How Diana touched the moon

An impromptu band of Army radio experimenters

established man's first contact with outer space in 1946

"A Jules Verne feat" ..."in a class with the atomic bomb" ... "Fantastic experiment" ... "Applications almost beyond immediate comprehension.” These were some of the exultant phrases that hit newspaper readers on the morning of Fri- day, jan. 25, 1946, as they learned how the IJ.S. Army had bounced a radar signal off the moon. "Man had finally reached beyond his own planet" was how *Time* magazine put it later.

Project Diana, which had achieved the feat, stirred the public', imagination to a degree that may seem surprising in today's more jaded world. Until then, man had been confined to Earth's ionospheric envelope. As the public perused photographs of a small radar squiggle indicating an echo from 238,000 miles away, it evidently sensed that planetary exploration was no longer a subject only for the comic strips.

Diana's great success was somewhat ironic, for it was a project that had net been specifically authorized nor even recognized by name until after it had accomplished its spectacular goal. Diana's only claim to legitimacy was a Pentagon directive to investigate means for detecting ballistic missiles that might he launched against the United States. This directive catalyzed a 39-year-old lieutenant colonel, John DeWitt Jr., who had long harbored a fascination for the moon. Col. DeWitt was an amateur astronomer and broadcast pioneer who was director of the Evans Signal Laboratory at Belmar, N.J.

A lunar love affair

He had spent his adolescence building radio sets in Nashville, Tenn., where his father had been an appeals court judge. In 1922, at the age of 16, he built and operated Nashville's first broadcasting station, the 15-WWDAA. A few years later he helped install the transmitter for WSM, a pioneering station whose l-kW output took the Grand Ole

Opry into thousands of homes. Mr. DeWitt continued to build radio stations until 1929, when he was invited to design broadcast transmitters at Bell Telephone Laboratories in New York City.

In his three years there, he developed the Western Electric700;A quartz crystal oscillator, which had a frequency stability better than any then available. While at Bell Laboratories, Mr. DeWitt became interested in astronomy. He read a great deal on the subject, especially about the moon.

In 1932, he returned to Nashville to become chief engineer of WSM and its new 50-kW transmitter on a clear channel of 650 kHz. He learned then that his brother, Ward, was also interested in astronomy, and together they built a 12-inch Cassegrain reflecting telescope. Mr. DeWitt pursued his hobby and his experiments over the next several years, and in 1935, he attempted to receive noise from the Milky Way, which Karl Jansky had discovered shortly before. The attempt failed, hut Mr. DeWitt persevered. By 1940, he had refined his equipment so that it was making successful measurements from the central galaxy.

Then, on May 21, 1940. the amateur astronomer wrote confidently in his notebook:

"It occurred to me that it might he possible to reflect ultrashort waves from the moon, If this could be done, it would open up wide possibilities for the study of the upper atmosphere. So far as I know, no one has ever sent waves off the Earth and measured their return through the entire atmosphere of the Earth. In addition, this may open up a new method of world communication."

He then described how he had attempted unsuccessfully to obtain reflections from the moon, using a 138 Mhz transmitter and receiver that he had developed and built for radio station WGN in Chicago. The frequency was unusually high for those days, and he had designed it into a relay link from studio to transmitter in anticipation of WGN's entry into FM broadcasting, Frequency modulation had only recently been shown to be practical by its inventor, Maj. Edwin H. Armstrong.

The WGN transmitter had a power output of 80 W, and the associated receiver could detect a l uV signal input. In his 1940 attempt to hit the moon on the night of May 20-21, Mr. DeWitt used a rhombic antenna that had a gain of 14dB and a manual switch from transmitter to receiver. Of the failure, he wrote:

"The negative result is easily understood. A considerable loss was known to exist in the transmission line, which, together with a small amount of absorption in the ionosphere, would place the received signal below the detectable value. "

Subsequent calculations revealed the transmitter power, antenna gain, and receiver sensitivity that would be required, and he wrote of plans "to build suitable equipment so that a definite result may be obtained."

Diverted by World War II

The onset of World War II forced postponement of these plans, however. By then a recognized authority in broadcasting and radio, Mr. DeWitt was invited to return to Bell Laboratories in 1942 to work on an important Navy antenna project at Whippany, N.J. However, he found the work insufficiently challenging, and he quickly seized an opportunity to join a number of Bell scientists who had gone to Washington. Soon, he was a civilian consultant to the Army's Electronics Branch. as well as a member of Julius Stratton's radar committee. which was advising the Air Force on radar requirements. Stratton was with the Massachusetts Institute of Technology's Radiation Laboratory at the time and later became president of M.LT. Following a reorganization of the Army Electronics Branch, Mr. DeWitt joined that service in uniform and subsequently was assigned to the Evan, Signal Laboratory at Belmar. He became director on Aug. 29, 1944, and a lieutenant colonel three months later.

