frantic efforts, the failures piled up and we came to fear the program was beyond our technological reach and would be canceled. On one occasion I was directed to represent GE at a massive failure review meeting at Lockheed. Included were high-level Lockheed, Air Force and CIA managers. The CIA group was led by "Mr. B." That was Richard Bissell but they could not use his name.

The Mark I recovery vehicle had been very cold and had clearly failed. Lockheed management presented their version of what would be done and when. I believed both those decisions were wrong and were trying to make GE look bad.

So literally shaking all over, I stood up to present GE's analysis and flatly disagreed with and contradicted their proposed plan. To make matters worse I had received that morning a letter stating GE management had no confidence in my ability to stand up to Lockheed. It bore the name of the vice president/general manager but I found out later it was sent unilaterally by a young engineer who worked for me.

We were in such technical trouble that the West Coast support at the Lockheed black facility, where the recovery system was integrated with the Agena spacecraft, could not cope. A tech or two, plus visits by key GE engineers that were flown in, could not keep up with the troubles. "Fixes" in Philadelphia were often based on inadequate information and were too late because Lockheed sometimes implemented their own version of what they hoped would be fixes.

The Discoverer Field Engineering Group

In a last ditch effort, Clausen established a "Discoverer Field Engineering" group of about half a dozen people stationed on the West Coast with the authority to make and implement design changes on the spot. I was manager of this group.

Included in the crew was Leon Okurowski, an "old time" mechanical tech with a large dose of technical smarts and common sense. The success of the knife mechanism that severed the tough Mylar film leading from the camera in the Agena spacecraft and sealed the slot through which the film traveled in the rear of the recovery capsule was his doing. Also on board was Bernie Mirowsky, an electrical engineer (see chapter 18 for his account). Mirowsky was a brilliant and intense engineer they named the "blue flash" both because of his frenetic pace and because he would, in haste, periodically connect wires incorrectly and cause a blue flash.

We rented some office space in Mountain View and leased a few cars to travel to the Lockheed plant at Sunnyvale to the "Skunk Works." We traveled to both the Lockheed plant and, for integration and test of the spacecraft, to the not-too-far-away black facility, Skunk Works. That facility bore the sign "Hiller Helicopters," the receptionist was a security agent, and we had to park our cars in back out of sight of the road.

The lead Lockheed person at the Skunk Works most of this period was Mike Favia. The GE evaluation of Mike was that he was sincere and hard working. He was also tough on GE and sometimes, out of frustration, made unilateral changes affecting GE. Others with whom we dealt included John Hart, Jim Ousley, and Lockheed Program Manager Jim Plummer.

The Impact of Working on a "Black" Program

During the summer of 1959, GE paid for my family to join me for about two months. We rented a house in Los Altos Hills and my family enjoyed the experience despite my extended hours and not being able to be truthful about my work.

Figure 111. The SRV and parachute assembly. Al Little, third from left. Photo courtesy of GE/U.S. Air Force.

My work schedule throughout my West Coast assignment was variable. The general pattern was Monday and Tuesday in Sunnyvale, Wednesday in Sunnyvale or Vandenberg Air Force Base (AFB), then Thursday back to Sunnyvale until Friday. Friday nights I flew to Philadelphia and spent Saturday at GE on Chestnut Street. Sunday morning I had off and Sunday afternoon flew back to California. This routine lasted my entire field engineering assignment with a few weekend breaks with my family.

In autumn, after my family returned to Philadelphia for school, I continued this routine for about three or four months. This ended when there was a management change at GE and the little group came under Edward "Big Ed" A. Miller (see his account in chapter 5) who visited and reviewed our activities. (There was also an Edward S. Miller, "Animal Ed," a Discoverer bioengineer.)

Ed's reaction was that we were worn out and "looked like the Bataan Death March survivors." He thought we had done about as much as we could, both good and bad, in addition to the problems of East and West Coast travel and communication. In those days communication was by phone or teletype so drawings had to be physically carried. This change-over included establishing a field engineering group performing more "normal" field engineering functions without the extraordinary power to make unilateral design changes.

During this time an anonymous letter was received by the Air Force stating that the unremitting series of failures and delays was due to a "sinister force" at work. This prompted the Air Force to convene a formal black board of inquiry presided over by a general and with sworn testimony, court stenographer, etc. The board lasted a number of days and included testimony from me. The board's conclusion was that there was no sinister force at work but that the technological challenges made success uncertain.

My work, together with the black nature of the work, had a profound effect on my personal family life. My children prepared and put in the family room window a sign saying "Daddy Come Home," which I kept the rest of my life. Neighbors believed me to be some sort of "low-life" both because of my neglect of my family and because the FBI periodically asked around the neighborhood about me to make sure I was still a "good guy."

I was also concerned because my wife Marian came from a strongly pacifist Quaker family. Due to his religious principles her brother had gone to prison during World War II for refusing even to register for the draft. My fear was that the security authorities might act on suspicion that I might be "infected" with Quakerism. One co-worker in Philadelphia had been removed from the program and debriefed because he came from a small town where his brother was the town drunk.

In fact I never told Marian what I was doing and she never pried. But I suspected she was able to deduce quite a bit. Marian died in 1993 without my ever being allowed to tell her of my work.

Mark IV and Success

When I returned from California about November 1959, I was assigned as project manager for an improved Corona/Discoverer SRV, known as Mark IV. "Improved" meant replacing much of the patched-up, panic design with rational, thought-out features for which there had not been time or resources to do initially. The Mark IV had a number of improvements that were in many ways a "wish list." As the design proceeded and as costs grew, we were forced to downgrade many of the improvements. At one point a Lockheed contracts lawyer named Jaffee stated that the way things were going we were going to end up with zero improvements for infinite cost. In response, as a joke, we prepared and presented a large presentation graph showing this calling it "Jaffee's Law."

In 1960, I was on a trip to California related to the Mark IV when the initial success was achieved, the recovery of Discoverer 13 with its U.S. flag payload. That night we all gravitated to Rickey's Hyatt House motel in Palo Alto. The group there included Lockheed, GE, and possibly the Air Force. The black program compatriots Itek and Eastman-Kodak could not attend for security reasons.

When the group was pretty well "lubricated," the Lockheed people started pushing each other into the swimming pool. All were wearing suits and ties. Then someone said, "How about GE?" Everyone, including me, ended up in the pool while cameras clicked.

Conclusion

When I completed my Corona assignments and was debriefed, I felt a terrible let down, as if I had been fired. My space work, subsequent to my contributions to Corona, covered more than thirty years during which I conformed to Corona black security requirements until the program was declassified in 1995.

In 1995, with the declassification of the program and encouraged by the National Reconnaissance Office (NRO), I gave a series of talks on Corona. These talks included MIT alumni, the Nassan Club at Princeton, the English-Speaking Union, and my church.

While I deeply regret never being able to tell my late wife what I had been doing all those years, there was satisfaction in sharing it with my children Patricia, Al Jr., Nancy, and Caroline.

For more information about Mr. Smith, Mr. Rossman, and Mr. Little, please refer to their autobiographical reflections in Appendix 2.

Figure 112. Myron "Mike" Peterson.
Photo courtesy of Mike Peterson.

Myron Peterson, Project Engineer in the Program Office

Myron "Mike" Peterson spent his entire career at General Electric (GE). Brought in to the Discoverer project by Edward A. Miller, Peterson spent time working on reconnaissance payload recovery as a project engineer. In the following recollection, Peterson shares his experience becoming involved with Discoverer and chronicles his time on the reentry vehicle recovery operation through the program's cancellation.

I spent my entire career at GE. Work primarily devoted to developing new jet engines was interrupted for ten years when a friendship with Edward A. Miller (see his account in chapter 5) threw me into the strange new world of reconnaissance payload recovery.

Ed Miller and Getting Involved with Discoverer

In 1960 Miller had spoken to me at the Society of Mechanical Engineers meeting about Discoverer and monkeys and mice. Everybody was, of course, really fascinated by it, but that's not the way it really was.

I got to know Miller very well and highly respected him. I talked with him at that time and he had an opening that was equivalent to what I had in the engine business. As a result I transferred to Philadelphia at the beginning of 1961. I was in Miller's program office as manager of operational systems. After years of developing engines, it was a different kind of work.

Philadelphia was looking for people—looking for engineers particularly. They had a lot more work than they had engineers so there was opportunity. I knew it would be a stretch but I had experience certainly with operations. Ed was willing to take a chance and I was anxious to get the opportunity.

I recall Edward A. Miller as an outstanding technical man, an engineer with exceptional legal knowledge, and an effective manager.

He was quite astute at pulling people together and getting a team to put out effective work. He was highly respected. People were willing to work hard for him. He was well respected for his technical knowledge, judgment, and managerial ability. He was very, very good with people—a good leader.

The Reentry Vehicle Recovery Operation

Most of my time was spent in the reentry vehicle recovery operation. That involved several trips to Oahu with the operational systems engineering and facilities people in 1961 to 1962. They planned the timing and operation and worked with the Air Force to get their team in place. The vehicle was to be separated, de-orbited, and land in the vicinity of Johnson Island. Facilities Manager Charlie Hood and I spent time planning the control room and the control panel layout for that operation.

In all of these assignments, where I was working with Bob Chamberlin (see his account in chapter 15) and some with George Christopher (see his accounts in chapters 13 and 16) and others in the planning like Charlie Hood, there was knowledge of recovery already, recovery techniques, and equipment, and that all fit into the 201 program that I was working directly with. I don't know what if any of that went into Discoverer.

In late 1961 Bob Chamberlin had a heart attack as they were starting the recovery operations. Others were off on other assignments so I took the task of leading the preparation of that program plan and had several people from Chamberlin's organization.

The End of the Operation

We had our first flight. The recovery was not successful. The problem was in the vehicle system somewhere. We had two more following that, but during that time, I led a team to do a follow-on contract for additional reentry vehicles. We negotiated a contract but as a result of the vehicle not being successfully recovered, the Air Force cancelled it.

That became a pattern in programs in the 1960's. Programs I worked on were cancelled for various reasons. I was assigned to Bell Systems as they sought to get into space systems. But at that time my first wife died and I was not able to continue my work effectively.

Figure 113. Robert Gross, center. Included in the photo are Roger Honebrink, left, and Howard Jones, right.
Photo courtesy of GE/U.S. Air Force.

Robert Gross
Program Office Engineer

As a Program Office Engineer on Corona, Robert Gross was intimately familiar with the security of the Corona project. In the account below, Gross shares some of his experiences regarding the secrecy of Corona.

I joined General Electric in 1951, right out of college, having attained a bachelor's degree from Rutgers University. I was a program control specialist dealing with costs, schedules, budgets, and administration. Later, I worked on Corona. How things have changed! Back then we couldn't even say the word. Couldn't even say it unless you were behind closed doors and you knew who you were talking to.

The Secrecy of Corona

I came into the program in the late 1960's. I had a good idea what the Corona engineers were up to and had seen some of the products. The secret was so closely kept I still have trouble talking about it and am surprised when I see articles about it now.

We referred to most programs by acronyms. I wrote a forty-page paper of just the acronyms they dealt with—and they all had caveats. You could talk to one person about one thing and couldn't talk to him about something else. Corona was completely compartmentalized. There were subsets below the main Corona program that I was not cleared for. Often we didn't know who the customer was.

Because of caveats attached to so many programs, you couldn't talk to a person unless you were formally introduced. You knew he was "Jack" but you didn't know what he was.

Figure 114. Dr. William Thomas Weir.
Photo courtesy of Thomas Weir.

Dr. William Thomas Weir
Manager, Reliability Program

As a manager in the Reliability Program, Dr. William Thomas Weir saw the Corona program through its "104 successful missions." In the account below, Weir recounts his experience with the Corona program and the power of a change in attitude.

As a long-time General Electric (GE) employee, I saw the Corona project through to nearly the end in the Reliability Engineering Laboratory. I saw the "one hundred-in-a-row" success of the program resulting from a change in attitude. Success breeds success.

Corona's Reliability Program

I was just the manager of the Reliability Program and I guess the Corona project needed some reliability engineering. I saw improvement over the years as the program progressed. By the late 1960's Corona was working very well. There were no failures and that is how the Reliability Program defines success.I guess it was just a change in attitude. People seem to take a greater interest in a successful program.

My department had about thirty people. I knew of only three that were cleared for Corona. I didn't even know who I was working for or who all the clearance was with. There was a lot of screening to get in. While I consider Corona important it was only one of many programs and projects that came under the eye of Reliability Engineering.

Figure 115. Ed Bryce, Logistics Supervisor, and Matt Dellarco, Logistics Manager, GE, 1965. Photo courtesy of GE/U.S. Air Force.

Edmond J. Bryce Sr. Logistics Supervisor for Military Space Programs

Edmond (Ed) J. Bryce Sr. joined General Electric (GE) in 1957 and enjoyed a thirty-six year career there. As Logistics Supervisor, he experienced first-hand the impact of being on a "black" program and the importance of security. In addition to his recollection of working on the Corona program and the challenges of its security, Bryce shares several memorable incidents in the account below.

"The Program"

After working for GE for some time and taking several GE courses, I was invited into the Corona Program.

To some, it was an honor to have worked on "The Program," as one wasn't just working on it as part of their job. The majority of the people were recommended by their peers and reviewed by management. Before they could become part of the team, they were screened not only for their skills and work ethics but also for their character. Security checked them out to make sure they were okay—what you might call a "straight arrow." Then once you were cleared and working on "The Program," they taught you how to lie or be deceptive concerning your activities.

Working on the Corona program was very different from all the other contracts as you felt that you were a part of a team moving forward—a pioneer on a new frontier. If there were problems, setbacks, or even failures, there wasn't the usual wasted time pointing fingers as to who was at fault. "There is a problem. What is it and who do we need to resolve it? So let's get started!" was the attitude of all on the team. Everyone worked very long hours, many on call twenty-four hours a day, seven days a week, with very few complaints about the grueling hours. Morale always seemed to be very high among those on "The Program."

Early in "The Program," after activity increased, there became a need for second shift personnel and I became part of that team as a Systems Test Technician/Electrical Inspector. We worked twelve-hour shifts, seven nights a week, for long stretches of time without the family or other co-workers knowing what we were doing. We worked on many vehicles, but the highlight for Robert Johnson, Thomas Doaks, and me occurred after the flight of Discover 13 when I learned that all of the systems acceptance test data had only our signatures.

The Logistics of a "Black" Program

In 1965 I joined the logistics component and became the Logistics Supervisor for Military Space Programs including Discoverer/Corona. Logistics were involved in most all of the facets of "The Program." They liked to call it from "womb to tomb." I participated in the Design Change Board (DCB) as the Quality Control and Test Board representative including field test sites. I reviewed changes and provided inputs that might affect those operations as well as any effect requiring retrofit of vehicles and/or test support equipment. My participation was required at the Vehicle Acceptance Buy Off meeting, preparing the buy off documentation (form DD250) and the "Vehicle Comparison Document" (established by myself), which became a part of the Vehicle Logbook. Logistics personnel provided supervision of the packaging and shipment of the vehicle along with the items shipped separately.

Figure 116. Part of the Milspace Team. Ed Bryce is fifth from the left, top row. Top row, Connie Olenik, Ed Hearn, Jim Fitzgerald, Gus Fisher, Ed Bryce, Joe La Blanc, and John McKenna. Front row, Tony Thomas, Barbara Tobias, Roger Gibboni, and Sam Corcoran. Photo courtesy of GE/U.S. Air Force.

Logistics developed a "first in, first out" (FIFO) spares program, which minimized loss due to shelf life limitation and obsolescence. The FIFO system resulted in a large cost savings to the program and could, in large part, be managed in the overt world.

I was responsible for going to Lockheed Missile and Space Division (LMSD) to integrate the program requirements and to sell it to the customer. I enjoyed working with the LMSD personnel as they were knowledgeable and had a great teamwork attitude.

Shipping activities included establishing phony shipping names and addresses and setting up ground handling services at Philadelphia International Airport to transfer our hardware to military aircraft. We were not allowed to be associated with GE and we paid for the services with cash to avoid leaving a paper trail. Those of us in logistics even had dummy ID cards. We provided security escorts and courier service as was often necessary. Shipping labels (with phony names and addresses or shipping codes) had to be removed prior to bringing the items into the facility. The majority of the shipping activities were accomplished under the cover of darkness.

Retrofit activity included reviewing the engineering change documentation and writing the retrofit instruction that detailed the changes to be made—the material/tools required and the tests required to prove out the incorporated changes. It also necessitated accumulating and shipping all items to complete the retrofit, assembling the team, making the flight and hotel reservations for individuals (same security requirements) and serving as the team leader for off site retrofit incorporation.

My wife never knew what I was doing and frequently even where I was. Often my job required me to leave in the middle of the night, travel, and make shipments under phony identification and be away for extended periods. If my wife needed to contact me under emergency conditions, she would have to call a person at GE who would, in turn, contact me. I then would call home.

Try doing this in today's world environment without winding up in jail or going to divorce court. (I am still considered a "straight arrow" and still married to the same wonderful woman after more than fifty years!)

The "Forebody" Challenge

Early in the Corona program there was a need for new test equipment, handling fixtures, etc. One such item was a turn over fixture for the "forebody" (with or without the recovery capsule installed) so that one could have access to work on or inspect all surfaces with ease.

When the design was complete and the fixture was built, it was time for the "first piece try-out." The try-out was begun near the end of the first shift so it was to be completed by the second shift personnel. Somewhere around 9:30 pm, with the "prime forebody" installed, the fixture was rotated and placed in a nose down configuration. Everything went well for about the first five minutes. Then, without warning, the forebody dropped from the fixture approximately eight to twelve in striking the tiled concrete floor. Needless to say the floor didn't budge. However the forebody cracked beyond repair.

