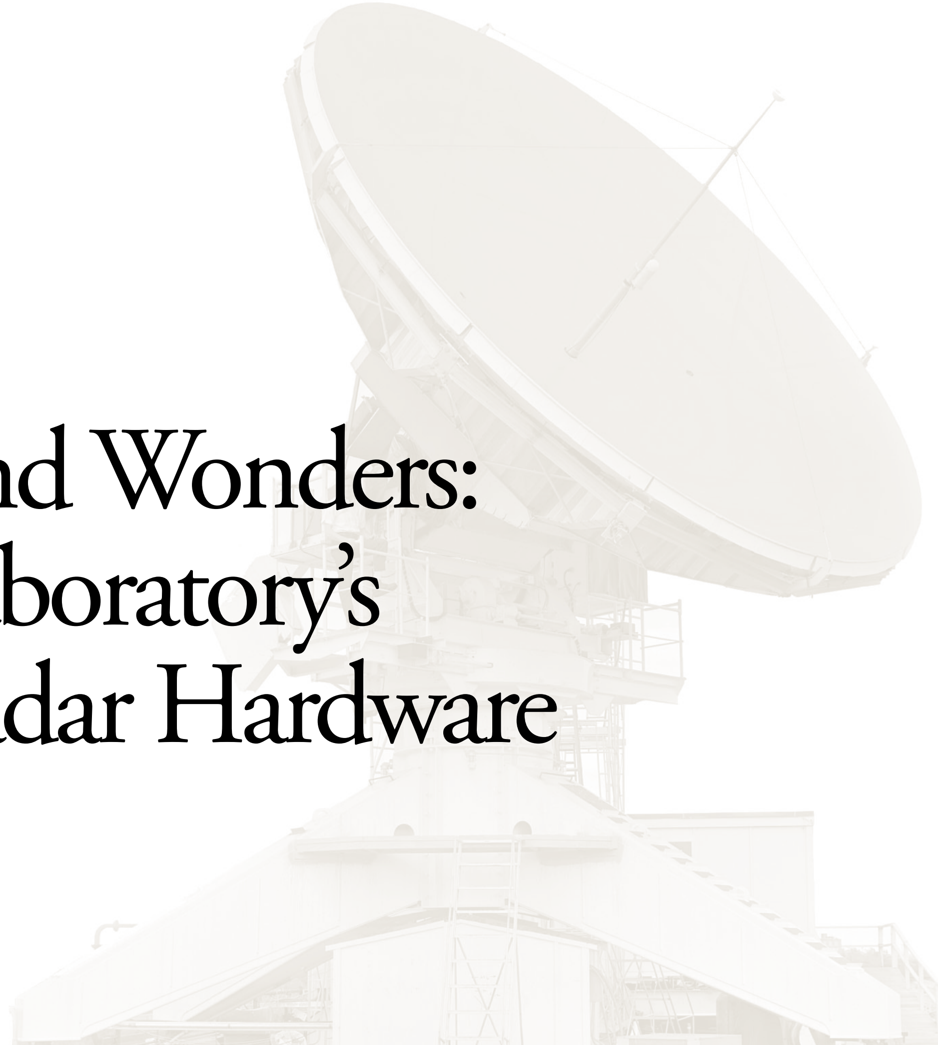


Widgets and Wonders: Lincoln Laboratory's Unique Radar Hardware Legacy

Richard L. Ferranti

One of the more distinguishing characteristics of Lincoln Laboratory is its insistence on analyzing real-world data from the advanced electronic systems it develops and operates. As a result of this commitment, the Laboratory must often build and field hardware with capabilities exceeding those available commercially. Over the past five decades, the Laboratory's profound devotion to data-based radar performance analysis has resulted in the production of many hundreds of small or specialized radar systems and supporting hardware items. These have ranged in size from an aurora-research radar [1], with its sixty-foot antenna, to tiny potassium-cobalt-cyanide crystals, used in the early UHF maser that made it possible to detect radar echoes from Venus [2].

Almost all of the histories of the Laboratory's large radar programs and field systems are discussed in this issue of the *Lincoln Laboratory Journal* or in Eva Freeman's history, *MIT Lincoln Laboratory: Technology in the National Interest* [3]. The purpose of the present annotated photo collection is to present a selected group of the lesser-known radars and related items, those generally excluded from the more traditional histories.

Other systems were simply too small or limited in application to appear in large project histories. They often had intriguing names, such as "Porcupine," "Chipmunk," and "Rocket-Plume Radar." And in some cases these hardware items were just plain bizarre in concept or in application. For example, the first of the Laboratory's simulators that generated radar reflections similar to echoes from moving targets was a large motor-driven "Doppler wheel" (looking rather like a large grindstone), while some of the Laboratory's early radar-waveform analysis was based on studies of *Noctilio Leporinus,* the fishing bat.

These lesser-known radars and components were not insignificant in the history of radar development. Perhaps the highest peak-power level ever developed at UHF was generated at the resonant-ring High-Power-Test Laboratory, located at the Laboratory in Annex 2 in the late 1950s [6]. Its legacy includes the successful development of components tested at the 100-MW level for long-range ballistic-missile-detection radars fielded forty years ago. The Caterpillar high-frequency groundwave radar, built in 1955 at Round Hill (MIT's Green estate in South Dartmouth, Massachusetts) [7],

AEW Aurora Research Radar Bat Laboratory Bat Research Caterpillar Radar Clarke-Dicke Fix Chipmunk Radar Flashlight Radar Fluttar High Power Test Laboratory High Power Tube Research Interim L-band 2-D Search Radar Jamming LCE Radar LITE Laser Radar Millstone Sisters

was an important contributor to the development of over-the-horizon radars, on which billions were spent in the 1970s and 1980s. The millimeter-wave Moon Radar [1] was the first to have sufficiently small angular resolution to subresolve the Moon; its development led to significant technology advances in stabilized transmitters and precision, large-aperture (1000 wavelength) antennas and mounts.

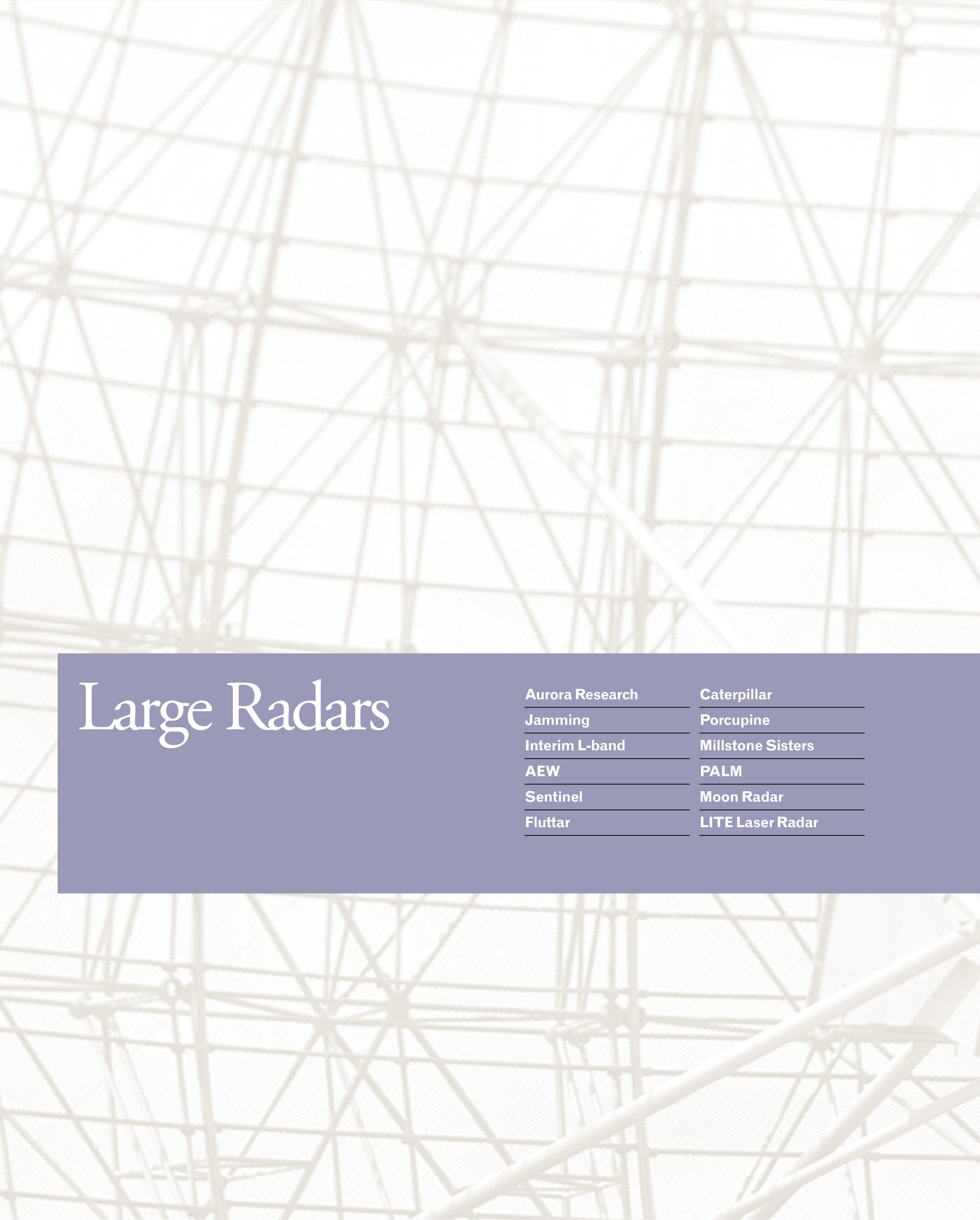
Often these radars and related items were part of other major developments such as ALCOR [4], but became overshadowed by the success and visibility of their larger companions. "Mini-ALCOR," ALTAIR [5], "Smalltair," "Flashlight," or any of the many radar repeaters and simulators are good examples of these radar siblings.

And Porcupine, one of the early pulsed-Doppler point-defense radars, was not only a progenitor of more modern systems such as Hawk and Patriot, its hardware was reused for some of the earliest work on Doppler-based radar weather measurements [8].

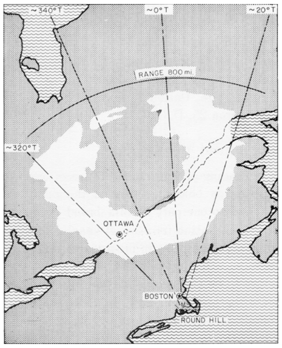
This photo essay is like a picture album of a long-deserted ghost town. Much of value was mined there in the past, but now it stands forsaken, the photos only hinting at its former vibrant existence. Focusing on the small, almost lost, and generally unreferenced radar hardware of the past fifty years, this section can present only a limited number of developments that were brought to the author's attention. Discussions with senior Lincoln Laboratory employees, archive and literature searches, suggestions from other authors of this issue of the *Journal*, and just plain luck in stumbling on some mysterious reference in the archives or the photo lab were the main sources of information. Nonetheless, there is a broad range of intriguing hardware presented here, much of it undiscovered since it was first built, successfully fielded, and then largely forgotten.