Col. DeWitt distinguished himself at Evans by leading the development of radar for locating mortars and directing counter- fire.

The set used the shortest pulses then known and required special oscilloscopes, the development which he credited to Capt. Howard Vollum. Col. DeWitt received the Legion of Merit for his direction of the project. Capt. Vollum went on to found Tektronix.

During 1944 and 1945, the Evans scientists and engineers were searching feverishly for the answers to a host of urgent military problems dealing with radar and communications, but their search came to an abrupt halt after the U.S. dropped the atomic bomb on Japan in August 1945, and the war ended before the month was out.

Work at Evans continued on a few long-range projects, such as a way to record video signals, but the urgency was gone and inevitably boredom, frustration, and indecision set in. For most of the researchers, the only searching to be done now was for the most rapid means of returning to civilian life. Col. DeWitt didn't have the necessary "points" to be discharged; his release was not to come until May 1946.

The birth of Diana

Amid this slowdown and reorganization, the Pentagon directed the Evans Laboratory to look for ways to detect and track enemy ballistic missiles. The Germans had used V-2 rockets against England, and the directive asked if there were any means of detecting missiles that might be launched against the United States. At that time, it was not known whether radar could penetrate the ionosphere and allow a signal to be reflected back to Earth. In effect, a whole new technology was being requested.

Col. DeWitt and his men found the directive a welcome challenge. Given his long-standing interest in the moon, there could be no question as to the nature of the test target. Thus was born the unofficial Project Diana-so named, Mr. DeWitt says today, because mythology books referred to Diana as both the goddess of the moon and a virgin.

During the war. the Signal Corps had an arrangement with Maj. Armstrong whereby he carried out investigative work for the Evans

Laboratory, working to determine the utility of frequency modulation for radar. This entailed developing higher-power transmitters and more sensitive receivers. For this, he had an SC'R-271 radar, a standard Signal Corps set similar to the one that had detected Japanese planes at Pearl Harbor and Guadalcanal. The major had made extensive modifications to the equipment. The result was a powerful transmitter and a sensitive and complex receiver with multiple superheterodyne stages, each with its own crystal-controlled heterodyning oscillator. All of this was tied together as an experimental system with jump wires and temporary connections.

With the cessation of hostilities, Maj. Armstrong returned to Columbia University and his Alpine, N.J., laboratory to continue his long, bitter battle over FM. His radar lay abandoned at Evans.

Col. DeWitt needed all the power he could find to reach the moon, and the Armstrong transmitter and receiver offered the best chance. He and a team, with E. King Stodola as chief scientist, had calculated that they needed a narrow bandwidth of about 20 Hz. This required frequency stability far beyond the then usual radar requirements. Consequently, they modified Maj. Armstrong's receiver so that, instead of using three local oscillators to step down three intermediate frequencies, a single crystal controlled the transmitter frequency and all but the last IF stage. This stage used a tunable crystal to heterodyne down to 180 Hz, with a bandwidth of about 50 Hz.

The final stage had to be tunable to pick up the return signal, whose frequency would be modified by the Doppler effect caused by the relative motion of Earth and moon. The maximum shift was calculated as 327 Hz, which would have put it outside the band of a fixed tuned receiver having 50 Hz bandwidth. Though relatively simple today, the receiver circuitry was quite novel then.

Antenna modification, too

The battle for decibels also required modification of the antenna. An antenna of the SCR 270-27! series was mounted on a nearby tower and available. However~ it rotated in azimuth only and consisted of a bedspring" of 32 dipole elements. The tower was

reinforced, and two such antennas were mounted side by side, making a 40 x 4O-foot antenna that pad a gain of 250 over an isotropic radiator. At 111.5 MHz, the path attenuation was calculated to be 198.7 dB, while the equipment was calculated to have a capability of detecting signals with path attenuation of 214 dB. It was hoped further that ground reflections would result in a vertical lobe structure, which might add 6 to 8 dB.

Rather than depending on these calculations and the resulting 23-dB margin, Col. DeWitt and his team built a 15-kWamplifier, using transmission lines to neutralize the feedback capacitance of the amplifier tubes. This, too, was novel circuitry for its time.