It was now time to rally the troops—circle the wagons. By about midnight the closed assembly area contained more people than one may have thought were cleared on the Corona program. Everyone was trying to determine why this had occurred. The fixture design engineer arrived later than most as he lived further away.

As he reviewed the procedure that was used, he asked if a particular bracket had been installed properly. The response was, "What bracket?" It came to pass that said bracket had not been provided between shifts. When it was eventually installed, the try-out was completed and the turn-over fixture was used successfully throughout the program. There were some trying moments, but the team responded as usual and results have been gratifying—even though we lost that first forebody.

Security Restraints and a Hijacking

Corona security restraints placed some additional stress upon those working within the program and the following incidents highlight that point.

One of the security restraints mandated that logistics personnel not be affiliated with GE while shipping Corona classified hardware. As a result, we established fake identities with bogus addresses and paid cash for ground handling services to load our hardware onto military aircraft at Cargo City—Philadelphia International Airport (as well as other airport facilities). Our shipping activity was nearly always under the cover of darkness, usually midnight or later.

On one such occasion in the middle of the night, Sam Corcoran of Logistics had acquired the service of ground support people at Cargo City, awaiting the arrival of the aircraft to pick-up our hardware, when not more than fifty yards away an attempted hijacking of a commercial cargo flight had just begun. Airport security and police were everywhere in the immediate vicinity. Now here were logistics personnel with fake identification, bogus addresses and packages in containers that they couldn't allow access to by anyone. They were standing in an area adjacent to the tarmac where usually only airport personnel belonged.

A telephone call was made to the Corona security person on call reporting the incident with a reply, "If anything unusual happens give me another call." Can you imagine what they would have gone through had the police decided to question them about what they were doing there at that time of night?

The hijacking was quelled and fortunately there was no encounter with law enforcement. The shipment was completed on schedule (with a lot of excitement and some stress). We couldn't even mention the incident to our families or co-workers other than Corona briefed individuals.

Figure 117. Clifford Barr, right. Photo courtesy of GE/Air Force.

Clifford E. Barr
Designer, Structure/Mechanical
and Manufacturing Liaison

Clifford Barr worked for General Electric (GE) for twenty-six years of his career, highlighted by time spent on the Corona project. In the following account he shares a brief recollection of his work on the project.

Work on Corona

I began work on Corona in 1958. Most of my work was done in the back room. We had our own numbering system and no one knew what we were doing. It was a very closed area. My job title was Designer, Structure and Mechanical. I worked on the structures for the forebody heat shield, the thrust cone recovery devices, payload structure and manufacturing liaison.

My main responsibilities were for documentation drawings of forebody heat shield involvement in recovery payload structure and the mounting/separation device. I was also involved with the thrust cone structure recovery parachute/flotation equipment. I maintained flow and control of manufacturing data and configuration records.

There were not that many mechanical designers—only about seven working in my area. They delivered the product to Lockheed Martin.

I enjoyed my years working for GE.

For more information about Mr. Peterson, Mr. Weir, Mr. Bryce, and Mr. Barr, please refer to their autobiographical reflections in Appendix 2.

Richard Lasher,
Lead Engineer on
Continuing Improvements

Richard Lasher spent twelve years working on Corona as a Lead Engineer. In that position, he experienced first-hand how Corona was ahead of its time in technological advancements. Lasher retired from General Electric (GE) in 1993 and shares some of the challenges, such as developing a durable shield material for reentry and improving the locator beacon, as well as successes in the account below.

In August 1960 I took a job in the GE Space and Missile Division starting just before GE's Corona reentry vehicle made the first successful recovery from space. That happy coincidence of timing led to a dozen fruitful years for me on the Corona project, which I joined in 1961.

As a project engineer, and later a manager, I would see the satellite from its infancy to more elaborate models that carried more film, stayed in space longer, and used new technologies to improve the chances for bringing quality reconnaissance of the Soviet Union and other world trouble spots safely back to earth.

Moving Corona Forward

Moving east from St. Louis to work for GE in 1960, initially I was assigned to the Mark VI Intercontinental Ballistic Missile (ICBM). I was aware of the Discoverer cover program but not the details of the Corona satellite. After several months I was recruited to Corona, which had just made the transition from a string of failed flights to what would be an unprecedented run of successes. The atmosphere among those working on Corona was ecstatic. There was a bit of jubilance. In those days

Figure 118. External picture of the SRV. The spherical cone dominating the bottom half is the reentry shell.
Photo courtesy of GE/U.S. Air Force.

most people were jubilant about the success, even if they did not know Corona's true purpose.

With the basic reentry vehicle proven in orbit and reentry, my fellow engineers and I went to work meeting new requirements for the continued program. These included finding ways to extend the life of the vehicle in orbit, ensuring materials used would hold up for longer periods outside the atmosphere, and coping with larger payloads as the amount of film increased. I also took advantage of advances in materials science to develop a more durable heat shield.

The Challenge of Developing a Durable Material

A major challenge for Corona, as the project progressed and time in orbit increased, was to find material that would not degrade in orbit and subsequently fail during the extreme temperature change of reentry. The original phenolic nylon heat shield was the best that could be created with existing material in the 1950's. The original heat shield worked for trips lasting no more than few days and didn't hold up real well for the long term. So I oversaw work to replace it with a foam silicone rubber system. The foam silicone rubber could be manufactured in a more uniform manner and was more stable even after several days in space.

We had to consider the long-term effects of temperature cycling. We had to consider what the effects (of space) would be, whether or not it would change the properties of materials so they wouldn't function properly when they came back into the atmosphere. New concepts were tested in simulated conditions on the ground, but engineers had almost no information about how the devices actually functioned in space.

Because the physical space on Corona was filled by its vital cargo and the recovery bucket contained almost nothing but film and a parachute, we had to work with virtually no guidance from telemetry. We had very limited information. Obviously, we had some evidence from previous materials in flight, (but) for all the successes, we probably knew less about those vehicles than other programs that flew less.

Improving the Locator Beacon

One innovation I did put into place involved getting the locator beacon, which helped pilots recover the reentry vehicle, to work earlier in each mission. Engineers found a way to modulate the beacon to give the most basic information about flight events. The beacon worked like an FM radio so information on one wave could be altered to signal an occurrence. For example the beacon was set to alter its frequency to signal when the thrust cone separated from the main satellite vehicle.

This method could also signal when the parachutes were deployed and a few other actions that occurred in the course of reentry. No more detailed or sophisticated data was available. Beyond that level of information, that was it. Despite the lack of telemetry data, however, engineers found creative ways to work backward from any problem that might occur in order to find a solution. Along with ground testing and limited flight-testing, the data proved sufficient, if not fully satisfying. We obviously continued to fly the systems, highly successfully, for a long time out.

Maintaining Reentry Capabilities

I also oversaw work on ensuring that changing the properties of the payload did not affect reentry. There was a lot of work spent looking at how to maintain the ability to recover successfully. Every aspect of the reentry vehicle was being developed beyond the standards and technology possible in the late 1950's. Changes to parachutes required detailed meetings with the parachute vendor. Alterations to the pyrotechnic devices that separated the reentry vehicle and launched the parachutes required yet more meetings. I spent much of my time in the typically managerial role of ensuring specifications had been met and projects were up to standards.

The Corona Team

Although I did not have staff reporting directly to me, as lead engineer for Corona I worked closely with three or four dozen people. I found the group dedicated and creative and appreciated that there was relatively little turnover—a factor that I attribute to the program's success but also to the strenuous process of obtaining the necessary security clearances.

The people I knew felt the program was making a major contribution. No one had access to the results of the missions—the photography of Soviet missile bases and other sites—but the contribution of Corona was nevertheless obvious. The string of successes from 1960 through the project's conclusion in 1972 also helped. It was a small cadre of dedicated people that did most of the work on it that ensured you had a high quality product. I saw that more and more.

Conclusion

When Corona was canceled in 1972, the team was philosophical. I think we all knew it was coming for a fair period of time before it actually happened. It had had its day.

Corona stands out among my work at GE, not only because it came close to the start of my more than thirty years with GE, but also because of the high success rate. I particularly enjoyed finally getting to share my triumphs in detail with my wife when the project was declassified in 1995.

Figure 119. Edwin Hearn, center, with Col Datema, NRO, left and Hilly Paige, right, on the occasion of the 1995 GE Aerospace Discoverer 50th Recognition Celebration. Photo courtesy of Lockheed/U.S. Air Force.

Edwin Hearn
Quality Control and Test Project Engineer

Edwin Hearn spent the bulk of his career at General Electric (GE), nearly twenty years on Corona and other related projects. With a background in mechanical engineering, he worked as a Quality Control and Test Project Engineer. In the account below, Hearn shares some of his duties on the Corona program and claims that his experience with it was the highlight of his career.

I attribute a great deal of my success in life to my thirty-three year career at GE and the almost twenty years I spent on Corona. I started my career as a technician working for systems test engineers, mostly on military antenna systems. I ultimately became Product Manager—Space Programs and was responsible for the implementation of all efforts within manufacturing, purchasing, quality assurance, test, logistics, and field operations.

Figure 120. Ed, his wife Ann, and daughter Elizabeth at the 1995 GE Aerospace Discoverer 50th Recognition Celebration.
Photo courtesy of GE/Air Force.

My Involvement with Corona

I began my career at GE in 1959 working as a technician. A short while later I was assigned to Discoverer to assist the Quality Control and Test Project Engineer. Later I was promoted to Project Engineer, Quality Assurance and Test Operations, a position I held when the program was completed.

During my tenure as Project Engineer, I led a team of Manufacturing, Design and Quality Engineers in a study to determine the cause(s) of the high failure rate of heat shields (30 to 40 percent) after they were virtually complete. The team ran statistical studies of raw material and process variations that led to the tightening of both material and process specifications. The net result of this "pre 6 Sigma type" activity in the 1960's was a failure rate reduced to less than 10 percent.

I spent almost twenty years on Corona and related programs and feel it was the major accomplishment of my thirty-three years with GE. I am proud to have been able to contribute to something so important to our country especially during the Cold War.

For more information about Mr. Lasher and Mr. Hearn,
please refer to their autobiographical reflections in Appendix 2.

Figure 121. Bruce Waechter.
Photo courtesy of Bruce Waechter.

Bruce Waechter
Manager of Component Quality Engineering, Later, Component Quality Control

Bruce Waechter spent the bulk of his career at General Electric (GE) in Quality Control (QC). Working there, he saw, first-hand, several problems with Corona corrected. In the account below, Waechter not only recalls the fixes, but also the camaraderie that contributed to the success of Corona.

I was one of those at GE who came onto the Corona project early and saw it through to the end. In QC I was responsible for making sure components were qualified and, by the final years, worked reliably, time and again. The sub-section's solving of a problem with ejection pistons was crucial in turning Corona into a success.

Early Concerns in Quality Control

I came to GE with a degree in Mechanical Engineering from Lehigh University to the three-year Manufacturing Management Program. I then went to Philadelphia Missile and Space in 1959 and was brought aboard the Discoverer program as soon as I had clearance, which was almost immediately. Initially, I was responsible for QC engineering and the testing of many Discoverer components for shock, vibration, temperature, and humidity. That included explosive devices and the ejection pistons used for cover ejection.

Most components passed but a critical component—the ejection piston and squib, which I was responsible for test-wise—did not. The squib, or explosive charge, as manufactured by Gould Labs in Pitman, New Jersey, failed humidity tests. After being subjected to humidity firing, the pistons showed either greatly reduced velocities or no firing at all.

This might have been a crucial discovery because many of the early Discoverer recoveries that went wrong were blamed on cover ejection or parachute deployment problems. The time pressures of Corona did not always allow for thorough qualification testing before the flight tests.

The cover had four ejection pistons, which were required to fire with approximately the same velocity. After the qualification test failure, the explosive charge was quickly changed to a more humidity-proof one and then passed qualification testing easily.

Though I was not privy to the issues of the early failures of the Discoverer launches, I believe the ejection piston contributed to the problems. As soon as that issue was solved, the other hardware seemed to work well from that point forward. Discoverer was soon on its way to successful flight after successful flight. There were other problems, and I'm not aware of those because I was at a component rather than a system level responsibility.

The Impact of Working on Quality Control

Working in QC meant long, often unpredictable, hours. But there was definite team camaraderie on Discoverer. They knew they could rely on each other day or night.

Occasionally, my sleep was interrupted—a few times at 3 am—by my manager, George Emmons, asking some information about one of my components.

And I wasn't the only one. One of my component quality engineers once received calls at 2 am, 3 am, and 4 am from a tester indicating he was having trouble with some test equipment on a critical test. And each time he provided advice. At 5 am he received yet another call from the same tester indicating that the 4 am advice worked, to which he replied, "You woke me up again just to tell me it worked?!"

I became manager of Component Quality Engineering and then Component QC, which included all vendor quality, quality control engineering, inspection, and testing. I had under me 275 engineers, inspectors, and technicians.

Conclusion

It was the hard work of the GE team that made Corona a success and a reliable program through to the end. Along with me, many people gave up nights and weekends to be sure the project would grow from its shaky beginnings to dependable maturity.

We were encouraged to work a fair amount of overtime as the workload dictated. My wife claims I didn't see the kids much, but it sure helped pay for the house.

With heavy responsibilities at a young age, I consider GE essentially my total career. When GE was sold to Martin Marietta, I was not in a situation to leave the program so I stayed on another year before retiring.

Figure 122. Bruce and Janet Waechter.
Photo courtesy of Bruce Waechter.

AFTERWORD: REFLECTIONS ON CORONA, WINNING THE COLD WAR AND BEYOND

Ingard Clausen
First General Electric Project Manager,
Corona Satellite Recovery Vehicle

In my view, no war in our nation's history has threatened our defenses and our cities as much as the Cold War during the period of 1950 through 1960. Families built bomb shelters. The "missile raid" sirens gave off their threatening wail, even in the then small city of Phoenix, Arizona. Today the memory of that has been lost, remaining only with our senior generation.

President Eisenhower and his close confidants thought there was a good chance that the Soviets had the capability to destroy 100 of our cities and to wipe out all of our Intercontinental Ballistic Missiles (ICBMs).

This threat estimate was lowered dramatically in 1961 as a result of Corona briefings to Eisenhower.

In that year he had seen enough photos to conclude that the Soviets had only six operational ICBM sites. Few knew about this and Eisenhower could not order the air raid sirens to stop without revealing our satellite secrets.

Disproving the Missile Gap

In the 1950's, the United States deployed two critical missiles, the Thor by Douglas Aircraft, and the Atlas, by Convair, along with several reentry vehicles, by General Electric (GE). These projects gave the United States approximately fifty key launch sites by 1958.

In the grandest propaganda feat since the Trojan horse, the Soviets set the stage each May Day parade and invited international reporters to attend their "show." Troops, tanks, and, best of all, giant ICBMs, rolled by and big bombers flew overhead. The newsmen saw 250 ICBMs, enough to wipe out all of our ICBM sites and 100 of our cities. The Soviet trick was to circle the vehicles and aircraft around many times.

Corona reported in the latter part of 1961 that the Soviets had only twelve ICBM sites and actually only six of these were operational. It was then clear that, as the CIA had been reporting, the Soviets had concentrated their efforts on 1,500-mile range missiles. The USSR was primarily interested in the potential command of all of their former republics, Europe, and the Near East.

Meanwhile, John Kennedy was campaigning against Richard Nixon for the presidency and held Nixon accountable for the alleged missile gap. Nixon could not rebut him because of the deep-black security. As a result, Kennedy took office, only to discover there was no need for a missile mobilization plan.

Winning the Cold War

With the U.S. economy unburdened with missile mobilization, it could more easily expand. The Soviet economy never was robust, although nationalized oil provided economic strength. Then, oil prices sagged, pinching the Soviet economic resources. The mainstay of the USSR's reputation as a world power was their space program. Thus, catching up to Apollo (NASA's initiative conceived by President Eisenhower and supported by President Kennedy to put a man on the moon) and Star Wars (an initiative also known as the Strategic Defense Initiative (SDI) started under President Reagan in 1983 to develop an anti-ballistic missile system to prevent attacks from other countries, the Soviet Union in particular) was mandatory to maintain their reputation as a world power. While many U.S. defense critics questioned Star Wars feasibility, the Soviet fear of U.S. technology made the Strategic Defense Initiative a real threat.

Biggest Win but Biggest Loss–1991

As I see it, the Cold War was the best war we ever won. No more air-raid sirens, no more missile crises, no more dictators pounding lecterns and tables and threatening to bury us. No shots fired. The Soviet "evil empire" disintegrated. The Arms Limitation Treaties initiated.

In winning the Cold War there was limited commendation (for example, see figure 125). But for all of that, we failed to execute a nationwide, vigorously executed, victory project aimed at winning public, press, and congressional recognition for advances in defense, intelligence, technology, and economy necessary to win world influence and the Cold War.

In my opinion, an accurate history of the Cold War would conclude that those who helped win that war, including the succession of U.S. Presidents and the Corona leaders and teams, never received full credit for saving our nation and the free world.

In 1991, the year that the Cold War was won, there were no ticker-tape parades with war heroes riding on the backs of four-door convertibles down Fifth Avenue. Times Square was not swamped with celebrities and the public, with pretty girls kissing the Cold War warriors and news photographers plastering their pictures on the front page of an extra edition. Hometown newspapers did not run a continuing saga of local heroes with great fanfare and local parades. All the trappings were missing such as proclamations, speeches, and high school bands leading parades in the hometowns.

