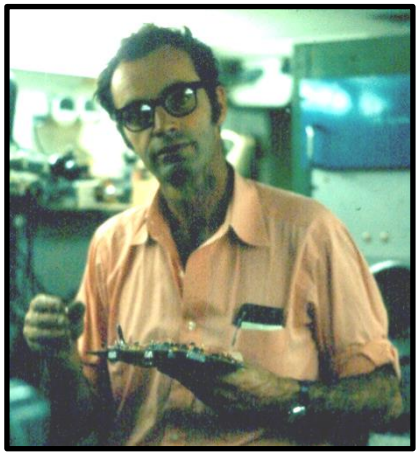
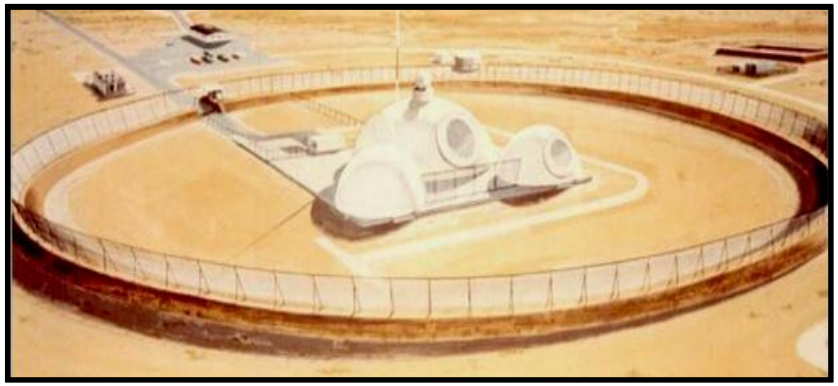
The Colgate Paramp

Stirling  **Colgate**



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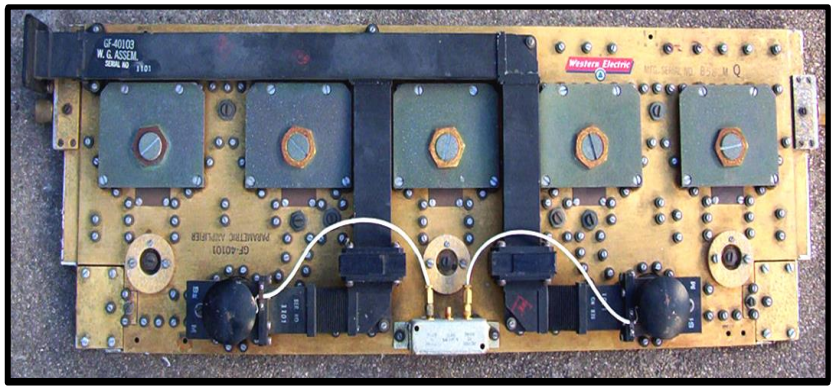


the *Multifunction Array Radar*

and Their Impact on Radio Astronomy

Bob Hayward

NRAO Senior Engineer (Retired), Socorro, NM

NMT Physics Department Colloquia - 13 Feb 2014 (updated 1 Nov 2014)

Setting the Scene
A Letter Printed in *Science* Magazine, Jan 1972

SCIENCE
7 January 1972
Vol. 175, No. 4017
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Radar System Dismantled

An extraordinarily complex radar system called MAR (multiple array radar) became operational in 1964 at White Sands Missile Range; it was designed to detect incoming missiles for national defense. The receiver of this radar was made up of approximately 2500 separate, circularly polarized, switched elements, each with its own wide-band, low-noise, parametric amplifier. Beam switching by means of aperture synthesis was completely controlled by computer. Such arrays are usually switched manually and never include the luxury of a low-temperature front end.

The aggregate cost of this radar was approximately $160 million. It was an incomparable instrument, operating near the 21-centimeter line for beam-switched observations of distant radio sources and possibly even of supernovas in distant galaxies. Its cost was greater than all the radio astronomical facilities that have been built in this country and possibly in the world. It was three times as expensive as the VLA (very large array), the largest radio astronomy telescope ever proposed.

The MAR radar was dismantled before a proper evaluation could be made of its astronomical capability. Regretfully, we at the New Mexico Institute of Mining and Technology performed the dismantling and salvage without access to the specifications of the ability of the whole system. It is a tragedy indeed that such a short-term military experiment could not have been made available to astronomers who could have made measurements that now may not be made for many decades. Fortunately, 2000 parametric amplifiers were salvaged, and 280 have been presented for use by radio telescopes throughout the world. These alone significantly improve the quality of many instruments.

STIRLING A. COLGATE
New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

***Radar System Dismantled*, S. Colgate, Science Magazine, Vol 175, No 4017, Jan 1972, p.10**

The Source of the "*Colgate Paramps*"

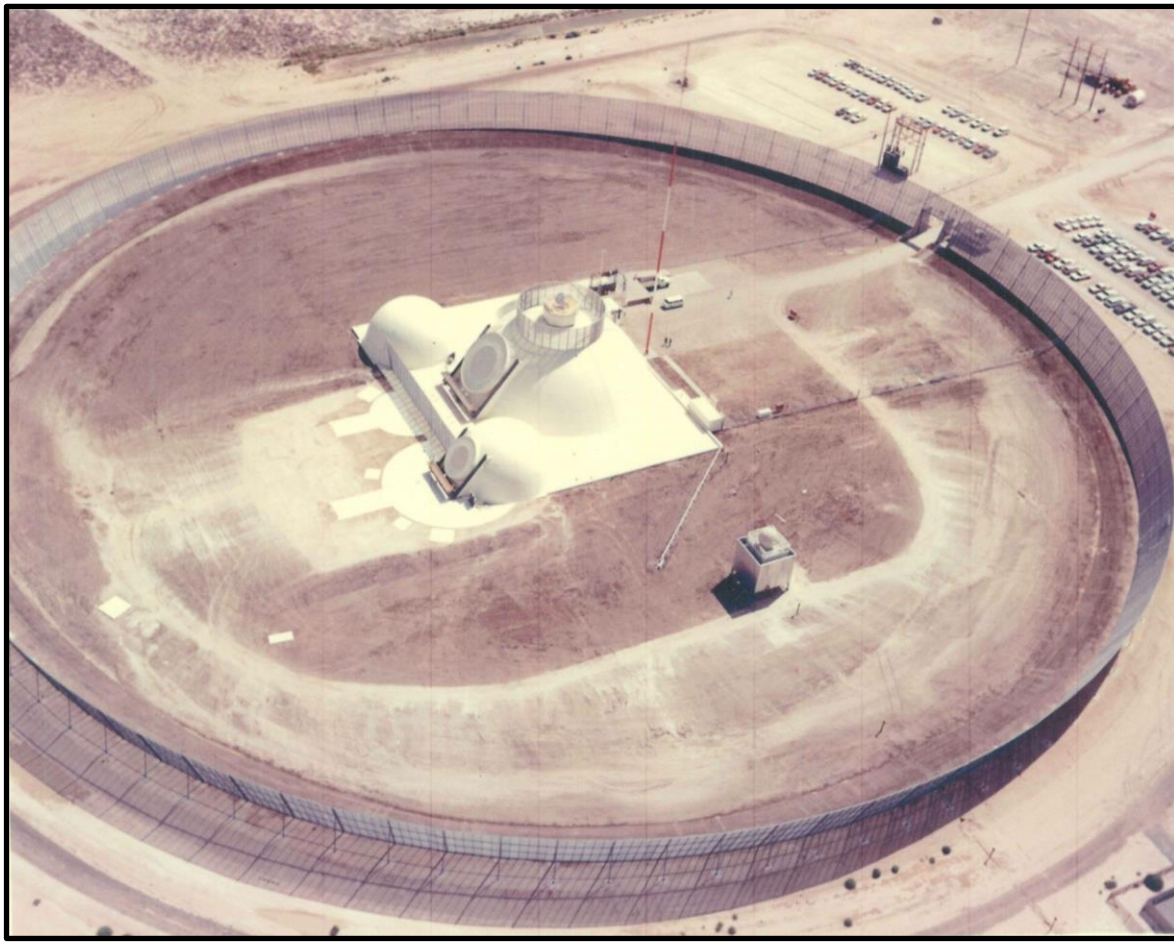
~ The MAR-I ~

Aerial views of the prototype Nike-X *Multifunction Array Radar* (designated "*MAR-I*") built on the *White Sands Missile Range* (WSMR) in the mid 1960s for evaluating *Anti-Ballistic Missile* (ABM) defense.

***Western Electric* was the primary contractor while *Bell Labs* was responsible for the overall design.**

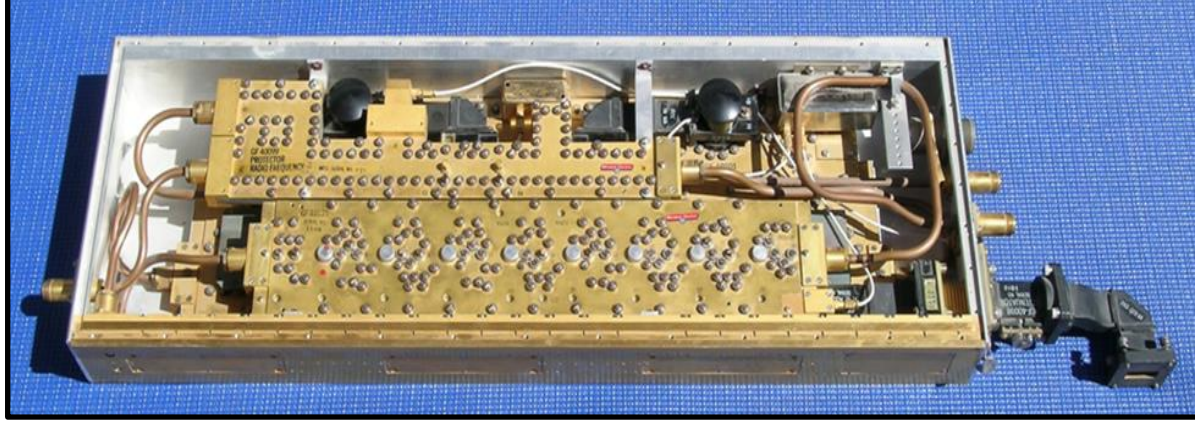
Newspaper Article in the *The Reading Eagle*, Reading, PA, May 28, 1965

"A briefing officer remarked that archeologists of the future, finding the MAR there in the desert, might think it a monument like the Egyptian Sphinx."



***Seize the High Ground*, pg 61, http://www.smdc.army.mil/2008/HistoryBook.asp**
Photo courtesy of Bob Gamboa

One of the over 2000 MAR-I *Preamplifier Modules* which came to be known as "*Colgate Paramps*"

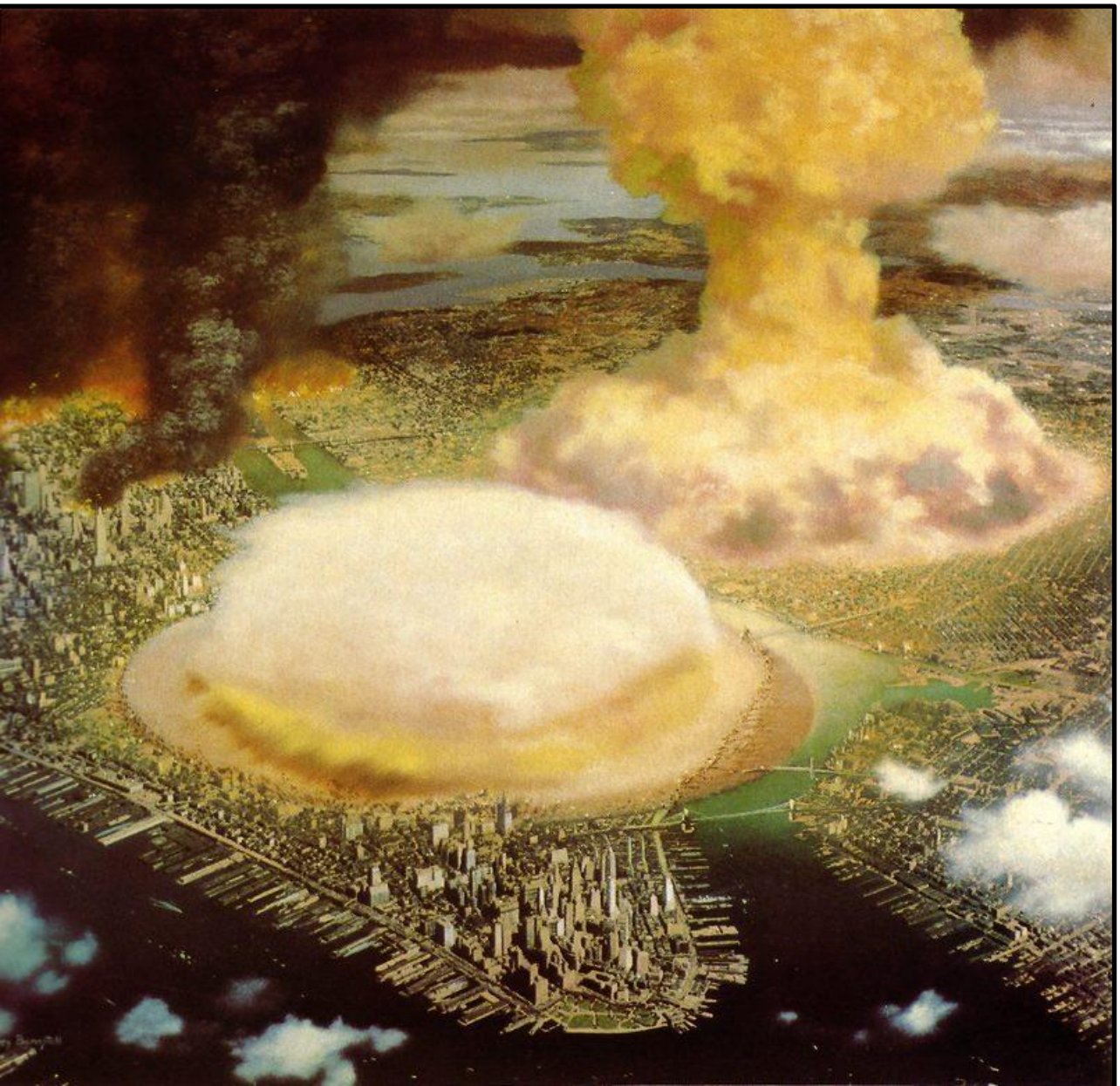


- **Talk Overview:**
  - ~~**Early Cold War Era Radars (DEW, BMEWS, Nike-Ajax/Hercules/Zeus)**~~
  - **The Nike-X *Multifunction Array Radar* prototype at White Sands.**
  - ***New Mexico Tech* and the Salvage of the MAR-I.**
  - **Stirling Colgate & SNORT.**
  - **The *Parametric Amplifier.***
  - **The *Colgate Paramp* travels the World.**
  - **The Rest of the Story.**

  - **Acknowledgements:**
    - **Miller Goss (NRAO) & Doyle Piland (WSMR Archivist)**
    - ***Bell Labs* : Norm Hillman. Charlie Johnson & Joe Nevarez**
    - ***Western Electric* : Sam Freshour, Vestal Fulp, Bob Gamboa & John Ondria**
    - ***New Mexico Tech* : Paul & Kay Krehbiel, John Reiche & Bill Winn**
    - ***Former NMT Students* : Bruce Blevins, Bill Holmes, Steve Hunyady, Joe Martinec, Charley Moore & Gary Schwede**
    - ***Radio Astronomers & Engineers from Around the World* : Ron Allen, Mike Balister, Bill Brundage, John Bunton, Pat Crane, Bob Dixon, Gloria Dubner, Neal Erikson, Paul Feldman, Bob Frater, Tom Gergley, Tom Landecker, Tom Legg, Ken Tapping, Adrian Webster & Kelvin Wellington**
    - **And Stirling Colgate (NMT &LANL)**

The Cold War Era & the Fear of the Bomb

"*Rocket Blitz From the Moon*"



Collier's Magazine
3 October 1948

The article was beautifully illustrated by famed space artist *Chesley Bonestell* and includes perhaps his most dramatic painting ever, that of *Manhattan* being blasted with 3 *Atomic Bombs*.