Ample equipment was available for the tests, particularly since there were no competing projects in the laboratory. However, the narrow bandwidth of the receiver and the higher power of the transmitter made many conventional measurement methods obsolete. When signal generators proved inadequate for achieving the necessary frequency stability, the engineers modified them with crystal control and other devices. Extensive measurements and calibrations were made to verify that the design goals had been met. A new test for receiver sensitivity was devised, with use of a noise diode to inject the signal. A novel directional coupler, using transmission lines, measured the power from the modified transmitter.

The moon watch begins

Since the antenna beam could not be elevated, all tests had to be planned for the brief half-hour periods that the moon was at or near the horizon. As the end of the calibration measurements approached, a watch was instituted each day at moonrise, when the antenna was rotated toward the Atlantic and to the azimuth of the rising moon, and the system was placed in operation.

To place the system in operation, the receiver input had to be disconnected from the signal generator, Of noise diode, and connected to the transmit/receive switch (antenna). Then the receiver and transmitter were turned on. The mechanical T/R switch made a great clatter as the 0.25-s pulse was transmitted, and there would be silence during the next 4.75 s as the team waited for the echo. Then the T/R switch would announce the transmission of the next pulse with a clatter and bang.

Detection was by a conventional A scope, especially built for Project Diana with a 3-s sweep and special phosphor, and by an audible tone taken from the 180-Hz stage. However, weeks passed before the equipment revealed any return signals: The difficulty lay in its many defects. Vacuum tubes died, soldered connections became open circuits, crystals refused to oscillate, and there were many circuits to be disconnected and reconnected in going from the calibrate to the operate stage. The only wiring diagrams were sketches, and sometimes these were not up to date. As a result, many of the lunar observation periods were gone before the equipment could be properly connected and warmed up.

During December i945, attempts were made each day. The antenna was even rotated toward the west in an attempt to make the tests on the setting moon. But Christmas and New Year came and went without any detectable echo.

In the meantime, every suggestion was tried for increasing the sensitivity and the power. Some of the project researchers had already been demobilized or transferred to permanent assignments elsewhere, and general interest in the project ebbed.

Mr. DeWitt contends he was never discouraged, however. Shortly after he started the project, the Army relieved him of his responsibilities as director of the Evans Laboratory~ and this left him free to devote his entire time to Diana. He received one memorable scare just before Christmas of 1945 when he was ordered to Germany to take over its broadcasting stations. He hurried to Washington and persuaded the Office of the Chief Signal Officer that because of his pending discharge in May, he shouid not be given the assignment. He returned to Evans and, with a few others, continued the daily moon vigil.

The moon replies

On Jan. 10, 1946, Col. Dewitt drove to the town of Belmar for lunch and to replenish his cigarette supply. (He no longer smokes.) Meantime, two co-researchers, Harold Webb and Herbert Kaufman, manned the rig, and at 11 :58 a.m, they heard the first sound of a reflection from the speaker. The trace on the oscilloscope made it clear that the reflection occurred ahout 2.5 s after the pulse was transmitted. Fading was very bad, and the variation from pulse to pulse was enough to lose the signal compietely at times. Finally, at 12:09 p.m., the last reflection faded and the speaker was silent; the moon had risen above the beam. Dr. W ebb and Mr. Kaufman were elated and found it difficult to wait for Col. DeWitt's return. They carefully rechecked the calibration and measured the return rime. There could be little doubt that this was a real reflection from the surface of the moon. For the first time, man had proof that electromagnetic waves could penetrate the ionosphere.

Upon his return, Col. DeWitt verified the results and calculated the time for the tests the following day. The project personnel were on hand on Jan. 11 at noon. At 12:27 the first echoes were received, and they continued with intermittent fading until 12:37, when the moon again rose above the beam of the antenna. On Jan. 12, Col. DeWitt, Mr. Stodola, IJr. Webb, and Mr. Kaufman saw the first echo at 12:51 p.m. and then again from I:02 to 1:11. On Jan. 13, Col. DeWitt, Dr. \\'ebb, and Mr. Kaufman manned the watch, observing the first echo at I:28 p.m. and then almost continuously frorn 1:38 to 1:47.

Mr. DeWitt-he is retired now and does consulting work from his home in Nashville-says he was "elated, to say the least." Mr. Stodola, who, after a long period in industry, is again employed by the Signal Corps at Ft. Monmouth, N.J., also remembers the thrill of that moment. Like the others, he was certain that only a nuke could have kept them from success.