Mini-ALCOR Model 1 Laser Radar Moon Radar PALM Porcupine Prince Albert Radar Radar Salesman Radar Truck Rail SAR Rocket-Plume Detection Radar Scanned Feed Antenna Test Array S-Band Tracking Radar Sentinel Smalltair Spectrum Analyzers Ultrasonic Bat Detector

The author hopes that the reader will gain a deeper appreciation of the breadth of the Laboratory's work in fundamental radar development, and will understand just how deep the Laboratory's commitment has been in exploring radar phenomenology by grappling with real-world hardware and data for five decades.



Large Radars

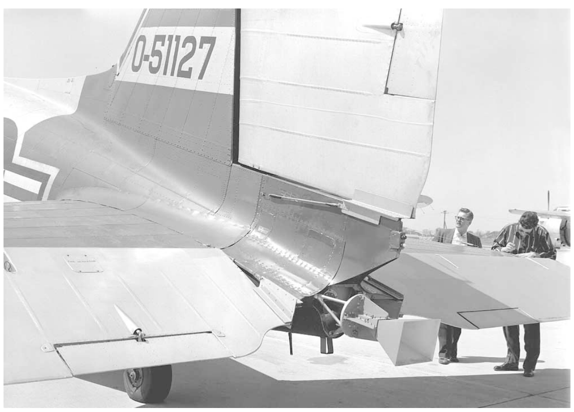


Left: diagram showing strong auroral backscatter from the dual-frequency UHF aurora-research radar, 1958.

Right: the control room of the third aurora-research radar, located at Round Hill Point [7]. This was a klystron-based system operating at 417 MHz with a 500-μsec pulse-width. The 10-kW radar became operational in 1956.

One of the Laboratory's three aurora-research radars. This system, with its sixty-foot dish antenna mounted next to Colonel Green's mansion at Round Hill (then owned by MIT), in Dartmouth, Massachusetts, was driven by two 1.5-MW magnetrons operating simultaneously at 425 and 675 MHz. It became operational in 1958. Two years earlier, a 200-kW, 50-MHz aurora-research system, driving Yagi antennas, was placed in operation in addition to a smaller UHF radar.

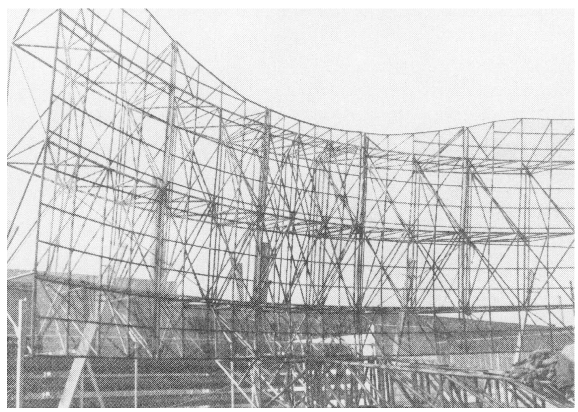
Jamming



Above: horn mounted in tail of a C-47 aircraft (a militarized DC-3) for radar-jamming experiments, against the AN/FPS-30 search radar, 1957 [4].

Right: radar-jamming truck used against various aircraft search radars, 1956.

Interim L-band



Model of the Interim L-band 2-D search radar, a circularly polarized 10-MW peak-power system intended for long-range bomber detection in the Distant Early Warning (DEW) Line system, 1955 [10].

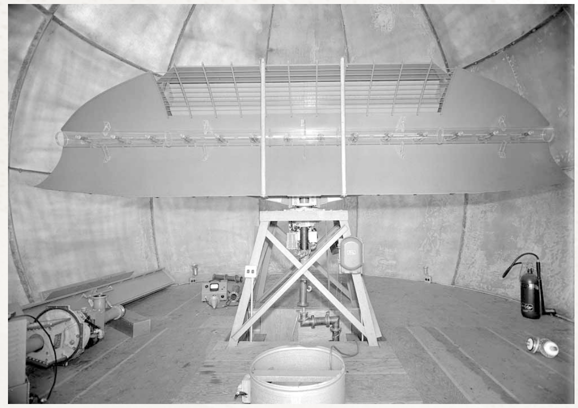
Top: actual Interim L-band antenna set up for mechanical-assembly checkout.

Bottom: Interim L-band radar in operation, 1956.

AEW

These antennas were part of our early work in airborne early warning (AEW) radar [11], based on the AN/APS-70 UHF system mounted in Air Force and Navy Super Constellation aircraft and Navy blimps.

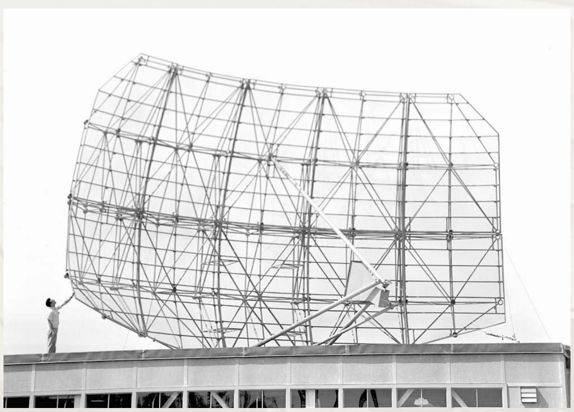
With Laboratory-designed signal processing improvements such as TACCAR, these radars were predecessors to the Navy Hawkeye and Air Force airborne-warning-and-control systems (AWACS).



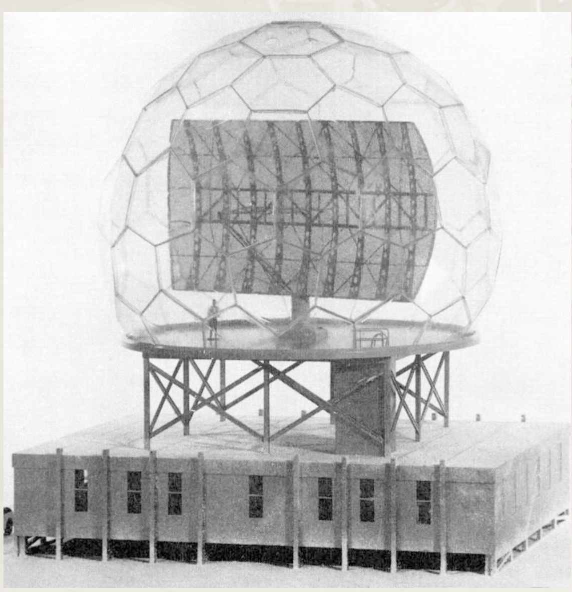
Top right: narrowband 425-MHz AN/APS-70 antenna (NRL), 1957.

Right: broadband AN/APS-70 antenna (Hughes), 1957.

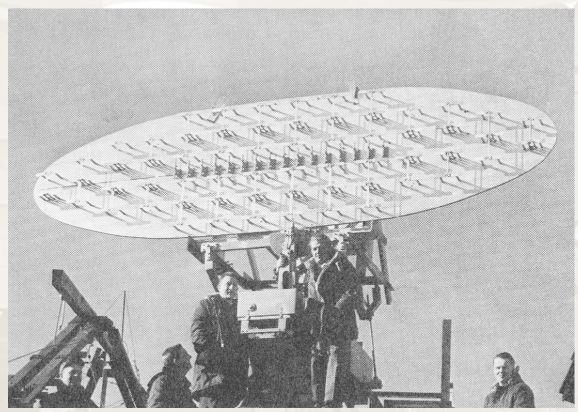
Sentinel [9]



Full-size Sentinel radar antenna on the roof of Building C at Lincoln Laboratory, circa 1955. The man at left shows the scale of the antenna.



Model of the Sentinel radar, a long-range Doppler-capable automatic-alarm radar operating at 600 MHz, 3-kW average power, part of the DEW Line system, 1955.

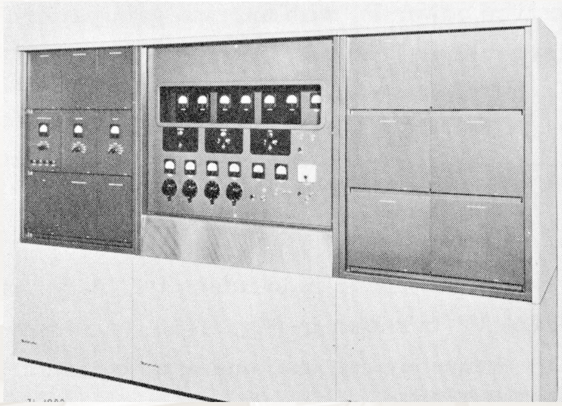


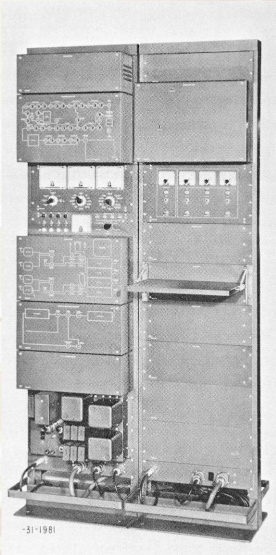
Top: 675-MHz interim AEW antenna, Radiation Engineering Laboratory, 1957. Bottom: 675-MHz AEW antenna with DPCA [12], (developed by NRC, Canada), circa 1957.

Fluttar

Below: a large Motorola transmitter built to the Laboratory's specification for the Flutter radar ("Fluttar"), 1955 [10]. Fluttar was a bistatic gap-filler 408-MHz continuous-wave radar that acted as a tripwire to alert DEW Line operators that an airborne intruder had passed through the transmit/receive path.

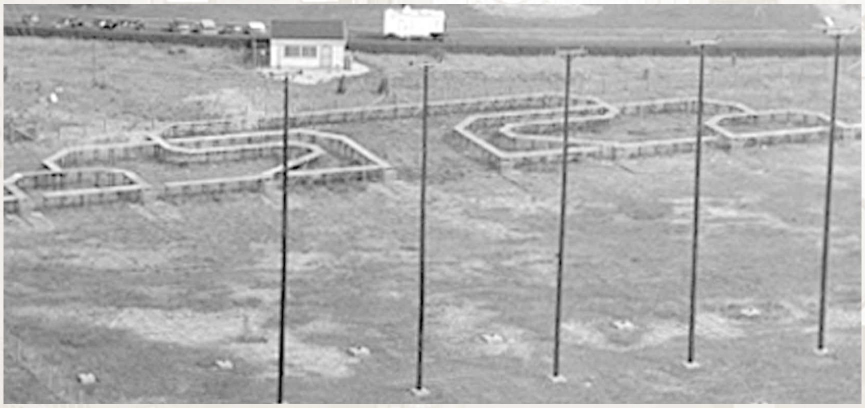
Fluttar UHF transmit antenna prototype.





Receiver for Fluttar, 1955.

Caterpillar



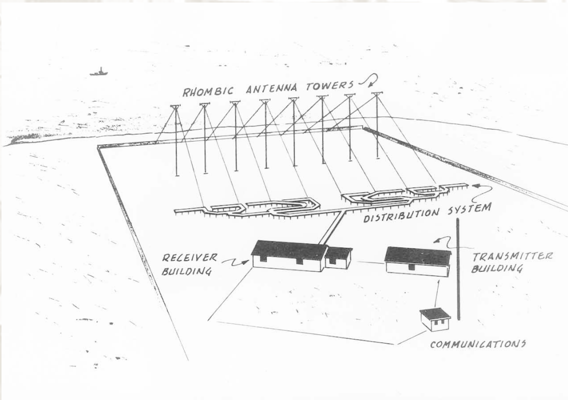


Photo of the Caterpillar radar showing the Caterpillar stripline feed and half-rhombic antennas, 1954.