The extraordinary secrecy surrounding Corona and other satellite reconnaissance programs (as I've discussed in chapter 10) prevented any victory treatment like that received after the end of World War II.

New Threats Demanding New Development Projects

By 1991, and as we moved into the 21st century, we entered a new era where both threats and critical resources to respond to those threats became decentralized. For example, the failure to halt nuclear proliferation and sharing of nuclear technology can be seen as a consequence of decentralized control over the nuclear threat. The emergence of terrorism and the operation of multiple terrorist cells also has become a decentralized threat – one that poses the most significant challenge to the United States at the start of the 21st century. Communications, a critical resource for responding to decentralized threats, itself, became decentralized through dependence on the internet. The same became true for another critical resource, computing, which became decentralized through use of the microprocessor and inexpensive multi-terabyte storage drives.

These decentralization trends have profound implications for intelligence efforts that have remained centralized. Intelligence organizations will likely need new Corona-like efforts to meet the challenges of a decentralized world. The new generation of trailblazers will need the foresight, courage, determination, and wisdom demonstrated by those who participated in and lead the U.S. intelligence revolution in 1960.

THE WHITE HOUSE

WASHINGTON

August 21, 1984

Dear Mr. Welch:

With great pleasure I extend my personal congratulations to the employees of General Electric Company who successfully developed and operated one of our Nation's vital space programs for over two decades. This space program achieved major scientific and technological advancements contributing immeasurably to maintaining a credible defense posture for the United States. The program's completion marks the end of an era in our space age, a time characterized by dedication and excellence of a combined government and contractor team. I extend to you my personal thanks and good wishes for your continued success.

Sincerely,

Ronald Reagan

Enclosure

Mr. John F. Welch, Jr.
Chairman of the Board
and Chief Executive Officer
General Electric Company
3135 Easton Turnpike
Fairfield, Connecticut 06431

Figure 123. Presidential letter of congratulations to General Electric for Cold War national security space programs, dated August 21, 1984. Copy of letter courtesy of Daniel Rossman's private collection.

APPENDIX 1: THE AFTERMATH FOR GENERAL ELECTRIC AEROSPACE BUSINESSES– A MERGER WITH LOCKHEED

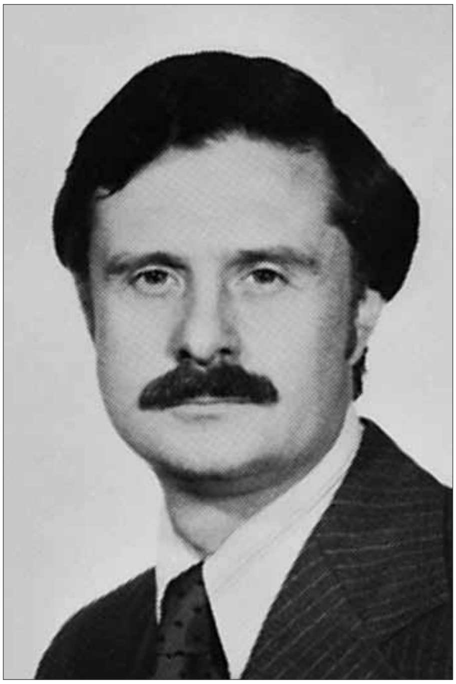


Figure 124. Ken Swimm.
Photo courtesy of Lockheed Martin.

Ken Swimm
General Manager,
Management and Data Systems,
Lockheed Martin

Near the end of a successful career in space-related projects, Ken Swimm was working as General Manager for Management and Data Systems (M&DS) at Lockheed Martin. He was there in 1993 when General Electric (GE) and Lockheed Martin decided to merge. In the account below, he shares his experience with the merger and its immediate effects on both companies.

Editorial Note from Ingard Clausen:

In the 1980s and 1990s, the history of mergers was in a questionable state with the rule being, "to the victor goes the spoils." The victor being the buyer. That typically meant that the buyer of a business usually dictated the organization and staffing of the surviving company, with the best jobs going to the buying company.

Ken Swimm's account in this section shows how the GE Aerospace and Lockheed Martin merger process was converted to the rule "merger of equals."

The GE/Lockheed Martin Merger

In 1993 at a social gathering of key U.S. executives, Jack Welch, Chief Executive Officer of GE and Norm Augustine, Chief Executive Officer of Martin Marietta met and discussed the potential of Martin acquiring the aerospace arm of GE.

Figure 125. Defense Satellite Communications System (DSCS III).
Photo courtesy of Lockheed Martin.

Jack actually scrawled an offer on a cocktail napkin and, several months later, the deal was finalized. Martin paid GE over $3 billion in cash and gave GE a 25 percent share of the new company, which moved the combined entity to the number one or two spot in the aerospace industry. Norm still has the napkin, framed and hanging on his trophy wall.

At the Philadelphia area organizations, there was complete surprise, given that GE had been supporting the government in its aerospace activities since well before WWII. The M&DS division of business, which I ran, was continuing to engage in a broad range of activities for the government. Headquartered in Valley Forge, Pennsylvania, the company had, over the years, absorbed many of the people who were a part of the Corona program. In so doing, the organization had continued the tradition of supporting the intelligence community.

The overall merger was, in general, a combination of complementary rather than competing organizations, and M&DS was acknowledged to be the “jewel in the crown” of the GE Aerospace Group. Nevertheless, many of the personnel had a 30-year history with what was generally considered one of, if not the best, company in the United States. There was an overwhelming feeling of loss and concern across all of the GE organizations.

Figure 126. Ken Swimm and Hilliard Paige at the 1995 GE Aerospace 50th Recognition Celebration, sponsored by Ken Swimm. Photo courtesy of Lockheed Martin, 1995.

Norm Augustine was an outstanding communicator and made it clear that this was a "merger of equals" and that the best organizations and the best people would be rewarded, regardless of which company they came from. This was born out in the combined organization which featured just as many group leaders from GE as from Martin, and a guarantee that the common practices that would be adopted would be those that were the "best of the best," again independent of the company source. In general, it turned out that most of the common finance, personnel, information technology processes, etc., adopted were from the GE culture, which by nature was a little more rigorous.

Still the company had to address the concerns of the GE personnel. For about six months, my major focus was communicating, in person, to my over 4,000 personnel. My message was that while there were pluses and minuses, we were now part of an organization whose only business was aerospace and one that really valued us. That was in contrast to the feeling in GE that we were outside the circles of focus for the company.

The natural synergy between Martin's launch vehicle expertise and our spacecraft development quickly became evident. We were also able to tap into a combined marketing organization headquartered in Washington, D.C., that we leveraged towards our business more effectively than we would have achieved as a minor entity in the global GE business.

At this time, M&DS was in the process of taking much of the expertise it had developed in the classified arena in system development, software design, and system engineering to leverage significant new business wins outside of that venue. This led to a rapid growth over the next few years across multiple areas of command, control, communications, and information. M&DS continued to expand, both inside and outside the intelligence community, and, in only 4 years from the merger, had revenues in excess of $1 billion and over 7,000 personnel.

The merger with Lockheed created one area of significant overlap—spacecraft development business. Lockheed in Sunnyvale, California, provided classified satellites as well as the Milstar communications satellites and the Hubble space telescope. The former GE/RCA facilities were producing the Defense Satellite Communications System, the Global Positioning Satellites, and a multitude of commercial satellite systems.

The Martin facilities in Denver were producing a few planetary spacecraft for the National Aeronautics and Space Administration (NASA). While the logic was not clear to many of us, the new company decided to close the Valley Forge, Pennsylvania, and East Windsor, New Jersey, facilities that were operating at full capacity. Today, over a decade later, Valley Forge continues to produce a limited number of spacecraft, as the various customers demanded that their programs not be moved.

Perhaps the most significant change that occurred in my tenure as the leader of M&DS was the acquisition of the GE aerospace business by the Martin Marietta Corporation—a merger of equals.

APPENDIX 2: AUTOBIOGRAPHICAL REFLECTIONS

This appendix is a collection of the autobiographical reflections of the contributors to this book. It will give you insight into who these people were and what was important in their lives. By reading their self reflections, you will learn something about their childhood, their education, their introduction to space and national reconnaissance, their experiences in the military, and their lives after their contributions to the Corona program.

In the chapters of the book you learned something about the contributions of these trailblazers in national reconnaissance. You learned about how they spent a portion of their careers contributing to the success of the Corona program—a part of their career that many considered to be a highlight of their life experience.

Who these people were as individuals also is an important part of the story of national reconnaissance, and we have assembled their personal reflections into one place so you can meet them as a group. They were amazing people who accomplished great things in engineering, space, and national security during the mid-point of the twentieth century—a challenging time for such contributions as the introduction to the book points out.

In this appendix, we introduce you to the personal side of the trailblazers of national reconnaissance.

Borge Andersen

Even before my introduction to Discoverer/Corona, I was no stranger to a little adventure. Born in Denmark in 1923, I graduated from the Maritime Academy and sailed the high seas on cargo vessels until I officially immigrated to the United States.

I worked for DuPont in Delaware and then joined the U.S. Air Force, gaining training in aircraft operational electrical systems. My work in the Air Force contributed to the improvement of the C-124 aircraft. I gained citizenship in 1953 and was honorably discharged from the Air Force in December 1954.

I then returned to DuPont, but I was soon convinced to join the Delaware Air National Guard as a senior aircraft electrician. In 1956, I became an industrial journeyman electrician at General Electric in Philadelphia. At the time, I had the seemingly mundane task of plant facility maintenance and then renovating an A&P food warehouse into a modern aerospace complex. That changed in April 1958, when I was transferred to the Satellite Aeromedical Recovery Vehicle (SARV) program.

Editor's Note: After providing this account, Borge Andersen passed away in May 2011.

Minoru "Sam" Araki

I was born in 1931 in Saratoga, California, and I went to school and spent most of my career there in the Santa Clara Valley. Since my retirement after 38 years at Lockheed Missiles and Space, I have continued to live and work in the Saratoga area still connected with Lockheed Martin and the NRO.

I spent my first two years of college at San Jose State, where I had to take a lot of remedial courses because I got bad grades in high school. I had attended Campbell High School in Campbell following the three years my family spent in a Japanese-American internment camp. After the disruption of living in the camp and returning to our home in San Jose, I didn't take school seriously and didn't study very hard. Initially I went to college only because my father wanted me to go.

At San Jose State I found out that I could get good grades and, at first, thought about going into drafting or architecture. I really wanted to study engineering because, at that time, there was a shortage of engineers and it was the best way to earn a living. But I didn't think I was smart enough to be an engineer. Then, when I started getting A's in math and physics, my father told me I had to go to Stanford—go take the test, he said. It was much harder than San Jose State, but Stanford really made me.

In 1955 I was in graduate school at Stanford, studying thermodynamic and heat transfer of jet engines and nuclear power, when I got an opportunity to visit several companies where I might be able to interview for a job. During the Easter break, one of my professors bought airline tickets for me and another student to go to Peoria to see Caterpillar. So we went to Peoria, where it was really cold! Then we flew to Chicago to visit Argonne National Lab, and Chicago was having a blizzard. After that we went to Cincinnati to see a jet engine plant and to Pittsburgh to visit Westinghouse Nuclear Division. Pittsburgh was covered with coal dust, and it was cold, too. When we came home, we said no way we're going back there. Then I got an interview with Rocketdyne in Southern California. That's how I got into space engineering. I'm glad I took that job because I got in on the forefront of space and rocket engine development.

When Lockheed started the satellite—the WS-117L—program, I really wanted to go work on that program. And, I didn't like Los Angeles; I had grown up in the Bay Area and wanted to go back, so when I heard they had opened a plant at Stanford Research Park, I said Lockheed is where I'm going. Besides, I really wanted to get into the interesting satellite business. But I didn't want to come to Lockheed as a propulsion engineer; I really wanted to come to Lockheed as a systems engineer. I broke with my past, and, in fact, turned down jobs in the propulsion field just to break into the satellite business, which I'm glad I did. I was hired atLockheed as a research scientist on the WS-117L program.

When I began at Lockheed, I knew that they had the 117L program, including Discoverer, Samos, and Midas programs, and I knew this work was on the ground floor [of satellite development]. But I really didn't know what I was getting into. They threw me right into the Discoverer Agena Program. I landed aboard a system engineering team and worked day and night, right off the bat. I joined Lockheed in November of 1958, and there was a launch scheduled in February 1959, as quickly as they could get the first satellite ready. They didn't have enough people, so they said to me, "You go work it."

Following Corona's successor program Hexagon, for which I was the Chief Systems Engineer during the proposal, development, and initial three flight phases, Lockheed wanted to branch out into new directions. Lockheed asked me to head up this whole area of preliminary design and advanced systems, so I was appointed Vice President of Advanced Programs and Development. In the early 1980s, Lockheed won Milstar, for which I was the Proposal Manager and the initial Program Manager. Milstar was a major win for us. Then I came back as Assistant General Manager for the Space Systems Division. After that, I became Lockheed's President of the Space Systems Division, then Executive Vice President for Lockheed Missiles and Space Company (LMSC), and finally President of LMSC. The last assignment before retirement was to conduct the Lockheed Martin merger to form Lockheed Martin Missiles and Space Company.

I retired from Lockheed in 1997 and continue to reside in the Saratoga area. I enjoy gardening and farming. I was named a Pioneer of National Reconnaissance by the National Reconnaissance Office (NRO) in 2004 and maintain my ties to the NRO as a senior scholar for the Center for the Study of National Reconnaissance (CSNR). With four other NRO pioneers, I also received the National Academy of Engineering Draper Award for the development of Corona Program.

Editor's Note: Most of this biographical reflection is from the NRO's Journal of the Discipline and Practice, Fall 2009, "First-person Narrative: Reflections of M. Sam Araki–Success Through Systems Engineering and Leading Lockheed Missiles and Space."

Clifford E. Barr

I was born in Lanes, South Carolina, in 1929. I grew up with two brothers and one sister in a farming community. I went to high school in Masten Park, Buffalo, New York. Next was a Marine Corps enlistment that ended in 1954. Following that, I obtained my certificate of design at Temple University in 1956.

Also from 1955-56 I worked for ITE Circuit Breaker in Philadelphia. From 1956 to 1982 I worked for GE. I attended Drexel Institute from 1958-59. After leaving General Electric (GE), I worked for RCA communication satellites for about twelve years.

I have been retired for fifteen years and enjoy the computer and reading about history and keeping up with political events. My wife Margaret and I take a vacation each year. Margaret is from San Francisco so we enjoy going there and Florida. We try to go to a different place each year.

I have one son who is an electrical engineer.

Harold Bloom

I came into space work after an early interest in science and math that I discovered while growing up in Providence, Rhode Island. I found high school math classes intriguing, while chemistry, physics, and aeronautics coursework further whetted my appetite. World War II still raged when I graduated from high school and I served in the Army for two years as an infantryman in Europe. Returning home after being wounded in France, I was determined to continue my education.

My father was a butcher and I used to go down and work with him as a kid. He would tell me time and time again, "Whatever you're going to be, you're not going to be a butcher." I enrolled in Rhode Island State University, graduating in 1948 with a degree in mechanical engineering and a specialty in aeronautics.

My first job, at National Advisory Committee on Aeronautics (NACA), involved the design of high-speed engines on a very theoretical level. After about four-and-a-half years of that, I decided I wanted to work in something more than research. I wanted to see more about applications. General Electric (GE) offered a position in Schenectady, New York, developing the Hermes missile. When GE got a contract to work on nose cones for missile reentry, I was transferred.

Florian Brent

Before joining GE, I worked at the Budd Company as a weapons engineer and for the Pennsylvania State Department after completing a civil engineering degree in 1950. As with many others of my era, my college career was interrupted by wartime service in the military. I was born April 9, 1924, a native of Pennsylvania. I grew up in the coal-mining region near Mahanoy City, where my father, an electrical contractor, worked on homes and commercial construction projects. He taught me a lot of the trade. My interests in high school ranged from playing trumpet to lettering in baseball and the family trade of journalism, but upon arrival at Penn State University in 1941, I settled on electrical engineering.

Then the United States entered World War II. I was recruited by the Army and spent three years serving. During that time, I married my first wife, Miriam, with whom I spent the next 57 years until she passed away in 2000. We had one daughter, Debbie.

Returning to college wasn't my top priority when I got out of the service in 1946, and I spent some time working with my father as a contractor. My wife encouraged me to give school another shot, so we moved to Fort Wayne, Indiana, for an accelerated engineering program at Indiana Technical College. Thirty-seven months later, with a bachelor's degree in civil engineering in hand, I took a job with the highway department back home in Pennsylvania.

Highways failed to hold my interest and I answered an ad for a weapons engineer at the Budd Company. There, my claim to fame is that I developed a brand new design configuration for an artillery shell that was to destroy tanks. The so-called HEAT rounds (High Explosive Anti-Tank Rounds), burned holes through armor-plated vehicles. I found a way to improve the aerodynamic stability of the artillery, allowing the size to be minimized so the rounds could be used in tanks. Despite the success, however, I felt I wasn't making progress at Budd, so I applied for a job as an engineer at General Electric (GE). I was hired by Lee Demerit, Manager of the Instrumentation Group, Missile and Ordnance Systems.

After the success of Discoverer 13 in 1960, I left GE and followed one of my managers to a position at Fairchild Hiller. I continued to work with the challenges of parachutes, including one for use by C123's in Vietnam. I worked on contracts for Goddard Space Center, and when my boss moved back to GE, I asked if there was need for me at my former company.

