"Pioneering Space"

By Gideon Marcus

In 1957, *Sputnik* blazed its trail across the October skies. Less than one month later, the United States had already come up with a plan to not just match the Soviet Union, but to do it one better. Wernher von Braun's U.S. Army team and the Johns Hopkins/Navy team worked feverishly to get their satellite up before the new year. At the same time, proposals poured in from Douglas, Convair, Martin, North American, Lockheed, the Jet Propulsion Laboratory (JPL), and, of course, the Air Force (USAF) and its favored Ramo-Wooldridge (R-W) Corporation. Their common goal was to send a satellite around the Moon before the end of the International Geophysical Year, preferably ahead of the Soviet Union. This article, the second in a series on the history of Space Technology Laboratories, will detail the history of America's first lunar attempt.

Conception

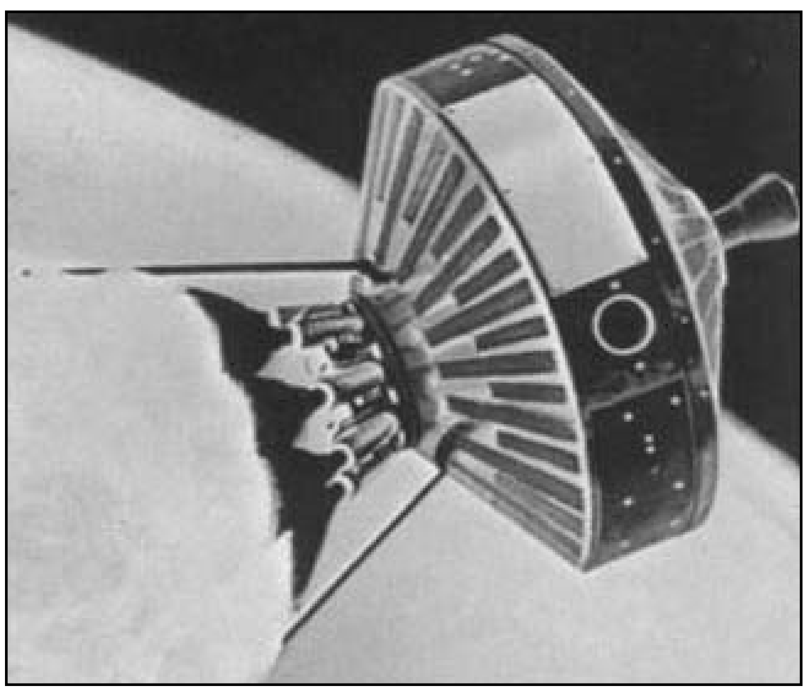
On 1 November 1958, Dr. Paul Degarabedian, a member of the Systems Development Group at the Guided Missiles Research Division of R-W (renamed Space Technology Laboratories—STL—the following month), sent a memo to Dr. Louis Dunn, president of the division. In this document, Degarabedian proposed that the Thor intermediate range ballistic missile (IRBM) be mated with the yet untested Vanguard second and third stages. He went on to show that the resulting booster would be capable of carrying a payload to the Moon and beyond.[1] Initially, the USAF was more interested in a military application of the new rocket. They contacted STL to build a two-stage version of the launcher for the purpose of flying a new type of ablative nose cone, also developed at STL, into the Atlantic Ocean at intercontinental ballistic missile (ICBM) velocities. The vehicle was named "Advanced Re-entry Test Vehicle" or ARTV. It was also called "Able-0."

The development of ARTV gave the USAF and STL an opening into the lunar competition. Colonel Charles Terhune, a senior officer at the Air Force Ballistic Missile Division (AFBMD) suggested that three of the *Able-0* Thors be allocated for a lunar landing mission, and that the first launch might take place that summer. This would put them ahead of the other proposals whose contractors had yet to develop boosters for the mission. STL's lunar project, called "Able-1" to distinguish it from ARTV, was originally conceived as a lunar lander. This was deemed too ambitious to be competitive, and the mission was scaled back to a lunar orbital mission.[2]

The STL/AFBMD studies were presented to various civilian groups. These included the Killian Committee (President Dwight D. Eisenhower's task force that oversaw space policy), the USAF Scientific Advisory Board, and the Ad Hoc Advisory Group on Special Capabilities, created by the Defense Department to offer input on International Geophysical Year (IGY) science satellites. The proposal was also presented to Air Research and Development Command, various Air Research and Development Centers (ARDC), and Headquarters USAF.[3]

On 7 February 1958, President Eisenhower formed the Advanced Research Projects Agency (ARPA) to direct all military and civilian space endeavors. By mid-month, despite the fact that no contracts had yet been made, Louis Dunn had already begun preparing for the construction of a lunar probe. As official approval would not come for another month and half, either Dunn knew something no one else did, or he was taking a big gamble—and Dunn rarely went ahead without at least a handshake agreement.