The general was skeptical

Col. DeWitt reported the success to his superior, Col. Victor A. Conrad, who telephoned Maj. Gen. George L. Van Deusen, head of research and development in the Office of the Chief Signal Officer. The general was skeptical and asked that the story be confinned by independent outside experts. He did not want the corps to be ridiculed for a story that might later be disproved.

With Col. Conrad's consent, Col. DeWitt asked George Valley of the M.I.T. Radiation Laboratory and Donald Fink, then with the Office of the Secretary of War, to go to the Evans Laboratory and witness the tests. They arrived on the day that Gen. Van Deusen was at Ft. Monmouth reviewing the troops. Moonrise was at about 7:30p.rn., and CoL Conrad persuaded the general to join Col. DeWitt, Dr. Valley, and Mr. Fink at the shack.

Mr. Dewitt recalls today that they arrived a little early and "all stood around waiting for the moon to rise.
"When it had reached the proper altitude," he recounts, "we started to bang away, but nothing happened. You can imagine that, at this point, I was dying. Shortly, a big truck passed by on the road next to the equipment hut, and immediately the echoes popped up. I will always believe that one of the crystals was not oscillating until it was shaken up or that there was a loose connection that fixed itself. Everyone cheered except the general, who tried to look pleased.

"Don Fink suggested that the general announce the result to the IRE banquet in New York which was to take place shortly thereafter. A press release was prepared, and it specified the time for the announcement as 11 p.m. I recall that we sat there after the dinner while the distinguished speaker droned on, putting everyone to sleep. Before he was through and the announcement could be made, I heard newsboys in the lobby of the hotel trumpeting the news. "

The moonstruck press

There was considerable embarrassment in the Institute of Radio Engineers over the general's being scooped in that manner. But this only proved to be the first of several unsatisfactory en- counters between the press and the Army resulting from Project Diana.

After Col. Dewitt had left the Army and his group had dispersed, no one in the service seemed to have cared enough about the experiment to maintain the equipment. It soon fell into disrepair, and today its ultimate fate is unknown. However, the experiment was of great interest to the technical world, and hundreds of scientists from all over began conducting experiments and wriring papers. With relatively powerful microwave equipment available both for radar and communications, antenna dishes were turned toward the moon, and its face was flooded with electromagnetic waves. The U.S. Navy established a microwave communication link from Annapolis, Md., to Pearl Harbor via the moon.

Meanwhile, schemes for using the moon as a reflector for broadcast programs and for television were detailed in newspapers and magazines. So, too, were speculations about radio control of "space ships," about verifying Einstein's light-deflection theory, and about mapping the surface of the moon by radar. This last speculation was particularly upsetting to the Army, because the press reported in 1948that Ft. Monmouth was actually going to do it. Newsreel companies clamored for permission to film the mapping. Such a feat was, of course, impossible, given the wide beamwidth of Project Diana radar. What happened was that a reporter had been told that the Army scientists would study the fine structure of the echo; he had misconstrued this to mean the fine structure of the moon's surface.

It was from such experiences that the Army concluded that further publicity on the project should be curtailed. And so Project Diana passed into history.

Today, it is difficult to remember what it was like in the days when most researchers had come to believe that all electromagnetic waves suitable for long-range communication might be confined to Earth's atmosphere. There were no satellites with radio transmitters, whose signals might be received on Earth. Researchers knew that light waves and invisible radiation in the infrared and ultraviolet penetrated the atmosphere, but they had little knowledge of the characteristics of the attenuation this radiation encountered on its one-way passage from the heavenly bodies through the atmosphere to their detectors. Researchers had studied reflections from the ionized layers about the

Earth; they knew the height of these layers and had learned to predict roughly when they would be most reflective. They surmised that at other times their emissions might penetrate the layers, but this was only surmise.

Diana was truly man's first step into the space era.

Technical reports of Project Diana equipment and results appeared in *Proceedings of the IRE,* March 1949, pp. 229-242, and *Electronics,* April 1946, pp. 92-98.

Recollections of Diana

At the end of the war, when so many were preoccupied with the resumption of their prewar activities, it was rare to find a group like the researchers of Project Diana, who not only looked forward, but also up. When I boarded the steam train in Boston’s South Station on my way to observe their results, I, too, had been chiefly interested in resuming my prewar work.