Soon the *A-Bomb* would be replaced by the 1000 times more powerful *Hydrogen Bomb*.
In the 1950's the terms *megaton & megadeath* would enter the lexicon.

http://designresearchgroup.files.wordpress.com/2007/08/nukebonestell.jpg

Gallop Poll on Nuclear War

The Lewiston Daily Sun

11 July 1956

INE MONDAY MORNING, JULY 16, 1956

THE TIMID

GALLUP POLL

PUBLIC HAS NO DELUSIONS ON A NUCLEAR WAR

39 Million Feel Their Families Would Not Survive It

N. Y. PRIME TARGET

By GEORGE GALLUP
Director, American Institute of Public Opinion

(First in a series of two reports by the Gallup Poll dealing with the public's appraisal of the destructiveness of the H-Bomb and their fear of another world war during their lifetime.)

PRINCETON, N. J., July 14—The question that is raised over and over again is whether the American public has realistically appraised the horror of modern nuclear warfare.

The answer, judging by the latest Institute poll results, is an emphatic YES.

Take, for example, these startling survey statistics:

39,000,000 Americans today believe that their families WOULD NOT likely survive an atomic war on this continent.

A larger number — some 44,000,000 Americans—think that the area where they now live would be wiped out.

Two out of every three adults think that New York City would be the Number One target of an enemy H-Bomb attack. About one in every three includes the nation's capital, Washington, D. C., on the list of cities that would be hit first.

Finally, nearly two out of every three adults or approximately 64,000,000 — think that the H-Bomb will be used against us if there should be another world war.

To determine just how realistically the public has appraised the H-Bomb's destructive potential, Institute interviewers put a battery of questions to a representative sample of adults, scientifically selected from all walks of life to provide an accurate cross-section of U. S. opinion. The first:

"1. If there should be another world war, do you think the Hydrogen Bomb will be used against us?"

WILL H-BOMB BE USED AGAINST AMERICA?

Yes, will be	63%
No, will not	17
Not sure, no opinion	20

Based on an estimated U. S. civilian adult population today of 102,000,000 — 49,000,000 men and 53,000,000 women—the above figures translate into approximately 64,000,000 adults who believe that the H-bomb will be used against this country. Of this total, 31,000,000 are men and 33,000,000 are women.

Interviewers then asked:

"2. If there should be another world war and Hydrogen Bombs are used, what cities in the United States do you think would be hit first?"

Here are the replies:

New York City	67%
Washington, D. C.	32
Chicago	24
Detroit	20
San Francisco	20
Los Angeles	15
Pittsburgh	9
Seattle	5
Philadelphia	4
Other cities	45
No opinion	6
	247%

Multiple answers were frequent, hence the table adds to more than 100 per cent.

"3. Do you think the area where you live would be wiped out?"

WOULD AREA WHERE YOU LIVE BE WIPED OUT?

Yes, would be	43%
No, would not	38
Not sure, no opinion	19

Forty-six percent of women said their area would be wiped out, compared to 39 per cent of the men.

Among residents of the nation's largest cities—those with populations of 500,000 and over—almost two out of every three (63 per cent) express the belief today that their area would be wiped out.

On the other hand, only one person in four (25 per cent) living in towns and cities under 50,000 population take this view. Most farm residents think they have little to be worried about on this score.

The last question:

"4. Do you think you and your family would be likely to live through an atomic war?"

WOULD YOUR FAMILY LIKELY SURVIVE AN ATOMIC WAR?

No, would not	38%
Yes, would	29
Not sure, no opinion	33

Thirty-seven per cent of the men said their families would be doomed, compared to 40 per cent of the women.

An Institute survey in March of last year found on overwhelming majority of 80 per cent of the American public believing that, if another war comes, it will be fought in a way quite different from anything that man has known so far.

Their picture of the next war was one in which thermo-nuclear weapons would be used extensively, requiring greater use of the nation's Air Force; as a war more disastrous than any we have ever known, with mass destruction of cities and bombing of civilians; as a war that would likely be fought on American soil, and as a war that wouldn't last long.

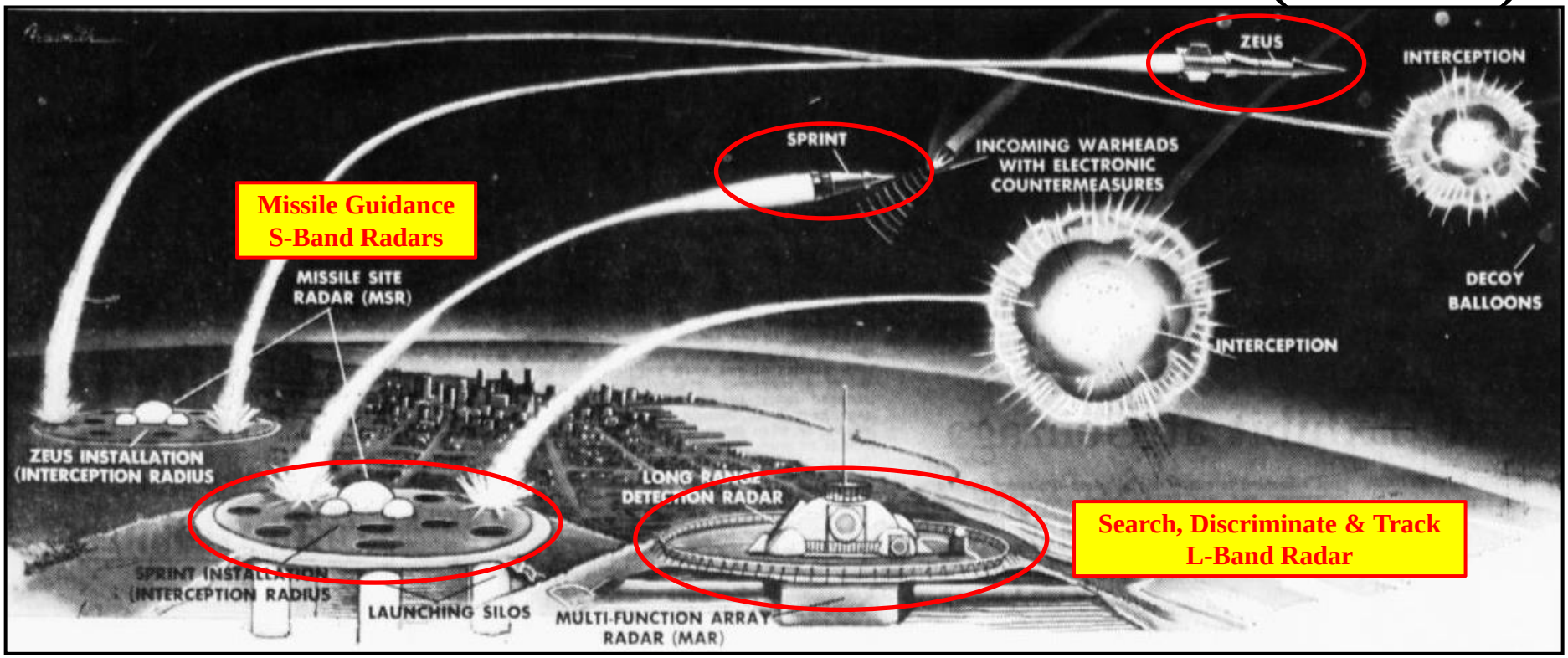
Five years ago, an Institute survey found that, in case of an all-out war with Russia, two out of every three Americans, or 66 per cent, would not be at all squeamish about using the Atom Bomb first, without waiting for it to be used on us. Nineteen per cent said it should be used only if Russia used it on us, while 15 per cent expressed no opinion.

The greatest difference found in the survey was between men and women—72 per cent of the men favored our dropping the bomb first, in case of an all-out war, compared to 61 per cent of the women.

In 1956, 63% of Americans believed the H-Bomb would be used against them.

http://transact.seesaa.net/article/176842254.html
http://transact.up.d.seesaa.net/transact/image/Gallup1956all.png?d=a1

The *Nike-X* Anti-Ballistic Missile (ABM)



Ballistic missile defense is often compared to "*hitting a bullet with another bullet*".

The *Zeus* (later *Spartan*) missile had a range of over 700 km and carried a thermonuclear weapon with a 5 megaton yield.

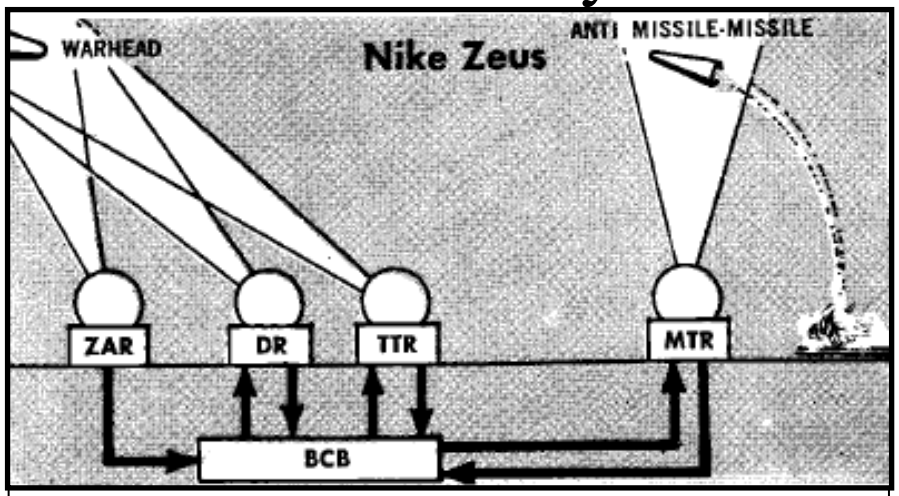
The incoming warhead was destroyed with radiation rather from the effects of heat or blast.

The terminal defense *Sprint* missile had a range of 40 km & carried an enhanced radiation nuclear warhead with a yield of a few kilotons. It accelerated at over 100 G's, reaching Mach 10 in 5 seconds, and was the fastest accelerating man-made object ever made.

From the Spokesman-Review Newspaper, Spokane, WA – 7 Jan 1967

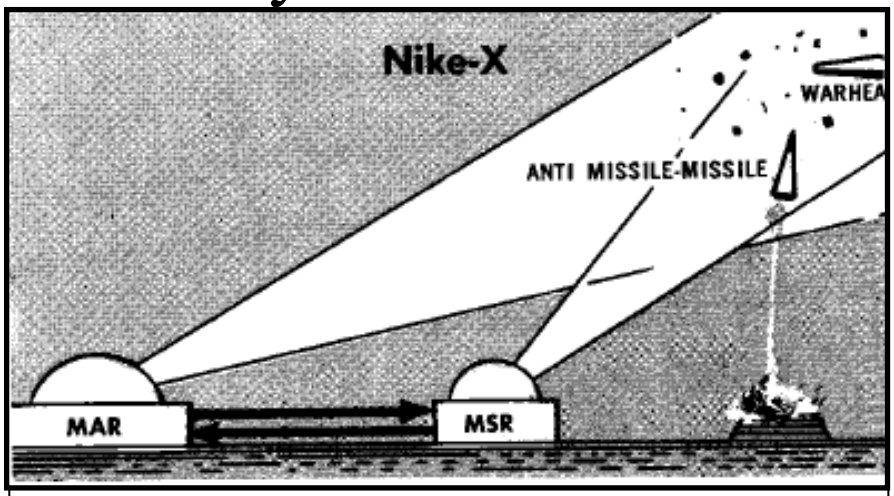
Nike-Zeus vs. Nike-X ABM Concepts

Late 1950s – Early 1960's



ZAR = Zeus Acquisition Radar
DR = Discrimination Radar
TTR = Target Track Radar
MTR = Missile Track Radar

Early to Mid 1960's



MAR = Multifunction Array Radar
MSR = Missile Site Radar

Nike-Zeus Emblem

The *Multifunction Array Radar* was one of the first electronically-steered phased-array radars.

It was built to replace up to four radar systems while being able to track more targets than a mechanically steered antenna and better able to withstand the blast effect of offensive missiles.

The less capable *Missile Site Radar* was planned to augment the more powerful (and far more expensive) MAR and would be located closer to the city or military installations being protected.

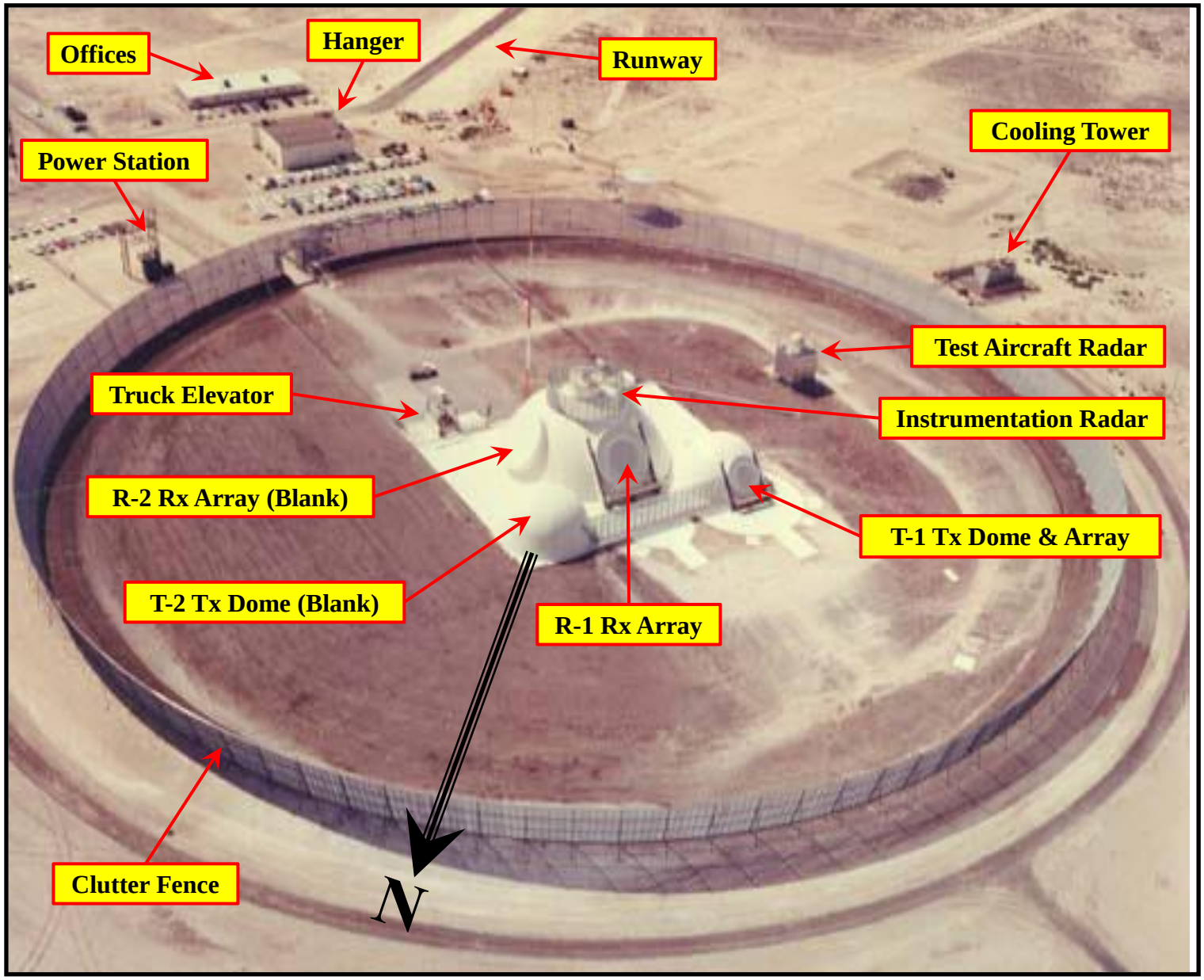
NIKE-X Emblem

From *Army Prepares Sprint Pop-up Flight*, Missiles and Rockets, May 17, 1965
http://www.smdc.army.mil/2008/Historical/Book/Chap2.pdf

MAR-I & White Sands Missile Range

Google Earth

Nike-X Prototype *Multifunction Array Radar* (MAR-I)



The large dome was 120 ft in diameter and 45 ft high.