This high-frequency radar was located at Colonel Green's estate at Round Hill (then owned by MIT), in South Dartmouth, Massachusetts [7].

Artist's sketch of the eight-element phased half-rhombic antenna array used in the high-frequency (18 MHz) Caterpillar ground-wave radar, 1954.

This vertically polarized array was used for early work in ground-wave propagation for detection of low-flying airborne targets approaching the sea.

Mini-ALCOR and Project Mercury

Top: Mini-ALCOR [15], a test-range radar intended to provide wideband measurements on echoes from typical missile targets, such as reentry vehicles and decoys, before ALCOR [4] was completed at Kwajalein. This radar was an S-band and C-band system that produced 500-W, 2-nsec pulses in 1971.

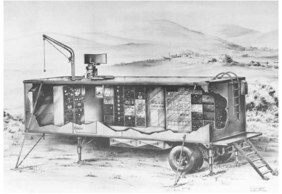
Bottom: quad-helix beacon tracker for Project Mercury capsule, designed to assist long-range tracking radars in acquiring the first U.S. manned space vehicle, 1960. Note the World War II surplus SCR-584 van and antenna mount.

Porcupine

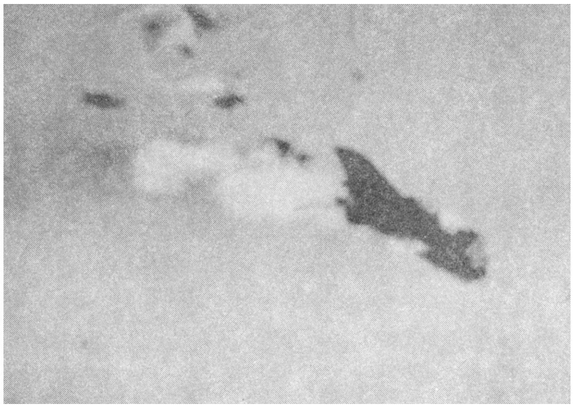
Porcupine was an early (1952) S-band pulsed-Doppler radar designed to detect and direct fire against low-altitude aircraft or missile threats.

The final prototype model (Porcupine II, at C-band) had an unusual flap-dish antenna that formed a fan beam (for search) or pencil beam (for track) by using electromechanical actuators. It had excellent clutter rejection of greater than 70 dB.

The radar directed a multi-tube clustered rocket launcher that fired two dozen small high-explosive projectiles (one version deployed submunitions called quills) as a kind of rocket shotgun.



An artist’s cutaway of the final radar configuration, and the prototype Porcupine equipment mounted in a World War II surplus SCR-584 trailer.



Porcupine makes a kill: a rocket salvo directed by the radar brings down a B-17 drone aircraft over the Mojave Desert in May 1955.

Porcupine II, a C-band coherent pulsed-Doppler radar with its dual-mode search/track antenna, 1955. This radar was used to provide definitive data on radar “angels” (for example, by tracking a seagull in flight), and was later employed as one of the first Doppler weather radars (after it was transfered from Lincoln Laboratory to the Air Force Cambridge Research Laboratory in the late 1950s).

A whole host of Millstone look-alike high power-aperture tracking radars, at frequencies from UHF to S-band, sprang from the original Millstone Hill UHF design. These included the famous and numerous 84-foot-dish Ballistic Missile Early Warning System (BMEWS) AN/FPS-49 radars, and the three less-well-known systems shown here.

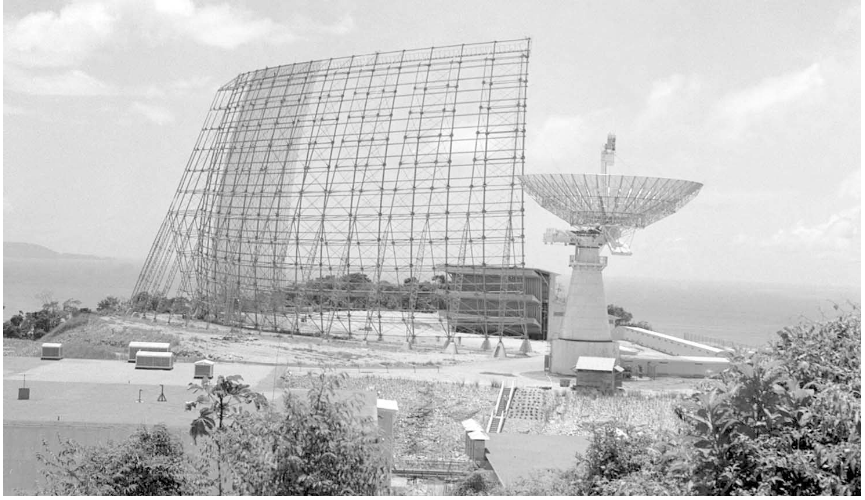
These "Millstone Sisters" [13] were all constructed with considerable Laboratory assistance.

The S-band tracking radar, with its 60-foot dish on a surplus Navy dual five-inch gun mount, shown in test at Millstone Hill and later at Wallops Island, Virginia, 1959.

The Prince Albert Radar Laboratory (PARL), Saskatchewan, Canada, operated by the Defense Research Telecommunications Establishment. The photo shows the 84-foot Millstone Sister radar antenna, and a new building, erected in 1961, after a fire destroyed an earlier Millstone-look-alike building. The antenna and much of the radar equipment were saved.

The air-surveillance radar for this site was the Laboratory-designed Chipmunk (see p. 409), which was the only known operational deployment of this system.

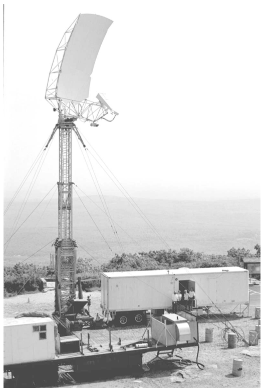
Site construction in process at Wallops Island, 1960.



BMEWS test site on the island of Trinidad. The two antennas are an organ-pipe-scanner-fed parabolic torus and a paraboloid tracker, another Millstone Sister.

Katahdin Hill at Lincoln Laboratory, 1975. From left to right: the Discrete Address Beacon System (DABS) [14] prototype, the AN/FPS-6 antenna fitted with the Laboratory-designed Automatic Reporting of Height (AROH) servodrive; the AN/FPS-14 SAGE gap-filler radar; and a long-range military/FAA AN/FPS-20 L-band radar with "hog-trough" identification-friend-or-foe (IFF) beacon antenna on top.

L-Band Experimental Radar



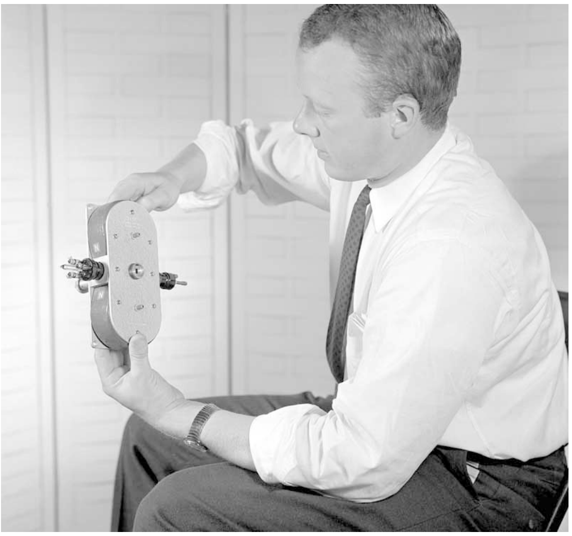
The L-band Clutter Experiment (LCE) radar, a 10-kW peak-power polarimetric system, which was built to measure the Doppler signature of wind-blown clutter [16]. It was designed to have extremely low phase noise at low Doppler frequencies, and it successfully detected the Bragg scattering from waves on wind-blown lakes. The radar is shown deployed at Wachusett Mountain in central Massachusetts in 1991.

Pat Themelis looks over an L-band cylindrical array antenna, used to demonstrate radar and communications functions. Similar Laboratory-developed cylindrical arrays for different frequencies and applications were used in the Camp Sentinel radar, the Long-Range Demonstration radar, and the Advanced Ground-Surveillance Radar (AGSR).

PALM

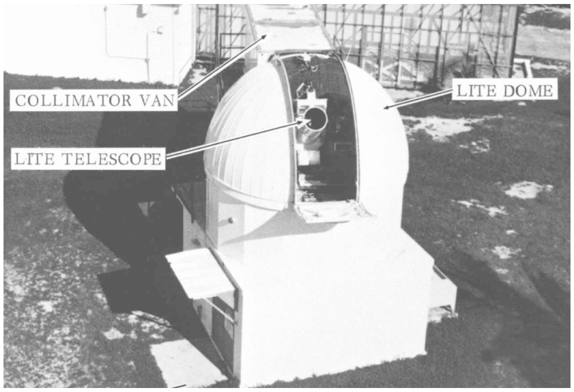
The Precision Altitude and Landing Monitor (PALM), an FAA-funded program intended to provide accurate stand-alone three-dimensional position data for radar-beacon-equipped aircraft. The Laboratory developed the PALM concept and experimentally evaluated the accuracy of elevation-angle measurements by using the five-element, 30-foot L-band array antenna system shown here. In 1975 this measurement system validated the 1-mrad elevation-angle accuracy predicted by Laboratory analysis. Though PALM was never operationally fielded, the analysis formed a basis for much of the precision superresolution technology later developed at Lincoln Laboratory.

The millimeter-wave Moon Radar [1]. This 28-foot precision paraboloid was developed by using spin-casting techniques. The antenna was formed by spinning a bowl of molten plastic; the resulting shape is paraboloidal to a high degree of precision. The solidified plastic surface was then made conductive with an over-spray of molten zinc. The modified Casse-grainian feed system was developed by Kim Keeping. This radar, with its 67-dBi-gain antenna, was the first to illuminate a small portion of the Moon's surface; its beamwidth was just a tenth of the angle subtended at the Earth by the Moon.



Larry Lynn, project engineer for the Moon Radar program, is shown in 1963 holding the floating-drift-tube klystron oscillator that served as the transmitter. The tube produced 12-W CW power, and sent 2.5-sec pulses to the Moon. The receiver then received the weak echoes for 2.5 sec. The process was repeated about ten times in order to integrate enough return signal to detect the Moon's presence with the radar.