Returning to GE, I worked on National Aeronautics and Space Administration (NASA) projects including the Nimbus and other satellites, measuring geological features such as land formations, snowfall, rainfall, and ocean temperatures. A highlight of the resulting work involved the discovery of a volcano near Spitsbergen Island, Norway. In 1984, at age 60, I retired from GE.

My wife and I moved to Florida but, missing friends and family, came back to Philadelphia. After her death in 2000, I moved to Waynesboro, Pennsylvania, closer to family in Maryland. Two years later, I subsequently married, Linda Susan. While I write this, I enjoy spending time with Linda Susan and her large family. My wife and I often take long weekend drives in the Pennsylvania, Maryland, and West Virginia countryside.

Editor's Note: Since providing this account, Florian Brent passed away in March 2010.

Henry (Hank) W. Bried

My determination and belief that any problem can be solved came from my intense college experience at the Stevens Institute of Technology in New Jersey. Although not particularly interested in engineering as a child, I did well in math and convinced guidance counselors that I could make it as an engineer. My father, who worked in various positions to support his wife and four boys, was at that time vice president of an ore-mining company, the president of which recommended Stevens to me.

On the way to graduating with a mechanical engineering degree in 1955, I spent 32 hours a week in class—almost exclusively engineering—and took 4-hour exams. Of 227 students in my class, less than one-third graduated. It made a Don Quixote out of me. There was no challenge you couldn't accomplish. There was no hill you couldn't climb.

Upon graduation, I was drafted into the Army and eventually received a commission as a lieutenant. In Huntsville, Alabama, at the Army's Redstone Arsenal, I got my first exposure to the space program when I witnessed reactions to the launch of Sputnik in October 1957 and the subsequent jubilation when the United States' first satellite, Explorer, succeeded in reaching orbit the following January. I worked on research and development of the Hercules missile, traveling around the country to speak with contractors and observe tests.

My stint in the Army completed and my space engineering credential established, I moved on to General Electric's (GE's) Philadelphia offices in 1958. The company offered the benefit of being close to my family and my wife's family in New Jersey. My title, Production Design Engineer, meant I served in a planning function, coordinating engineering and quality control to improve the flow of a project. Specifically, to insure that design changes were properly implemented as a piece of equipment went into production. I made sure to keep the engineers communicating with the technicians. While a production design engineer for the Mark III nose cone project, I met Ed Miller, who would later bring me onto the Corona project.

I moved on from Corona to other GE space programs, eventually leaving the space division to move into computers. GE's computer division in Phoenix eventually was sold to Honeywell, at which point I and many of the GE engineers left for Motorola. I had earned an evening MBA at Drexel University while still working for GE in Philadelphia. I directed a program for Motorola (Participative Management Program) designed to change the company's management- employee working relationships and working techniques.

I have since started several of my own businesses and subsequently began work in financial planning, mortgages, and real estate. I have not lost my determination but I think I have softened. You learn there's more to life than producing products.

In addition to my work, I spend time with my four children and 10 grandchildren, who live in California and Arizona.

Dino A. Brugioni

Growing up in Missouri in a family of coal miners, I aspired to be a doctor but I knew my family couldn't afford the tuition. College was an important goal, however, to parents who did not want their children to follow them into the mines.

After high school I attended Jefferson City Junior College and took a job for 10-cents per hour in dairy making and selling ice cream and putting my money aside to fund my hobby, photography. I became fascinated with photography. In those days, they were box cameras. They were all pre-set. I wanted a better camera. Many hours of work later, I bought a camera that allowed the operator to set the exposures and used better film. The knowledge I developed with this hobby was indispensable during the war.

The war experience also convinced me I should become a diplomat, so when I returned from Europe, I investigated which schools offered such training. I chose George Washington University in Washington, D.C. During the next several years, I earned both a bachelor's degree and a masters degree and took courses toward a Ph.D. I also met and married my wife, Theresa.

With the burgeoning Cold War came a number of opportunities for aspiring diplomats that drew me away from my academic studies. I looked at the Federal Bureau of Investigation (FBI) and work on the Marshall Plan but eventually joined a new federal organization, the Central Intelligence Agency (CIA), founded in 1948.

My job was to help develop the Industrial Register, a catalog of Soviet and other foreign industrial production facilities. A specialist in the Soviet Union and Far East Asia, I learned as much as anyone knew at that time about Soviet military facilities. That knowledge, along with my reconnaissance experience during the war, would play perfectly into my next position. I spent the rest of my career working with Arthur Lundahl, co-founding and working at the National Photographic Interpretation Center (NPIC).

I continued to make improvements to operations at NPIC until my retirement in 1982. After retirement, I remained an active researcher and historian of photoreconnaissance missions and technology. In 1986, I was awarded the prestigious Pioneer in Space Medal by the U.S. Government for my role in the development of satellite reconnaissance. Although I have received numerous awards, I am most proud of the commendation I received from President Kennedy for my performance during the Cuban Missile Crisis of October 1962.

I have written several books, including Eyeball to Eyeball: The Inside Story of the Cuban Missile Crisis, and, at the time I am writing this, I am also working on a book about Eisenhower's use of technology in national security.

Over the years, I have had contact with presidents, senators, and foreign leaders of all types through intelligence briefings, appeared on television programs, and served as a technical adviser for the Cuban Missile Crisis movie, Thirteen Days. In April 2005, I was inducted into The National Geospatial-Intelligence Agency Hall of Fame.

In retirement I have remained professionally active. I also spend time with my two children and six grandchildren.

Edmond J. Bryce Sr.

I am the great grandson of Ebenezer and Mary Ann Bryce. Bryce Canyon National Park, Utah was named for Ebenezer. When he first saw the canyon he purportedly could only say, "It's a helluva place to lose a cow!"

My ancestors were pioneer millwrights, farmers, and carpenters. Their pioneer spirit forging the early western states of Utah and Arizona must have trickled down to me as I wound up becoming part of the "Corona Space Pioneer" team.

I was born March 6, 1932 on a farm in Ashurst, Arizona (South East Arizona) across the Gila River from Eden and Bryce, Arizona. I am the youngest of ten children (five boys and five girls) born to William Carlos (Carl) Bryce and Beulah Bertie (Means) Bryce.

After graduating from high school and not finding work at all in the Phoenix area, I packed some clothes in a black tin suitcase and with thirty dollars traveled to my sister's place in Williamstown, New Jersey. I took a temporary job as a grocery stock clerk in a super-market (Baltimore Markets, later Best Markets). I was only going to stay six months. This was in 1950.

In 1952 Uncle Sam wanted me for the Army but I couldn't afford to go all the way back to Phoenix so I enlisted in the Navy for four years as an Electronics Technician, Seaman. After boot camp I attended Class "A" Electronics School in Great Lakes Naval Center. The rest of my naval career was spent aboard DD671, the destroyer USS Gatling. My tour of duties serving as an ET 3rd Class included the Korean War, a world cruise, two Mediterranean cruises and a South American cruise. During this time I celebrated crossing the Equator twice, once as a "pollywog" and then as an illustrious "shellback."

I met my future wife Ann in 1953 after the world cruise while docked in the Philadelphia Shipyard to undergo updating and refurbishing. We later married in 1955.

I was discharged in 1956 and my family of four (two boys and two girls) was just starting. I pounded the pavement looking for work in my line (electronics) for over a month. I finally took a job as a grocery clerk at Best Markets although I really wanted a future in electronics.

General Electric (GE) had opened a plant in the missile industry at 32nd and Chestnut Streets, Philadelphia. After no response to my applications for systems test technician, I was so determined to work in this field at GE that I had a friend teach me how to operate a floor finishing machine (a scrubber) and applied for an opening in plant maintenance (janitor). At my interview, the personnel manager read my resume and upon seeing the background of electronics and grocery stock keeper I was offered a job as a tallyman in a stockroom.

After joining GE in 1957 and with our second child on the way, I considered going to college to further my education. However, already working extra hours and/or jobs, if I were to add the additional time for school, I would miss out on all the joys of being a part of my children growing. Thus, I decided not to continue schooling.

I also took several GE courses at work to enhance my work performance including Electronics I and II, Logic, Effective Listening and Supervisor Training.

I am the husband of Ann Marie (more than 50 years) and the father of four (two boys and two girls), the grandfather of five (three boys and two girls), and I have been retired since 1993. I have loved every minute of it.

One of our hobbies is making stained glass windows (no sun catchers - there's no challenge). Every window in our house has stained glass panels as well as other items made from stained glass throughout the house. My wife and I have been enjoying this hobby together for more than twenty years and do not sell any, as it would take the pleasure out of it.

Since my retirement, Ann Marie and I have really enjoyed being grandparents to our grandchildren. Being a part of their activities (sports, band concerts, etc.) and being able to care for them, or provide support as needed, has been a great joy just as it was in raising our own children. I never regretted giving up the extra education in order to spend more time with my family.

Robert Chamberlin

I was born in Concord, New Hampshire, and was the youngest of three. When I was seven my father left the family. We lived on Spring Street and our land backed up to a state institution's garden which, incidentally, helped my mother feed us. We gleaned the fields after the state staff was done for the season. My father's mother owned the house and made it easy for us to continue to live there. Concord was a good place to grow up. School came easily. I worked summers for owners of large homes, changing storm windows to screens and mowing lawns.

I painted buildings at St. Paul's prep school, rode my bike everywhere, and went fishing as often as possible. Airplanes always intrigued me. I made model after model, and my pal and I shot them out of the upper floor of the barn aiming them next door. Upon graduation from Concord High School, my buddy and I signed up with the Navy Air Corps.

We were assigned to Dartmouth for 12 months of study. When challenged with the question, "Are you committed to flying for the Navy Air Corp?" I was able, in a few moments of reflection, to answer, "No" whereupon I, along with six others, were ordered to leave immediately for reassignment. This was a pivotal moment, for soon I was off to Rensselaer Polytechnic Institute (RPI) where I continued studies, earning a degree in aeronautical engineering. Without even knowing it, I was well on my way to my finest hour.

Upon graduation and earning my commission as Ensign, orders came to report to Philadelphia Naval Aircraft Factory for twelve weeks of training on how to operate and maintain aircraft arresting gear and catapults. My next orders were to report to airplane carrier CVE116 in San Diego. The war was ending so my time in San Diego was short. My discharge came and I left the Naval Air Corps just about halfway between VE day and VJ day.

Hoping for a place in my field of aircraft design, I found that work on the development of planes was declining. When offered a place at Curtis Wright, I headed to Columbus, Ohio to design post-war four engine transports, my first job designing airplanes. This was fine until they cancelled the project and laid me off. Happily, in New Hampshire I found work as an engineer in the New Hampshire State Fish and Game Department. I said goodbye to my old Ford jalopy, purchased a 1948 Kaiser and fully enjoyed driving anywhere.

Nancy and I met at Fish and Game and soon we were dating. Within a year we knew we wanted to marry, and did so in June 1949. That year, I had been scouting for work again in my chosen field and was offered a job at Wright Patterson Air Force Base (AFB) back in Ohio. We combined the move to Ohio with our honeymoon via Niagara Falls, arriving at Dayton ready to start work two weeks later.

I was involved with evaluating airplane performance, utilizing U.S. Air Force methodology.

After being laid off from GE, I moved my family, returning once again to New Hampshire State Employment. I worked in the Water Resources Board, early on as a dam engineer, traveling throughout the state inspecting dams in rivers, brooks, ponds and lakes. From dam inspections, I moved into a second state career and became engineer to the Wetlands Board of the Water Resources Department for the state of New Hampshire. The Wetlands Board oversaw the process through which landowners submitted requests to alter any waterway in the state. For thirteen years, I oversaw this process, from individual applications through to the decisions of the Board. I met many good people and enjoyed the challenges in working with them.

In 1987 I retired from the state and thus began many pleasurable years traveling with Nancy in our RV, camping and relaxing with seven grandchildren, trout fishing, and subsequently purchasing shore land in the woods of Maine and building a small second home in Hancock, a few miles east of Ellsworth.

As I write this, a mysterious illness has relegated me to a wheelchair for most of the past eight years; yet we still travel and enjoy half of each year in Maine and half in Keene, New Hampshire.

Editor's Note: Since providing this account, Robert Chamberlin passed away in September 2008.

George Christopher

I was born February 3, 1926, in New York City. I attended Brooklyn Technical High School, my first exposure to the engineering field. After two years as a B-29 gunner during World War II (an experience I describe as just looking out the window), I sensed the expectation that I would go to college, though I couldn't imagine how my family would pay for it.

I was 20 when I was accepted into the eminent Rensselaer Polytechnic Institute in Troy, New York. There I earned a Bachelor of Aeronautical Engineering in 1950. With an opportunity for paid tuition, I sought my Master of Science degree at Ohio State.

With these degrees in hand in 1951, I married Mary, a nurse, and took my first job.

I worked with Curtiss-Wright propellers. But I realized back in those days that propellers weren't really going to be that big. So after one year I went to a job with General Electric (GE) up in Schenectady, New York.

At GE, I was a functional engineer of a vibration and shock group. I was under the tutelage of Sam Levy who taught me tolerance and leadership as well as coached me in vibration. I stayed with this task for four or five years before becoming involved with Corona.

As I write this, my wife Mary, a retired certified nurse practitioner, and I live in Pennsylvania. We have three children and three grandchildren.

Lt Robert Counts

I was born February 13, 1935, in Yuba City, California, where I lived in the Sierra foothills. My father worked in heavy construction building dams. Our family moved to Southern California during World War II and my father constructed military installations, including Camp Pendleton. In 1942, my father was killed in an accidental explosion while working demolition.

My two siblings and I grew up in the Los Angeles area where I stayed through my high school years, graduating in 1953. I had saved bus fare, so I left. I went off to New Mexico to work the oil fields, something that paid well but did not require experience.

I was trying to earn money for college but discovered I was about to be drafted into the Army for the Korean War. Instead, I joined the Air Force. I remained in the military for 16 years.

Though I started out as an enlisted man, I attended electronics tech school and was stationed in Denver. I found that the military had re-activated the Aviation Cadet Program that had been in use during World War II. The military needed a lot of pilots so they had opened pilot training. Usually you already had to be an officer to become a pilot.

I became an aviation cadet after passing a battery of physical and mental tests. I earned my pilot's wings and was commissioned a second lieutenant after a year or so of training in the program. When the Korean War was over, there were too many pilots, so I retrained as a navigator, which took another 14 months.

I was in Hawaii for four years as a recovery navigator and then was rotated back to Edwards Air Force Base (AFB). I was an engineer designing parachutes and recovery equipment for the next five years. That included expanding the flexibility of the system by developing equipment for recovering at night.

The nighttime low-orbit experiments were a source of several UFO sightings at the time in Southern California. They used a strobe light shining up into the coated canopy. When combined with the lights of the recovering aircraft, it made quite a spectacle for the unknowing on the ground.

It was a similar situation earlier in Roswell, New Mexico, something the military officially said was only a high-altitude weather balloon. It was in fact a balloon-borne camera capsule, but too secret to admit, and a mythology was established.

Discoverer was only one of several similar programs I was involved in, but many of the others are still classified. We would also test other people's designs, such as work for Lockheed.

One of the many small recovery operations involved the X-15, the fastest airplane in the world. They placed external fuel tanks on it, which required a new design involving an extra fin on the bottom of the tail to compensate for drag. The tanks and the fin had to be dropped off before the aircraft landed. My crew and I developed a parachute system for recovering those high-value items.

I stayed in the military for 16 years, leaving in 1968 as a full captain. Early contacts with Lockheed had invited me to work there, but by the time I arrived, the company was going through cutbacks. I then went to World Airways in Oakland as a navigator. Though most airlines had modernized to automatic equipment, World Airways had a contract flying in and out of Vietnam which required a navigator. But they, too, were shedding navigators, so I looked to new endeavors. I had always been a sailor, so I ended up buying a sailing school and a sailboat charter business in Sausalito. I owned and ran that for 16 years.

My wife Judy and I own a cabin in the woods in Northern California with no electricity that sits on gold mining property. I tend to be drawn to weird things. As I write this, I am in the process of trying to retire.

Max Dienemann

I came to General Electric (GE) from RCA, where I had taken a job after college working on radar systems. Mechanical engineering always interested me. I liked to take things apart, but I often couldn't put them back together. That piqued my interest. I finished courses at Baltimore Polytechnic Institute on an accelerated program and, after a year working as an industrial sales representative at Westinghouse, went on to the University of Maryland, where tuition was low enough for me to earn next year's funds each summer. I found my interests focusing on thermodynamics and work with heat engines, more so than bridges and electrons.

GE beckoned with a raise and the promise of help in earning a Master's degree through an evening program at Drexel University. I went to work in Philadelphia in 1956, immediately focusing on reaction control systems. The basic design involved gas tanks filled with nitrogen. When a valve opened, the gas rushed out through a nozzle, creating thrust. Opening and closing valves for various lengths of time could control the attitude of a reentry vehicle, with primary importance being on its orientation back toward the atmosphere and a target. Such systems were used on prototype Intercontinental Ballistic Missiles (ICBMs) before being applied to the Corona satellite.

Although I did not have experience with such systems, I felt GE gave me the support I needed to learn and enjoy the task. They gave you a great deal of latitude in work assignments and responsibility. You could make the job whatever you wanted with little external control. Sometimes that backfired, but in general, it worked out really well.

One of my funniest memories from my time working on covert systems is of my oldest child, who insisted I was a spy. In those days you had to travel under the name of another company called B&H Associates. You had to travel with cash. Your wife had to have a special phone number to call if she was trying to reach you. It was very controlled security. The one exception: you weren't allowed to tell anybody you were working for GE, but you had to get the GE discount when you rented a car. My son wanted to know where I hid the trench coat.