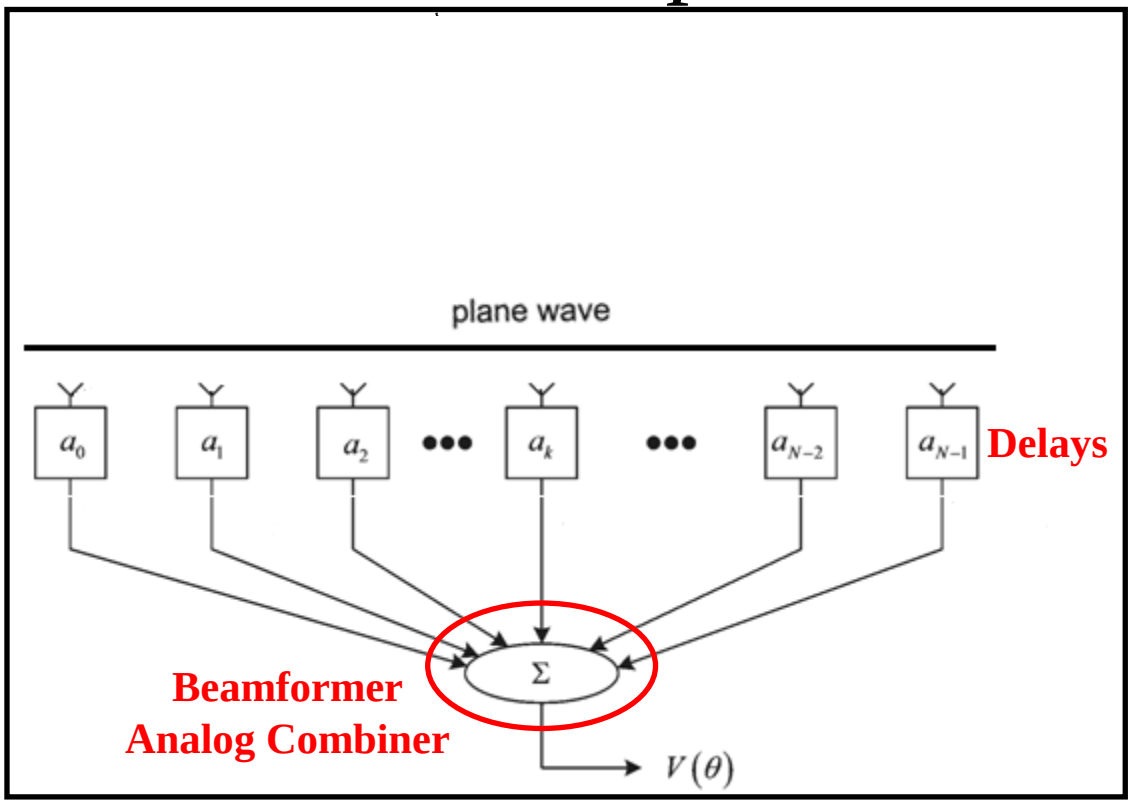
Most of the 195 x 155 ft structure is underground and extends 42 ft below surface grade

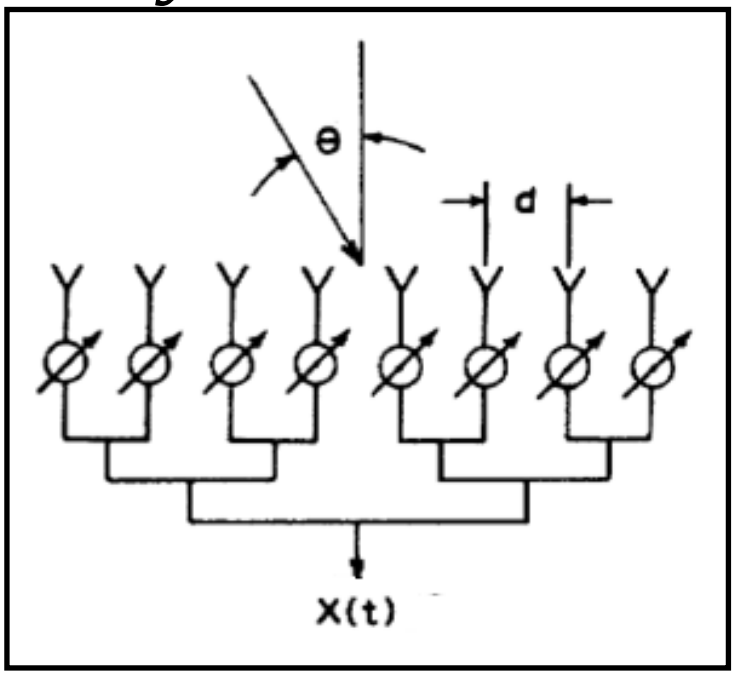
It had 2 floors underground and 2 floors in each of the domes for a total interior floor space of 90,000 sq ft.

Photo courtesy of Doyle Piland, WSMR Archive

Electronically Steered Phased-Array Radar

Corporate-Fed Array





A phased-array is made up of a number of broad beamwidth antenna elements. Its radiation pattern is determined by adjusting the time at which the signal emerges from each element.

By inserting a delay "d" which increases incrementally from element to element, the resulting beam will be shifted away from the boresight. Thus by varying the delays in the *linear array* above, the beam can be steered to any forward direction within the plane. For a 2-dimensional *planar array*, the beam can be steered both vertically and horizontally to cover an entire quadrant.

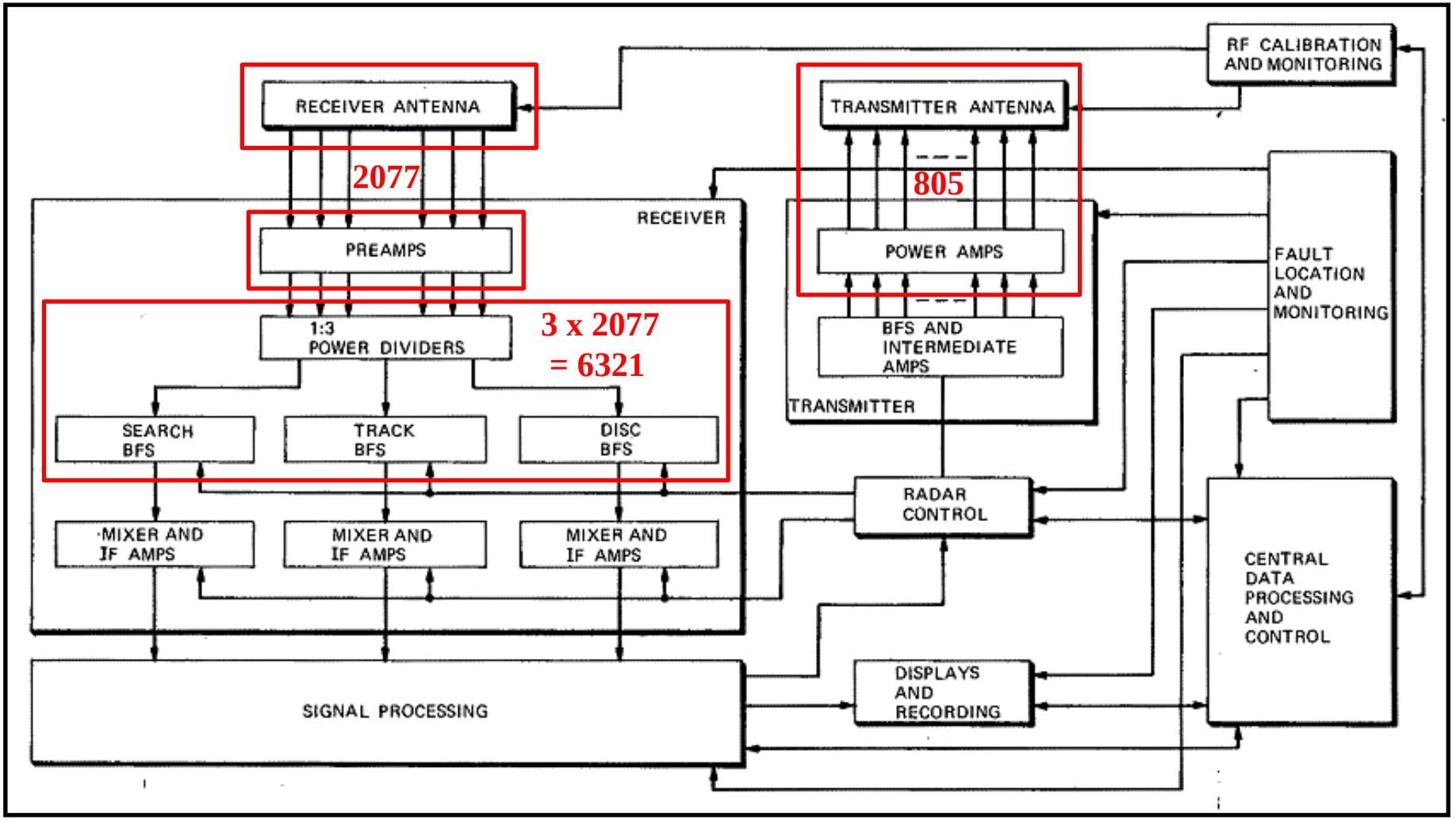
In a *Corporate-Fed Array*, like the MAR-I, the transmission lines connecting the elements to the beamformer are all of equal length.

The only time delays needed to steer the beam are the relative delays across the aperture face.

MAR-I Functional Diagram

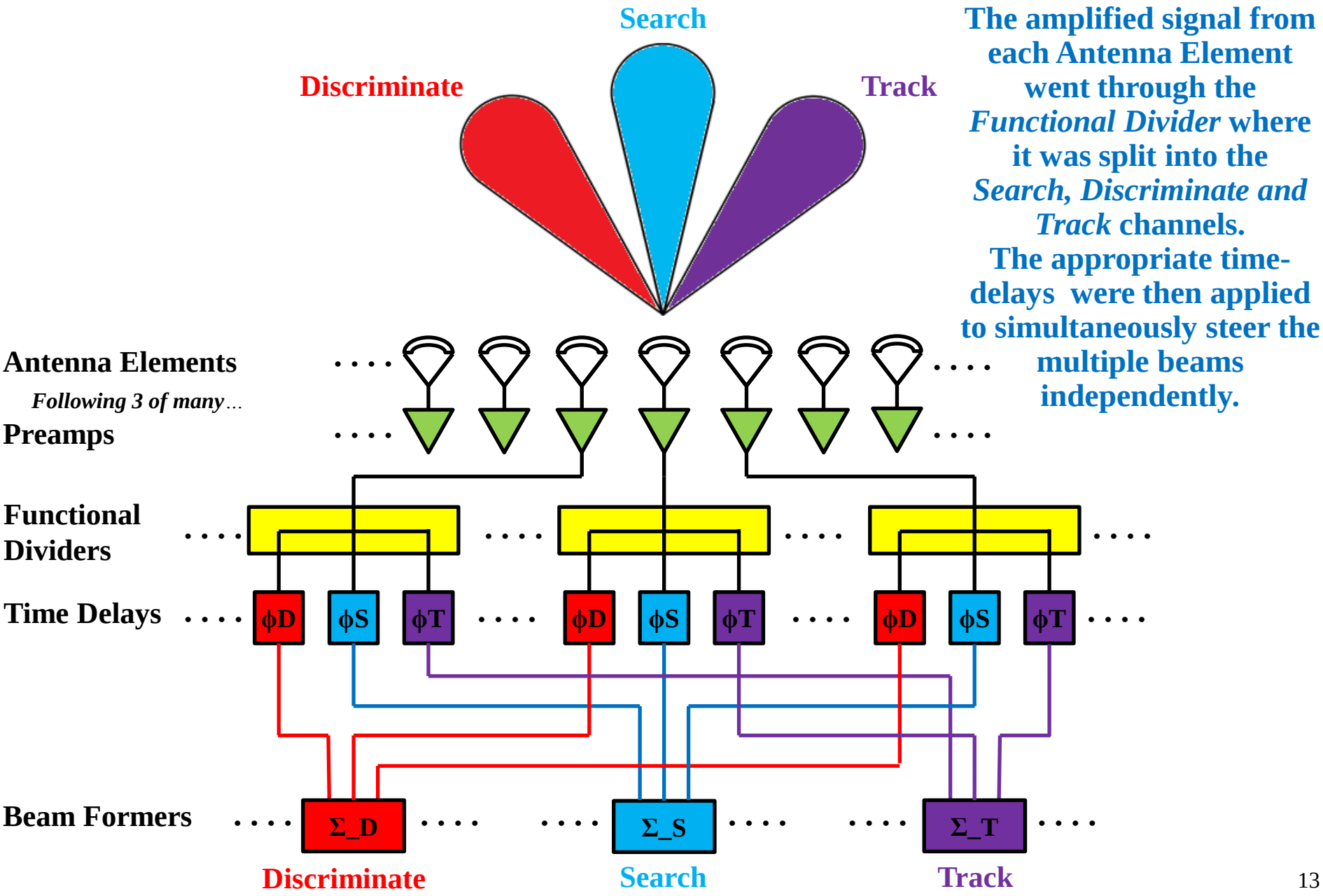
The only one to be found in the unclassified literature.

It is incredibly devoid of vital information !!!



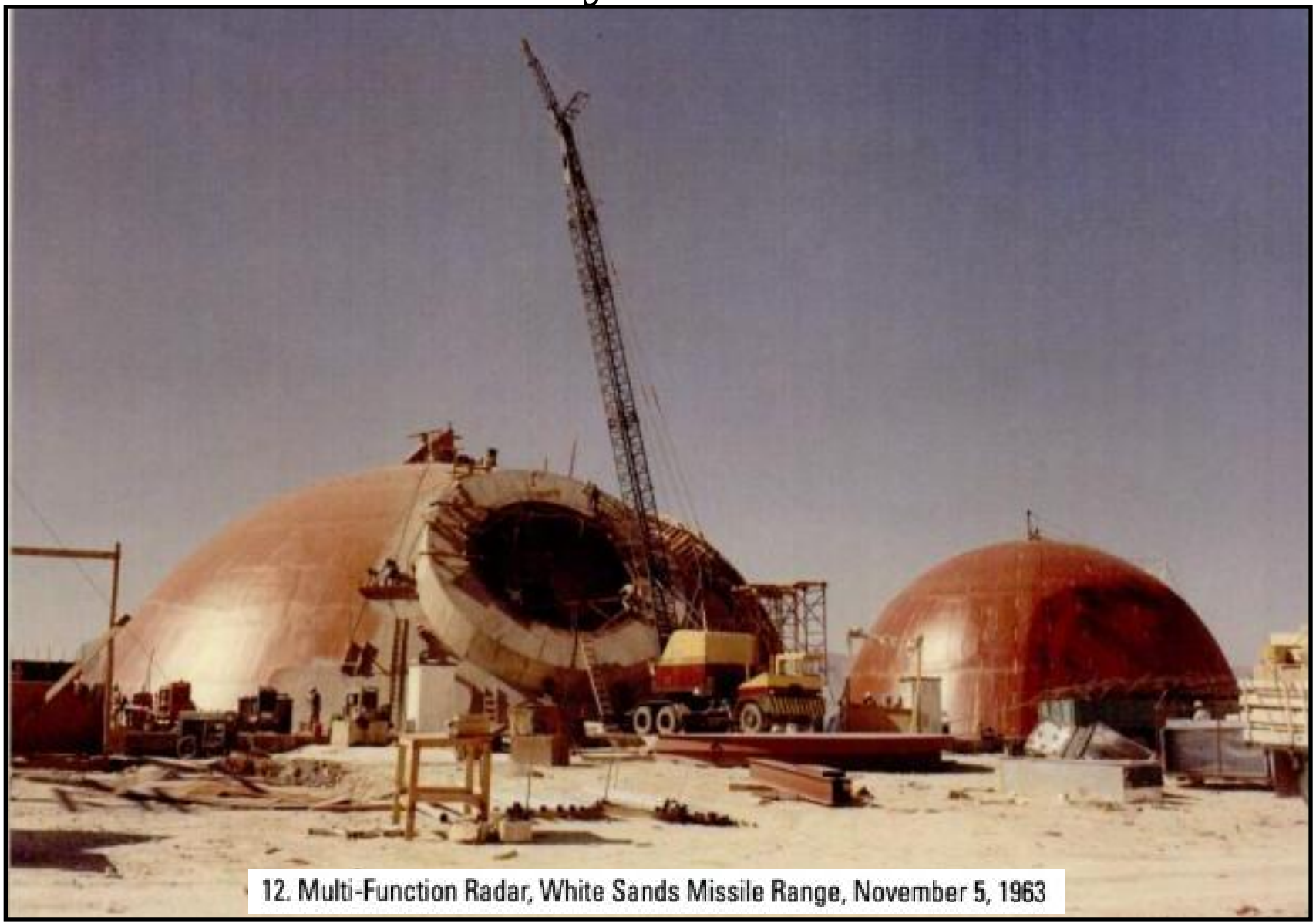
ABM Research &Development at Bell Laboratories – Project History, Oct 1975, pg. 2-20