On 14 February, Dunn held the first significant meeting on the modification of



Artist's conception of the *Able* spacecraft in flight, all vernier rockets firing Image Credit: NASA the Able vehicle for *Able-1* (referred to as *Baker* at the time). In attendance were Rube Mettler, STL executive vice president; George Mueller, head of the ARTV project and director of the STL Electronics Lab; Richard Booton, head of the missile support equipment section; A. F. Donovan, director of the Astrovehicles Laboratory; G. E. Solomon and Frank Lehan, propulsions experts; and Adolph Thiel, formerly of Peenemünde and now integral to Thor IRBM development and a strong backer of the *Able-1* proposal.[4] Dunn announced at this meeting that STL would be building a lunar probe. It would launch in mid-August. Dunn explained that in addition to the construction of the actual satellite, STL would be in charge of the mission-specific modifications to the several stages of the Moon rocket, not Douglas or Aerojet (the booster stage manufacturers), and stressed this point to Thiel. It was a risky move, one that was sure to annoy the people at Douglas, but at least for the time being, STL successfully challenged its role as an instrumentation-only shop.[5] On 27 March, ARPA made an informal agreement into an official one, commissioning STL to make three of the five lunar probes scheduled for launch in 1958. The U.S. Army team, led by von Braun, was contracted to launch the other two.

The *Able-1* Booster

The ARTV rocket and the *Able-1* boosters employed the Thor IRBM as their first stages. The Thor was a stop-gap missile developed for basing in England to counter the Soviet ICBM threat. It was not necessary to modify the Thor much for the booster role—the onboard guidance was removed, the flight control system was modified to account for four-stage dynamics, and STL engineers added an interface section for the first- and second-stage connection.

Both boosters used the same second stage—the Aerojet booster developed for the Vanguard. The *Able-1* second stage differed from the ARTV second stage in its incorporation of guidance control and a self-destruct system. These were features deemed unnecessary for short range, unguided nosecone testing, but guidance was vital for the successful orbital placement of a satellite, whereas the ability to destroy an out-of-control booster on its way around the globe was equally important. These new systems were installed at the head of the second stage in a compartment custom, built for the purpose by STL. Additionally, a stainless steel sheet and REFRASIL™ cord heat shield were attached to the forward end of the same second- to third-stage transition shield used in the ARTV flights.[6]

Originally, the USAF had intended to use the Vanguard solid-fuel third stage developed by Grand Central Rocket Co. However, it became quickly apparent that this rocket's conservative design would loft only a small payload to the vicinity of the Moon, perhaps 20 pounds at most. This was hardly bigger than the payload the Army intended to launch with its Juno-2 rocket. As luck would have it, Grand Central's booster was not the only option. In 1956, Glenn L. Martin Co., prime contractor for the Naval Research Laboratory (NRL) Vanguard project, awarded construction of the third stage to Grand Central as its design looked to be the quickest to develop. At the same time, however, the government hedged its bets and commissioned a second booster to be developed in parallel with Grand Central's effort. This third stage was developed by Hercules at its Allegany Ballistics Laboratory (ABL).

Where the Grand Central rocket used a conventional metal cased design, the ABL rocket used a fiberglass filament wound case. This new design reduced the weight of the rocket considerably. Named the X241, the motor completed trials and was ready by January 1958—too late to be incorporated in the first Vanguard flights, but just in time for *Able-1*. The X241 was impressive enough that in February 1958, NRL contracted with ABL to improve the rocket still more. Design and process improvements increased propellant load and reduced the inert mass without changing the actual rocket dimensions. This new booster was designated the X248.

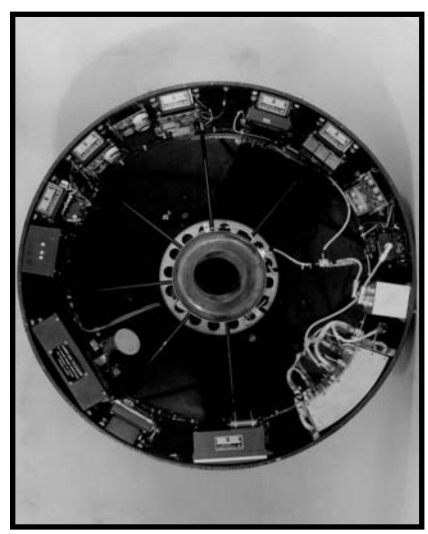
STL first ordered a series of X241 tests during which the design of the X241's fiberglass exit cone was found to be marginal. When replaced with a steel exit cone, performance was nominal, but the extra weight diminished the advantages of the X241 over Grand Central's motor. STL therefore rejected the X241 in June 1958 and ordered a ten round qualification series for the X248. The X248 performed so well that not only was it selected to fly on all the *Able-1* flights; it later replaced the Grand Central third stage on Vanguard III in 1959.