After seeing the Corona program through the first few successful launches, I found my services were no longer needed. I returned to designing advanced nose cones and also spent some time on the Manned Orbiting Laboratory (MOL). Other projects included a concept for intercepting satellite vehicles in orbit and inertial guidance systems for reentry vehicles with multiple warheads. I continued to work for GE until its space division was bought by Lockheed. I retired from Lockheed in 1994 and moved to Florida. As I write this, I still live there, playing tennis, golfing, kayaking, and generally enjoying my time. I have three children from my first marriage and four grandchildren.

David S. Doyle

I was born in Oakland, California, and got my first experience with an aerial view of the earth while serving as a pilot during the Korean War, partway through college. After completing my term of duty, I returned to Berkeley to finish my degree in forestry and then found a way to combine my two interests, founding an aerial photography company with friends in the Bay Area.

The company didn't last long and I began searching for other jobs. I received offers in forestry but photo interpretation had drawn my interest. My professor, who had worked with Lundahl as an interpreter with the Navy in World War II, wrote me a letter of recommendation and soon I was on my way east to Washington D.C. I didn't know what I was getting into. I had no idea the U-2 was flying at the time. It just seemed like a good thing to do.

I continued working at National Photographic Interpretation Center (NPIC) after Corona, advancing to management positions until my retirement. After retiring, I began raising llamas on a farm in West Virginia with my wife, Eda. I have three children from my first marriage and one from my second, and six grandchildren living in California, Kentucky and West Virginia.

After thirty years of working in a windowless building, I enjoy spending my days outside.

Alfred (Al) M. Gross

My mother didn't attend high school and my father had only one year. My parents, a German immigrant and a working class girl from rural New Jersey, met at the hosiery mill where they worked as a seamer and a knitter, respectively. Married not long after the stock market crash of 1929 and having no work at all for long stretches of time, they struggled through the Great Depression. For me, their eldest child, they hoped for something more.

I spent my early childhood in Washington, New Jersey, and later in the small town of Port Colden a few miles away, where our family moved to take care of my grandfather who was also a worker in the hosiery business. As my mother spoke no German, and my grandfather spoke German most of the time, the move to Port Colden strained my parents' marriage. Then World War II happened and I found myself the target of taunts and fists at school because of my grandfather's sympathies for his German homeland. Of course, he "wasn't always cautious about voicing these opinions." The hosiery factory shifted its manufacturing to parachutes during the war and a wage squeeze prompted my parents to send me to nearby farms to help out with tasks like cleaning the barn for 15 cents an hour.

My parents always felt their lack of an education hindered their ability to find a way into the middle class and encouraged me to continue my education. I didn't need much of a push. When I got into high school, I didn't know what I wanted to do with my life, but I knew I didn't want to shovel manure. My grandfather resisted a shift from the family business of hosiery but I persisted and enrolled in Lafayette College in eastern Pennsylvania. Following an interest I had developed thanks to a neighbor back home in New Jersey who was an electrical engineer and a ham radio operator, I studied electrical engineering.

But I couldn't leave behind my background overnight. I found myself ill-prepared for the academic track and struggled with prioritizing the study of seemingly abstract subjects like integral calculus. I didn't pursue education for its own sake. Less than stellar grades did not impact my ability to find a job, however, and upon graduating in 1954, I moved to Niagara Falls to work for Bell Aircraft on an air-to-surface missile designed to carry a nuclear warhead. The concept involved a bomber dropping the missile while someone in the plane guided the missile. The concept was great, except the technology was not far enough along.

The experience introduced me to telemetry, the idea of collecting data from the vehicle about its performance. The subject was new to me but intriguing. It also earned me a few trips to the White Sands Missile Range in New Mexico to test the rockets. There the work was interesting but the outback existence, as a single guy, wasn't so great. Eventually, the program was canceled for failing to work reliably.

I was out in New Mexico at the time and took the opportunity to stop by a telemetry conference a few hours away in El Paso. I spent the conference interviewing with companies such as Martin, Convair, and General Electric (GE). I took an offer from GE in 1957 and moved back closer to home to work in Philadelphia.

After completing my work on Corona, I moved on to other programs at GE, including the National Aeronautics and Space Administration's (NASA's) Nimbus satellite and the 206 flight vehicle, as well as projects that remain classified. In 1984, I was named chief engineer of the Milstar communications satellite, which I enjoyed because I came into the design process at the beginning instead of part way through and was able to apply many of the design techniques I had picked up along the way.

I retired from Lockheed in 1992 and, as I write this, I spend my time stock trading online and fixing up the house my wife, Evelyn, and I built in Philadelphia. Married for over 45 years, we have two sons, one daughter, and six grandchildren.

Edwin Hearn

I was born in Rhinebeck, New York, during the Depression. My father worked for a cousin in the plumbing business and my mother was a homemaker and tended to my two older sisters. I was the third child, and shortly after I was born, we moved to Newark, New Jersey where my father returned to his chosen field of manufacturing engineering, even though he did not have engineering training beyond math and science at the high school and college level.

Math and science were my strongest subjects. My father's interest in engineering, plus his encouragement (and perhaps insistence), led me to take the full math and science load available at my high school. My parents expected their children to go to college and my older sister and I did. My middle sister chose to work, but later as an adult graduated with a degree in accounting.

I attended Rensselaer Polytechnic Institute (RPI) in Troy, New York and for several reasons (lack of discipline, a major family illness, and marriage), it took me eight years to complete my degree, the last three years at night school. I graduated with a degree in Mechanical Engineering.

Part of the time when I was not attending RPI, I worked for the Engineering Department of the University of Florida. I was a technician on an Air Force project developing test methods to simulate the effects of high-speed flight on various shapes of wing leading edges and nose cones. This project used large (200 KW) radiofrequency generators to provide the heating. Eventually the idea was to have a facility at Dayton Air Force Base (AFB) that could test full-scale wings and missiles. This was during the period of Sputnik and Vanguard.

Later I worked as a technician for a small company, which developed the first version of the high power diodes for use in automotive generators. Unfortunately this company sent out samples to auto manufacturers before getting the design patented.

My first job with General Electric (GE) was in the Ordnance Department in Pittsfield, Massachusetts, as a technician. One of the benefits was that GE provided transportation to RPI as well as paying for my tuition. I was there from 1959 to 1961 when I transferred to Philadelphia. At that time I was assigned to a program known as Samos and later 698BJ.

For about the ten years following my time on Corona, I was involved with other "Milspace" programs up to the end of the Satellite Recovery Vehicle (SRV) era. Starting in 1979, I became the Product Manager Military Space Programs and continued this job until the end. After that I was the Product Manager on other programs until I retired.

My wife Ann and I are retired. Ann and I (she retired as an English-as-a-second language teacher) spend our time traveling, including a Russia by River trip that included a trip to Red Square at night. My reaction—how did I ever get here?

Richard Lasher

I came to General Electric (GE) from McDonnell Aircraft where I had worked for five years after graduating from Tri-State University in Indiana with a degree in engineering in 1956. At McDonnell I indulged my love of all things flying and mechanical as an engineer on missile projects. Growing up in Auburn, New York, with a machinist father and housewife mother, I was an avid builder of model airplanes in college and earned an Ace Award with my local Air Scout Squadron, the equivalent of an Eagle Scout rank.

I attended the vocational high school in Auburn rather than the college-prep school but decided nevertheless to continue my education.

Upon graduation I applied to several engineering firms and was drawn to work on missiles. In those days missiles were very much like an airplane except without a pilot. They were smaller systems and you were more intimately involved in them.

While working on Corona, I had had responsibilities on other projects as well, and I moved on to various other engineering positions at GE including work on the Peacekeeper and Minuteman systems.

I retired from GE in 1993 and have been simply enjoying myself since then. My wife, Beverly, and I moved to North Carolina in 1999 where I have a woodworking shop and a boat. We have three children and six grandchildren.

Alfred Little II

I was born July 20, 1925, in Plainfield, New Jersey. I graduated from Thomas Jefferson High School in Elizabeth, New Jersey, in 1943 in the middle of World War II. As part of the war effort, each member of the class was required, before graduation, to take a standardized test and to check off any preference as to which of the Armed Forces they would prefer to be in. With a strong academic record (third in my class), I checked "Navy."

I was selected to be in a Navy officer candidate program, called V-12, and reported to the facility at the graduate house at the Massachusetts Institute of Technology (MIT) on July 1, 1943. I started as an apprentice seaman and was to be educated as an engineer. When the choice of engineering specialization was required, I chose aeronautical (structures option, the other being power plants).

I received my degree and commission in February 1946 and was posted to the Naval Air Material Center at the Philadelphia Naval Base. I ended up on the Experimental Structures section of the Structures Laboratory of the Naval Air Experimental Station. I remained in this organization until September 1956.

During my time in the Navy, I obtained my MS in Mechanical Engineering from the University of Pennsylvania and my MBA from Temple University.

I was released from active duty and became a civilian employee in August 1946. When the section supervisor, J. Albert Roy, left for Martin-Orlando, I became section supervisor. The section contained about five people including two techs, a physicist and a couple of engineers.

In 1948 I met Marian Newlin at a dinner party. We married in 1949 and soon began a family that would include four children.

In the Experimental Structures section, much of the effort was devoted to establishing a laboratory of tension-compression testing machines. This included a 5-million-pound capacity machine (billed as the "world's largest"), a 600,000-pound machine, 60,000-pound machines and an inherited German 100,000 pound structure fatigue testing machine.

I became less and less satisfied with their productivity and with the usefulness of their work and when General Electric (GE) was frantically searching for engineers to work in Philadelphia on the national priority programs of Intercontinental Ballistic Missiles; I made the change and joined GE.

Following the success of Corona, though still involved in the space-related programs, the stressful workload lifted enough for me to pursue outside interests with my wife. An avid outdoorsman, I was also a long-time announcer at the Delco Scottish Games and was an enthusiastic participant in Scottish country dancing.

My assignments included proposal manager of Manned Orbiting Laboratory (MOL), member of MOL negotiating team and manager of integration engineering on MOL. Apparently this was the Air Force's bid to lead in manned space. Subsequently I became manager of engineering integration and evaluation on MOL (until it was cancelled) and program manager of a partly National Aeronautics and Space Administration (NASA)-funded preliminary design of an Orbital Medical Lab.

I was caught in the cutbacks at GE and went to work for RCA. There I worked on a number of commercial communication satellites. My last assignment before retiring in 1991 was as manager of mission assurance on the NASA Advanced Communication Satellite.

In 1985, I was among the Corona veterans who received a United States of America Space Pioneer medal from William Casey, Director of the Central Intelligence Agency. My wife Marian was allowed to see the medal but I could not tell her what it was for.

Editors Note:

The editors would like to express their appreciation to Nancy Little for her successful efforts in gathering the material for this chapter.

Alfred Little II died in August 2002 of liver cancer. He was 77.

Robert Lowe

I was born February 6, 1929, in Wilmington, Delaware, where I grew up the fifth of six children. My father, who was a commercial fisherman in his early years, was a plasterer by trade. He and his brother formed a plastering contracting company.

I had an early interest in constructing things, possibly because of my father's business and having a construction yard out back. I was always building something—shacks out in the back yard, and tree forts, anything I could put together.

My two brothers and I all attended college while my sisters went to business school. I received my Bachelor of Science degree in Mechanical Engineering from the University of Delaware in 1951.

I worked for the Navy for four years as a test engineer and as a design engineer on test equipment. During my college years, I had a military deferment, but the Army draft caught up with me and placed me in a special program called "Scientific and Professional Personnel." A requirement to qualify was a degree and three years experience. I served in the Army from February 1955 to February 1957. I was assigned to the Edgewood Chemical Center, a civilian agency of the Army. I was in uniform but worked mostly as a civilian on assembly line test equipment to test for, among other things, leakage in gas masks.

My brother-in-law worked for General Electric (GE) as an engineer and I knew that by reputation it was an exceptionally fine company. So, while I was stationed in Maryland, I saw a newspaper item about General Electric opening a space department in Valley Forge, Pennsylvania. A friend and I left the Army within months of each other and both got jobs at GE.

Valley Forge was not far from both my home in Bucks County, Pennsylvania, and from my family's home in Wilmington, so the situation sounded perfect. But in fact, the facility in Valley Forge was not built until the early 1960's, and the program actually started in Philadelphia.

Following my work on Corona, I was manager of Search Engineering/Recovery Engineering on other programs, which lasted a long time until finally being phased out. I then was a liaison at Vandenberg Air Force Base (AFB) for a year. Back east, I was Engineering Manager in ground support equipment, among other things.

We did proposal work, lost a big proposal and then everything seemed to disintegrate. I was assigned to Manned Orbiting Lab (MOL) in 1967 but that was cancelled in 1969 by the Air Force which put many people out of work. In turn, GE laid off many people. I moved to the main center in Valley Forge in 1969 before transferring to Philadelphia for a while.

With an offer to go into technical recruitment looking for personnel for other companies (head hunting), I quit GE in 1970. Soon I was in business for myself for about five years.

Because I had been in the military during peacetime, I did not qualify for GI benefits, but I learned about VA benefits and found out I was entitled to free education. So during this time, I went back to school at Drexel to earn my MBA, getting my last 12 credits from Bryant College.

I said, "Why not? I've got time." It's always good to learn. An MBA can always help me. I was in the recruiting business, and the more I could learn about business the better off I would be. So I did it.

In the mid-1970's, I started work as chief engineer for a paper-coating company in Rhode Island. The company had two plants, one for coating book-coverings to look like leather, the other for laminating vinyl to paper stock, embossing it with the texture of any animal or textile. I retired in December 1991.

As I write this, I keep busy doing tax work. For 17 years I have worked for H&R Block, and, more recently, have been doing the work on a non-profit basis. I also spent six years renovating a cottage I bought in Maryland.

I have four children, a son who works as a contract manager, and three daughters, one is a CPA, one is a paralegal, and one is a stay-at-home homemaker. They all live on the east coast now, making get-togethers a little easier, and there are 10 grandchildren.

Bernard Mirowsky

I was born April 29, 1927, in McAdoo, Pennsylvania. My father had come through Ellis Island at the age of 5 where the family name received an unwitting spelling change. The "I" on the end was changed to a "Y" and thus Mirowski became Mirowsky.

I joined the Navy at age 16, reported after my 17th birthday and went to Fleet Sonar Operating and Maintenance School in Key West, Florida. I was assigned to the destroyer USS Joseph P. Kennedy Jr., where Robert Kennedy was also assigned to Combat Information Center during General Quarters' activity. I remembered Bobby as very seaworthy. Once during rough seas, most of the "land lubbers" in the Mess Hall were getting sea sick. Across the table, Bobby offered, "Bernie, I'll eat your pie if you don't want it."

The destroyer was newly christened, and its new sonar had not performed in two trials before I reported on board. Reading the manuals, I gave up liberty to work into the early-morning hours to find and fix the wiring faults in the system. It was a precursor to my engineering future.

I was only 18 when the war ended, and I was discharged. I earned a high school war diploma to take advantage of Bayonne Junior College. That meant night school while working at an embroidery mill. Also attending that school was Veronica Maak. Veronica and I were married in 1947 between our first and second year together.

I attended the University of Missouri and by the time I received a BSEE in 1951, Veronica and I had two children.

General Electric's (GE's) Carl McEckron, who was famous because he conducted lightning experiments on the Empire State Building (and was a boyhood friend of Veronica's father, Charles Harry Maak), hired me. I entered the GE Engineering Training program, eventually supervising a short circuit lab that evaluated the effects of lightning.

From 1954 to 1955, I designed and built a prototype automatic in-process and warehouse inventory control system for production control of a GE manufacturing department. GE adopted the system of production scheduling and inventory management, using IBM computers.

After my work on Discoverer, I worked on the largest satellite ever flown, the first time that the first flight article of a major satellite performed successfully throughout a mission as did five more when they transferred to Apollo. I also created a simple electromagnetic code (two-page drawing) so that every wire and connector pin was EMC codified and harness bundled so as to preclude cross wire and cross bundle magnetic interference.

I also designed the control, electrical power and recovery aid systems for the Discoverer.

Later, I moved on to designing and testing large satellites, managing the preliminary design for the Apollo Launch Checkout Complexes, serving as consultant to the Joint Technical Advisory Committee to the President of the United States, (passed up the opportunity to become a National Power Czar), created preliminary designs for space stations, built a prototype hospital for a space station that was demonstrated with Astronauts for Dr. Berry (Chief Astronaut Physician), and developing other space-related work. I wrote a "landmark" paper on the effects of short duration power outages (5 to 40) on computers and transistor electronics.

I was personally commended by President Johnson for my work on Apollo. President Johnson looked me square in the eye, firmly shook my hand, and said, "Thank you for your service to our country!" I wonder, to this day, what exactly earned me that handshake.

Veronica and I have been married over 60 years. We have seven children, 16 grandchildren and ten great-grandchildren. We live on the edge of New Jersey farmland in Annandale, about 18 miles from the Pennsylvania border.

Lt Col Harold Mitchell (Ret)

I arrived in Hawaii in 1958 with extensive flight experience and significant experience catching objects in mid-air. Born in Bloomington, Illinois in 1925 and growing up in the small farming community of Greenfield, Illinois, my first loves were horses and airplanes.

Although I had an appointment to West Point for the fall of 1944, I eagerly enrolled in the Army Air Corps Aviation Student Program in the spring of 1943 when I graduated from high school. My subsequent experience as a chin turret gunner on a B-17 during World War II started a lifelong military career.

I spent the last six months of the war with the Eighth Air Force, 95th Bomb Group completing 10 combat missions over Europe.