At that time, I knew a lot of truths that I really didn't feel. One of these was that large quantitative variations in the oarameters of a phenomenon could make qualitative changes in it. Another fact I knew was the distance from the Earth to the moon. The fact that it would take a light beam more than 2 s for the Earth-moon round trip. I knew in my head, but I didn't really feel it.

Project Diana gave me a feel for those truths: for, instead of the continuous trace that I was accustomed to see, the A scope of Diana's radar showed only a single spot of light, slowly crawling across the tube face, eventually to draw but a single pulse! That truly made me feel, not only the qualitative difference between this radar and the ones I was accustomed to use. but also that the moon really was a long, long way off.

And afterward, when we all went outside and looked up. I saw that the moon, although no nearer, now seemed more approachable. I went home wiser than when ! had come, a little more inclined to plan something new.

- George E. Valley Jr.

Today, a third of a century later, i recall vividly the excitement I felt as the moon rose over the horizon. For a few minutes, nothing happened; the expected echoes were not observed. Then, suddenly I saw the blip on the A scope and heard the audio tone. It was real! Valley and I had independently computed the expected signal returns - he by a much more sophisticated analysis than mine-and we agreed the echo signals previously reported were observable and had so informed Gen. Van Deusen. However. the actual event carried an emotion that mere figures could not.

Since then, laser mirrors set up by the Apollo astronauts have revealed the distance to the moon at any instant to within a few feet, and amateur operators have communicated by moon-bounced signals. With these commonplace events in mind, it is difficult to remember how close to the limit the technology at the Evans Laboratory was in 1946. Armstrong's contribution of a stable receiver with 50-Hz bandwidth was crucial. as was DeWitt's provision for tracking the Doppler shift to keep the signal within the bandpass. Diana was, indeed, the high frequency of its day, the first milestone on the road to the space age.

-Donald G. *Fink*

About the author

Trevor Clark (LF) is a consultant to industry on ways to increase the flow of inventive ideas from employees. He has written a book on the subject that is to be published soon. He was formerly manager of information services in the Aerospace and Electronics Systems Division of the Westinghouse Electric Corp. in Baltimore. During World War II, he helped develop radio direction finders, radar, and radio countermeasure equipment. For this work, he received the U.S. Navy Certificate of Commendation and the Certificate of Merit from the U.S. Office of Scientific Research and Development. He later developed microwave communication equipment and held administrative positions in research, development, and manufacturing at ITT and the Southwest Research Institute. Mr. Clark received a bachelor's degree in physics and mathematics in 1930 from Friends University in Wichita, Kans., and a master's degree in physics in 1933 from the University of Michigan.

Meanwhile in Hungary

On February 6, 1946, three weeks after DeWitt's lunar contact, a Hungarian team led by Zoltan Bay announced that it had made radar contact with the moon. In "Reflections of • Microwaves from the moon," *(Hungarica Acta Physica,* vol. 1, c.1,1946), Dr. Bay wrote that he had proposed the experiment in March 1944 while at the Research Laboratory of the United Incandescent Lamp and Eiecirical Co" Ltd. ("Tungsram") in Ujpest. However, Allied air raids and other wartime exigencies forced the lab to move several times and Bay had to rebuild hi8 equipment twice, eventually completing it in January 1946.

Experiments began immediately, outside of regular plant working hours because of electrical disturbances. Bay had no crystal-controlled transmitter or receiver and was thus forced to devise a special method of cumulation, using water voltameters (coulometers), to increase the receiver signal/noise ratio. A retrospective article on the 30th anniversary of Bay's experiment credited his use of integration with playing "a decisive role in the later development of radar astronomy." (P. Vajda, J.A. White in *Acta Physica Academiae Scientiarum Hungaricae,* 40, 1976). The authors pointed out that this was foreseen by Bay in 1946 when he wrote, "The fact that American investigators carried out successful moon-experiments without the method of cumulation, does not diminish the value of using coulorneters. In the future, the coulometers (or other methods of cumulation) can be used for more exact measurements without increasing the transmitted energy substantially, or the measurements can be extended to other celestial objects, too. In this field, the best results would be yielded by a combination of the highly developed American technique with our method of cumulation."

Bay, who came to the United States shortly after performing his experiments and is currently a senior research scientist at The American University, Washington, D.C., also wrote in his 1946 paper, "It is significant that electro- magnetic waves of 2.5 m wavelength *can* pass through the ionosphere. This fact may receive practical importance in interplanetary navigation and in spreading reflected microwaves over the whole surface of the Earth."- *Ed.*