MAR-I's Search, Discriminate & Track Beams



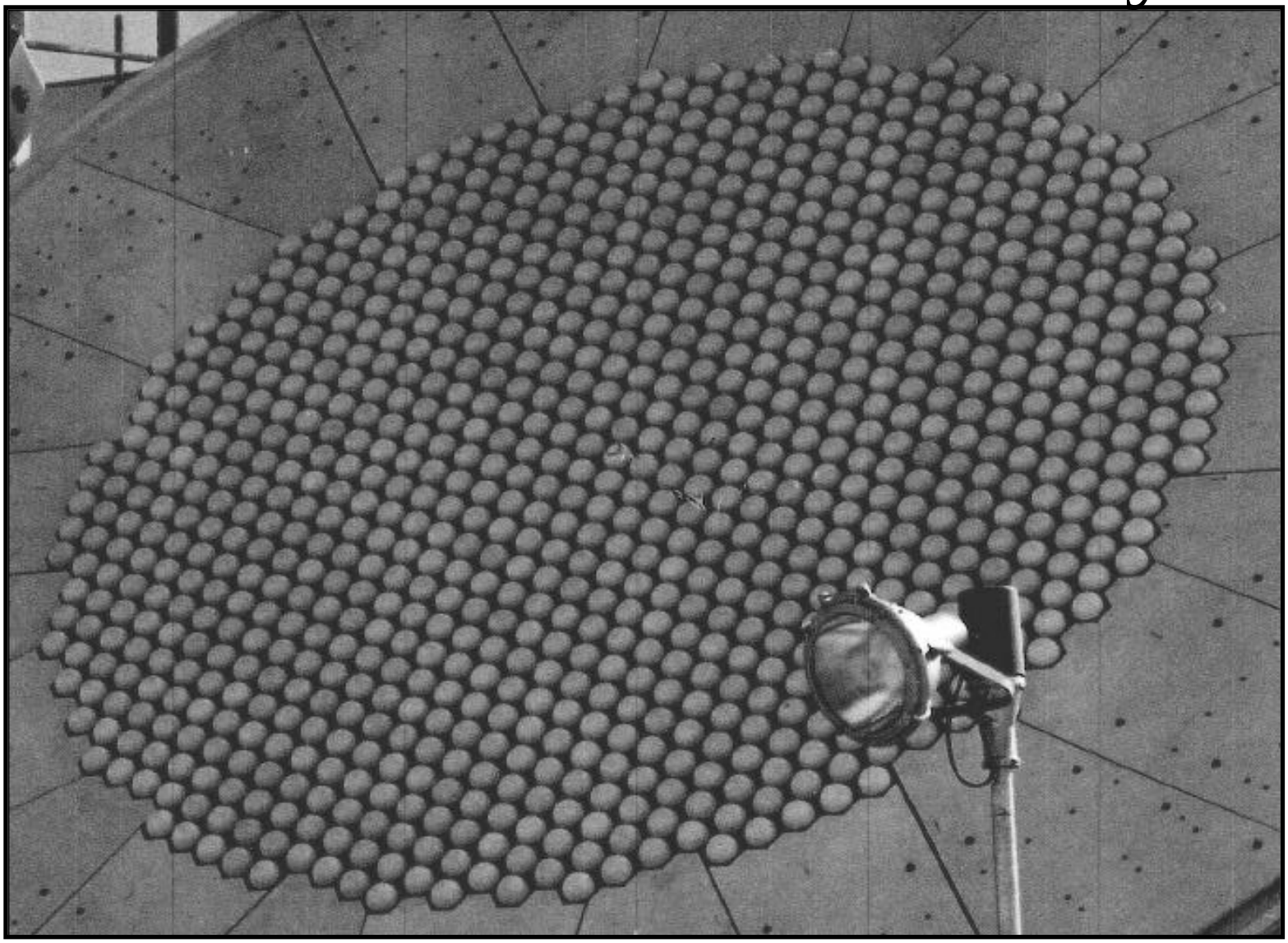
The amplified signal from each Antenna Element went through the *Functional Divider* where it was split into the *Search, Discriminate and Track* channels. The appropriate time-delays were then applied to simultaneously steer the multiple beams independently.

Color Photo of MAR-I Construction on Nov 5, 1963
R-2 Rx Array & T-2 Tx Dome



***Blazing Skies: Air Defense Artillery on Fort Bliss, Texas, 1940-2009*, J. Hamilton, Dept. of the Army, 2009, p.168**

MAR-I Transmitter Array Face



Diameter ~15 ft

Its large steel antenna support structure weighed 30 tons.

The output power from each antenna element was a few kilowatts.

Thus the peak output power from the MAR-I Transmitter was in the megawatt range.

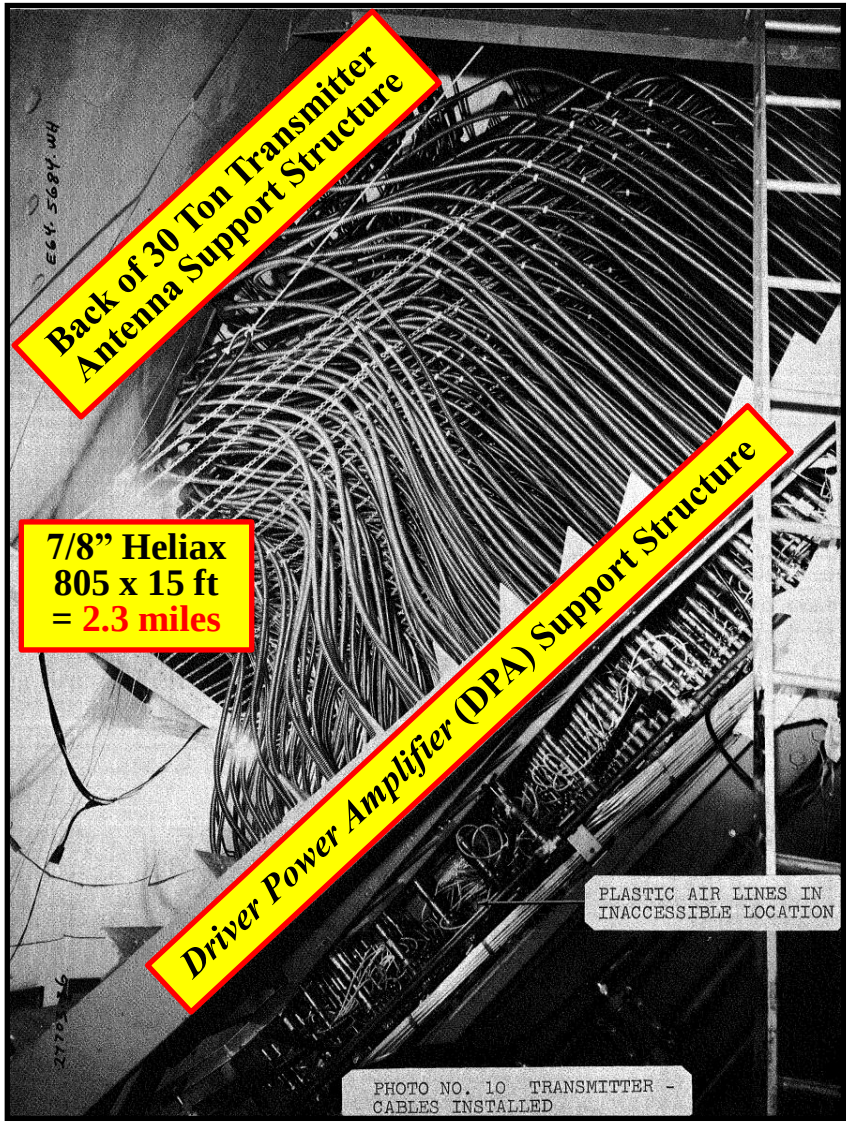
Number of Antenna Elements = 805 Active + 108 Passive = 913

"Dummy" elements were placed on the periphery to ensure the mutual coupling was identical.

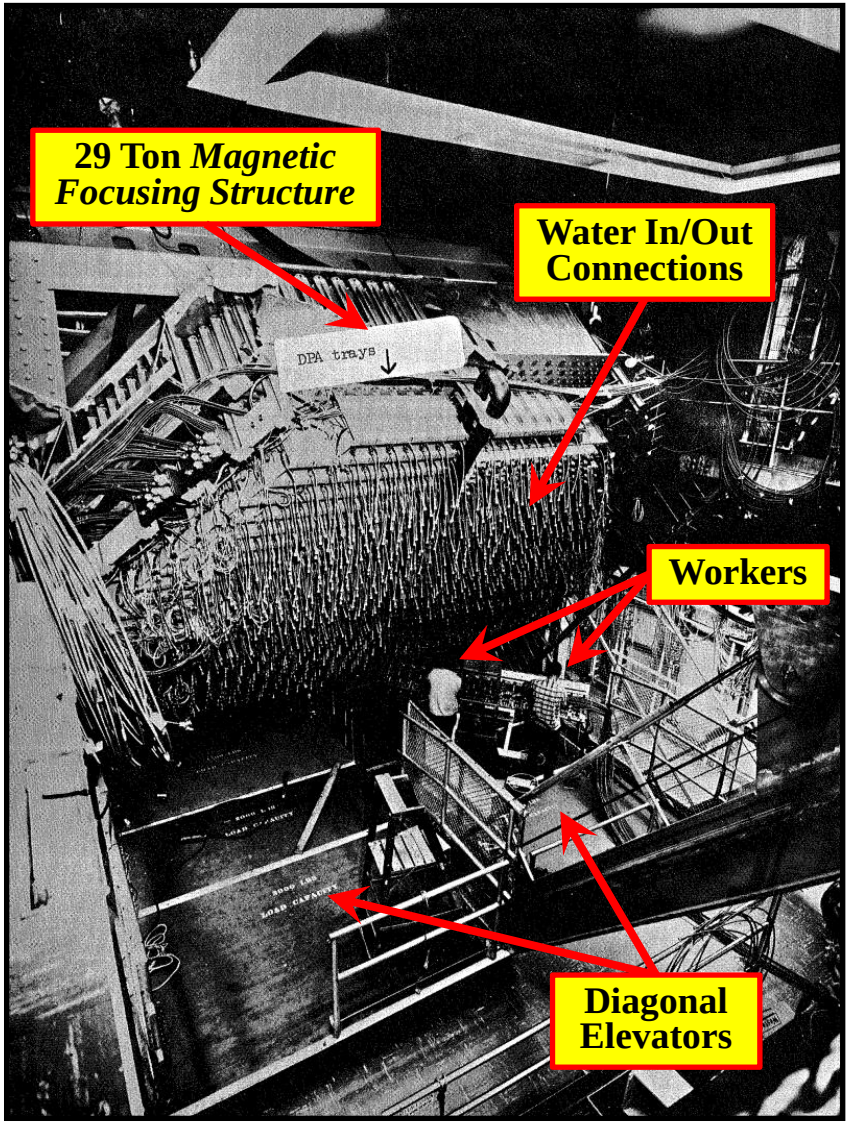
Photo courtesy of Bob Gamboa

Inside the MAR-I Transmitter Dome

Side view of the ~900 cables between the Antenna Elements and the TWT Amplifiers



Back view of the ~900 Driver Power Amps. Note the unconnected water cooling lines.

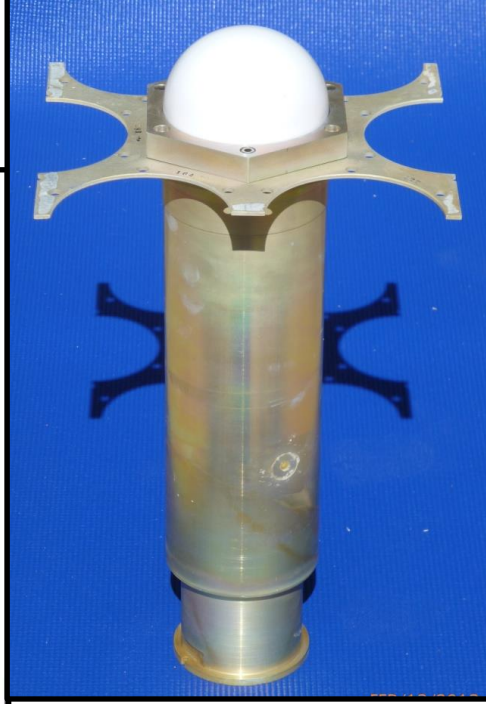


Review of mechanical Problems Associated with the Multi-Function Array Radar (MAR-I), G.R. Tobias, BTL Report, 5 June 1964

MAR I Critique (Preliminary), BTL Report, W.G. Graves II & W.E. Kelley, 15 June 1964

MAR-I Receiver Array Face

All 3158 Tx & Rx *Antenna Elements* were identical and covered by a *Ceramic Window*.



Receiver Array Face Diameter ~25 ft

The array's large steel antenna support structure weighed 92 tons.