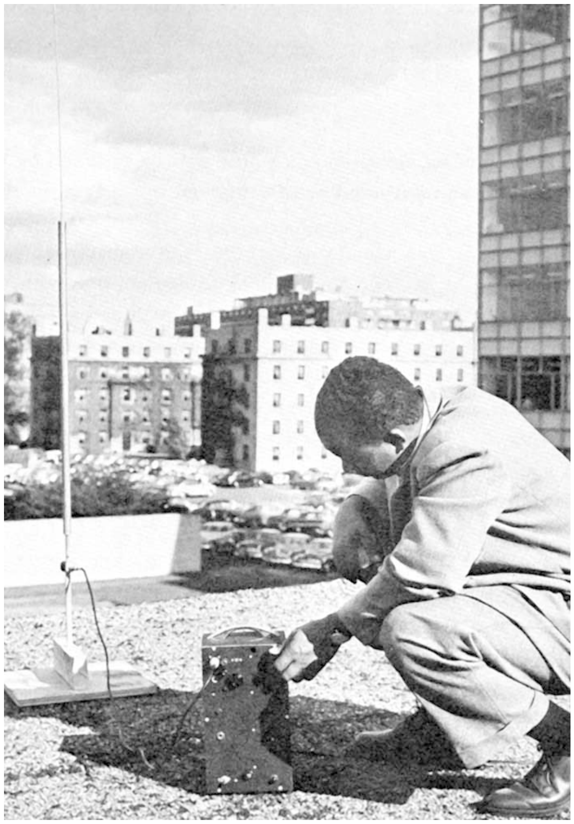
LITE Laser Radar

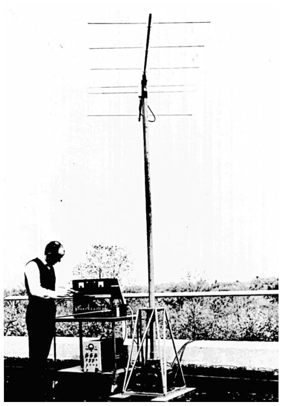


The Laser Infrared Tracking Experiment (LITE) was deployed at Kwajalein and was operational in 1977. This was a 1.06-μm noncoherent Nd: YAG laser radar with 50 MW peak power, a 20-nsec pulsewidth, and a pulse-repetition frequency of 10 pulses/sec. This early laser radar took signature data on reentry vehicles and their wakes. LITE was also used to demonstrate the fine metric accuracy capabilities of such sensors, and it executed real-time handovers to other sensors.

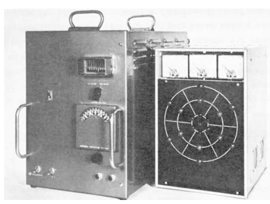
Small Radars

Chipmunk [18, 19] was a man-portable radar designed to alert ground troops of approaching aircraft. It began life as a very simple (five-tube!) superregenerative transmitter/receiver, similar to those used in World War II proximity fuzes. Designed by Roy Sallen and Edwin L. Key (the same designers of the famous active filter circuit), Chipmunk was to evolve from the elementary 100-MHz prototype shown here on a Cambridge rooftop with its omni-directional antenna, to a 400-MHz unit with scanning Yagi antenna and primitive plan position indicator (PPI) display. This "low-power radar" dates from 1953.



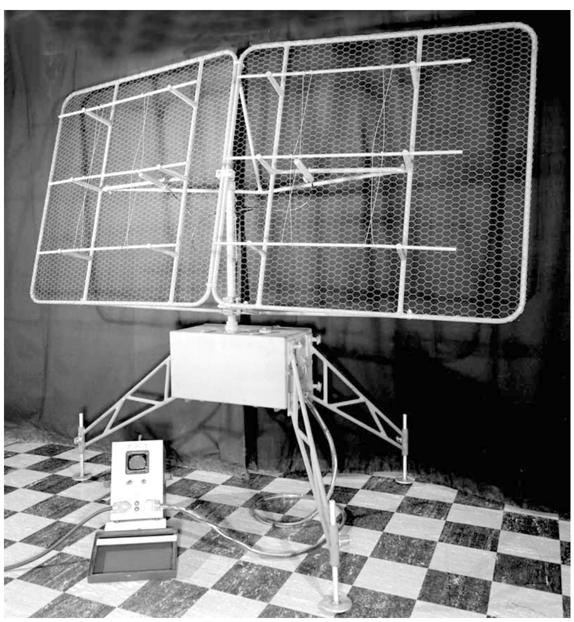


Chipmunk radar with a much more elaborate transmitter, superheterodyne receiver, and Yagi antenna, now operating at about 110 MHz, 1954. Haines H. "Hook" Danforth on the roof at the controls.



Left: an even more advanced Chipmunk radar with antenna-azimuth, A-scope, and light-bulb-PPI displays, 1955.

Preproduction UHF Chipmunk, with reflector antenna and miniaturized display, 1957.



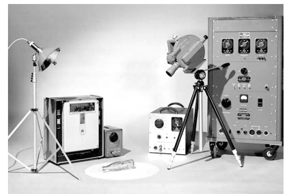
Final production Chipmunk (one of eight models made by National Company, Malden, Massachusetts), designated by military nomenclature AN/TPS-23.

The system was never put into full production, and was never deployed except as a stop-gap air-surveillance radar for the Prince Albert Radar Laboratory in Saskatchewan, Canada.

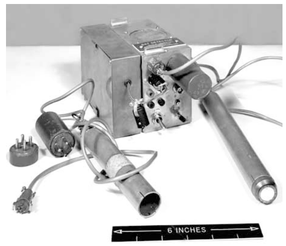
Above: Chipmunk at UHF, with traveling radar salesman Dan Bromaghin, 1955.

Bat Research

The Laboratory was deeply involved in radar waveform design in the 1950s and 1960s, including extensive research on the acoustic "radar" used by bats for navigation and feeding. The animal chosen for most of the bat studies at the Laboratory was *Noctilio Leporinus,* the fishing bat, which certainly qualifies as a small, real-time echolocation system.

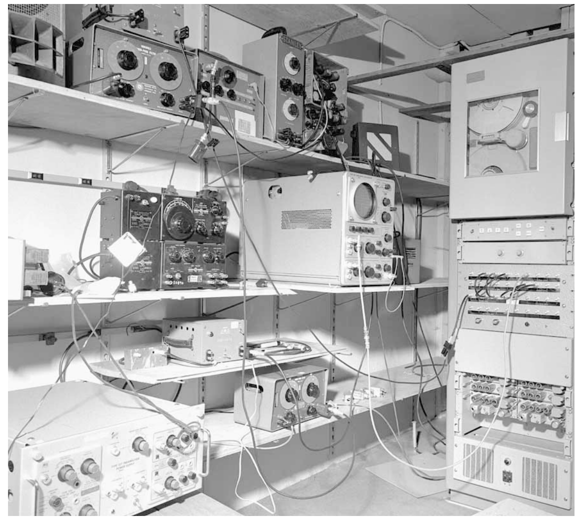


High-speed camera and detector setup.

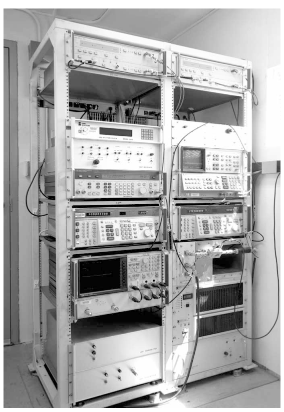


Ultrasonic bat detector, showing transducers and early solid-state amplifier system.

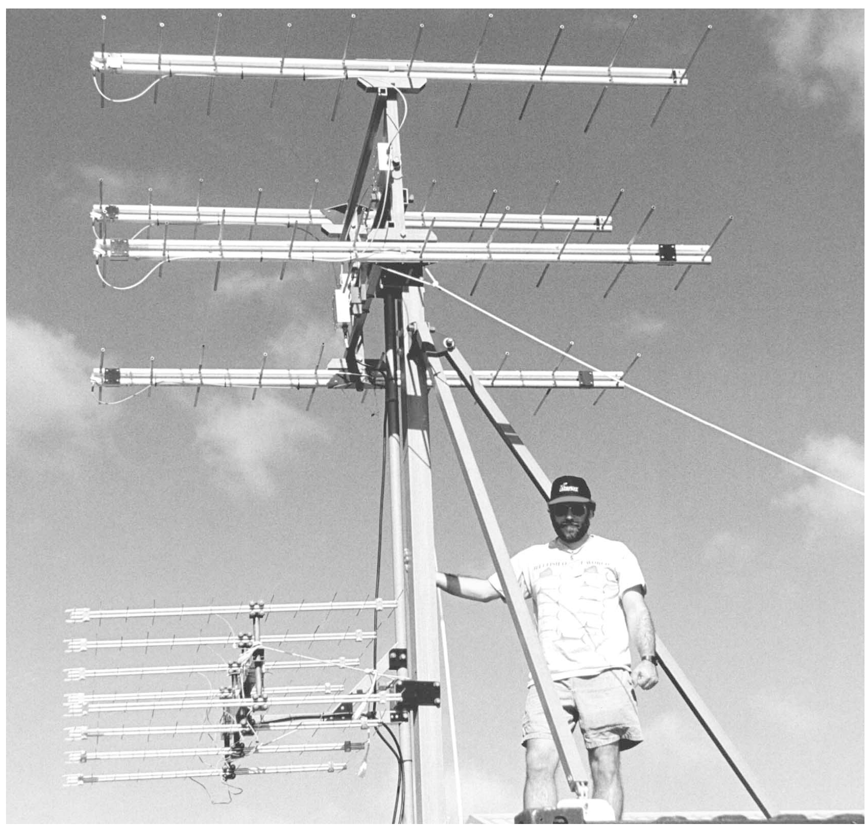
Right: the bat laboratory.



Rocket-Plume Detection

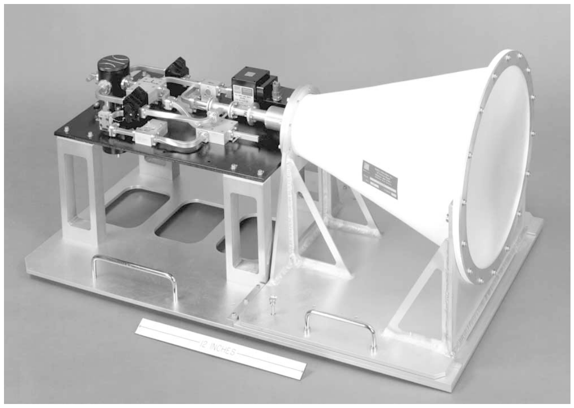


Rocket-Plume-Detection Radar, a three-frequency short-range VHF system mostly built out of commercial test equipment, 1987.



Scott Coutts on a Kwajalein range-safety ship with the antenna arrays for the Rocket-Plume-Detection Radar.

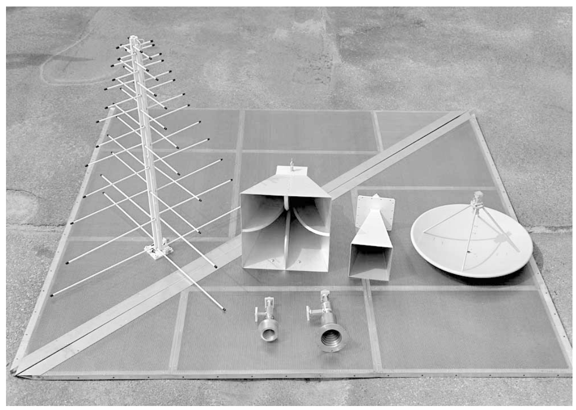
Flashlight



The Flashlight radar [18], a 35-GHz low-power high-resolution FM-CW scatterometer with a focused-beam antenna, designed to be scanned over large military vehicles to form polarimetric radar images, 1986.

Rail SAR

The Rail SAR (1991), a wideband low-power synthetic-aperture radar, covering 0.1 to 18 GHz by using a stepped FM waveform and pulse widths down to 10 nsec [17]. A successor to Flashlight, this radar could form polarimetric 2-D and 3-D SAR images of various military objects.