Construction of a Payload

Able-1 borrowed a lot from ARTV, but it quickly dwarfed the earlier project in scope and expenditure. The number of staff involved ballooned as personnel were recruited to develop the payload, construct the experiments, and coordinate worldwide tracking. ARTV had been a secret USAF project. *Able-1* was international in scope and a lynchpin to American prestige. The most significant difference between the two projects was that the spacecraft that would fly to the Moon.

The *Able* Spacecraft Photo Credit: NASA

This spacecraft was constructed at a USAF facility at the intersection of El Segundo and Aviation in Redondo Beach, California, in the early 21st century known as Northrop-Grumman's sprawling "Space Park." Offices ringed the outside of the building while the windowless labs occupied the center. Most of the labs were devoted to the construction of ballistic missile components, then Ramo-Wooldridge's stock in trade. Despite its importance in the Space Race, *Able-1* was merely a sideshow at the time compared with the tremendous resources employed by the rest of the



The *Able* Spacraft Experiment Package
Photo Credit: NASA

Dr. Louis Dunn, STL President
Photo Credit: STL

Dr. Ruben Mettler, STL Executive Vice President
Photo Credit: STL

Dr. George Mueller, Able Project Director
Photo Credit: STL

defense industry.

In order to make the August deadline, *Able-1* had one of the most accelerated development timelines in the history of spaceflight. An engineer described working on the project at the time as "like being in a war." STL's engineers and technicians worked 120-hour work weeks, lived at the lab on six hours of sleep, hardly saw their families, and could tell them little about what they were doing, anyway. Yet they loved the experience. "We knew that we were doing something important."[7]

On April 15, *Able-1* had assumed its first configuration--a flat disk with a retrorocket at its center of gravity. The largely hollow, spin-stabilized craft had a projected payload weight of around 20 pounds. By May 23rd, the probe's design took on its final polyhedral form. The payload weight had grown to around 22.5 pounds. Along with its four-pound container and the 1.5 pound third stage interface, the total spacecraft weight was approximately 28 pounds.[8] The probe's Thiokol TX-8 retrorocket, also known as the *Able-1's* "fourth stage", was designed to decelerate the spacecraft into lunar orbit. The spacecraft also had eight small vernier rockets originally designed by the Atlantic Research Corporation for the Vanguard program. These verniers would put the spacecraft into proper orientation, impart a stabilizing spin of two revolutions per second, and then be jettisoned in preparation for retrorocket firing.[9]

STL developed a new kind of environmental control system to deal with the wide temperature extremes of space. A temperature range of 60-85 degrees had to be maintained inside the spacecraft to ensure optimum performance of both the experiments and batteries. However, an electric heating system would have been far to heavy to be included in the payload. Instead, the spacecraft was adorned with a painting scheme designed to absorb enough sunlight to keep the interior warm without overheating the equipment. Though the innovative plan required no special paints and weighed next to nothing, it was, of course, inflexible. Before each launch, a specialized pattern had to be painted, tailored to the expected insolation the probe would experience on its way to the moon. As long as the spacecraft stayed on course, *Able-1* would stay warm.

The hull of the spacecraft was made of a honeycomb fiberglass material provided by Hexcel, a company which did a lot of business in aerospace at the time and which is still around today. To keep the spacecraft from wobbling as it flew to the moon, the Naval Ordnance Test Station developed a nutation damper, a ring of mercury concentric with the spin axis and above the center of mass. The revolving of the mercury at a different rate from the spacecraft acted like a gyroscope, keeping the spacecraft from precessing so that direction-specific experiments like the onboard television scanner could function without using heavier compensating mechanics.[10]

A Worldwide Tracking Network

The telemetry transmitter on *Able-1* operated on 108.06 MHZ, a standard frequency used by satellites in the IGY. Sub-carriers transmitted on the main phase-modulated signal were designed to carry data on the temperature of the retrorocket propellant, the deceleration after the retrorocket fired as well as data returned by the onboard experiments. Information from the TV Camera would be sent on the same frequency but with more power and on an amplitude modulated signal.[11] The decision was made during the latter part of April to employ a doppler transponder and command receiver "to permit velocity adjustment and retrorocket firing upon command from the ground."[12] Work on the 300 milliwatt Doppler transceiver began in early May and was only completed shortly before launch. This was straightforward engineering. The difficult task was not building an onboard transceiver, but ensuring that communications between Earth and the spacecraft could be achieved at all.

Tracking and communicating with *Able-1* required, for the first time, a worldwide network. Prior to *Able-1*, information could only be received from, and transmitted to, a satellite when it was over its country of origin. This was acceptable for Earth orbital missions since the satellite was sure to fly overhead every ninety minutes or so. The Vanguard program used the first international network of receivers which spanned both hemispheres with a north-south line of Minitrack antennae from Maryland to Chile. Since *Able-1* would spend hours out of sight of the Western Hemisphere on its way to the moon, that network was insufficient--a truly global distribution of stations was required to maintain constant tracking.