After being discharged in February 1946, I returned to the Midwest and studied agriculture and business at Kansas State College in Manhattan, Kansas. While enrolled there I joined the first Air Force Reserve Officer Training Corps (ROTC) class. Upon graduation in 1948, I was commissioned a Second Lieutenant and recalled to active duty to attend pilot training in June of the same year.

The next three decades would be filled with frequent moves and many challenges as I became both an ever more proficient pilot experienced in training and administrative roles. I served tours in both Korea and Vietnam in the early 1950's. I was also involved in flying supply missions to support Distant Early Warning radar stations in Alaska. These missions involved airlifting steel beams, generators, timbers and other material to short dirt airstrips that had been bulldozed up the sides of mountains in Alaska. I became experienced flying into remote areas as well as instrument flying into places like the fog-bound Aleutian Islands.

I was promoted to Major in 1961, transferred to the States and assigned to Operations Plans Staff, Nuclear Testing Group 8.4. Following a three-year tour at Kirtland Air Force Base (AFB), I was reassigned to the Nuclear Weapons Development and Simulations Division Air Force Space Command (AFSPC) Headquarters, Andrews AFB, Maryland. In 1966, I was promoted to Lieutenant Col. and received orders for Southeast Asia in September 1967. While in Vietnam, I was assigned to the 14th Special Operations Wing flying night reconnaissance missions in AC-47 Gunships. May through June of 1968 I was assigned temporary duty to Eglin AFB, Florida to fly the Modification Acceptance Test on Modified AC-119J Gunships. Returning to the 14th Wing at Nahtrang, I was appointed In-Country Project Officer for introduction and operations concept for the AC-119J night reconnaissance gunships. During the remainder of my tour, I maintained proficiency and flew night armed reconnaissance missions in both the AC-47 and the AC-119J gunships.

At the completion of my Southeast Asia Tour, I had flown 117 combat missions with an accumulated flight time of 468 hours. On my return to the States, I was assigned to the 821st Combat Support Group, SAC, Ellsworth AFB, South Dakota. After two years at the 821st, I was awarded the Air Force Meritorious Award for my outstanding achievements in maintaining the highest level of proficiency and operational readiness in the units under my command.

In June 1971, I was reassigned to Office of Operations and Training, Headquarters Strategic Air Command. In that capacity I was associated with Command Base Support activities as well as Base Disaster Preparedness and Civil Defense. While assigned at the headquarters, I was tasked with and completed numerous assigned projects unrelated to my primary area of responsibility. For my achievements as a Command Staff Officer, I was awarded the first Oak Leaf Cluster to the Air Force Meritorious Award.

On July 1, 1971, I retired from the United States Air Force to my farm in rural Missouri to raise quarter horses and Angus cattle. After selling the farm in 2002, I moved to Sedalia, Missouri.

Nancy, my wife of 35 years, and I raised four children. Nancy died of lung cancer in 1987.

I subsequently married Anna Marie Klien Mitchell.

My children are Dennis E. Mitchell, Retired Navy Captain; Michelle M. Hanko, former Navy Lieutenant; Patricia H. Mitchell, Doctor's Assistant; and Theresa K. Mitchell, Commander, US Navy Judge Adjutant General.

Walter Overstreet

While many of the engineers who worked on Corona landed at General Electric (GE) right out of college, I bounced around for several years, getting a broader variety of job experiences. Graduating from high school in the small town of Bradfordsville, Kentucky, in 1944 with an eye on an engineering degree, I knew I would be drafted when I turned 18 and deferred college, taking a position with BF Goodrich.

After a year in the Navy, I spent a year at a junior college in Kentucky and transferred to the University of Louisville, earning a bachelor's degree in chemical engineering in 1950. From there, jobs at DuPont plants in Kentucky, Delaware, and a number of other short-term positions followed.

My career path changed when I found work with the Army at the Aberdeen Proving Ground, where testing on missiles and warheads traveling at high speeds laid the ground for future work on satellites. I briefly left the missile and space world to return to a construction job once more before landing at GE in the missile ordnance group. Things then settled down for a while, as I spent the next 15 years working in aerospace.

Several months after the successful recovery of Discoverer 13, I moved on to working on another program at Vandenberg Air Force Base (AFB), where my experience in testing proved useful as new concepts brought new failures and challenges. In 1963, I returned to Florida to work on Apollo and later back to Philadelphia for work on the Manned Orbiting Laboratory (MOL). When the latter program was canceled, I switched from aerospace to nuclear engineering and moved to New York to work on building nuclear submarines for the Navy and commercial nuclear power plants. I also spent time working on electro hydrodynamic and fusion power super conducting magnets.

Upon retirement in 1987, I elected to remain in Schenectady, New York, where my wife grew up, but I still retain my ties to Kentucky, where my own family has roots stretching back to the eighteenth century. A genealogy buff, I have traced my family back to the earliest American colonies. As I write this, I also play bridge and spend time with my children and grandchildren from my two marriages.

Hilliard W. Paige, Sr.

I graduated from Worchester Polytechnic Institute and joined General Electric (GE) in New York. Then, I moved to Aircraft Engines in Cincinnati and then to Aerospace Projects in Philadelphia.

With GE in New York I worked on a variety of engineering projects. I headed up the development of the first sonar mine sweeping system, and the first naval nuclear reactor, which powered the Sea Wolf nuclear submarine.

At the start of the Korean War, I transferred to GE Jet Engine Operations in Cincinnati, where I was the Project Manager for GE's J-47 and J-73 engines. It was during this time I developed the confidence of the Air Force that would later gain me permission for placing a camera on the Intercontinental Ballistic Missile (ICBM) reentry test vehicle.

I continued to be promoted to higher management positions, eventually running the GE Aerospace Group in charge of all military and space contracts except jet engines. I oversaw the sale of the company's computer business to Honeywell and later served in the newly created position of Senior Vice President for Technology. I did not find this position, which was basically staff work, to be a good fit, and I retired from GE in 1971 after thirty years.

Upon retirement, I became president of General Dynamics, organized a communications satellite venture, and started a nuclear power consulting firm. Since the mid-1970's, I have spent most of my time as a "professional board member" serving, over the years, on as many as eight corporate boards. At age 87, I was still serving on three.

I spend my free time with my wife of more than 60 years, Dorothea, and our three children and six grandchildren, dividing my time between a home in Florida and another in Virginia.

Myron (Mike) Peterson

I was born May 10, 1925, in Omaha, Nebraska, one of four brothers. My father was a rate specialist for the Missouri Pacific Railroad. Neither of my parents completed high school and advanced education wasn't necessarily foreseen for me. They did encourage me to finish school and I earned a partial scholarship to the University of Nebraska at Omaha.

After one semester, however, I entered the Navy Reserve.

I went into a Navy program called V-12, which was to train engineering officers. They were very short of engineering officers in early 1943. We were actually sent to engineering colleges. I went to Iowa State in Ames.

I was in the program for two and a quarter years. I was within one semester of finishing when World War II ended and the program ended. I then received my commission and was sent to the Pacific. I was stationed in Oahu and then on the Bikini Atoll where they had the first atom bomb tests to test durability of naval surface ships and submarines. I was in Special Communications handling special mail.

Still short of my degree in July 1946, I got married and went to Tucson to attend the University of Arizona. There I completed my education in electrical engineering.

I quickly received an offer of employment from General Electric (GE) so my new wife and I packed up and moved to Schenectady, New York. I started in an engineering training program, with assignments in various locations. After I completed the training program in 1949, I received my first permanent assignment in Lynn, Massachusetts, where I was in charge of testing engines. When a major portion of the business moved to Cincinnati, I followed in 1951.

I led testing of the new models of jet engines under development during the Korean War. They were developing a larger engine than the one that flew the initial F86s. After that engine was qualified for flight in 1955 I was assigned to a brand new development engine—the first turbo fan for GE.

In 1957 the Air Force cancelled its funding after they were not successful in that design configuration. GE then assigned me to a small team developing an aft turbo fan and I was subsequently assigned to initiate testing on other new jet engines. In 1958 to 1959 the program went through serious cutbacks because we didn't have the work.

Rather than take a lesser job, I called on an old friendship with Edward A. Miller who had worked with me in the early 1950's in fan development. This led to my involvement in Corona.

In the fall of 1963, after the reentry vehicle contract was cancelled, Miller assigned me to lead a study team to look at the benefits to reconnaissance of adding maneuverability to the orbiting spacecrafts. This study team was located in Valley Forge. While that was continuing in 1964, I was asked to go to a proposal team that was forming to provide a spacecraft for orbiting and landing on Mars.

I led the business part of that proposal in providing logistics for the vehicle. (The spacecraft and the program had several different functions.) The proposal was submitted but never went forward at that time. It was a good learning experience. I think we did a lot of good work. It just didn't end up in a successful program.

Beyond the Mars Lander proposal, Miller asked me to take over and build up an engineering program in Los Angeles to interface with Aerospace and the Air Force systems on another program. I worked on this from 1966 to 1969 when it was also cancelled.

After looking around for other aerospace opportunities, I noted that the future was not looking bright in that field. I spoke again to GE's engine people and learned they were just getting started on the commercial aircraft application of the engines. So I chose to go back into the jet engine business in Cincinnati. There I continued in a variety of assignments, mostly in commercial and military applications of the turbo fan family.

I knew I was lucky in my successful return to engine development after a decade in the reentry vehicle program. Usually if you're gone out of a business more than three years, you're out of it. But I found when I went back I was able to work my way back in and able to make a contribution.

I remarried in 1965 but after I retired in 1987, we divorced. With my mother then in the Phoenix area, I moved back to Arizona. I also have brothers living in the area as a family anchor. And not far away are my three children, four grandchildren and two great-grandchildren.

I admittedly had an odd career path at GE. For all my successes in the jet engine field, I do not regret my space adventures.

Charles L. Robinson

My background had prepared me for the critical challenge of qualifying the Satellite Recovery Vehicle (SRV) for the Discoverer/Corona project.

My training near the end of World War II kept me on U.S. soil just long enough that my preparations to ship out to the Pacific were halted by the Japanese surrender. I had passed all the Army Air Forces tests to train as a pilot, navigator, and bombardier. With the war's end, they let me out of the service.

My father had been a soldier in World War I and I was eager to serve. The end of the war meant missing out on America's great effort of the 1940's. My decision was to continue my postponed education in order to prepare me for future challenges.

Growing up in a family whose father was a self-educated construction carpenter in Tulsa, Oklahoma, I understood that success was driven by self-motivation and that my intelligence would open doors. Watching newsreels and air shows in Tulsa early in World War II, I became intrigued with how airplanes worked. Tulsa was home to a plant that built bombers, and it was just natural to want to know about it. I decided I wanted to fly one, and later, to learn to build one. Later I won a scholarship to the local Spartan College to study aeronautical engineering.

I joined the recently opened intensive two-year program (founded by J. Paul Getty) that rewarded students willing to do little else but study with a thorough knowledge of aeronautical engineering that allowed them to compete with graduates of Massachusetts Institute of Technology (MIT) and elsewhere. All you had time to do was go to school, do your homework, and do a little eating and sleeping. You didn't have time to fool around. I went to theoretical classes an hour a piece, five hours a day and five days a week. Most people couldn't get through this. It was just too difficult. You could not mess around. You would never catch up.

The program served me well in my first job at McDonnell Douglas in St. Louis, where I worked briefly before deciding to finish my bachelor's degree at Tulsa University.

With a friend who had recently finished his service in the Navy, I moved to the Dallas area after graduation and found a job at Chance Vought Aircraft. The quality of my education again became clear when Chance Vought included me in a group of employees sent to Connecticut to supervise MIT graduates in the design of a pilotless aircraft. Throughout my career, I felt the Spartan College program placed me on a level with engineers from the top schools in the country.

While in Connecticut, I married my wife, Janet. She was a flight attendant with American Airlines whom I'd met in Dallas. Less than a year later, the first of our three children was born. Looking for a better job opportunity, I contacted General Electric (GE) based on a job ad I'd seen in Dallas after contacting a friend who worked there. I started at GE in 1956 in Philadelphia and would spend the rest of my career working on various spacecraft projects before retiring in 1991.

After the Discoverer 13 launch, I stayed on at Lockheed's facilities through several more launches, always working long hours. After that, I returned to GE's Philadelphia office and moved on to other tasks, including a commercial satellite project with the Japanese and aspects of the International Space Station.

I returned from California with a reputation for being good at solving problems—I had taken Corona from a string of failures through the first of what would be a much longer string of successes. I never returned to work on my first love, airplanes, but ended up being pretty happy with spacecraft and their accompanying challenges.

After retiring from GE in my 60's, I moved to Florida, where I have kept a busy schedule conducting duplicate bridge tournaments six days a week. My new wife Peggy and I have taken 20 cruises all over the world while teaching bridge, visiting China, Australia, the Mediterranean, and other exotic locations.

Daniel Rossman

I showed an early affinity for flying. My mom often told the story that when I was two years old and playing in the back yard, I put two clothespins together to make an airplane. More than once, when an airplane passed over, I "followed it" until neighbors brought me home.

I built my first model airplane when I was six and Jimmy Doolittle was always my boyhood hero.

Just after my 19th birthday, the military dropped the Aviation Cadet training age requirement to nineteen and I was off and running.

After pilot training I was assigned to B-25s, trained in South Carolina, and then was sent to Hunter

Field in Savannah, Georgia, to pick up an airplane and fly it to "The War" in the Southwest Pacific.

By war's end, I had been flying for 22 months and lost six planes.

After V-J Day I was stateside by Thanksgiving and headed home to Philadelphia. I stayed in the Air Force Reserve and studied industrial engineering at Drexel Institute of Technology.

In 1950 I started work at Piasecki Helicopter Corporation, which pioneered the tandem helicopter. I'd been a neighbor of Frank Piasecki, who gave me "lessons" on building model airplanes, but I did not even think of using that relationship to get a job. During my afterhours interview for a design job, the three interviewers left the room. They came back with an unexpected offer—the company was starting an engineering planning and scheduling operation. They asked me to try it for ninety days with the option of going into design if it didn't work out. I was game to try.

And that's where I stayed. Joining Piasecki early in their first expansion allowed me to be closely involved in the development of all the management systems used by engineering. Also, by being in the project office, I gained insight into all technical, business and administrative aspects of the business. One change I was able to effect, that would become important in my General Electric (GE) career, was to convince management that the engineering division should do the basic man-hour estimating of engineering effort rather than finance department.

In 1956 I returned to flying and joined the Pennsylvania Air National Guard as an aircraft maintenance officer.

Piasecki later became VERTOL (Vertical Takeoff & Landing), now a division of Boeing. I stayed six years until realizing that the business environment and company structure limited my growth. When GE moved the reentry vehicle project to Philadelphia, I decided to try for the "major league." One of the project engineers went to GE and I gave him my resume. That's how I met Ingard Clausen.

I retired from GE in January 1984 after spending my last year as project manager for a facility built in Sunnyvale, California to house GE people supporting various classified space programs.

Sylvia and I have been married over sixty-three years. We have two daughters, Lynn Beth and Hope Ellen, and two grandchildren.

Walter J. Schafer

I was born in New York City on January 2, 1929. My mother was a homemaker, my father, a 1915 graduate of New York University (NYU) School of Commerce, was an active entrepreneur in many businesses. I had an older sister and a younger brother.

I became interested in engineering as a young boy while working in my dad's air conditioning business. Higher education was always a priority in the Schafer family and, given my interest in engineering, I applied to NYU upon graduating from high school in 1948.

To put the time to good use, I joined the Army for a two-year hitch. Because I had some technical experience, after basic infantry training I was assigned to an engineering operation and sent to Japan to 8th Army headquarters. These two years were a great learning experience. I was also lucky to serve between WWII and Korea and earn the benefits of the GI Bill as well.

I married my lovely wife, Irene, in the last year of college and over the years we were blessed with four wonderful children, Jeffrey, Eric, Michael, and Leslie.

After graduation, I got a job at NYU as a Research Associate while attending graduate school. I majored in Engineering Mechanics and Applied Physics. My activities involved the development of solid and liquid propellant casings for rockets and boosters.

In 1954, I joined a subsidiary of Curtis Wright to design and develop jet engine afterburners and ram jets. The work was very interesting but in a very bureaucratic environment.

I searched for a better opportunity and I was attracted by an advertisement placed by General Electric (GE) to join their newly formed Missile and Space Vehicle Department and help develop solutions for atmospheric reentry vehicles. I applied and was hired as a Design Engineer in the Vehicle Engineering Group. I helped develop early designs and advanced materials for the Thor and Atlas Intercontinental Ballistic Missile (ICBM) programs and, with a reorganization, was named Manager of Space Vehicle Engineering, which included the recovery capsule for Corona.

GE was a training ground and a wonderful industrial education for me. Even at the young age of twenty-five, I was given challenging management responsibility as well as technical experience with great freedom. I carried those concepts throughout a very successful post-GE career.

I worked with GE through most of 1961 and then went to Fairchild Industries in 1962. I was involved in starting AVCO's space division and worked in laser research at Everett Research Lab. In 1972, I started my own company, W.J. Schafer Associates, Inc., which I sold in 1988. The research and development company continues to operate as Schafer Corporation in Massachusetts. When my son was seriously injured in an accident, I became involved in spinal cord research with Dr. Ron Cohen of Acorda Therapeutics.

At this writing, I continue work as a consultant to company presidents and officers. My three surviving children are all professionals and Irene and I have two granddaughters.

John Segletes

I had a few false starts before landing the job at General Electric (GE) that would help define my career as a mechanical and aerospace engineer. A Philadelphia native, I graduated from the Drexel Institute of Technology (now Drexel University) in 1957 and first took a job with RCA and later the Atlantic Refining Company, each for only a few months before joining GE and eventually the Discoverer project in 1958.