Antenna Element Field of View > 90°

Phased-Array Beamwidth ~1.8°

Number of Antenna Elements = 2077 Active + 168 Passive = 2245

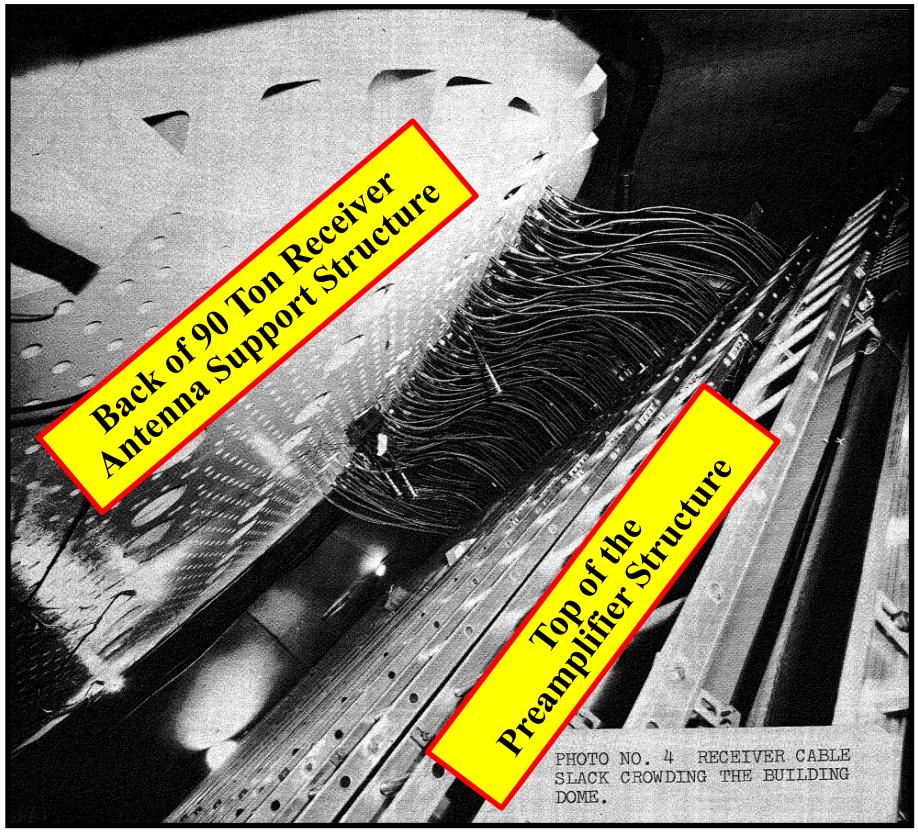
Photo courtesy of Doyle Piland

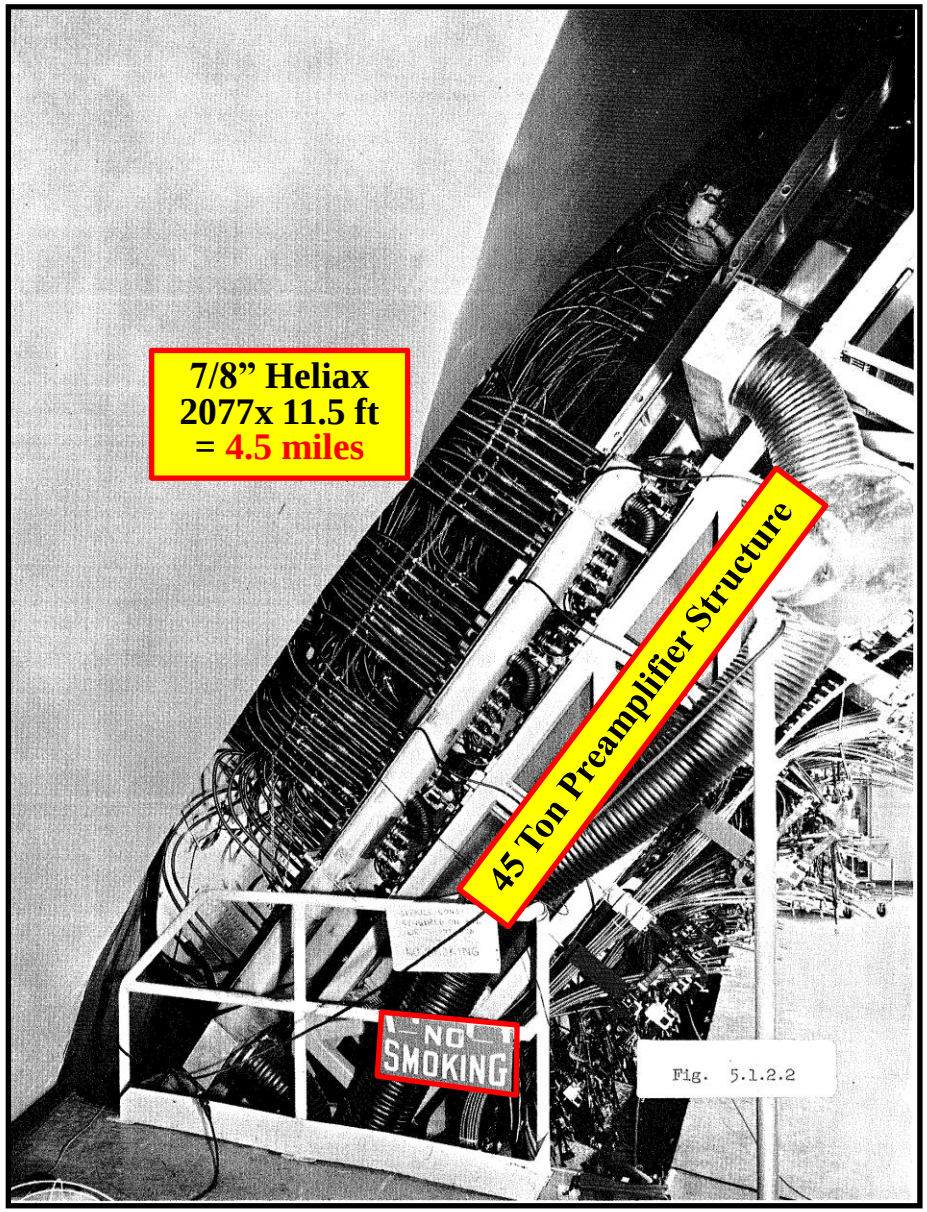
Inside the MAR-I Receiver Dome

Views of the phase-matched coaxial cables running between the Antenna Elements & Paramps.

Picture at left shows the start of cable installation seen from the *Lower Dome Level*.

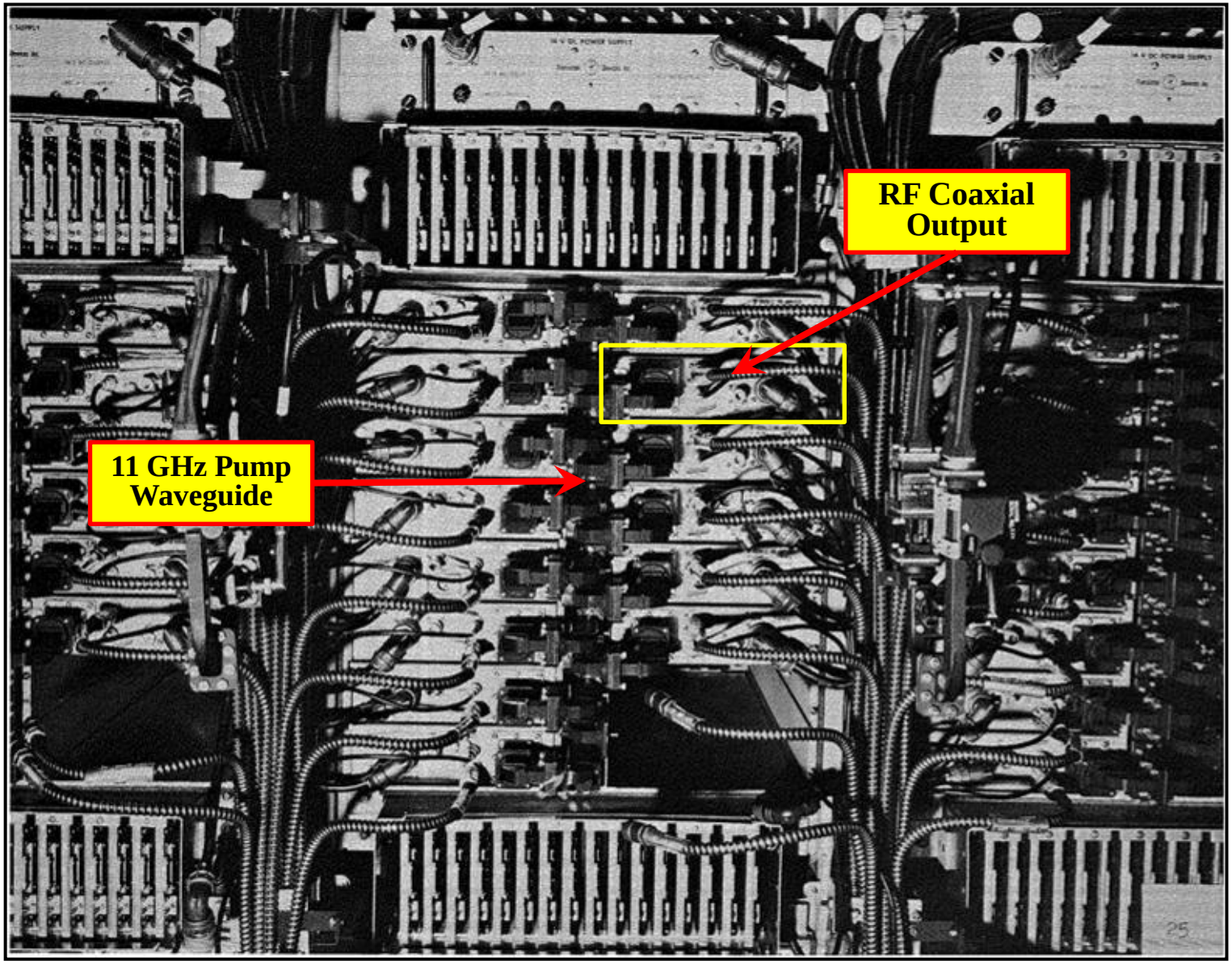
Picture at right shows the final cabling configuration seen from the *Upper Dome Level*.





Review of mechanical Problems Associated with the Multi-Function Array Radar (MAR-I), G.R. Tobias, BTL Report, 5 June 1964
MAR I Critique (Preliminary), BTL Report, W.G. Graves II & W.E. Kelley, 15 June 1964

View of the Back of some of the 2077 MAR-I Preamplifiers



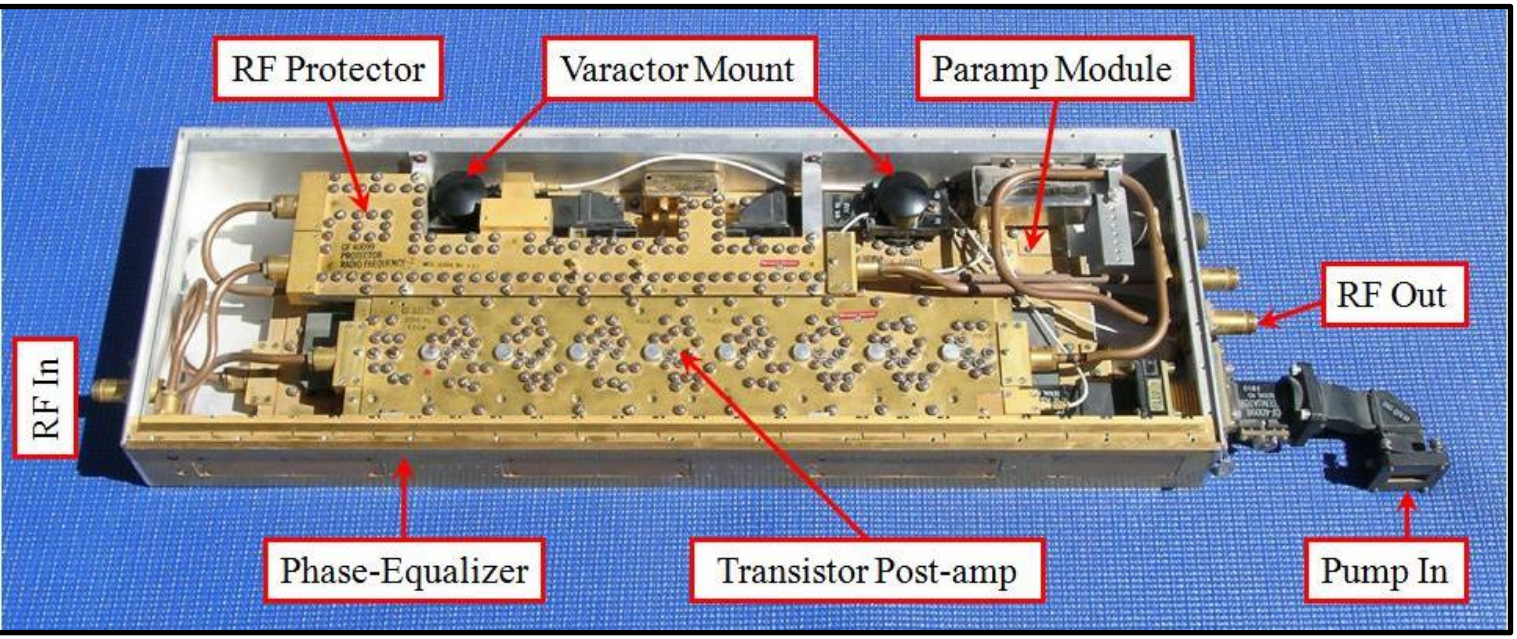
The L-Band signal received by each of the active *Antenna Elements* first passed through a WECo *Preamplifier* Module.

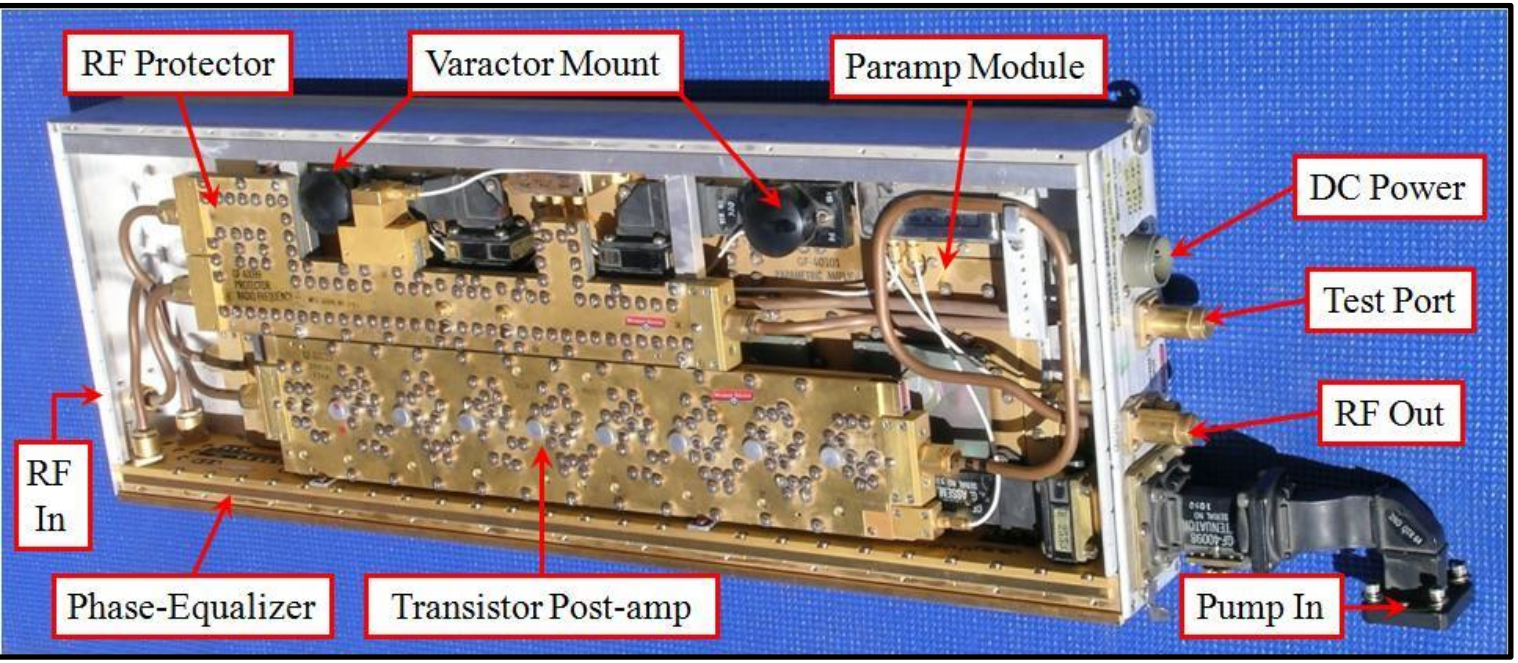
Each rack may have contained 32 *Preamplifier* Modules.

Over 64 of these racks would have been required to accommodate the radar's 2077 active *Antenna Elements*.

***MAR I Critique (Preliminary)*, BTL Report, W.G. Graves II & W.E. Kelley, 15 June 1964**

Western Electric *Preamplifier*, Model GF-40096-L2, S/N 930





Photos by R. Hayward

The MAR-I *Preamplifier* unit consisted of a 2-stage *paramp* plus several additional modules .

It was obviously built to take a beating (or a nuclear strike).

Dimensions (inches)
L x H x W =
26" x 9⅛" x 2⅝"

Weight = 32 lbs
On the MAR-I, the 2077 preamps would weigh 33.2 tons.

The early 1960's transistor amplifier required 8-stages to achieve a gain of 40 dB and had a noise temperature of ~1800°K.

Today's version of this *Preamplifier* would require 4 or 5 stages and have a noise temperature < 100°K in a package ~1/100th the size.