The first serious discussions on developing this communications network began in late February between STL Vice President Rube Mettler and Brigadier General Osmond J. Ritland, vice commander of the Air Force Ballistic Missile Division, stationed at the Test Center at Cape Canaveral.[13] On receiving the go-ahead from ARPA on 27 March, the USAF and Army teams began the frantic task of building a series of stations around the globe. The Army's deadline was somewhat more forgiving—the first of its flights would not launch until December, whereas the first of the *Able-1* satellites was scheduled to launch in August, just five months away.

In fall 1957, Robert Bennett, associate director of STL Electronics Laboratory, invited Dr. Richard Booton, former professor at Massachusetts Institute of Technology (MIT), to work at STL on the radar system for the Atlas ICBM and manage the ballistic trajectory computers. On arriving at STL, Booton was drafted to manage all aspects of communications with the nascent lunar probe.[14] Booton and his USAF counterparts set up a series of formal and informal contracts to create the first worldwide tracking network. Installations built and crewed by the USAF were set up at Cape Canaveral, Florida; near Naalehu, Hawaii; and Singapore. Antennae were erected at STL's Redondo Beach, California, headquarters; in Florida; and in Huntsville, Alabama. The existing stations at Millstone Hill, Maryland, and Jodrell Bank, England, were solicited for their support, but their facilities and crew remained autonomous.[15] Vanguard's Minitrack was also brought into the network. The makeup of this constellation of stations remained unchanged throughout the entire *Able-1* program.

A Plethora of Stations

The Cape

The communications office at the Air Force Missile Test Center (AFMTC), which came online on 8 July 1958, was responsible for gathering launch and flight data that were then passed on to the operations center in Los Angeles where they were used to support the Manchester station. The ground station at AFMTC controlled launch operations, received telemetry data after launch, and tested the payload and second-stage Doppler transceivers during countdown.[16]

Reception and transmission capability was provided by a six-turn helix at the Cape and a 60-foot diameter D. S. Kennedy and Company reflector at Huntsville.[17] A Kennedy reflector was also operated at Melbourne, Florida.[18]

Hawaii

The Kalae Field Station, a USAF installation later transferred to NASA, was built near the town of Naalehu, the southernmost point on the big island of Hawaii. A 60-foot antenna was taken from storage in Florida and mounted at Kalae on a 70-foot tower. This in turn was surrounded on all points of the compass with helical array antennas. The station was designed for complete dual reception with a pair of phase-lock receivers allowing simultaneous recording of telemetry from two frequencies. Teletype communications were maintained for 8 hours per day, increased to 24-hour coverage during operations.[19]

Singapore

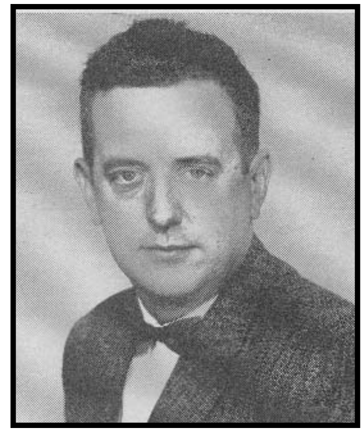
The Singapore station was built on the site of the receiving antenna farm of Cable and Wireless, Ltd., about five miles north of the city. A helical array, identical to the ones composing the Hawaii interferometer, was set up near a row of bungalows, one of which was converted into an office and ready room. The antenna could be pointed in any direction with a one-speed electric motor, but its beam width of 30 degrees proved too broad[20] to provide significant tracking information.[21]

The effectiveness of the Singapore station was also hampered by the difficulty in maintaining communications with STL headquarters. All transmissions traveled across the United States, through the sub-Atlantic cable to England, by radio across the channel, and then across Eurasia to Singapore. This made setup particularly laborious. Louis Dunn once quipped that Singapore would finally telegraph, "We're ready!" two weeks after *Able-1* had launched. As it turned out, had the *Able-1* missions gone precisely as planned, the Singapore station might have had some utility, but in the actual event, the single array simply was not powerful enough for the job.[22]

Jodrell Bank

In 1957, the tremendous *Mark 1* steerable dish telescope at Jodrell Bank, associated with the University of Manchester in England and designed for radio astronomy research, was the only facility in the West that could track *Sputnik*. The USAF deemed this large receiver invaluable for its power and its location. Immediately after ARPA authorized the *Able-1* program, STL and the USAF solicited the University of Manchester for its aid. The USAF gave the University the details of *Able-1*'s telemetry system on 8 May, and preliminary correspondence continued into late May when Jodrell Bank provided its geographical coordinates on George Mueller's request.