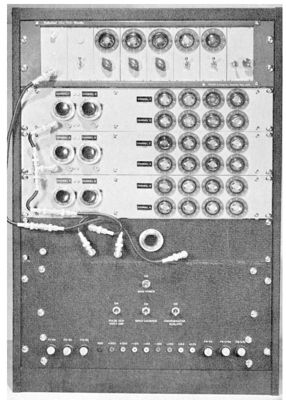


Interchangeable wideband antennas for Rail SAR.

Model 1 Laser Radar

The Model 1 Laser Radar, an early solid state laser system, built in 1964. This exploratory system was used to understand how laser radar might benefit the Apollo Moon-landing program. The GaAs injection laser-diode transmitter was liquid-nitrogen-cooled, while the receiver used a photomultiplier tube.

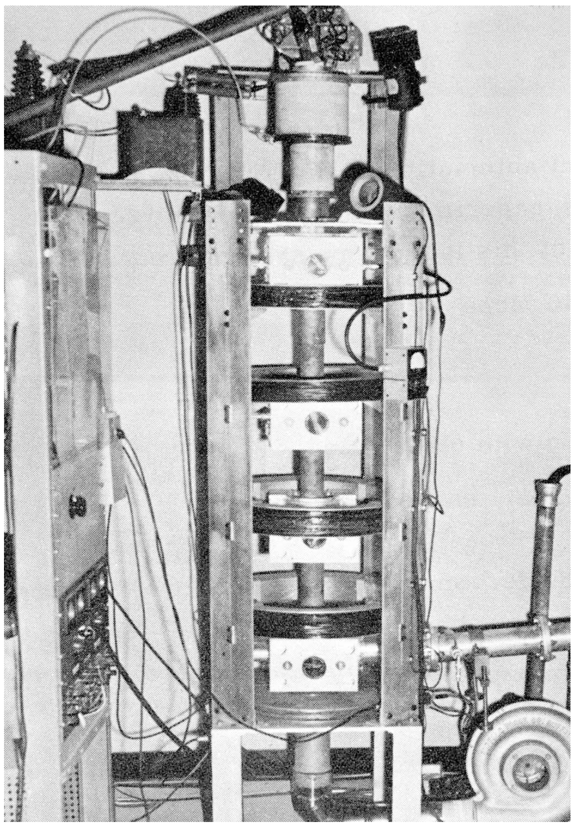
Radar Components

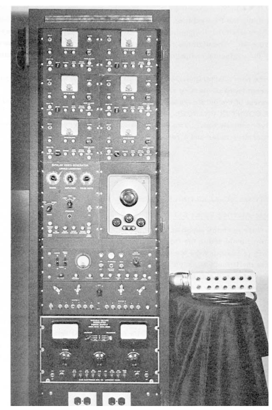


Left: receiver and Doppler filters for the Porcupine II radar, 1954.

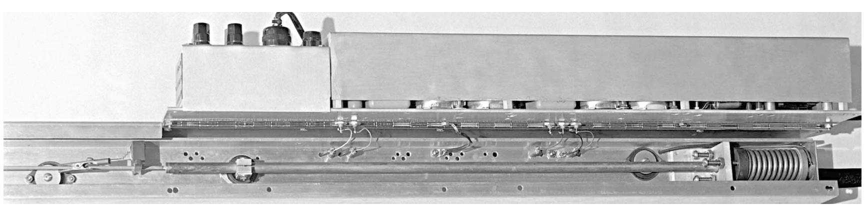
Right: pulse height analyzer using "Dekatron" counter tubes, 1957.

Eimac four-cavity klystron for the Sentinel radar [9]; 150-kW/3-kW peak/average power at 600 MHz.



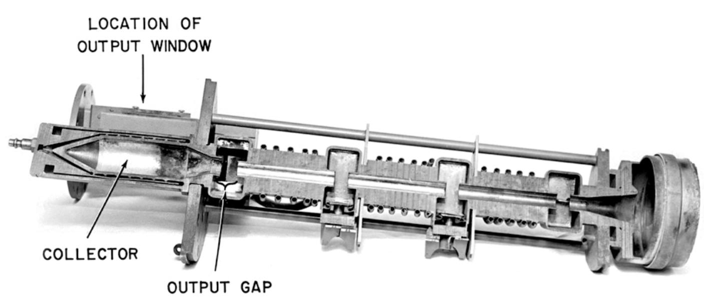


Above: radar alarm X-2, a very early automatic alerting system for DEW Line radars, 1953.

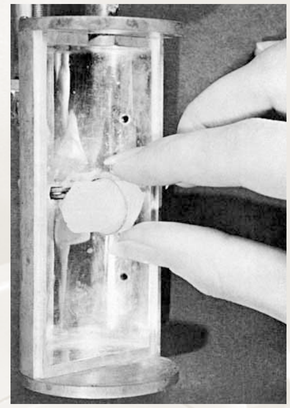


Above: delay-line test system, early 1950s. These devices, made from mercury, quartz, invar, or other materials, were used as delay elements in moving-target indicator (MTI) and early pulse-compression radars such as the Laboratory-designed coded-pulse receiver/exciter for the AN/FPS-17 [20].

Right: cutaway view of the Varian VA-87 S-band klystron, originally developed for the Laboratory's SAGE gap-filler radar in the mid-1950s. A variant of this tube, the VA-87F, is used today in the FAA's ASR-9 airport surveillance radar [21], which also uses Laboratory-developed moving-target detector (MTD) signal processing techniques [19].

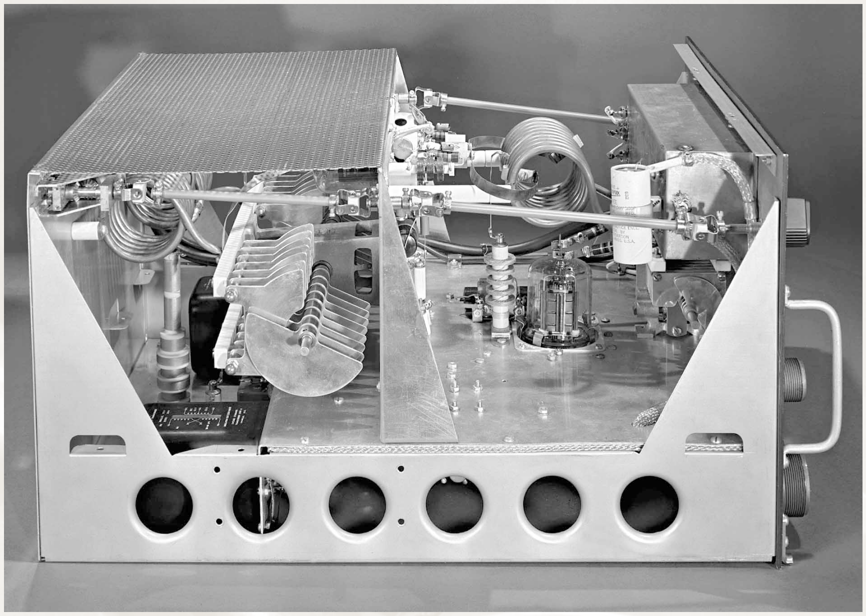


Transmit/receive tubes, used to protect a radar receiver from the high-power transmitter pulse, 1956.



Bob Kingston and the potassium-cobalt-cyanide crystal used in the earliest operational UHF maser [22]. It was applied at the Millstone Hill radar to the radar detection of Venus, 1957 [2].

High-power coaxial diplexing system used to simultaneously transmit 1.5-MW pulses at 425 MHz and 675 MHz to the single 60-foot dish antenna for the Round Hill UHF aurora-research radar, 1958.

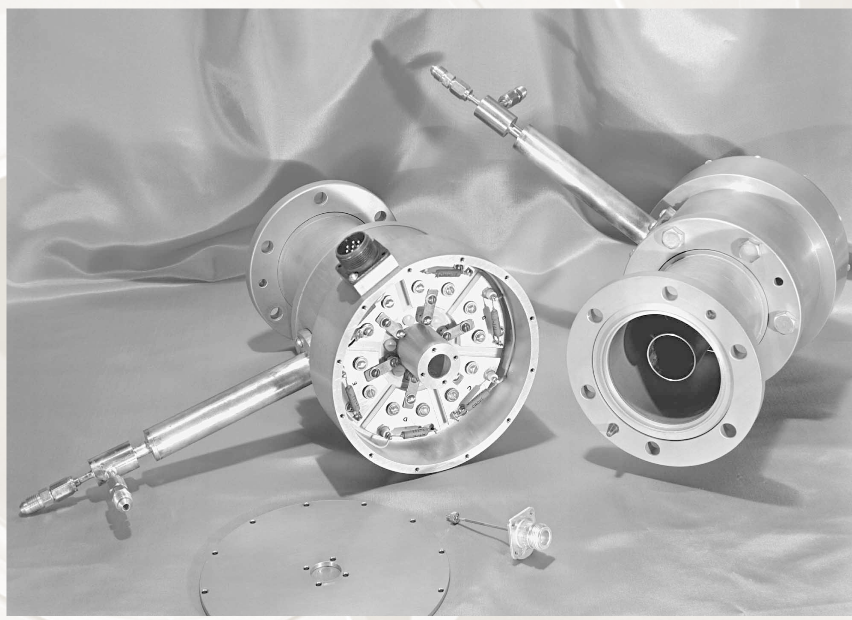


Push-pull 18-MHz RF power amplifier used in the Caterpillar HF propagation measurements in the presence of Arctic ice at Thule, Greenland.

Clarke-Dicke Fix

Clarke-Dicke Fix antijam system for the Nike Ajax air-defense radar, 1958. This radar add-on is a counter-countermeasure device that comprises a wideband hard-limiting IF amplifier followed by a narrowband linear filter. The combination acts like a CFAR under typical wideband (Gaussian-noise) jamming conditions and prevents blooming of the radar display while still allowing detection of stronger targets. The Laboratory built four more Clarke-Dicke Fix receivers for use in the Experimental SAGE Subsector's AN/FPS-20 radars during this time period, as part of the Cross Over program. The Clarke-Dicke Fix was later produced by Western Electric for operational use on the Army's Nike-Ajax receivers.

Smalltair

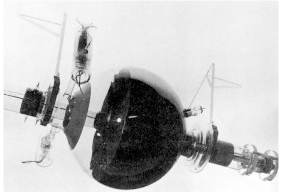


Smalltair was a VHF radar system added to the TRADEX UHF/L-band radar at Kwajalein to give it capabilities at two new frequencies, 60 MHz and 150 MHz. It was an interim design used before the ALTAIR radar was completed.

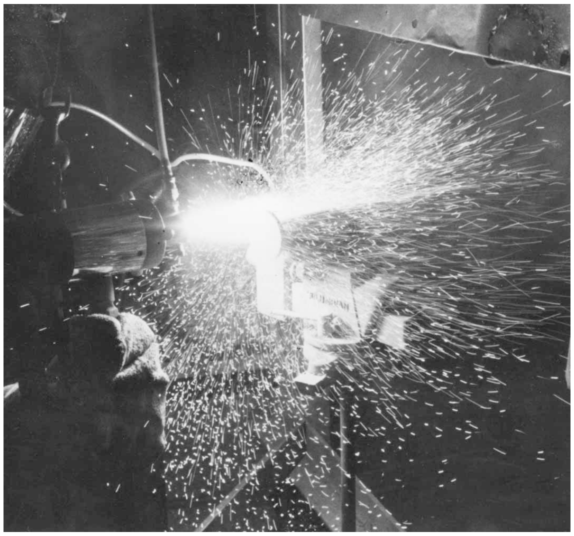
The Laboratory specified and procured Smalltair, but its high-power duplexer was not designed properly by the vendor and failed repeatedly. The high-power VHF diode duplexer shown above was the result of Charles Edward Muehe's successful Lincoln Laboratory redesign, built in 1966.