I initially had been accepted to an engineering training program at RCA with about 300 other soon-to-be college graduates. But just before we were supposed to graduate, we were all called into the auditorium—and we were all told we were being laid off. I ended up being among the lucky few for whom RCA did find room, but the experience left me less enamored with the company. Combined with a long commute from my home and new wife in Philadelphia, I found RCA lacking and started to look elsewhere.

My next job was closer to home, at the Atlantic Refining Company, which made petroleum products. The job looked good, but it wasn't really one that required a lot of skill so I started looking around once again. While still at Drexel, I had worked briefly for GE under a co-op program that had students get a total of 18 months of on-the-job training while earning their degrees. The co-op experience introduced me to GE's Missile and Space Division, where I applied again in early 1958 and was hired. The job I had at GE (during the co-op program) was really a high quality type job from an engineering standpoint.

My interest in engineering stretched back to my childhood, when my father worked as a mechanic repairing Greyhound buses and my mother for a time worked at a ball bearing company, where I also worked while a teenager. My high school offered a mechanical arts course which exposed me to wood shop, electric shop, mechanical drawing, and other related subjects. Taking those courses made it clear to me that I was interested in mechanics and engineering.

Over the course of high school, I realized I wanted to study engineering in college rather than following in my father's footsteps but I also realized my high school courses left me ill prepared for that. I started at Drexel in an evening program, taking college prep classes. Four years later, the army drafted me, and I spent two years doing clerical work in a logistics operation in Japan.

Upon returning to the United States, my determination to get a college degree was even greater and I had the GI bill on my side. I enrolled at the day school at Drexel, completing my mechanical engineering degree in 1957.

Shortly after Discoverer 13's success, GE moved me onto another project. I stayed with the company for another few years, working on other space-related jobs. After deciding to leave GE because the grass always looked greener on the other side of the fence, I did stints at Fairchild Hiller and Martin Marietta. Through sales, acquisitions, and divestitures among aerospace companies, I also ended up working for Teledyne and Lockheed. In 1985, I returned to GE on a classified aerospace project. My group was sold to Martin Marietta, which later merged with Lockheed to form Lockheed Martin, the company from which I retired in 1999.

Since then, I keep busy doing genealogical research on my family and traveling around the country to meet relatives. My wife of more than 50 years, Irene, and I both have family in Germany, where we took a trip that would involve meeting dozens of relatives still living there. We have five children and six grandchildren.

Anthony M. (Mac) Smith

I was born on August 7, 1931 in Baltimore, Maryland. My father came from a very poor background and rose to become the Vice President of a major Surety Insurance firm. My mother was the youngest of six girls, married at age 18, and became a stay-at-home mom to raise my brother and me.

I attended The Cathedral Grammar School, Loyola High School, and Johns Hopkins University and received my B.E. degree in Mechanical Engineering in 1953. Although I was an honor student in high school, I found the engineering courses at Johns Hopkins to be very difficult. In fact, many others did also, since only 9 of the original 45 in the freshman class graduated in 1953.

I had pursued a career in engineering because of my early interests in mechanical toys, model airplanes and automobile repair. Despite my early struggle with the courses, I have never regretted the effort it took to pursue a technical career. At my brother's urging, I joined the Army ROTC in 1949 and was commissioned a 2nd Lt. in the Corps of Engineers in 1953. I served in positions as a Heavy Equipment Platoon Leader, Company Executive Officer, and Company Commander. I actively practiced my specialty in demolitions during a one-year assignment with the 332nd Engineering Aviation Battalion constructing airstrips to support the downrange rocket tracking stations in the Bahaman Islands.

After discharge, I continued my education at night school on the Korean Bill of Rights and received my MSME in 1961 from Drexel University. Unlike my aforementioned undergraduate difficulties, my graduate work went smoothly and led to a 3.8 grade point average and graduation with honors.

In June 1953, I met Mary Lou Downey and we were married in June 1955 when I returned from my Army assignment in the Bahamas. We have six children, six grandchildren, and celebrated our 50th anniversary in June 2005.

After my Army duty, I spent a brief 7 months time with Westinghouse—Bettis in the nuclear submarine program as a thermal hydraulics engineer. The work at Bettis was quite fascinating and included an opportunity to experimentally demonstrate my analytical solution to the presence of natural water circulation on a long pipe run on the Nautilus engine mockup. But my tenure at Bettis was short lived. So I left to join General Electric (GE) in late 1956 at their missile and space business in Philadelphia where I spent 18 years in aerodynamics, test, and reliability positions.

During the time I was working on aerodynamic testing and Corona (1958-62), I also led one of the teams on the GE contract to study design options for Apollo. My team specifically investigated several recovery schemes for the Command Module and ultimately recommended the three parachute system that the National Aeronautics and Space Administration (NASA) selected as the preferred design for implementation. I also led the team in the first Jet Propulsion Laboratory (JPL) sponsored study to develop a parachute system for a soft landing on Mars.

After my work on recovery systems, I managed a reliability engineering group on a classified space project for several years. I was also a member of a select team that was chartered to develop technical approaches for "Long Life Space Systems". My work here supported the creation of a unique "Defect Flow Analysis" method to evaluate failure characteristics and screening effectiveness. I also led the development of the "Dynamic Mission Equivalent" test compression technique.

As I write this, most of my time is spent traveling with my wife, which includes visits with our children and six grandchildren and friends. We are both in good health and enjoy swimming and working out to keep fit.

Walter D. Smith

I was born in May 1922. My father was an organic chemist educated at Columbia University. My mother was a graduate of Barnard College. They provided a home environment for my two sisters and me that brought many early learning experiences.

Charles Lindberg generated a strong interest in aviation for me with his "Barnstorming" flights in World War I vintage aircraft and the solo transatlantic of the Lone Eagle. This interest continued as I designed and flew model airplanes and gliders and resulted in my decision to pursue a career in aeronautical engineering. I enrolled in Purdue University in 1940 and graduated in 1943.

Following graduation, I joined the Navy and was commissioned an Ensign in the Navel Reserve after completing the "ninety day wonder" school at Columbia University. My navy career consisted of three major duty postings.

I was first assigned to the Demolition Research Unit where I participated in the design and development of explosive devices that the underwater demolition teams used for beachhead clearing throughout the Pacific theater.

My second assignment was with the Ordnance Investigation Laboratory where I participated in the disassembly and analysis of "live" enemy explosive devices (i.e., torpedo warheads, mines, and etc.) that had been captured and returned to this country to determine if the enemy had anything new we were unaware of.

The third and last assignment was with the Office of Naval Intelligence. Following V-E Day, the Navy had taken possession of a German submarine headed for Japan loaded with forty tons of blueprints and specifications of some of the latest German aircraft and I was given the job of helping to evaluate and catalogue these prints.

After being separated from active duty, I took employment with the Glen L. Martin Company in Baltimore and remained with them for twenty-two years as they progressed from Glen L. Martin to the Martin Company and on to Martin Marietta after the merger with American Marietta.

During my early years in Baltimore, I met Edith Miller. We married in 1952 and have one daughter.

After the Air Force opened Cape Canaveral, I was promoted to the position of Chief Engineer of the Canaveral Division where I undertook the technical oversight of all Martin missile testing at "The Cape," as well as the activation (installation of missile system unique equipment) of the launch complexes. During this time, they were launching Titan-I, Titan-II and Pershing missiles. I directed the feasibility study that showed that launch complex 19 could be modified to safely accommodate the launches of the National Aeronautics and Space Administration's (NASA's) Gemini two-man spacecraft.

After Martin Marietta was awarded the contract to supply the launch vehicle for the Gemini, I transferred back to Baltimore as Chief Engineer to direct the redesign, modification and "man-rating" the Air Force Titan-II Intercontinental Ballistic Missile (ICBM) to boost the astronauts into space. I became the Program Manager after the first four flights for the remainder of this 100 percent successful program.

When Gemini was completed, I transferred to the Denver Division as program manager on the Titan-III satellite launcher program. I then ran the successful proposal for the contract for the Skylab Payload Integration for NASA.

In 1972, I received the Distinguished Aeronautical Engineer of the Year award from Purdue University. The year before, Gus Grissom had received the award, and the year after, the award went to Neil Armstrong.

I worked for GE for 14.5 years and retired in 1983. Since then I have been involved in volunteer work and I relax by golfing, fly-fishing and bowling.

In 1999, Purdue University named me a Distinguished Alumnus. Edith and I celebrated our 54th wedding anniversary in 2006. As I write this, we live in Valley Forge, Pennsylvania.

Dr. George Sutton

In the mid-1950s, I received a bachelor's degree from Cornell University and a PhD from Cal Tech. I had worked briefly for Lockheed and was looking for a new opportunity. When General Electric (GE) came calling, I knew I had found it.

I joined GE after a whirlwind decade of engineering study, an interest I developed as a child growing up in Queens, New York, near the new LaGuardia airport. Some children like cars. I just loved airplanes. I must have built about 100 models and they were all hanging from the ceiling of my bedroom.

My father used to take my siblings and me to LaGuardia to watch the passenger planes. I would bike over to a nearby naval airfield and I remember being fascinated by the retractable landing gear. Already drawn to engineering, a pivotal moment came for me when my uncle, a doctor, showed me a college physics textbook. Inside was a cutaway drawing of an internal combustion engine. I thought that was the most beautiful thing I had ever seen.

With my goal of becoming an engineer in sight, I applied for and was admitted to Brooklyn Technical High School, a prestigious magnet program in New York City. I took an intense course load of machine shop, drafting, and mathematics, but also found time to co-author the student newspaper's humor column with a friend.

Before college, I enlisted in the merchant marine. After three months, I decided I really didn't like the ocean at all. In the meantime, I found out I had won a scholarship to Cornell University, which could be deferred if I joined the armed services, so I joined in the Army in October 1945, shortly after the end of the war. I was trained as a card typist, a position for anyone who could spell. After a stint in Okinawa, where I was a passenger on some military training flights, I returned to New York in early 1947 and started at Cornell the following fall.

During the next five years, I studied mechanical engineering with an "administrative option" — business and management coursework for the equivalent of an MBA. I also earned a National Science Foundation fellowship to fund graduate study anywhere in the United States. I chose Cal Tech in Southern California.

Cal Tech was a shock to me because the teaching techniques were completely different. You had to derive everything. You have a textbook, but you have to derive all the equations. It was a great learning experience for me. I studied hard and rushed to finish my PhD in mechanical engineering and physics in three years when I found out my wife, Evelyn, was pregnant.

Upon graduation, I found a job with Lockheed in its research laboratory working out of a hangar at the Van Nuys, California airport. My first proposal was for a method of thermal protection during reentry for the Intercontinental Ballistic Missile (ICBM). I learned that there was no satisfactory material, a discovery that would prove useful later on at GE.

I moved on to help write a proposal for the Polaris missile, a contract that Lockheed won from the government. The company wanted new blood for the actual development of Polaris, so others and I looked for work elsewhere. The position at GE appealed to me, as did its location, closer to my family and my wife's family on the East Coast, now that we had a small child.

By late 1957, I was moved off the Reentry Vehicle project and assigned to work on hydrodynamic power generation. I taught a course at the Massachusetts Institute of Technology (MIT) and wrote a book. In 1962, I moved to Washington to become a scientific advisor to the Air Force. One of my assignments during my two-year term in Washington was as an alternate delegate to a North Atlantic Treaty Organization (NATO) committee trying to develop joint programs for aircraft development among member nations.

Although the committee made little progress, I enjoyed seeing prototype aircraft. In 1964, I shifted my focus to ballistic missile defense and spent much of the rest of my career doing research on lasers and optics. While I write this, I still work one or two days a week for various government contractors. In addition, from 1968-1998, I edited the journal of the American Institute of Aeronautics and Astronautics.

In semi-retirement, I spend time with my four children and four grandchildren and have taken up piano lessons.

Ken Swimm

My own involvement in the aerospace business was not too surprising. I was born in 1934 and raised in New York City in an era where adventures in space were constrained to the Buck Rogers Sunday comic strip. In addition, I had the good fortune to attend the Bronx High School of Science, one of the best high schools in the country, and from then on, I focused my attention on engineering.

From there I attended Columbia College, and as the Korean War was still ongoing, I joined the

Naval Reserve Officers Training Corp. My time at college was made all the more pleasant as I met and dated my soon to be wife, Sheila Ahern.

I graduated with both a Bachelor of Arts and a Bachelor of Science in Electrical Engineering. In one busy week in 1957, I graduated, was commissioned, and got married.

After four years in the Navy, I left as a Lieutenant, having served at sea and as an Atomic Weapons Liaison Officer at the Sandia Base in New Mexico. While there, I spent the evenings getting a Masters Degree in Electrical Engineering at the University of New Mexico.

We returned to the East Coast to be near our families and I joined the Norden Division of United Aircraft (now United Technologies). After designing and project managing some radar developments, I fell under the lure of the country's emerging focus on space technology.

I joined the Military Systems Department of General Electric (GE) at Valley Forge in 1965. It was a time of considerable excitement. We were going to the moon, we were involved in a competition with Russia for leadership in space and we needed the information, only available from space, about what was going on behind the Iron Curtain.

I became manager of System Integration and then was asked to lead the Business Development organization. This resulted in the pursuit and capture of the Defense Satellite Communications System (DSCS III).

I became the Program Manager with the satellite, which never had a mission failure in over 20 years of being the backbone of the nation's space communications. The program received the Carlucci Award as the Air Force's best-managed program.

In 1985, I was appointed to General Manager of GE's Strategic Systems Department in Pittsfield, Massachusetts. Here we were responsible for the successful design and delivery of fire control and missile guidance systems for the Trident nuclear submarines.

In 1989, I returned to my origins at Valley Forge to lead the Military and Data Systems Division (M&DS) as we grew the business outside the confines of the intelligence community. It grew to include the Army Global Command and Control System, the Advanced Tomahawk Weapons Control System, Communications Gateways for Communication Satellites (COMSATs), and the Second Tracking and Data Relay Satellite Ground Terminal for the National Aeronautics and Space Administration (NASA). The division grew to 7,000 personnel and over $1 billion in profitable annual revenues.

Nevertheless the core of the business and the "hearts and souls" of the personnel involved remained as the continuation of that tradition started by those bold innovators of the original Corona Program. I am personally most proud of receiving the Medal of Superior Service by the National Reconnaissance Office (NRO).

I retired from Lockheed Martin in 1997 and continue to consult and serve on multiple charitable and business boards. I also served as CEO and then Chairman of the Board for a "turn around" company (now Multimax Inc.) which has made that transition successfully to significant profitability.

Dr. William T. Weir

With a master's degree in physics from Drexel University and a PhD in Systems Engineering from the University of Pennsylvania, I taught evening classes in physics at Drexel while working for various companies. I was working at RCA as a component engineer, having gone to the company straight out of college and worked on electromagnetic relays used on a number of systems for three years.

In 1958, I saw that General Electric (GE) was advertising for engineers in the Minuteman, and many other projects, so I switched companies. I was with GE for the next 17 years.

I left GE in 1974 to start my own reliability engineering company, Evaluation Associates. My firm contracted with up to 10 GE departments and operated three offices at its peak. The Navy was our biggest customer and we became the smallest company to win the Polaris, Poseidon and Trident award. We also contracted with the Air Force and Army.

I was a member of the U.S. scientific delegation that visited the Peoples' Republic of China in 1979. The delegates lectured all over China in universities and technical centers, had dinner with the President, and were interviewed by the Vice President of China.

After selling my company, I worked for Public Services Electric & Gas Co. for seven years. I retired at age 66.

All this time, for nearly 50 years, I had continued to teach in the graduate school of Engineering Management and Physics at Drexel. When I moved to Ocean City, New Jersey, I decided the night drive was too far and retired from that as well.

William Woebkenberg

A degree in philosophy and classical languages seemed an odd preparation for my career as an aviation engineer. However, my studies at Xavier University were followed by a stint as a 1st Lieutenant Navigator aboard B-36 aircraft in the U.S. Air Force from 1952 to 1956. I was stationed at Holloman Air Force Base (AFB), White Sands, New Mexico, and flight became a crucial center of my vocation. My subsequent completion of a BSAE from Purdue University in June 1959 led me straight into employment at General Electric (GE). By then, the Corona project was already under way.

After working on the Discoverer project, I remained employed by GE through December 1992.

APPENDIX 3: BIOGRAPHICAL TRIBUTES

Editor's Note: In this appendix, you will find tributes to two important contributors to the Corona program. Both Dr. Mark Morton and Walt Roman, whose names are featured on the cover as contributors to this book, were deceased when the idea for this book was conceived. Their contributions to the program should not, however, be dismissed. We include these two tributes by family members and colleagues here for recognition.

Figure 127. Dr. Mark Morton.
Photo courtesy of Kenneth Morton
and S. Bruce Morton.

Dr. Mark Morton
A Tribute to Dr. Mark Morton by Kenneth Morton and S. Bruce Morton

Dr. Mark Morton was the General Manager for General Electric's (GE's) Reentry Systems Department and supervised the scientific, engineering and technical teams that designed, fabricated and tested Corona, the first photoreconnaissance satellite. Corona's Satellite Recovery Vehicle (SRV) and other follow-on film recovery satellite systems provided overhead reconnaissance imagery that was vital to United States national security during the Cold War. In the following tribute, written by his two sons, Morton's contributions to Corona are highlighted.

Mark Morton was born in 1913 in New Jersey and graduated from Atlantic City High School. He attended New York University's Guggenheim College of Aeronautics and earned a bachelor's degree in aeronautical engineering. He received his doctorate in aeronautical engineering from Rose-Hulman Institute of Technology, Indiana.