Main Floor "*Beta*" (Elevation) Delay-Racks

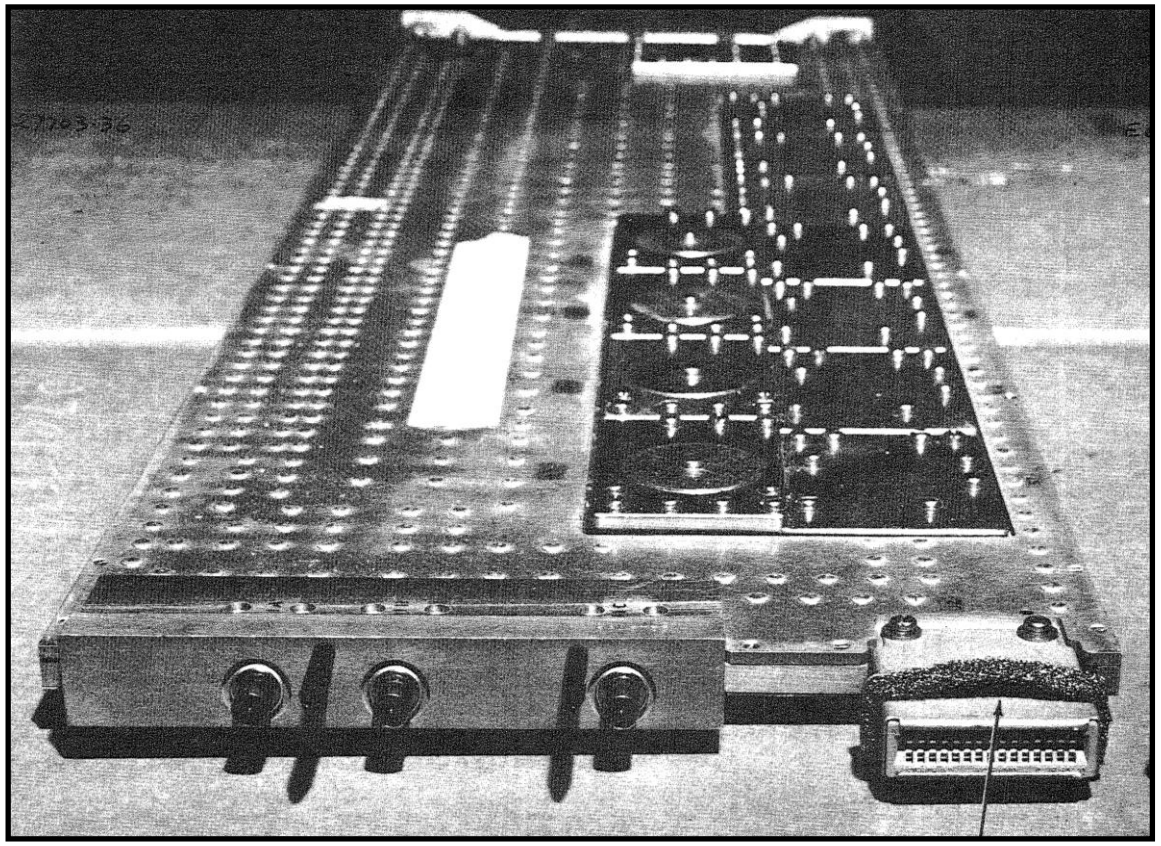
The *Beta Racks* was where the time delays *w*ere inserted to steer the beam in *Elevation*.

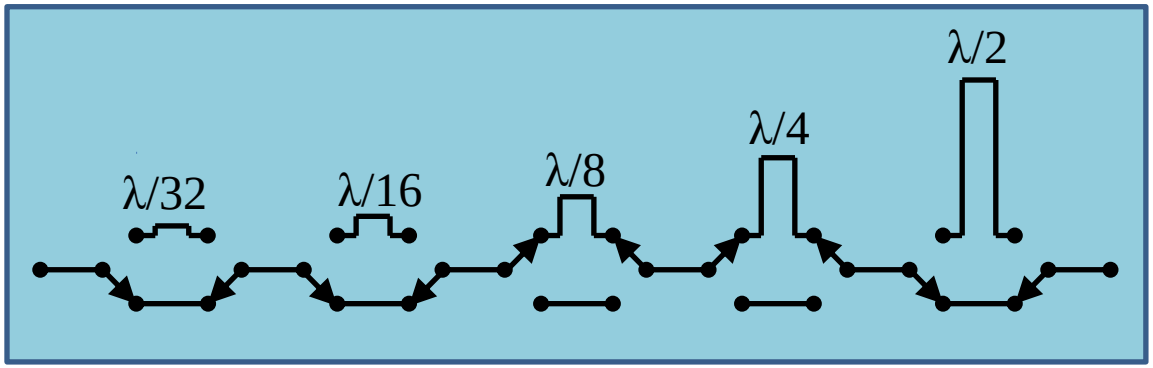
Length of factory pre-cut 3/8" Heliax microwave cables > 27 Miles.

Signals then went to the *Alpha Racks* where the *Azimuth* delays were added.

Photo courtesy of Doyle Piland

MAR-I Digital Delay Stripline Board





A programmable time delay was applied to the signal from each *Antenna Element* to steer the beam. This was done with the *Digital Delay Board*.

There was a total of over 9,000 *Beta Delay Boards* steering the Receiver Array in Elevation.

For the *Search* mode beam, each *Antenna Element* used one *Beta* (Elevation) *Delay Board*. For the *Discrimination* mode beam, there were 3 *Beta Delay Boards* per *Antenna Element*.

After the *Beta Racks*, the signals went to a smaller number of *Alpha* (Azimuth) *Delay Boards*.

The MAR-I used a 5-bit digital phase-shifter with λ/32 (or 12.5°) quantization.

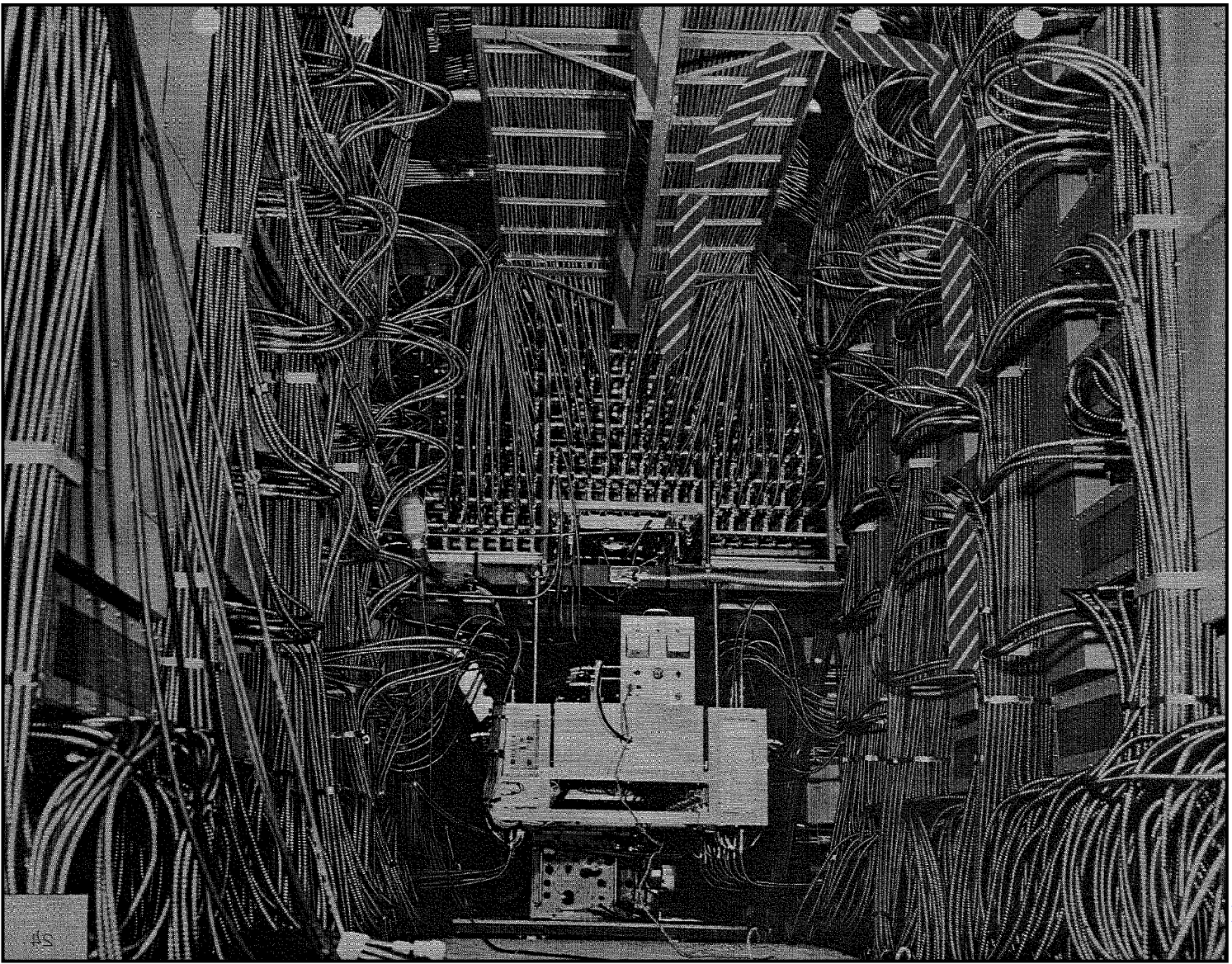
The switch positions shown in the example give 3/8·λ or 135° phase delay.

For the big-radars built since, most designers consider 3-bits as not enough and 4-bits as too much.

***Review of Mechanical Problems Associated with the MAR I Phased Array Radar*, BTL Report, G.R. Tobias, 5 June 1964**

MAR-I Beam-Former

Miles & Miles of 3/8” Heliax cables feeding the *Alpha Search, Track & Discriminate 16:1 & 12:1 Combiner*



The MAR-I *beamforming* was done with *analog power combiners*.

The *Alpha Chamber* was where the signals from the summed columns in the *Receiver Array* were combined.

The *Elements* of each row in each column of the *Array Face* have already been combined before reaching this room.

***MAR I Critique (Preliminary)*, BTL Report, W.G. Graves II & W.E. Kelley, 15 June 1964**

IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS

VOL. AES-1, NO. 3 DECEMBER, 1965

A New Approach to Equipment Interconnection

N. S. CHRISTOPHER, Associate Member,
Sylvania Electronic Systems
Waltham, Mass.

MAR Program Equipment Interconnection

Generation of Required Information

MAR is a Multifunction Array Radar at White Sands, N. M., consisting of a pair of circular planar arrays mounted in hemispherical domes. The larger dome contains the receiving array and receiving equipment housed on three floors. The smaller dome houses the transmitter array and its associated equipment, also on three floors.

Each of the six floors contains cable tray networks for distributing the signal, control, electronic data, and monitor cables to more than two hundred racks of equipment contained in the two domes. These cable tray networks are analogous to city streets and avenues over which traffic is routed.

In order to achieve this goal, it was apparent that each of 30 000 cables would have to be prerouted and cut to a degree of accuracy seldom found in systems other than of the Phased-Array type. The normal methods of hand routing and scaling lengths from drawings were determined to be inadequate.

In an effort to meet this challenge, Sylvania undertook what is believed to be a tried but heretofore unsuccessful approach, namely, the prerouting and calculation of cable lengths by means of a computer.

Sylvania 9400 Main Computer Program

In an effort to preroute and precalculate cable lengths accurately, a program was written for Sylvania's 9400 Computer which selected the optimum route and length for each interconnecting cable in the system. Given an origin and a destination rack (from among some 200 racks) for each of 30 000 cables, the computer selected a route for the cable to follow through the maze of cable tray networks. These networks were predetermined cable tray layouts on each of the six floors housed in the two hemispherical domes, i.e., buildings. The program routed cables between racks on the same floor, between racks on different floors, and even between racks in different buildings.

The amount of available tray capacity was determined by keeping track of the number of cables passing through a given cable tray.

The MAR Wire Run List contained some 7000 pages of system interconnecting cabling documentation.

Conclusions

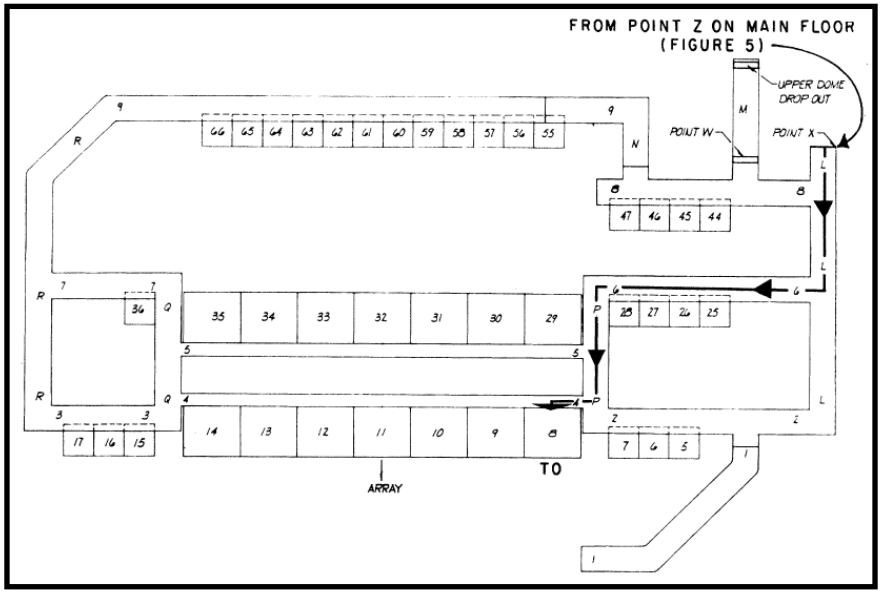
The use of computer techniques to perform moderately complex highly repetitive processes accurately for equipment integration on large scale systems has resulted in a considerable time and cost reduction as well as freeing skilled people for functions requiring human judgment.

The existing and proposed uses of computer techniques as aids to equipment integration as described in this report are a manifestation of the level of success which has already been attained. The number of applications and the level of sophistication can be expanded further for even greater cost and time savings.

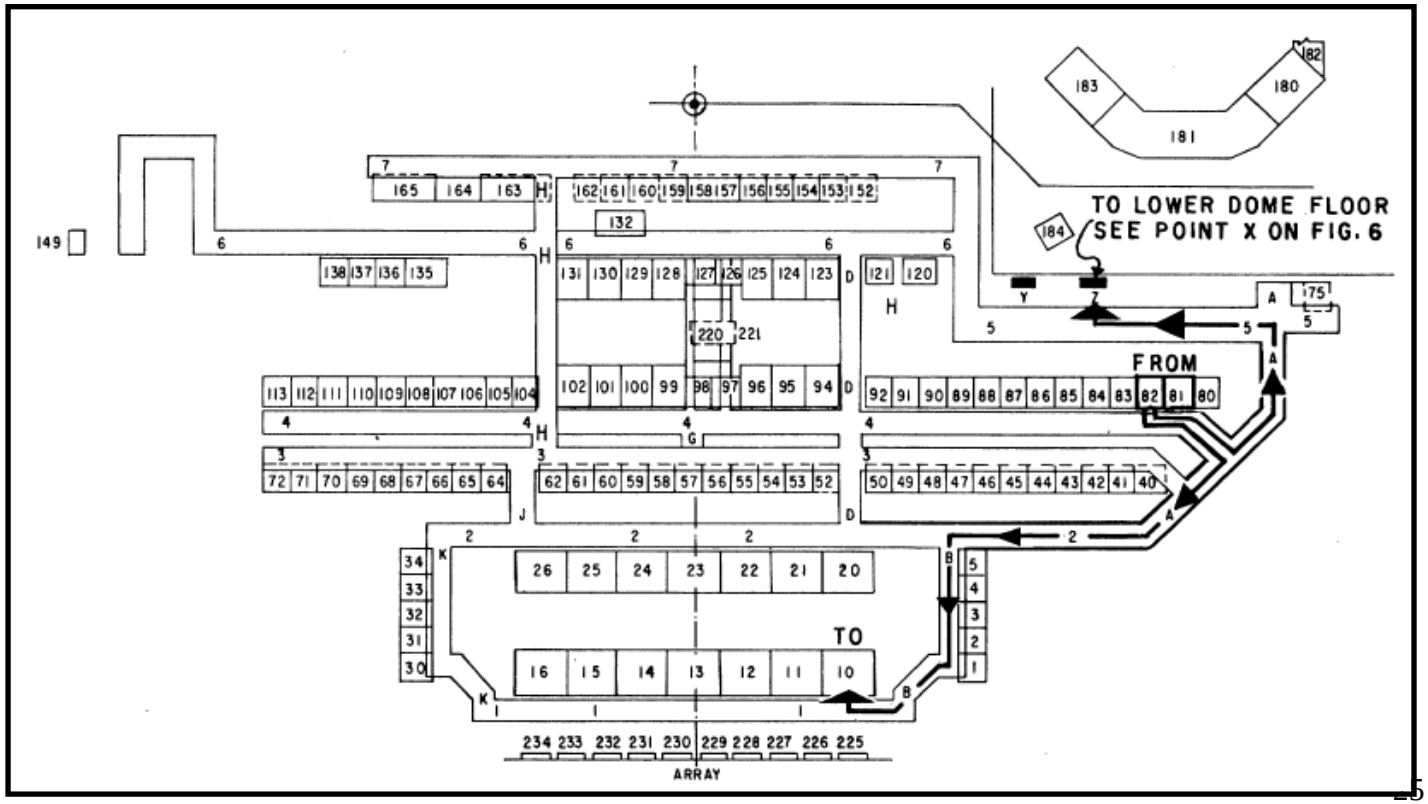
A New Approach to Equipment Interconnection

The MAR-I was the 1st large project to successfully use a computer to route & calculate cable lengths, as well as determine weight & thickness of cable bundles.