Special Research and Test Apparatus

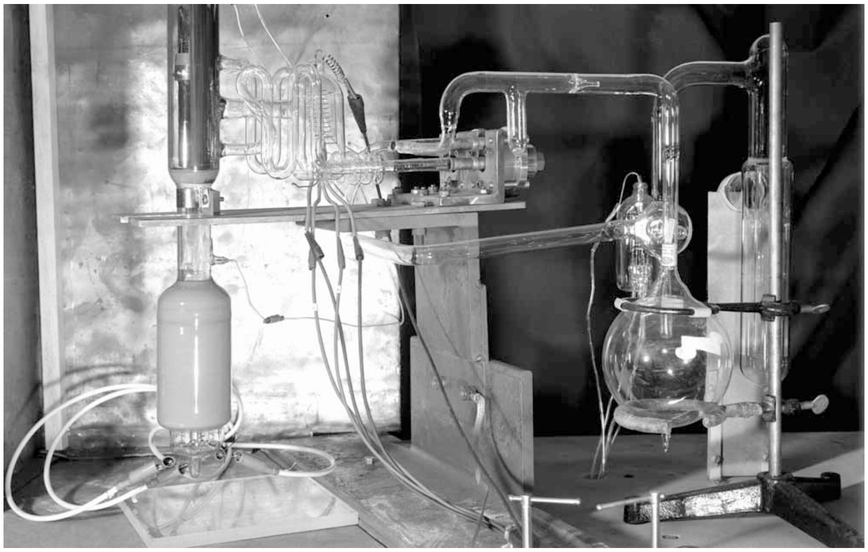
- High-Power Tube Research
- Spectrum Analyzers
- High-Power Test Laboratory



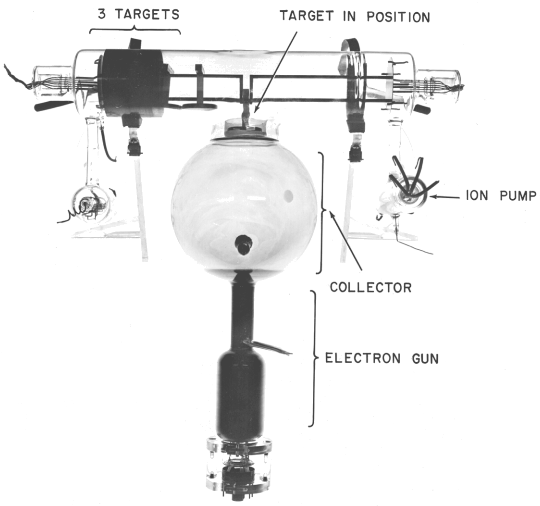
Beam-viewing tube, 1960.



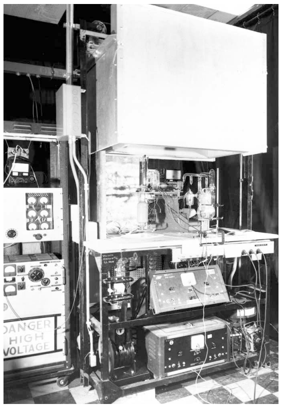
A high-power tube laboratory was in operation from about 1960 to 1963, for the purpose of investigating various materials, shapes, emissions, beams, and target effects in mostly microwave electron devices. Left: dramatic high-voltage discharge, 1961.



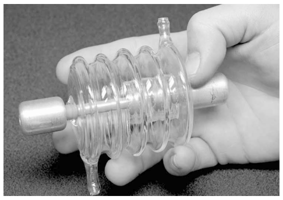
Tube of unknown purpose, a fine example of glassblower's art, c. 1960.



Tube built to enhance understanding of secondary-emission effects, 1961.



Right: the above tube in Laboratory test-stand setup.

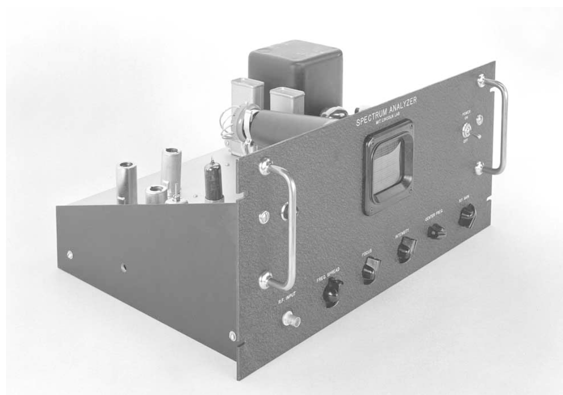


Top: an "Impulse Generator" tube, 1960. Bottom: glow discharge, 1961.

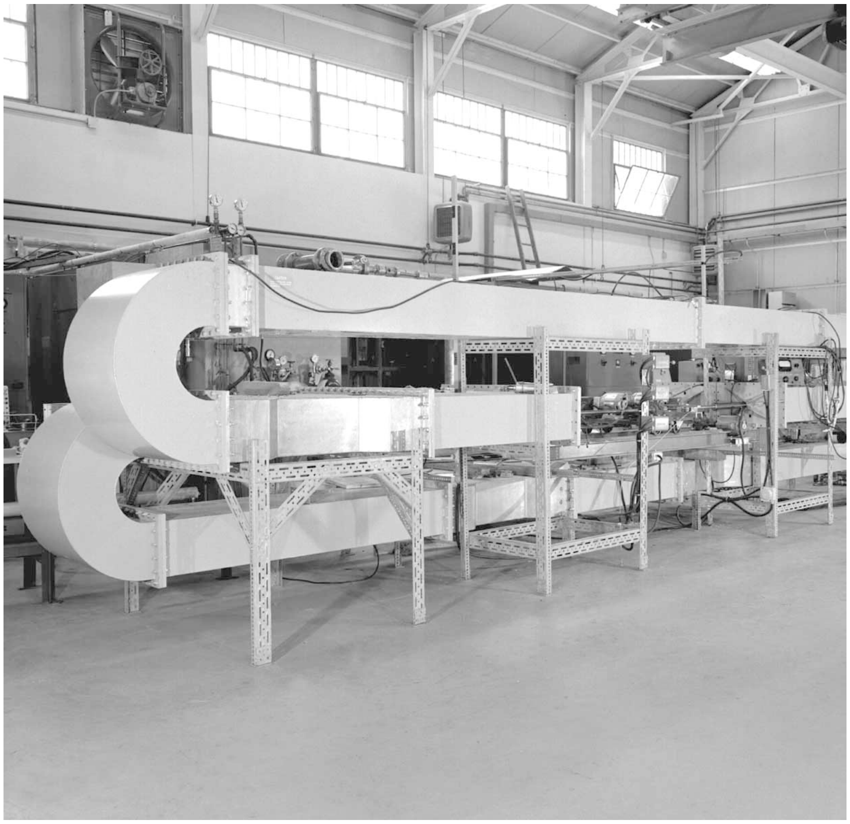
Westinghouse WX4450 experimental tube used in a high-power radar modulator, 1962 [6], similar to those used as switch tubes for ALTAIR UHF and VHF transmitters.

Spectrum Analyzers

Old-model analyzer alongside miniaturized version, 1955.

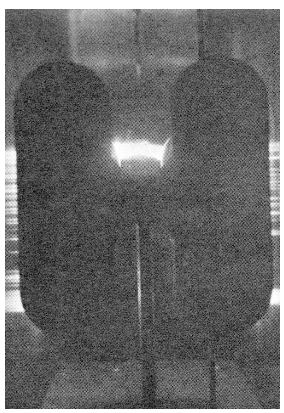


Early Lincoln Laboratory–developed spectrum analyzer, 1954.



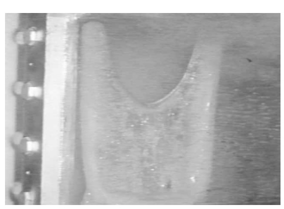
A traveling-wave resonator used to perform very-high-power testing of UHF (400-MHz) two-port radar components, 1958. This system, which was located in Annex 2 [6], was powered by a 5-MW magnetron. Traveling-wave reinforcement of the in-phase UHF voltages and currents in the resonant ring allowed testing of high-power components at up to a 150-MW level, among the highest power levels ever achieved at these frequencies.

The ring was excited by a lower-power input signal and tuned by a complex array of motor-driven stubs and hybrid junctions. Other high-power resonant rings were built at L-band, S-band, C-band, and X-band for testing components for later radar systems.

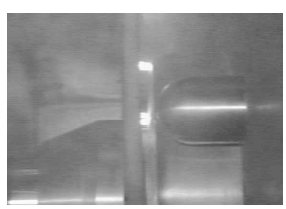


A waveguide switch breaks down in the traveling-wave resonator at a power level of 95 MW.

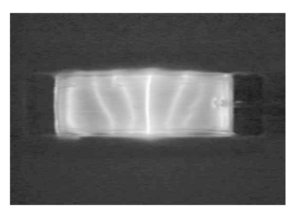
A color movie (1960) was made of the UHF resonant ring in operation; shown here are still photos of a plexiglass window, a UHF rotary joint, and an argon gas tube.



A plexiglass window smoking and melting under the influence of tens of MWs of UHF power.



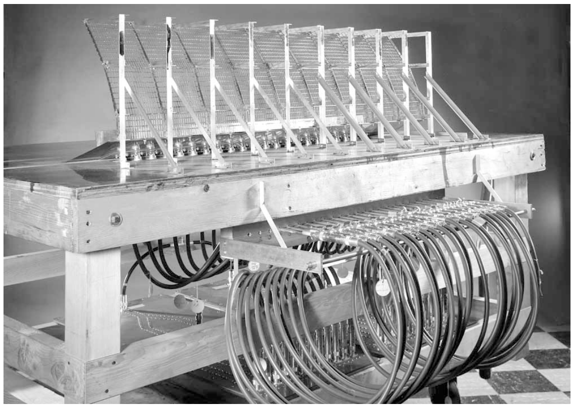
A UHF rotary joint arcs in the high-power traveling-wave resonator.

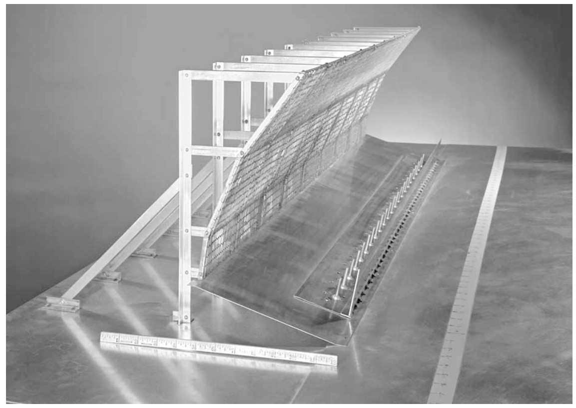


An argon gas tube shows bright blue striations when subjected to high-power UHF fields. Gas tubes, used in high-power radar duplexers, ionize in various patterns, depending on the gas pressure and cell design.