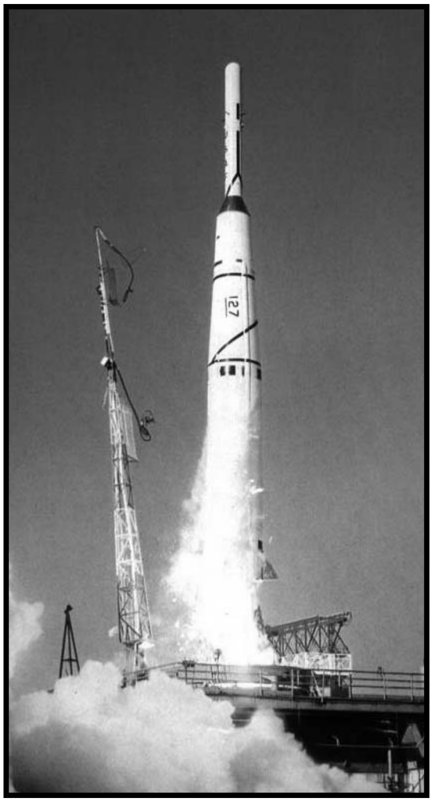
Information about British involvement in the *Able-1* project was strictly controlled by the USAF. An entry in a memo dated 8 August 1958, penned by Lt. Col. W. G. Hingston admonished, "Nothing was to be said by Jodrell Bank until the rocket had been launched." Sir Bernard Lovell, director of the telescope facility, was not allowed to release



Dr. Richard Booton, Able Communications Manager Photo Credit: STL

Dr. Charles Sonnett, Able Experiments Manager Photo Credit: STL

Stuart Baker, Project Engineer Photo Credit: STL



Above: Launch of *Pioneer 0*
Bottom: Launch of *Pioneer 1*

Photo Credit: NASA

even the most basic information regarding the upcoming launches and was required to refer such inquiries to ARPA. And yet attempts to keep the American presence in England a secret were foiled in short order. On 25 July, newspaper reports leaked a story about trailers marked "Jodrell Bank, U.S. Air Force, Project Able" arriving at the telescope facility in preparation for the lunar probe attempts. Lovell would not comment on the story, except to say that the equipment would be used in conjunction with Jodrell Bank's own systems for joint work on "various satellite projects."

The Hallamore Ground Support Equipment vans and their microlock receivers were set up just in time for the Jodrell Bank facility to monitor America's fourth successful satellite, *Explorer IV*, which launched on 26 July. The satellite broadcast on 107.997 and 108.03 MHz, close to the frequency to be used by *Able-1*, and these signals were used to test the receiving equipment before the August flight.[23]

Millstone

Millstone Hill, Massachusetts, was home to an 84-foot parabolic reflector operated by MIT. In early 1958, the telescope conducted the first successful probing of the planet Venus by radar. Its size made it highly coveted by the USAF, and R-W and Dick Booton quickly established a friendly relationship. As with Hawaii, communications with the Operations Center in Los Angeles was accomplished via teletypewriter exchange (TWX) service, and this coverage was continuous during operations. This service was augmented by conventional long distance telephony between Millstone and AFMTC.[24]

The Experiment Package

As originally conceived, *Able-1'*s primary objective was to demonstrate the USAF ability to orbit something around the Moon, and in its original configuration, the sole experiment was a large TV camera for photographing the Moon's far side. However, in spring 1958, America's third successful satellite, *Explorer III*, confirmed the discovery of the Van Allen belt, first hinted at by *Explorer I*, and it was clear that there was much that was yet unknown about the space above Earth. *Able-1*'s flight path afforded a unique opportunity to observe heretofore unknown orbital phenomena from an unprecedented altitude. The scientific community urgently requested that *Able-1*'s experiment set be augmented. The National Science Academy Working Group on Internal Instrumentation agreed and mandated the inclusion of several new experiments. But by then, it was already the beginning of June, the spacecraft design had been completed. There were only two months left before the first scheduled launch of *Able-1*, and in this time frame several experiments had to be added and the body of the spacecraft modified to facilitate them.[25]

STL management approached a young employee, Dr. Charles Sonett, for his ideas on the construction of a hypothetical lunar satellite. After presenting his suggestions, Sonett found, to his surprise, that he had been selected to oversee the creation of *Able-1*'s experiment package. He and his team of eight or so engineers and technicians were taken off other defense-related tasks to devote 100 percent of their energies to the new project. In addition to managing and contributing to the development of in-house experiments, Sonett also coordinated the external efforts of universities in Illinois, Minnesota, and Iowa. These institutions would ultimately construct many experiments for *Able-1*. However, several of the instruments were developed entirely in-house. This created a storm of controversy among many members of the scientific community. That ARPA would task that a handful of unlettered corporate employees for such an important job was deemed a slight. It was felt that scientific research should be in the hands of civilians, not military personnel and for-profit corporations.