"*Street map*" of racks on the <u>Lower Dome Floor</u> of the MAR-I



"*Street map*" of the numerous electronic racks on the <u>Main Floor</u> of the MAR-I



MAR-I Preamplifier Test Area

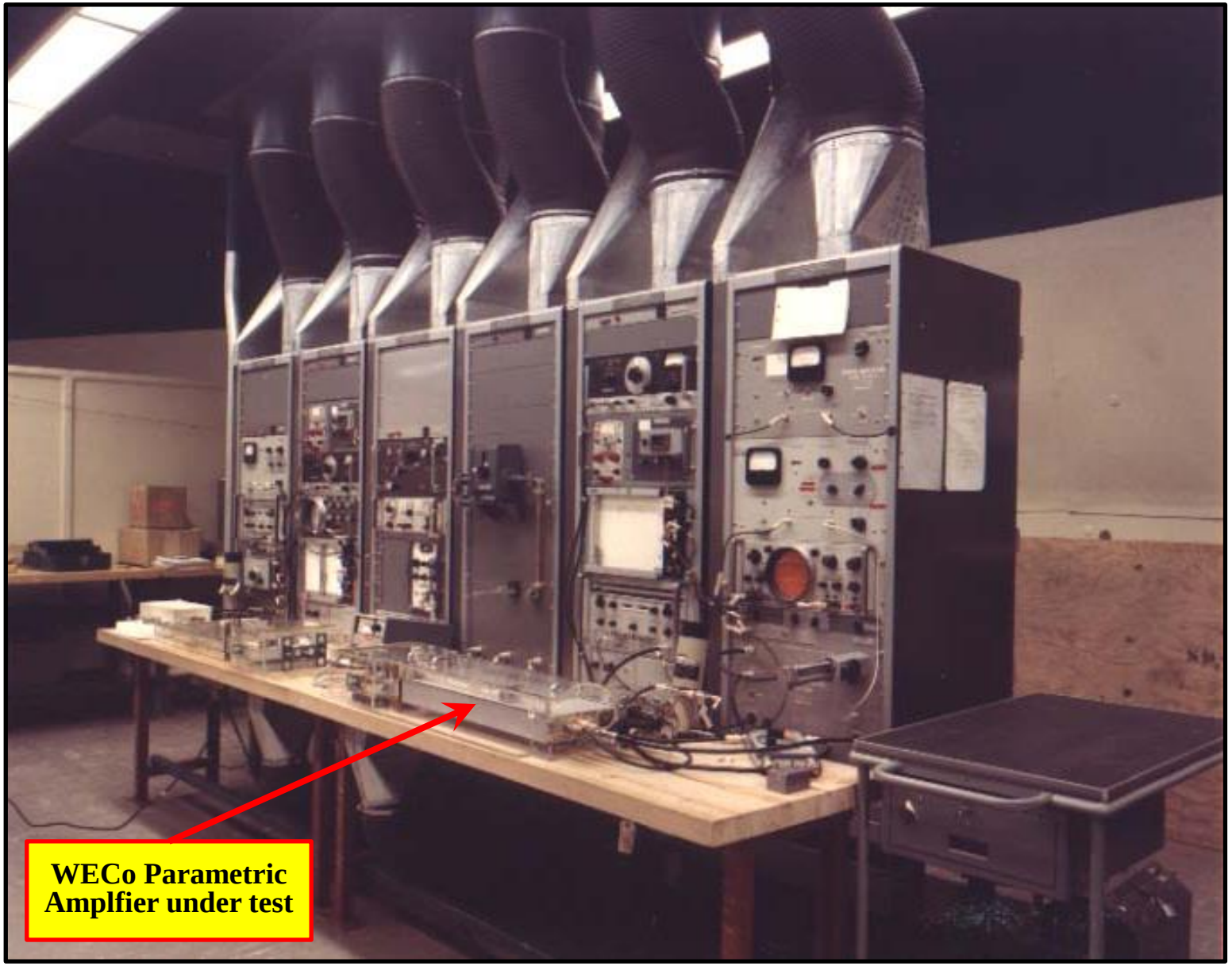


Photo courtesy of Doyle Piland

Comprehensive MAR-I Timeline

1960	**Engineering studies and conceptual designs for a multifunction array system developed at BTL.**
June 1961	**WECo authorized to proceed with the design of a prototype phased-array radar. BTL was responsible for supervising the design. Sylvania was selected as the subcontractor for the detailed design & fabrication of the prototype model at WSMR.**
1961 - 1962	**Proposals for the MAR-I system were solicited and the final design of the MAR-I completed.**
1962 - 1963	**Many of the numerous electronic components of the MAR-I were manufactured.**
March 15, 1963	**Groundbreaking for the MAR-I at WSMR.**
December 1963	**Construction of the MAR-I building and facilities completed.**
January 1964	**Installation of electronic equipment on the MAR-I begins.**
June 15, 1964	**Installation of the MAR-I completed and the power is turned on for the first time.**
July - Sept 1964	**All components of the MAR-I facility undergo systematic testing.**
September 11, 1964	**MAR- I successfully tracked a real target - a balloon - for the first time, following it for 50 minutes while intentionally dropping and automatically re-establishing lock several times. The balloon was successfully handed over in the automatic mode, which included transfer from search to verification, to acquisition track, and target lock-on.**
Septe 30, 1964	**MAR-I demonstrated one of its multifunction capabilities by successfully performing automatic search, & tracking of real targets using *Highball* and *Speedball* rockets.**
November 19,1964	**MAR-I participates in a *Pershing* missile firing with ~71 seconds of tracking data obtained. This was a significant first.**
March 1965	**Shutdown of MAR-I Transmitter for design changes. Receiver tests continue.**
October 1965	**First full power radiation from full array with rebuilt transmitter on MAR-I.**
December 1965	**Completion of beamwidth, range capability & absolute track accuracy evaluation tests on MAR-I.**
May 20, 1966	**MAR-I successful in its first attempt to track a satellite. The USSR *Polynot II* was detected & tracked over the entire sector of expected path. This test was the first in a series to gain experience with satellite & other high performance targets.**
October 1966	**First demonstration of autonomous multi-function operation tracking a satellite target with MAR-I.**
March 2, 1967	**First full test of MAR-I with an *Athena* missile to test autonomous acquisition and handover to precision track mode which maintained lock on the closest object through target separation.**
April 27, 1967	**The MAR-I successfully tracked five objects ejected from a *Highball* rocket in a multiplex tracking demonstration. The test completed an operational demonstration milestone.**
June 1967	**First demonstration of multiplex-frequency tracking of multiple *Pershing* targets with MAR-I.**
September 1967	**Completion of MAR-I tests demonstrating "chaff" cloud survey and fine frequency techniques.**
Sept 30, 1967	**MAR-I test program terminated.**
1968 - 1969	**MAR-I continues operations at reduced level as a *Sentinel* Evaluation Agency training facility.**
May 1969	**MAR-I site placed in care-taker status.**
Nov 1969 -1981 (?)	**The unused MAR-I facility is identified as the main fallout shelter area for all 5,800 dependents of the military staff assigned to Holloman Air Force Base, located 24 miles away.**
Late '70//Early '71	**Electronic equipment and hardware salvaged from the MAR-I site by New Mexico Tech.**
1981 to 1984	**Construction of the High-Energy Laser Test Facility (HELSTF) at the MAR-I site, representing a ~$800 million investment over several decades.**
Sept 1985	**HELSTF becomes operational when the Mid-Infrared Advanced Chemical Laser (MIRACL), the first megawatt-class, continuous wave, chemical laser built in the free world, was used to destroy a Titan missile booster in a static test.**

The MAR-I in the Popular Press & Trade Journals
A Few Examples

ARMY RESEARCH AND DEVELOPMENT
MONTHLY NEWSMAGAZINE OF THE OFFICE OF THE CHIEF, RESEARCH AND DEVELOPMENT
Vol. 5, No. 8 August 1964 • HEADQUARTERS, DEPARTMENT OF THE ARMY • Washington 25, D.C.

WSMR Tests Multi-Function Array Radar

The Multi-function Array Radar (MAR), combining functions of three radars into one concrete and steel package at White Sands (N. Mex.) Missile Range, is expected to provide Nike X with a more effective defense against long-range ballistic missiles.

Development of MAR is being managed by the Nike X project office of the U.S. Army Missile Command at Redstone Arsenal, Ala. Ultimate performance of Nike-X against ICBM's and submarine-launched missiles conceivably may depend on the tests conducted with MAR at White Sands.

Three concrete and steel domes covering an acre and a half house the MAR system. Projections called radiating elements beam high-powered electrical energy into space. When energy is pumped from two or more of the radiating elements simultaneously, the beam flickers from side to side at nearly the speed of light and can be halted to focus on a tiny point in space.

The test version of MAR at White Sands, which has been operating since July 1, has only one receiving eye and one transmitting eye. Later versions, including one scheduled for Kwajalein Island in the Pacific—major test site for Nike X development—may appear different but should employ the same prinicple.

MAR works on the theory that radar beams can be bent electrically by playing one beam against the other—a delicacy in timing which requires computerized operation.

Another impressive capability of MAR is that only the operator's chair will have to be oiled. Nothing else moves. Because MAR has no moving antenna, there is no friction to overcome or inertia to keep it from changing direction and speed instantly. In fact, MAR will be capable of operating so quickly that it will appear to look in every direction at once.

MAR is being designed to replace radars used in the Nike Zeus antimissile missile system, predecessor to the Nike X system. They are: acquisition radar for detecting missile warheads at long ranges; target tracking radar for pinpointing location of warheads; and discriminating radar which sorts live warheads from decoys.

MAR stops just short of performing maintenance on itself but does spell out trouble spots. Flashing lights point out the ailing part to the repairman and the system also diagnoses its troubles and prints out the remedy on an electric typewriter.

MAR has been hailed as a great step forward in the art of electronic ranging and tracking of flying targets. It is the latest of the Army's air-defense radar developments begun only a few years ago with the Nike Ajax system of defense against manned aircraft.

Western Electric Co. is prime contractor for the Nike X System and Bell Telephone Laboratories has responsibility for the system's design and development. Sylvania Electric Products, Inc. is subcontractor to Bell for the White Sands MAR.

Army R&D Magazine
Aug 1964

Army Research and Development Newsmagazine, Vol. 5, No. 8, Aug 1964, p.23
http://asc.army.mil/docs/pubs/alt/archives/1964/Aug_1964.PDF

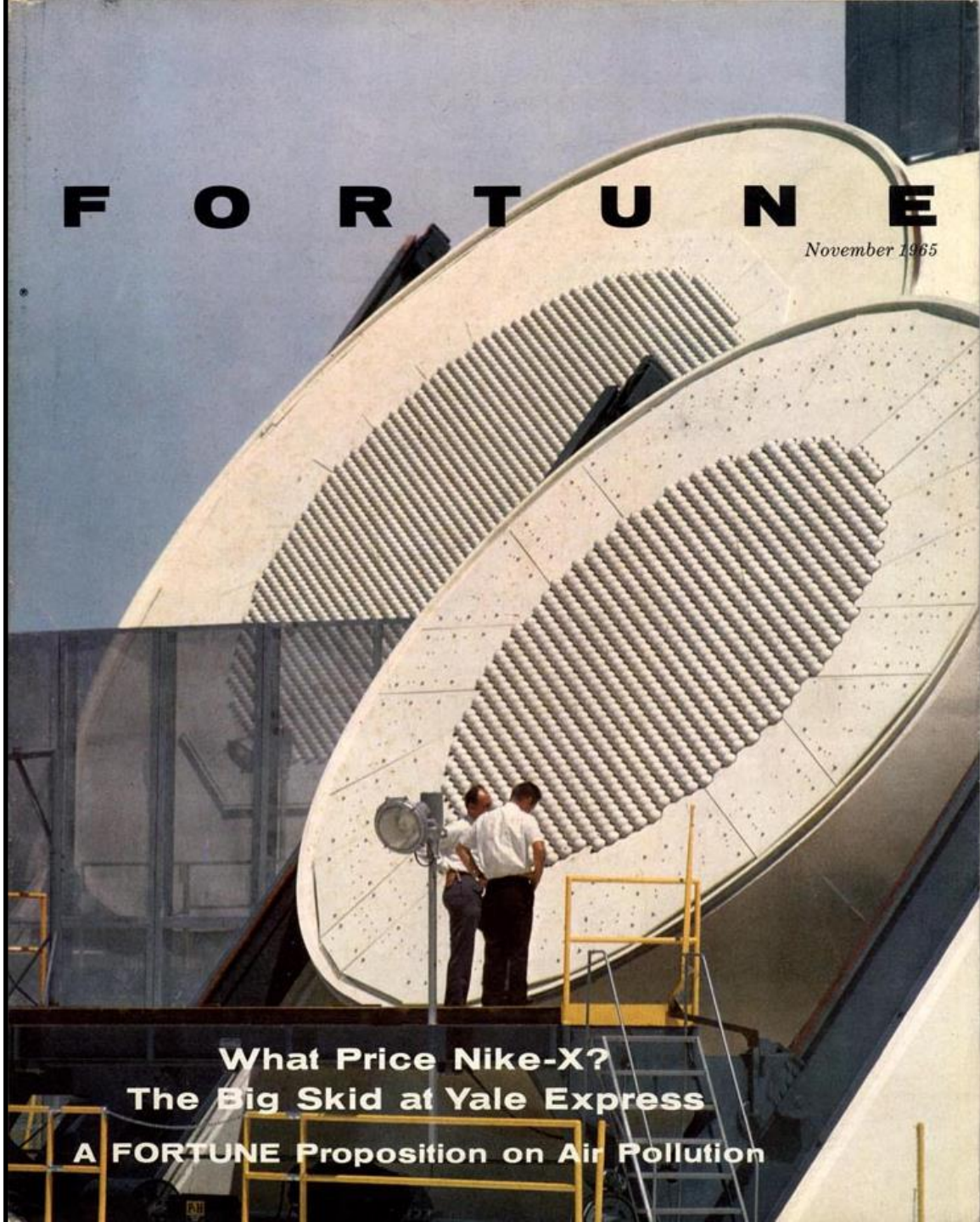
FORTUNE Magazine

November 1965

"What Price Nike-X?"

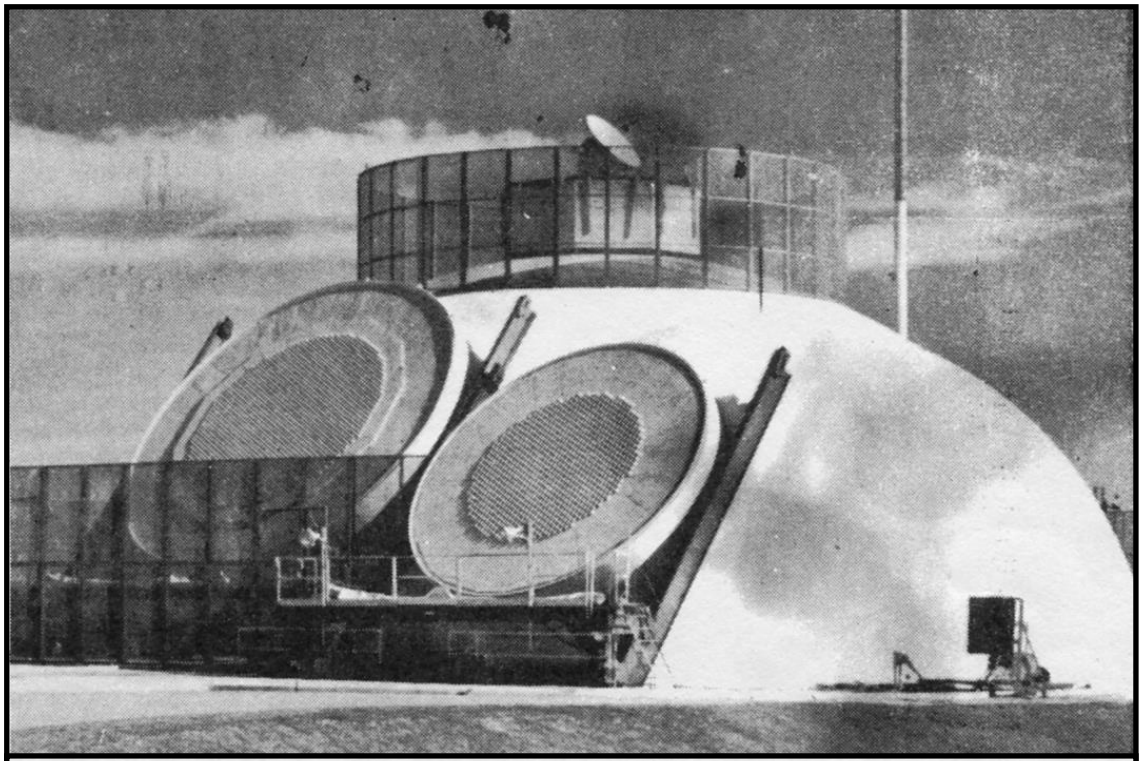
This contemporary article mainly discussed the pro's & con's of the Nike-X ABM system. It does contain a couple of rare pictures of the MAR-I, including this ground-level view of the Tx & Rx Arrays…

FORTUNE's cover photograph, taken at White Sands Missile Range, New Mexico, by John Bryson, shows the heart of a pilot Nike-X missile defense system (page 133). The disk shape in the foreground contains a transmitter antenna, and the one in the background a receiver, for the multi-function array radar, which detects and tracks hostile missiles and discriminates within seconds between warheads and decoys.