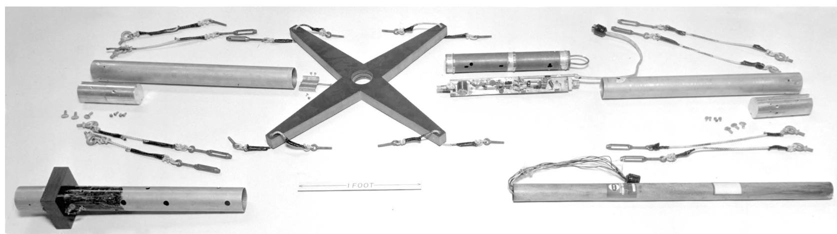
Antennas and Antenna Components

Below: scaled test antenna for the Caterpillar HF ground-wave radar, 1954.





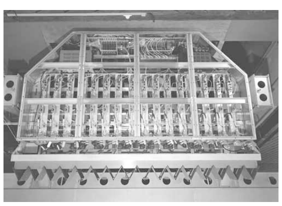
Phasing lines for electronically steering the Caterpillar radar scaled test antenna array. The full-size version of this array was never built, but similar full-size phased arrays were deployed in the over-the-horizon-backscatter (OTHB) radar system, the AN/FPS-118 (1985).



A test transmitter and antenna used to check the antenna patterns of Caterpillar.

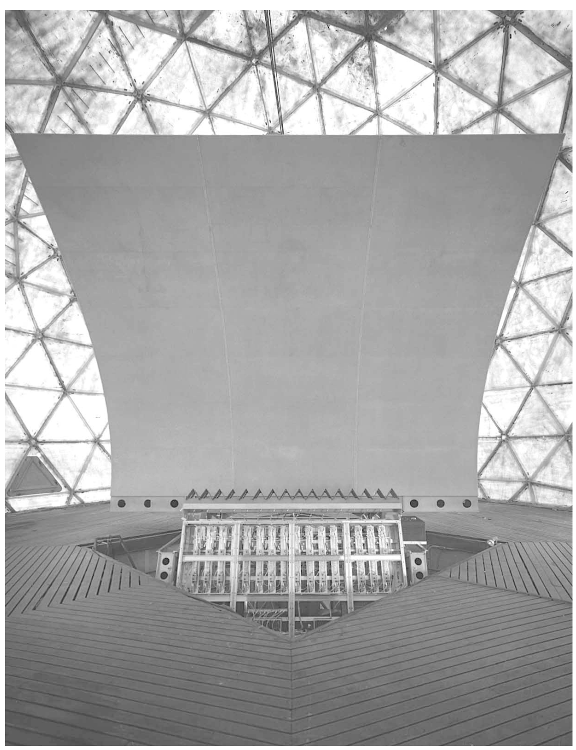
The tubular device to the right of the crosspiece is a small battery-powered vacuum-tube transmitter.

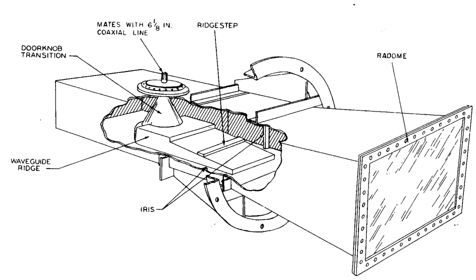
The rest of the kit is a dipole antenna that, when assembled, is lofted by a balloon in front of the Caterpillar array.



Feed-structure detail.

Right: scaled antenna test array for a satellite-surveillance radar with scanned feed structure, 1958.





Dual-frequency feedhorn used in 425/675-MHz aurora-research radar, c. 1955.

Polyrod antenna test array, c. 1955.

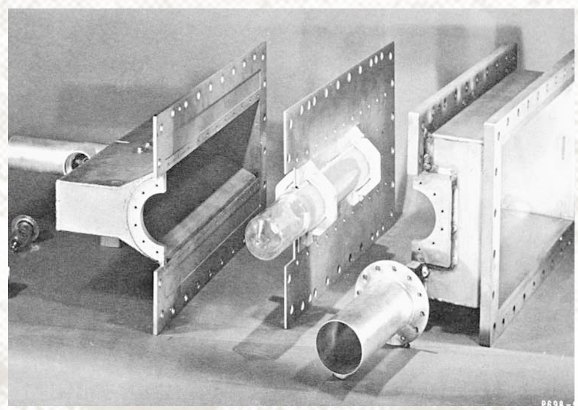
AN/FPS-6 nodding-beam height-finder antenna modified with a servo drive system for the Automatic Reporting of Height (AROH) project, c. 1975. The rest of the AROH system was never built.

Unknown test item with an interesting prop substituted for the canonical photo-lab ruler. The revolver is a Daisy BB-gun replica, and not a firearm!

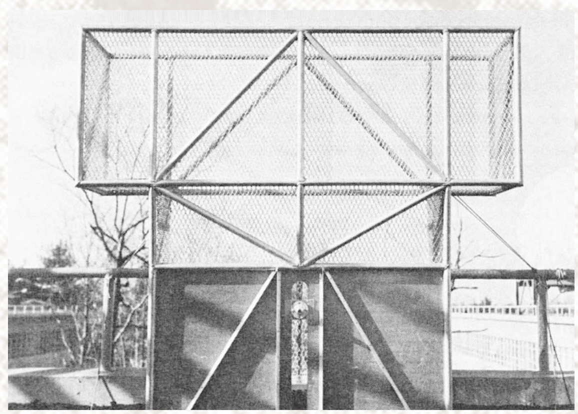
Below: five-dipole test array for the 38-MHz El Campo phased-array space radar, 1960 [24]. The full-size array used 1024 similar dipoles in eight rows, each 1750 feet long.

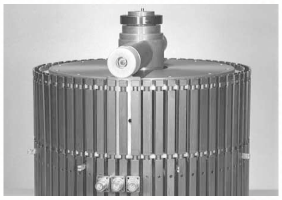
UHF horn feed system for the original Millstone Hill radar, 1957.

Right: UHF transmit/receive cell, exploded view, c. 1955. It was used in various systems such as Jug Handle Hill, Boston Hill, and early Millstone Hill UHF search/tracking radars.

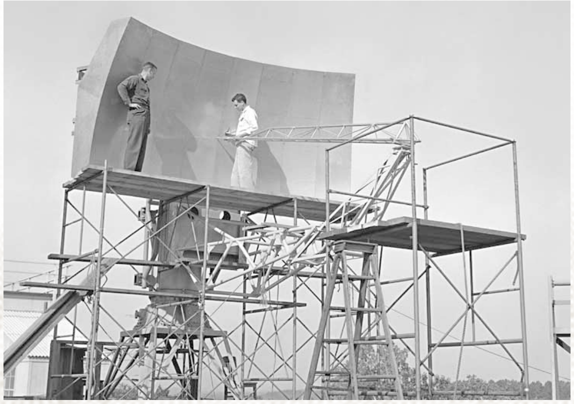


Box-horn feed prototype, one of the 32 scanning feed horns (two rows of 16) employed by the long-range 200-MHz AN/FPS-17 pulse-compression radar in 1955. The box feed horn is much smaller than the equivalent tapered-horn structure. Though the AN/FPS-17 was originally intended to operate over the 175-to-215-MHz range, this box horn feed could be matched only over about half that band. As initially deployed, the AN/FPS-17 operated on only one frequency near 200 MHz.



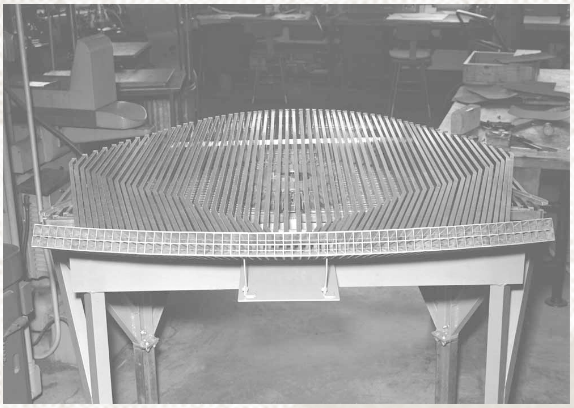


X-band scale model of coaxial organ-pipe switch, part of a BMEWS scanner model, 1957 [25].

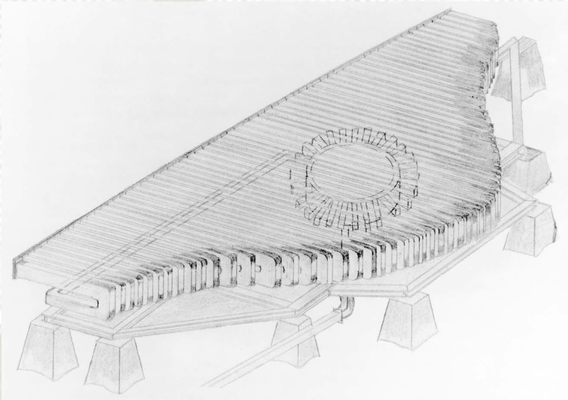


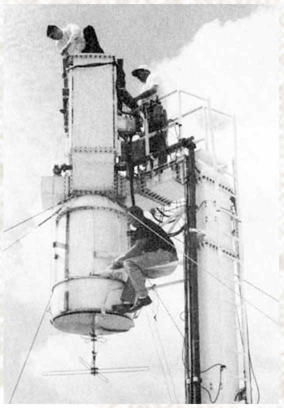
X-band scale model of BMEWS parabolic-torus antenna reflector, 1957.

X-band scale model of BMEWS organ-pipe scanner and feed array, 1957.

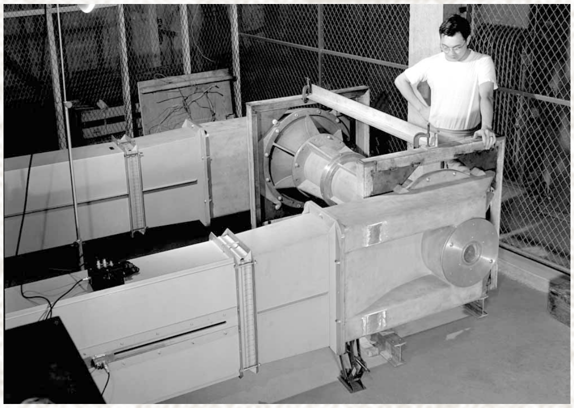


Right: artist's drawing of the BMEWS organ-pipe scanner, 1956.

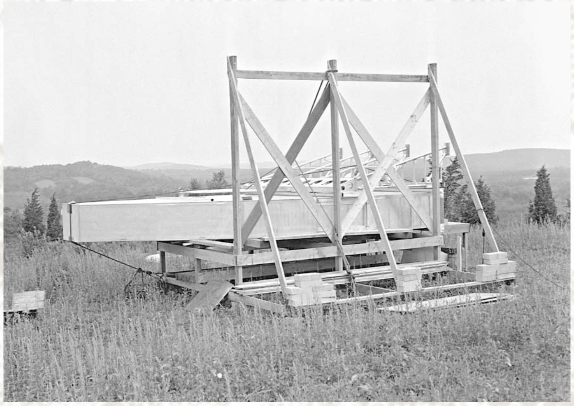




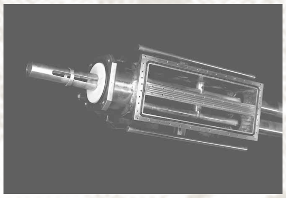
Left: Millstone Hill radar feed system converted for reception of Explorer VI ("Paddlewheel") satellite telemetry, 1959.