Even the scientists who had been contracted to produce experiments often chafed under their working relationship with STL. Some expected special treatment or at least a degree of autonomy. Instead, STL treated the universities like any of their industrial contractors. Moreover, STL insisted that assembly of the experiments should be done entirely in Los Angeles by STL employees. Chicago's Dr. Simpson refused to work this way, and he built and tested his own instruments. His sour experience with STL was the direct impetus for Simpson to organize his Fermi Laboratory at the University of Chicago where he could control all aspects of the integration of his instruments into spacecraft. Simpson would go on to produce many more experiments for STL, but on his own terms.

The simple truth was that times had changed even in the short space between 1956 and 1958. For the Vanguard project, the Academy's Working Group had solicited proposals from a select group of scientists and then evaluated them by a list of set criteria. By the time *Able-1* was authorized, it had become imperative that the United States beat the Soviet Union in the race to the Moon, and time pressure made the process more haphazard. As John Naugle succinctly put it: "Personal acquaintance, experience with rockets, the ability to get clearance to work with classified launch vehicles, and proximity to the manufacturer of the spacecraft, as well as the scientific merit of the proposed experiment, began to influence the selection of space scientists."[26]

In this light, it is easy to understand why STL worked the way it did. Sonett had already been chosen to direct the development of the entire experiment package on *Able-1* and the experiments his team proposed were as viable as any. In addition, the close relationship between the USAF and STL naturally led to such ad hoc personnel choices that made up for in expedience what they might lack in political acumen. STL treated outside agencies like its other independent contractors because that was how it did business, and also because STL was always trying to keep its pivotal status in a highly unstable playing field. In the end, its satellite did fly with an excellent inventory of experiments that returned good data, but at the cost of a rift with the scientific community.

Television Camera

Able-1's TV camera weighed 8.5 pounds, making it the heaviest experiment onboard by a significant margin. The Naval Ordnance Test Station (NOTS) at China Lake, California, was tasked to provide the miniature imaging system to be carried on the three Able-1 missions. With the exception of its integration into the hull of the probe, this experiment was designed without the assistance of STL personnel.

The camera's design was simple. Light was collected on a parabolic reflector and focused on a sensor. As the light intensity varied, the received signal was amplified and modulated by a crystal-controlled Amplitude Modulation (AM) vacuum tube transmitter and broadcast on the same frequency as the other telemetry but at much higher power (up to 50 watts). To keep the size of the required batteries down to a manageable level, the camera was activated by the firing of the attached final stage, and the system only operated when there was something to see, coming online when light was actually shining through the aperture. Even with this energy-saving measure, it was expected that the batteries powering the transmitter would only last a few hours. No one was certain whether this would be sufficient time to transmit even a single image, both because the vantage point of the spacecraft was not likely to be ideal and also because broadcast bandwidth was reduced to just a few kilocycles—far less than a conventional television, but the most the limited power supply could support.[27, 28]

Ion Counter

The most important of the new *Able-1* experiments was the Ion Counter, whose purpose was to investigate the mysterious belts of orbital radiation that had been recently discovered. America's first satellite, *Explorer I*, launched on 31 January 1958, discovered the presence of these charged particles high above Earth. Two months later, while passing through these belts, the Geiger-Mueller counters on *Explorer III* mysteriously stopped working. The counters dutifully recorded the radiation flux, which increased with altitude. Then at around 700 km above Earth, the counters stopped returning data. Professor James Van Allen, director of the physics department at the State University of Iowa and head of internal instrumentation for the U.S. IGY Committee's Technical Panel for the Earth Satellite Program, was baffled. His understudy, a new graduate student named Carl McIlwain, suggested that there was nothing wrong with the counters. Instead, they were simply being saturated by a belt of unexpectedly high intensity radiation.

McIlwain was tapped to create an experiment for *Explorer IV* that would return meaningful results:

> I decided to put on a detector that could look at low energy particles, but could not be easily saturated. This detector, consisting of a scintillator on a photomultiplier tube, looked into space through a nickel foil only one milligram per square centimeter thick. A circuit of special diodes and multi-billion ohm resistors provided a wide dynamic range for the current to voltage conversion. Field effect transistors hadn't been invented, so a vacuum tube was required to take this voltage and drive one of the subcarrier oscillations feeding signals to the transmitter. Knowing vacuum tubes tend to drift, I included a miniature mechanical relay to periodically provide the zero signal level. This system performed well in orbit, and did not go near the upper limits of its dynamic range.[29]

This sort of detector had the disadvantage that it could not distinguish between the various radioactive particles it encountered. Ion tubes instead returned a sort of "qualitative" report, recording the aggregate radiation encountered from all sources. While this was somewhat unfortunate with regard to sky science, the data returned was critical in determining how dangerous the newly-dubbed Van Allen Belt, announced on 1 May, would be to potential space travelers.[30]