From the late 1930's through the Korean War, Dr. Morton developed pilotless aircraft, guided missiles and special classified projects as an engineer with the Naval Air Development Center. He received many U.S. Navy commendations for outstanding service during World War II. This work prepared him for his future work at General Electric (GE) on Corona and other space projects.

In 1956, Dr. Morton joined GE and rapidly advanced from General Manager, Reentry Systems Department in 1962, to Vice President of GE and head of Missile Space Division in 1968, and finally Senior Vice President of GE and head of GE's Aerospace Business in 1969.

As General Manager for Reentry Systems Department, Dr. Morton supervised the scientific, engineering, and technical teams that designed, fabricated, and tested the SRV. The revolutionary idea of returning film images taken from satellites in a reentry capsule might never have been realized without the design that Dr. Morton and his team devised. Prior to their work, no satellite had ever been recovered from space.

Also during this time period, he supervised teams responsible for developing reentry systems for the Air Force, Atlas, Thor, Titan, and Minuteman ballistic missile programs in addition to National Aeronautics and Space Administration (NASA) satellites and satellite recovery systems such as the Biosatellite and Earth Resources Satellite. He worked on a variety of other projects including global radar systems, avionics systems, environmental and oceans technology systems, and manned space systems such as Apollo and Skylab.

Dr. Morton was present at the command center, Cape Kennedy, in 1968 when Apollo 8 launched to the moon. In 1969, National Aeronautics and Space Administration (NASA) presented him with a Public Services Group Achievement Award in connection with Apollo 11, the first mission to land men on the moon. Presidents Nixon and Carter both gave Morton commendations separately in 1970 and 1977.

Dr. Morton was appointed to the National Advisory Committee on Oceans and Atmosphere by President Nixon in 1971.

Throughout his career, Dr. Morton lectured about the importance of science programs in public school education. He received many awards for his community activism, including in 1973, the Opportunities Industrial Center's Pathfinder Award for his work on behalf of minorities and the disadvantaged. His championing of educational programs never abated.

In 2000, the National Reconnaissance Office (NRO) named him a "Pioneer in Space Reconnaissance" for his work on the Corona photoreconnaissance satellite.

A year after being honored as a pioneer, Dr. Morton donated to the NRO the bottom portion of a Corona film return bucket. This artifact, which is on display at the visitor's center at the NRO Westfield's complex, stands as further testimony to the dedicated career of this national reconnaissance pioneer.

Dr. Morton passed away in 2005. He is survived by his sons, Kenneth Morton, S. Bruce Morton, and one grandson. His wife of 52 years, Ruth Neznamoff Morton, died in 1997.

For further information and a first-hand account, please see Mr. Morton's section in *Beyond Expectations—Building an American National Reconnaissance Capability: Recollections of the Pioneers and Founders of National Reconnaissance*, edited by Robert A. McDonald of the Center for the Study of National Reconnaissance (CSNR) and published by the American Society for Photogrammetry and Remote Sensing.

Walt Roman, Tributes to Walt Roman by Flo Brent and Robert Lowe

Figure 128. Walt Roman.
Photo courtesy of the Roman family.

Walt Roman was a dedicated and hard-working technician on the Corona project. The following two tributes, written by his colleagues, Flo Brent and Robert Lowe (see their accounts in chapter 18), illuminate his character and highlight his contributions to the Corona SRV System.

Tribute by Flo Brent

Walt Roman and one or two of the electronic techs were the first hired for the data capsule. "Walt was one in a million," Florian Brent recalled.

Roman was a veteran of World War II, a prisoner of war and a survivor of the Bataan Death March. He had every reason to love every minute of life and to make as much of it as he could. And he did by giving everything he possibly could to whatever he did. "We became the best and deepest of friends," Brent said. "He never let me down on anything he did or tried."

Together, Roman and Brent developed the foam formula and manufacturing technique to get it to rise and fill the forms they designed and, many times, Roman redesigned by himself. Brent conceived how to box and pot the battery packs and then Roman made them without drawings. This was also the case with the internal harness assembly.

Roman also participated in most of the drop tests at Wallops Naval Station. He made the first recovery net to capture the capsule from the water. The net was constructed of chicken wire wrapped around a 50-gallon oil drum.

In the first tests of the live sonar bombs, Brent said the wires broke and they were "in effect looking at a mortar shell, which could have fired in our faces if the wires had touched." However, because there was nothing else they could do, they carefully fished it out. Sometimes, Roman and the others were moved to the back of the boat while Brent successfully cut the wires to disarm the bomb with an 8-in hunting knife. But when that did not work, they had to take it ashore and place the live bomb in the back of a car to return it.

"On several occasions, they activated due to a bump in the road," Brent said. "Made for an interesting return trip!"

The drop test operation early on was a very wet process. During a winter drop test amid 4- to 5-ft waves, Roman and Brent were soaked up to their armpits and had to change into Navy yellow weather gear. The shivering pair completed the drop and then quickly returned to the motel to dry out and warm up—or try to.

"I don't know of any tech that contributed more of himself and to the program than Walt Roman," Brent said. "If anyone should have received an Ace of Space Award, it should have been him. But it didn't happen."

Tribute by Robert Lowe

Walt Roman was the senior member in our engineering lab. He started there at General Electric (GE) before I did. He worked with Flo Brent on the data capsule, did a lot of the fabrications, and supported the test programs and all kinds of programs on the data capsule. He was a major contributor to our program, where we had to build and test all these drop-test vehicles, and all that was done in our engineering lab.

To give you the measure of the man, Walt had been at Holloman Air Force Base (AFB) conducting drop tests with some of our people. It was around the Christmas holidays because we were having a Christmas party. That group got back the night we were having the party and they joined us. I said to Walt, "You can't imagine how much I appreciate you guys giving up your Christmas holidays with your families and being out there at Holloman conducting these tests." And his response was, "Bob, no problem at all. We would do anything you want. If you told me right now to get on an airplane, go out to Holloman, and dig a ditch across the air field, the only question I would say is, 'How deep do you want it?' and I'd be on my way."

Walt had unusual handwriting. He had the most beautiful script you can imagine—a script out of the Palmer handbook on writing. I asked him, "Where did you ever learn to write that well?" And he told me, "I spent a lot of years on a ship. Some played poker, some got into scrimshaw. I got my hand on a Palmer handbook." He just wanted to work on improving himself. I enjoyed working with him. Everybody did. He was a big asset to our group.

Figure 129. Above is a tribute to Walt Roman and the service he gave to his country. Pictured are the medals he was awarded, including the Purple Heart and the American flag from his burial. Photo courtesy of the Roman family.

APPENDIX 4: THE PEOPLE OF CORONA

Ingard Clausen's Honor Role of Corona Recovery Trailblazers

Trailblazers are pioneering individuals who initiate and develop something that is challenging and new. An example for military technology could be a systems development project that leads to a new and unique operational capability. The entire Corona project—its innovative idea and creation of a capability to launch a camera into space, take reconnaissance images while orbiting the earth, and bring the reconnaissance film back to earth from space—was initiating and developing something new. It was trailblazing! The challenge to define and identify the individual Corona trailblazers who initiated and developed that capability is a fuzzy target.

"Defining and identifying" the individuals requires first describing the time period for trailblazing activities, i.e., to select a starting point for trailblazing and then selecting an end point for when the initial trailblazing work was complete. Those two points may be open to debate, but I have selected two events to help define this trailblazing period. The first event is Corona's mission that brought back the first operational images from space—that was Discover 14 on August 18, 1960. Those who contributed to that success were trailblazers. The second event was when the Air Force transitioned recovery operations from the C-119 to the C-130. Those who got us to that point also were Corona recovery trailblazers.

My estimate is that during the period from initiating the Corona project to the transition to C-130 recovery operations, nearly 600 recovery trailblazers were involved. That would include about 200 General Electric (GE) personnel involved with recovery system development, about 300 U.S. Air Force (USAF) personnel involved with recovery operations, and about 100 National Photo Interpretation Center (NPIC) personnel involved with exploiting the recovered film. However, there are only 250 names on my list in this Appendix. That number will have to suffice for several reasons. First, the Corona project was a highly classified, compartmented program, and security rules isolated information about people and activities in the program. Second, only a few of those involved in the program kept lists of individuals who served on the Corona project. Third, at this writing it has been fifty years since the Corona program was initiated. Organizational records are difficult to locate, and memories are hazy. And finally, fourth, the death rate for people who served in World War II and were part of the "Corona generation" is now 10 percent per year. There are few remaining to go to for this information. In short, I do not know all the names on the list, and there is no way for me to learn who is missing from my list. So I apologize to those whose names I may have missed.[1]

For the names that I was able to identify and list in this appendix, I am indebted to several individuals. I am indebted to Charles Dorigan, a former USAF recovery air crew member, for the names of the Air Force Corona recovery trailblazers. For the NPIC trailblazers who interpreted the

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1 Editors' Note: In addition to the Corona Recovery Trailblazers on Ingard's list, there are other Corona trailblazers from other parts of the program. There were those involved at the program office, program staff, launch base, operations group, Lockheed, Itek Corporation, and Eastman Kodak, as well as other organizations and locations. For a list of some of the pioneering Corona trailblazers from these activities, see pages 141-152 in *Corona Between the Sun The Earth—The First NRO Reconnaissance Eye in Space*, American Society for Photogrammetry, 1997. Of course no list will be complete for the reasons Ingard noted.

recovered film, I am indebted to David Doyle, a retired Central Intelligence Agency (CIA) officer, who assembled the names of his team. Note that the listing for his team not only includes CIA personnel, but it also includes the names of personnel from the U. S. Army, the U. S. Air Force, and the U. S. Navy. Lastly, I am responsible for reconstructing the list of the GE recovery trailblazers. Here is the list.

General Electric (GE) Satellite Recovery Vehicle (SRV) Trailblazers

Robert A.	Aiken	Len	Cooper
Angelo P.	Anastasio	Sam	Corcoran
Borge	Andersen	George A	Crain
George	Arthur	Harold	Crane
John	Baker	Samuel	Crawford
Mark	Baker	Thomas W	DeJohn
Clifford E.	Barr	Sal	Depaolo
Shelly	Baylinson	Max W.	Dienemann
Norman	Beckett	Ronald	DiNicola
Milton	Berkowitz	Linda Allgire	Dowd
Laurence	Blomstrom	Edward J.	Duffey
Harold A.	Bloom	Tom	Duffy
Victor	Boccelli	William	Eaton
Edward J.	Bonner	Joseph	Fanelli
Robert	Boyd	Frank	Ferrante
James	Bradley	Peter J.	Ferrara
Florian T.	Brent	Albert J.	Fiumara
Henry W.	Bried	Norm	Frederick
Ed	Brogan	Emanual	Fthenakis
Charlie	Bryant	Jack	Gaffney
Edmond J.	Bryce Sr.	Joe	Giacoponello
Ken	Buckwalter	Roger A.	Gibboni
Richard	Burton	Richard B.	Gibson
James	Canfield	Donald	Gimpel
S. V.	Canonica	Jonathan	Gispan
Hugh	Cart	Stanley	Gottlieb MD
Robert	Chamberlin	Alfred M.	Gross
George	Christopher	Robert R.	Gross
Marvin	Clarke	Jack J.	Guy
Ingard M.	Clausen	Sheldon	Haas
Bryan	Cockshutt	Harry	Halvorsen
Roy	Condron	George J.	Hammond
Pete	Contompasis	Ken	Hanson

William Harper
Dale Harvey
Neil E. Hauft
Robert P. Haviland
Edwin Hearn
Warren A. Heiser
Raymond Herot
John Hoda
Fred Hoffken
John Hoffnagle
Tom Hogan
Arthur C. Hopewell
Larry Huggins
Stacey Hunt
James Jopski
Alex Kaplan
Jay Karlin
Robert Kirby
Otto Klima
Walter Korn
Murray Kornhauser
Leonard Kornstein
Richard Lasher
Richard W. Lawton MD
Alec Lengyel
Charles Leonard
Alfred Little II
Robert Lowe
Ed MacDonald
Donald Matteo
Edmund Mazur
Charles McDowell
Sheridan McGhee
Edwin McKeon
Hugh McMenamin
Edwin. J. Merrick
Walter Midura
Edward A. Miller
Edward S. Miller
Bernard Mirowsky
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Helen M. Montague
Bill Moos
Dr. Mark Morton
Robert R. Moser
Kathy Mueller
Martin R. Mulkeen
Joe Nemer-Kaiser
Chuck Niemann
Frank Nistico
William Nolan
John O'Brien
Nora P. O'Brien
Leon P. Okurowski
Conrad Olenik
Gene L. Olson
Walter Overstreet
Hilliard W. Paige
Fred Parker
Richard A. Passman
Sal E. Patti
Robert F. Peck
Robert J. Peel
Myron Peterson
Paul Pettey
Larry Podrasky
John Pollis
James Polski
Charles Rabolli
Art Rachild
Bernard Rachlin
Elwood Richards
Richard Rininger
Richard E. Roberts
Charles L. Robinson
Walter A. Roman

Daniel Rossman
Paul W. Salter
Andrew Sannino
Joe Scarcelli
Walter J. Schafer
John Segletes
Carl Sells
Thomas E. Shaw
William Sindoni
Robert A. Smevog
Anthony M. Smith
Milt Smith
Robert J. Smith
Walter D. Smith
Edward Spangler
Clayton Stahl
Frank R. Stearns
Leo Steg
Frank H. Stratton
Dr. George Sutton
Frank Swan
Kenneth Swimm
James J. Tague
Richard L. Taylor
Tony Thomas
Barbara A. Tobler
Alan Tompkins
Stanley C. Tracz
Larry Tyrrell
William Ussler, Jr.
Jim Vitale
Bruce F. Waechter
Millard Wagon
Richard A. Walsh
Lad Warzecha
Dr. William T. Weir
Edward C. Weissman
Gene Wenning
Kurt Wesley
Lenore Bailey Williams
Myron Wilson
Paul Wisler
Howard Wittner
William Woebkenberg Jr.
Carl F. Zapf
John Zappitelli
George Zilling

U.S. Air Force Corona Recovery Trailblazers

Louis Bannick
Floyd P. Barrow
Lester Beale
Robert D. Counts
Donald R. Curtin
William J. Deere
George Donohue
Charles J. Dorigan
Walter Godwin
Donald Hard
Algaene Harmon
Daniel R. Hill
Arthur Hurst
Charles H. Keek
Wendell King
Kenneth Klein
Charles E. Leech
Frank J. Linseisen
Walter L. Michelini
Harold E. Mitchell
Andrew A. Radel
Warren Schensted
Marvin Shields
Jack R. Wilson

National Photographic Interpretation (NPIC) Corona Trailblazers

Central Intelligence Agency (CIA) Corona Photo Interpreter Trailblazers

George Arthur
Norman Beckett
Robert Boyd
Dino Brugioni
Vince Direnzo
David Doyle
Gordon Duvall
William Fitzgerald
Ray Gripman
Joseph Seng
Earl Shoemaker

U.S. Army Corona Photo Interpreter Trailblazers

Mark Baker
Tom Hogan
Art Stevens
Richard Rininger
Oliver Wilson
Greg Zipple

U.S. Navy Corona Photo Interpreter Trailblazers

Clayton Dalrymple
Paul Dietz
Tom Hardy
Jack Rooney

U.S. Air Force Corona Photo Interpreter Trailblazers

Wilber Dodd
Mary Ferry
Robert Keil
Dale Heintzleman
Jim Holmes
Charles Susong

GLOSSARY

AFB – Air Force Base

AFL – Aeromedical Field Laboratory

AFSAM – Air Force School of Aviation Medicine

AFSC (or AFSPC)– Air Force Space Command

BRL – Ballistic Research Laboratory

C&K – Chalmers & Kubeck

CIA – Central Intelligence Agency

DCB – Design Change Board

DOD – Department of Defense

FIFO – First in, first out

GE – General Electric

GMA - Gas Management Assembly

HANL – Humidity, Altitude, Noise, and Life Tests

HEAT – High Explosive Anti-tank Rounds

IAF – International Astronautical Federation

ICBM – Intercontinental Ballistic Missile

IMINT – Imagery Intelligence

IR (sensors) – Infrared

IRBM – Intermediate Range Ballistic Missile

JPL – Jet Propulsion Laboratories

LMSC – Lockheed Missile and Space Vehicle Company

LMSD – Lockheed Martin Space Division

M&DS – Management and Data Systems

M&DS – Military and Data Systems Division

MATS – Military Air Transport Service

MOL – Manned Orbiting Laboratory

NACA – National Advisory Committee on Aeronautics

NASA – National Aeronautics and Space Administration

NATO – North Atlantic Treaty Organization

NCO – Non-Commissioned Officer

NERV – Nuclear Emulsion Recovery Vehicle

NPIC – National Photographic Interpretation Center

NRL – Naval Research Laboratory

PACAF – Pacific Air Force

PCM (telemetry system) – Pulse Code Modulation

PT boat – Patrol Torpedo

QC – Quality Control

R&D – Research and Development
R/RV – Reentry and Recovery Vehicle
ROTC – Reserve Officer Training Corps
SARV – Satellite Aeromedical Recovery Vehicle
SIGINT – Signals Intelligence
SOFAR Bomb – Sound Fixing and Ranging Bomb
SRV – Satellite Reentry Vehicle
STVA – Shock, Temperature, Vibration, Acceleration
UNIVAC – Universal Automatic Computer
VERTOL – Vertical Takeoff and Landing

INDEX

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APRIL 2012