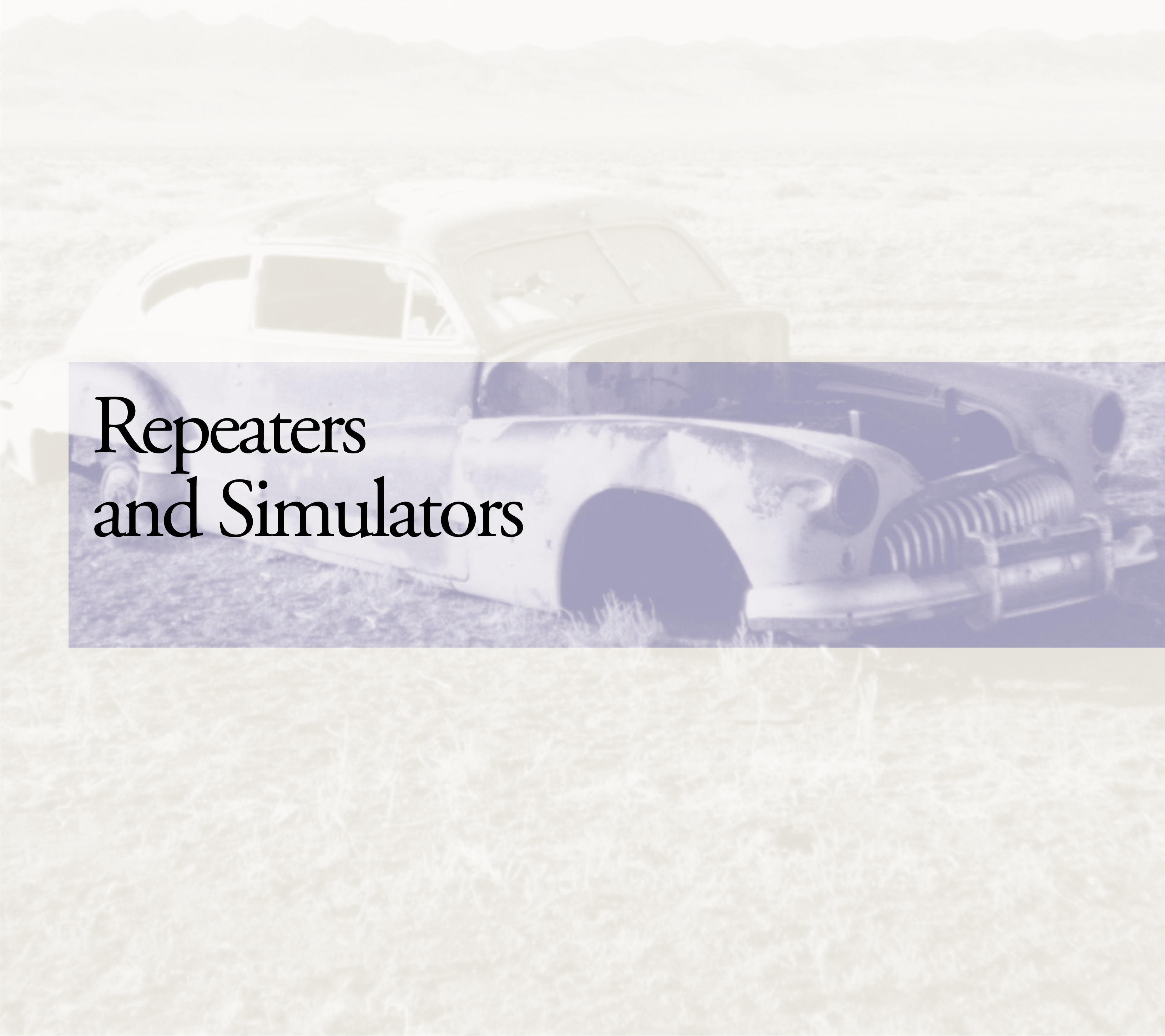
High-power rotary joint for Jug Handle Hill UHF radar, West Bath, Maine, 1955 [26].



Hogg horn-feed [23] impedance-matching device for Boston Hill UHF radar, 1958.

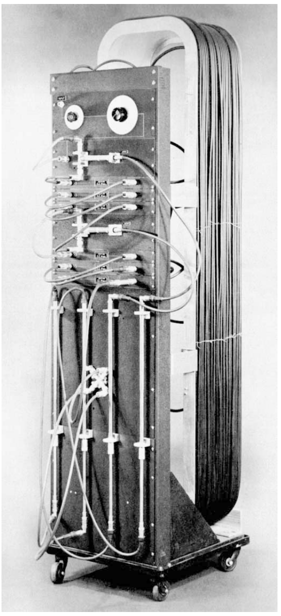


Displaced phase center antenna (DPCA) feed horn, National Research Council, Canada, 1959. This early example of DPCA technology is now used in the Joint STARS airborne ground-surveillance radar.

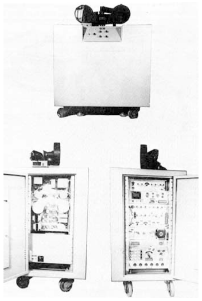


Repeaters and Simulators

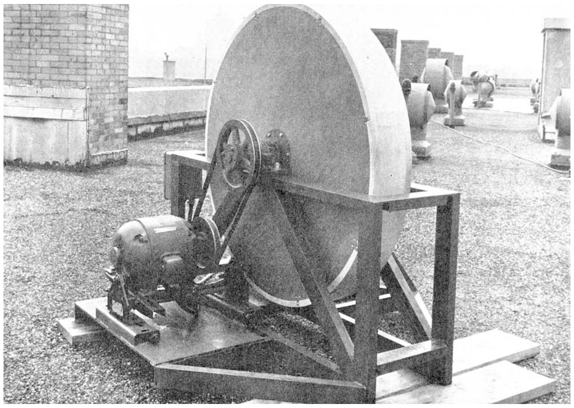
Radar systems are often calibrated and operationally checked against targets with known, stable characteristics such as their location, size, and Doppler shift. Usually, fielded radars cannot rely upon targets of opportunity to provide the kinds of calibration information required, so specialized test targets known as radar repeaters are deployed. A large variety of such devices have been designed and fielded by the Laboratory, from simple mechanically driven contraptions to elaborate repeaters that can return complex artificial target signatures to the host radar. These generally small devices, often overshadowed by the radar they were built to complement, have an ongoing heritage stretching back to the beginnings of the Laboratory.



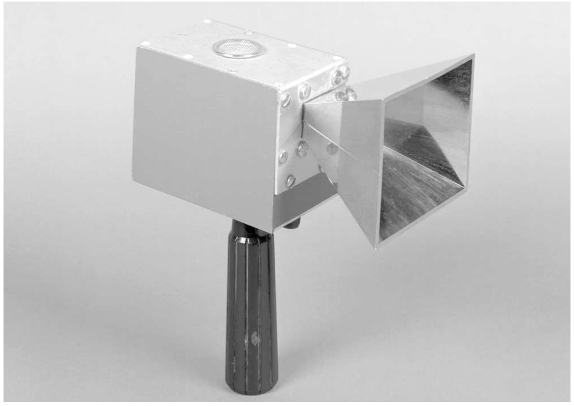
Radar-propagation simulator, 1957, a group of delay lines, combiners, attenuators, and a very large cable spool intended to simulate RF propagation loss and multipath affects.



Right: an early radar simulator. This three-piece device employed a flying-spot scanner and a 35-mm film transport, apparently for the purpose of simulating a radar display for the SAGE system in 1953.

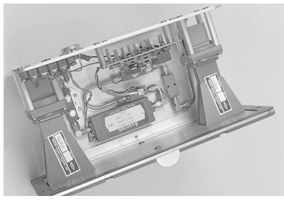


A Doppler wheel, a primitive motor-driven radar reflector that simulates a moving target. Mounted on a Cambridge rooftop, it was used to test the Laboratory's earliest moving-target indicator (MTI) radars in 1952.



A repeater tester, 1988, used in conjunction with the X-band moving-target simulator (MTS) shown below. This short-range hand-held device (which resembles something out of a Bugs Bunny cartoon) enabled the operator to confirm that the solar-powered repeater he or she had just set up on a remote mountain top was indeed operational.

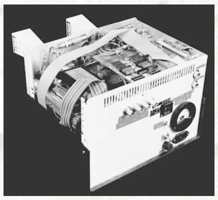
MTS used for VHF/UHF foliage penetration radar experiments, 1992 [27].

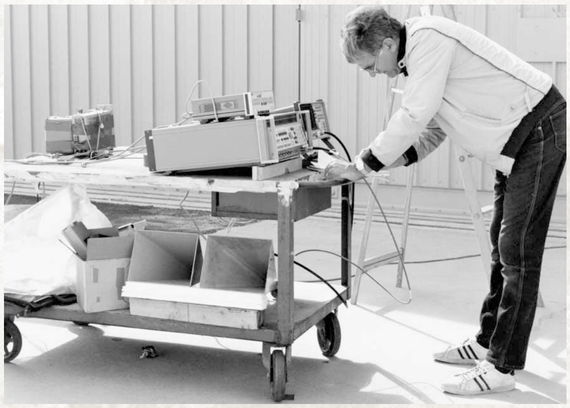


X-band MTS, used in field evaluations of multifunction fighter radars, 1984. Many of these repeaters were deployed on Western mountain ranges and were solar powered.

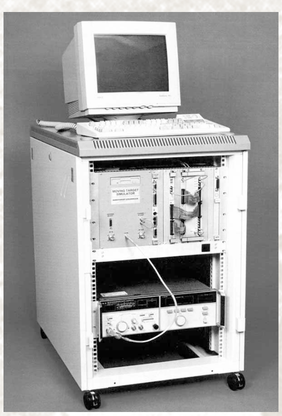
Dual-channel VHF repeater with variable Doppler shift and selectable delay capabilities, 1993.

Andy Vierstra field-testing an X-band radar repeater (left photo) with stored modulation capabilities, allowing it to provide target returns mimicking a helicopter, 1990.





A "clutter discrete," the rare instance of a target of opportunity that hasn't moved in decades. It was used as a fixed test reflector in a western desert for the L-Band Clutter Experiment radar, 1991.



Sophisticated wideband moving-target simulator built by Northrop Grumman to Laboratory specifications. The unit can provide radar returns with programmable modulation as well as stored signatures taken from previously observed targets. This repeater was used to perform tests on an upgraded AWACS radar in 1996.

Above and left: multiple-antenna surveillance radar (MASR) target beacon transponders, used in ground-vehicle tests, 1973 [28].

100-W radar repeater from the L-Band Clutter Experiment (LCE) Radar, 1991 [16]. One of five units providing Doppler modulation and selectable time delays, with provision for locking onto the host radar's unique pulse repetition frequencies and pulsewidths. This repeater was mounted on a 100-foot boom truck and could be slowly lowered while being illuminated by the LCE radar, providing two-way L-band propagation information over a variety of terrain types and path lengths.

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Bill Ward

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