Explorer IV went up on 26 July and immediately created a stir. The Van Allen Belt was deadly: 50 hours in the zone would prove fatal, according to Explorer's ion counter. Even lead shielding would not offer adequate protection for astronauts. These belts doubled in intensity every 100 km starting at 400 km above Earth's surface, and went up at least as high as 2,000 km. The only hope for human space travel lay in the possibility that the radiation belts did not extend indefinitely into the cosmos. *Able-1* was the perfect probe to resolve this issue, for its trajectory would carry it higher than any probe had gone before.[31]

The 17 August launch date for the first *Able-1* flight came too quickly for any sort of ion counter experiment to be included. On 23 August, however, STL employees George Mueller and Charles Sonett, accompanied by Lt. Colonel Donald Latham of the USAF, traveled to the State University of Iowa to talk to Carl McIlwain about including an ion chamber experiment on the next *Able-1* mission.[32] Two days later, McIlwain flew to the west coast for the first time for a meeting with the *Able-1* staff in Redondo Beach.[33] The graduate student was asked to duplicate the circuit he'd created for *Explorer IV*. STL would take care of the power supply and other ancillary electronics.

The Anton 714 ion tube was calibrated on 28 September 1958 using the cobalt-60 source at the Radiology Department of the UCLA Medical Center. Under the supervision of Dr. M. Greenfield, the components were irradiated and their outputs monitored such that they could be measured against later results.[34] Anton Electronic Laboratories reported that the chamber had been filled to 13.6 atmospheres of pressure on 10 September, but test results showed it had dropped to only 2.42 atmospheres by 2 October. Extrapolating this trend, it looked as if pressure inside the tube at launch would be just 1.58 atmospheres with a corresponding reduction in sensitivity by a factor of 1.5.[35] That was not a significant problem, however, as a correction factor was easy enough to introduce to fix the data. Given that the recording time during the flight would be just four hours, and the leak was a slow one, a constant correction would be sufficient.[36] The primary concern was not that the gas in the tube was leaking, but that outside air had gotten *in.* The introduction of oxygen into the pure argon atmosphere of the tube would throw off the measurements considerably. However, as long as the pressure in the tube remained higher than one atmosphere, there was no danger of this happening.[37]

Magnetometer

It was still unknown, in 1958, whether or not the Moon had a magnetic field. In addition, while current theory suggested that Earth's magnetic field might extend out five to ten radii, no spacecraft had gone high enough to confirm this. The boundary between the geomagnetic field and the Sun's magnetic influence was also a complete mystery. A magnetometer sent on an unprecedented journey some 230,000 miles from Earth would contribute a great deal to the understanding of these phenomena.[38] Chuck Sonett was a new PhD with virtually no published papers to his credit, but he did have a firm background in nuclear physics. Around the time he was selected to manage the *Able-1* experiment package, he drafted a design for a magnetometer to be carried by the yet unnamed lunar orbiter.

Sonett was assisted by Paul Coleman, a physics graduate student who joined him in summer 1958. He had gone to California with his roommate on a lark—and been left stranded. STL was recruiting aggressively at the time, so Coleman interviewed and was hired. He immediately fell in love with the unfinished spacecraft laid out on the testing table. Hired as a jack-of-all-trades, Coleman worked as integrator on all the experiments and also on the shielding for *Able-1*'s retrorockets.[39]

It was Coleman who came up with a unique solution to the problem posed by the magnetometer requirements. Of particular importance to the design of the experiment was that it would have the maximum possible range, so as to detect the conjectured lunar magnetic field even if the probe did not end up orbiting the Moon.[40] At this time, there was no single analog-to-digital converter with sufficient range to cover enough of the scientifically important spectrum. Therefore, he instead devised a series of switched magnetometers of varying sensitivities that would provide adequate coverage and could be housed in the single experiment.[41]

The experiment consisted of a search coil and a non-linear amplifier (the latter being Coleman's contribution) enabling it to cover the large dynamic range of Earth's field: from 0.3 to 0.5 oersted at the surface of the planet to the projected micro-oersted strength level at the field's extremities. As the spacecraft rotated, the coil would experience a change in magnetic flux. From the resulting sinusoidal voltage, the character of the measured field could be determined.[42]

Teammates Dick Benjamin and George Takahashi did much of the actual engineering, while Coleman did a lot of the data analysis on the experiments after the fact.[43] To this day, Sonett refers to their magnetometer as a "perfect experiment."

Micrometeoroid Detector

The danger of micrometeoroid collision was a serious concern in the first days of space exploration. Menacing swarms of tiny projectiles that could rip apart the hulls of crewed spacecraft were a staple of 1950's science fiction and uppermost in the minds of mission planners. However, when the micrometeoroid detectors on *Explorers I* and *III* showed that the population of dust and small rocks in orbital space proved little danger to satellites and spacecraft, interest in micrometeoroids became more scientific than pragmatic. *Able-1* offered a unique vantage from which to detect micrometeoroid distribution. Without the bulk of Earth obstructing half the sky, a high-flying probe could provide a more accurate picture of the distribution and velocities of cislunar particles. *Able-1* would also be able to investigate the nature and density of micrometeoroids in the vicinity of the Moon, thus providing a comprehensive map of micrometeoric dust out to some 225,000 miles from Earth.[44]

The micrometeoroid detector on *Able-1* was largely developed by outside contractors. Maurice Dubin of the USAF Cambridge Research Laboratory (AFCRL) was tasked to furnish the experiment. Dr. Dubin had also developed the experiment on *Explorer I* and was the most experienced scientist in the field at the time. After some time, Dr. Merle Alexander of Goddard replaced Dr. Dubin as principal investigator on the experiment and assumed responsibility for interpreting the data and publishing papers.[45]

While the AFCRL was responsible for providing the microphones and other detection equipment, STL's lot included the development of the logic circuit, and a good portion of this work fell on Stuart Baker, a bright and unassuming engineer with a Master's degree from MIT who had spent a six-month stint at Lockheed working on the Electra, gotten a job at STL designing downrange instrumentation for missiles, and had been transferred to the *Able-1* project with Sonett. He was responsible for the assembly and calibration of the experiment, in addition to integrating the detector plate into the satellite structure.[46] Sonett described him as "the most critical person [involved in making] the whole experiment package."[47]

The actual experiment was simple. It consisted of a detector diaphragm and a microphone, both mounted along the outside of the spacecraft, a bandpass amplifier, and two logic circuits whose outputs were fed to the subcarrier oscillators of the telemetry system. When a micrometeorite struck the diaphragm, it would create an acoustic pulse that traveled to the microphone. A piezoelectric crystal in the microphone would convert the sound to a 100 kc tone that would then be amplified and reported by a logic circuit. Sufficiently large micrometeorites required less amplification and would trigger both onboard logic circuits.

As the diaphragm took up a lot of the external surface of the spacecraft, its impact on temperature regulation was non-trivial. To address this, two impact plates were constructed—one made of uncoated aluminum for maximum reflectivity, the other coated with black anodized aluminum for maximum absorption. Depending on the flight path, determined by launch date, one or the other would be installed. As it turned out, only the shiny impact plate was ever used.[48]

Calibration of the experiment was straightforward. A number of glass spheres of weights varying from 5 to 500 micrograms were dropped onto the diaphragm from a height of about one inch. These weights bounced with diminishing energy until the experiment could no longer detect the impacts. From the period of the bounces, Baker estimated the velocity of the particles and thus the momentum.[49] Naturally, the test spheres hit the plate at speeds far under the speed of sound in aluminum (~5km/second) and real micrometeoroids were expected to strike the plate at supersonic speeds. It was not known whether or not supersonic impacts might produce voltage differently from subsonic ones, and there was no real way to test this. It was concluded early on in development, however, that the instrument would be suitable for returning at least a rough estimate of micrometeoroid flux.[50]

Other Experiments

Two different types of thermometers were included in the instrument package. One, a thermistor, was mounted on an insulator inside the vehicle. The thermistor's resistance varied with the local temperature and controlled the frequency of a subcarrier oscillator. The second thermometer was an electronic circuit whose voltage output varied with the temperature. Housed in a metal can, this circuit was primarily used to provide a calibration voltage for the ionization chamber experiment.[51]

Several experiments were slated to be flown on the first and/or second *Able-1* flights but were either delayed or failed to be included entirely. Dr. John Simpson of the University of Chicago was to build and provide a proportional counter telescope that would not be ready until the third flight. ARPA also selected Dr. John Winckler from the University of Minnesota, to prepare a complementary radiation experiment. According to Chuck Sonett, this experiment fell apart on the "shake table," the dynamic testing device at STL. An operational version of Winckler's ion chamber/Geiger-Muller tube combination would not be ready to fly until after the course of *Able-1* flights had ended.[52]

Ready for Flight

Despite the grueling development schedule, *Able-1* was ready for flight just six months from authorization. A marvel of technology and management, the program represented America's best chance to take a quick lead in the early days of the space race. Part 2 of this article is planned to tell the story of the three flights, the exciting information about deep space that they returned, and the legacy they left for future space missions.

About the Author

Gideon Marcus is a graduate of the University of California San Diego history department. Until last year, his interest in space history was largely recreational. A short stint in post-graduate work reinforced his desire to pursue active research. he currently is working on a comprehensive recounting of the almost forgotten first days of the U.S. uncrewed space program, particularly the Space Technology Lab missions. This work has the advantage that many of the key players are still alive, but the time sensitivity of the materials and the interviewees lends a somber urgency to the project. The opportunity to do this valuable research at such a critical time is truly a blessing. A previous article on the Pioneer rocket appeared in *Quest* Volume 13 #4.

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