From the Las Cruces Sun News, November 2, 1970

Bell Laboratory Shuts Door On Quarter-Century Period



MAR-I INSTALLATION — One of Bell Systems' off-springs at White Sands Missile Range is the Multi-function Array Radar (MAR-I) built in the early 1960s for use in the Nike-X program. The huge radar installation surrounded by a 30-foot high clutter fence, is a prototype of the radar to be used in the Safeguard program now being implemented.

October ended on a note of nostalgia today for Richard W. Benfer, head of Bel Telephone Laboratories at White Sands Missile Range since 1952.

As he left the range's Nike Building, the door behind him will close on the final chapter of Bell Laboratories and Western Electric's quarter-century of work at White Sands.

Benfer represents thousands of Nike contractor engineers, physicists, technicians, clerks and laborers, who, over the past 25 years, have built an enviable record in electronics research and development, crowned by a family of missiles. The firm's last contract at WSMR Oct. 29.

Since August, the laboratory's employes have been engaged mostly in mop-up operations at Nike Building, preparing to close the 25-year-old operation.

The article describes the "*closing of the doors*" of the *Bell Labs* building in Oct 1970 after 25 years at WSMR. This appears to have occurred at the same time as NMT began to salvage the MAR-I site.

Courtesy of Vestal Fulp & Bob Gamboa

How Well Did the MAR-I Work ?

- **The US Army eagerly waited for a number of years with the hope that the *Nike-X* program would be approved by the LBJ Administration and finally enter into full production.**
- **As the MAR-I was a developmental prototype, what evidence is there that the design was indeed successful and actually worked?**
- **From a weekly trade journal issued about 6 months after the "turn on" of the MAR-I…**

The Countdown missiles and rockets, December 14, 1964

Nike-X To Wait Another Year . . .

It now appears *Nike-X* will have to wait another year for pre-production funds. With the budget squeeze on, there will be no money in the '66 program for initial tooling. This also means a year's slip in deployment. Now the first battery could not be operational until 1970-71.

. . . While MAR Performs Well

Tests at White Sands Missile Range of the Multi-function Array Radar are surpassing all expectations. This has always been the critical component in *Nike-X*—some Defense officials have questioned whether it would work at all. Test results to date are making believers out of even the most adamant skeptics.

- **Approval for *Nike-X* never came and its elaborate (and very expensive) shield covering the entire U.S. landmass was eventually descoped into a single *Safeguard* site located in North Dakota designed to protect only a small number of ICBM missile fields in the Mid West.**

From Missiles & Rockets Dec 14, 1964, pg. 9

NMT & the Salvage of the MAR-I

Photo by R. Hayward

Three former students of NMT who were involved with the savaging of MAR-I in the early 1970's inspect a WECo/Colgate Paramp. From left to right…

Joe Martinic looked after the large amounts of electronic hardware hauled back to Socorro.
Bruce Blevins used salvaged antenna elements & paramps in Stirling Colgate's SNORT project.
Steve Hunyady was a member of the demolition team & made several trips to the MAR-I.

The Salvaging of the MAR-I

- **NMT had a good reputation for acquiring copious amounts of military & government surplus material & equipment from numerous installations in the Southwest. The MAR-I work was the single largest salvaging effort ever carried out by NMT.**
- **The demolition teams only spent the weekends working at the MAR-I site. They would leave Socorro before dawn on Saturday morning and return late Sunday night so as not to miss their weekday classes. They would stay at the *Holiday Inn* in Alamogordo on Saturday night. It was essentially 2 very long days.**
- **They typically drove down in 3 carryall trucks with a total of 15-20, mostly students.**
- **On each expedition, usually two semi-trucks would go along. The students would pile everything they had salvaged onto pallets and fork-lifted them onto the truck trailers. When the trucks were filled up, they would put the pallets on the big freight elevator and send the folk-lift up with it.**
- **A small crew of 3 or so full-time staff would drive down later in the week and load the rest of the pallets onto the trailers and drive them back to Socorro.**
- **The salvaging work lasted about 6 months. It was a big effort - maybe 250 truck loads. There was literally at least a truck a day showing up with surplused stuff.**
- **Joe's primary job was to look after all the "*arrival stuff*" and deal with the endless number of racks & modules returned from the site to Socorro.**
- **He has strong memories of seeing three 30 gallon barrels filled with 6-32 screws, nuts & washers that had come from all the disassembled electronics. This was before the availability of powered screwdrivers, so it was a non-trivial task for the students.**
- **Joe Martinic was a student when the MAR-I salvaging took place in 1970/71. Since those days he has worked at the *Langmuir Lab*, the VLA, and on Colgate's *Liquid Sodium Dynamo* experiment.**

Steve Hunyady & the MAR-I

- **Probably the most amusing story about the MAR-I salvaging effort was the one about Steve Hunyady being abandoned at the site.**
- **He was a freshman when 1st assigned to go with a demolition team in Dec 1970.**
- **He came to the salvaging effort towards its tail end. Other students had been working on it for the whole semester. The *Clutter Fence* had yet to be removed.**
- **He was working at the far end of one of the floors cleaning things up when he noticed that it had gotten awfully quiet. Being the "new guy" on his first trip, the others had forgotten all about him when they headed home on Sunday evening.**
- **He had a lot of time to wander around. There were phones everywhere – whatever Western Electric builds will have lots of telephones. The regular phones were big green sets with lots of buttons. Next to one of them was a red phone labeled "White House". He checked - it was dead, as were all the others.**
- **There was a stairway up to the surface but it was locked from the outside, so he couldn't get out.**
- **He eventually found that the huge freight elevator still worked, but there were no controls for the elevator from the outside, so if he did escape the building, he wouldn't be able to get back in.**
- **The situation could get desperate. There was running water and the bathrooms were functional (and like everything else at the site, they were big) but there was no food available. It could be days, before the next demolition team would return.**
- **He had to give some deep thought as to what to do next. Even if he got out, it was a 2 mile walk south to Highway 70 and about 25 miles to Organ, the nearest town to the west.**
- **He remembered that one of the NMT trucks had broken down and had been abandoned outside. He made the decision to exit the underground building via the freight elevator. He managed to fix the truck and get it started. "*It was a real heap*". As he drove away, he couldn't get the doors to stay shut.**
- **He drove to Organ, the nearest town to the west, and called his roommate back in Socorro. He had to sleep the night in the truck until his friend could drive down to pick him up the next day.**
- **No one had missed him until he arrived back late on Monday. There were sheepish looks on a lot people.**
- **After that, Steve made 3 or 4 more trips back to the MAR-I site. He became a real popular guy. People would always ask "*Is Hunyady in the vehicle*?"**
- **Steve is now an Instrumentation Engineer at the NMT's *Lagmuir Lab* and has been there since 1988.**

USGS EarthExplorer

MAR-I Aerial Photos - 1 January 1973

Unfortunately, no photos are available from the 1960s.
Taken about 2 years after the site was salvaged by NMT.
Judging by the long shadows, the sun angle was low.
Clutter Fence has been removed but the berm can still be seen.
No sign of any ubiquitous cars or trucks at the site.

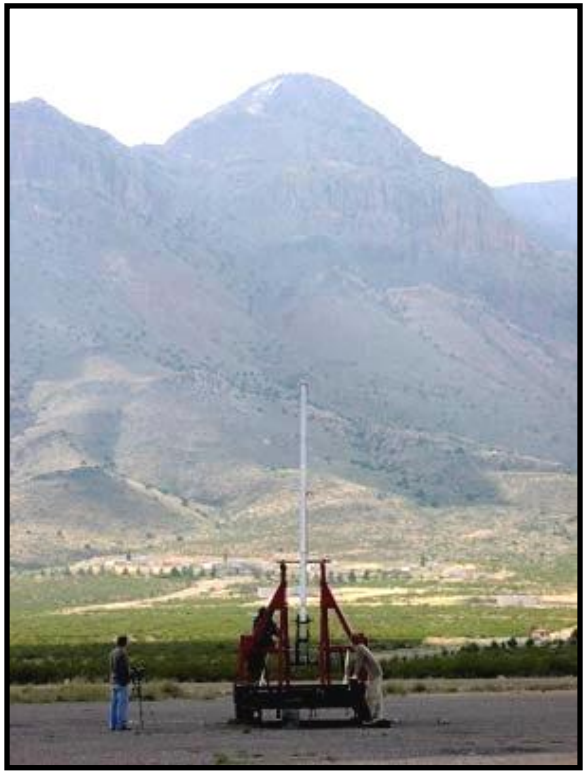
http://earthexplorer.usgs.gov/

The MAR-I *Clutter Fence* I-Beams

- **The first scouting parties from NMT to visit the MAR-I immediately realized that there was one item of incredible material value at the site…**
- **Not just the paramps but the fencing surrounding the radar.**
- **The *Clutter Fence was* 700 ft in diameter and 30 ft high.**
- **It consisted of hundreds of 20 foot aluminum I-beams with lots of steel cross-members and brackets.**
- **When hauled back to Socorro, the I-beams ended up being put to use all over the NMT campus…**
  - **In various building construction sites.**
  - **In the addition of a second floor in Doc Holmes' high-ceiling lab in the old Workman Building.**
  - **In Campus fencing.**
  - **In the parking lots as vehicle dividers.**
  - **In the construction of Bill Winn's first generation *Time-of-Arrival* lightning array.**
  - **In numerous projects requiring large structures fabricated by the Machine Shop.**
  - **In various equipment & instruments constructed at the Langmuir Lab.**

The MAR-I *Clutter Fence* I-Beams & the *Bone Yard*

- **Joe Martinic took a stroll through the *Bon eYard* in Oct 2009 and found at least 3 of the old MAR-I *Clutter Fence* I-beams.**
  - **Lower left : A ubiquitous I-beam, all alone in the *Bone Yard*.**
- **One of the ubiquitous 20 foot I-beams was also used as the lever arm in the award winning trebuchet built by the NMT Physics Club in 2002-2003.**
  - **Right : The pumpkin tossing catapult has been retired to the *Bone Yard*.**



I-Beam Photo by R. Hayward

http://infohost.nmt.edu/mainpage/news/2003/31oct01.html & http://infohost.nmt.edu/mainpage/news/2003/1apr01.html

MAR-I & the Bone Yard

Joe Martinic has found a number of MAR-I bits & pieces still residing in the NMT *Bone Yard* after nearly 45 years, including…

A box full of Antenna Elements (upper left).

A MAR-I Power Supply Rack (upper right).

The Beamformer rack full of 12 and 16-way splitters (lower left).

Three of the mini-racks which were believed to have held the MAR-I *Preamplifiers* (lower right)

The NMT Physics "Bone Yard"

A Brit's Recollection

Adrian Webster spent several weeks in Socorro in early 1972.
He would later became the Director of the *James Clerk Maxwell Telescope* (JCMT) in Hawaii during the late 1980s.
He had come "across the pond" to see if Stirling's DigAss project was something he wanted to get involved in. He eventually ended up going to UC Berkeley for his post-doc but he had a great recollection of what was going on at Tech at the time.

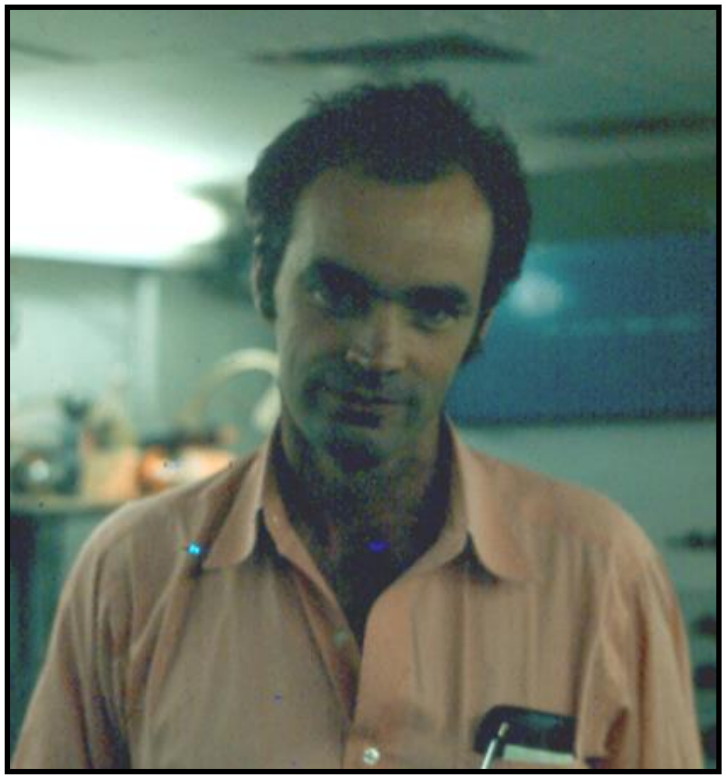
His description of the *Bone Yard* was memorable:

"The scrap yard at Tech was a huge culture shock.
All this high-tech stuff, some of it gold-plated, outside in the desert,
under a perfectly blue sky with the odd creosote bush here and there.
It was like something out of a Dali painting, with only the melting clock-face missing."

Bone Yard Photo by R. Hayward
http://www.roe.ac.uk/ifa/people/asw.html

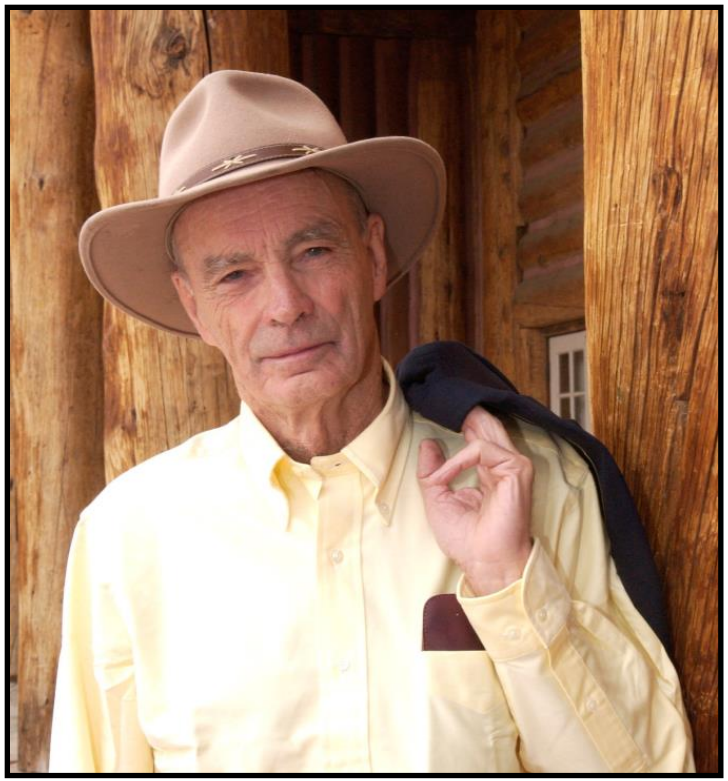
Stirling A. Colgate

President of New Mexico Tech, 1965-1975



Inside the SNORT Trailer (~1973)

Photo courtesy of Bruce Blevins



Los Alamos National Lab (~2005)

http://www.lanl.gov/news/albums/people/Stirling_Colgate.jpg

"***Toothpaste scion by birth and thermonuclear physicist by choice***"

The 4 Percent Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality **by Richard Panek, 2011**

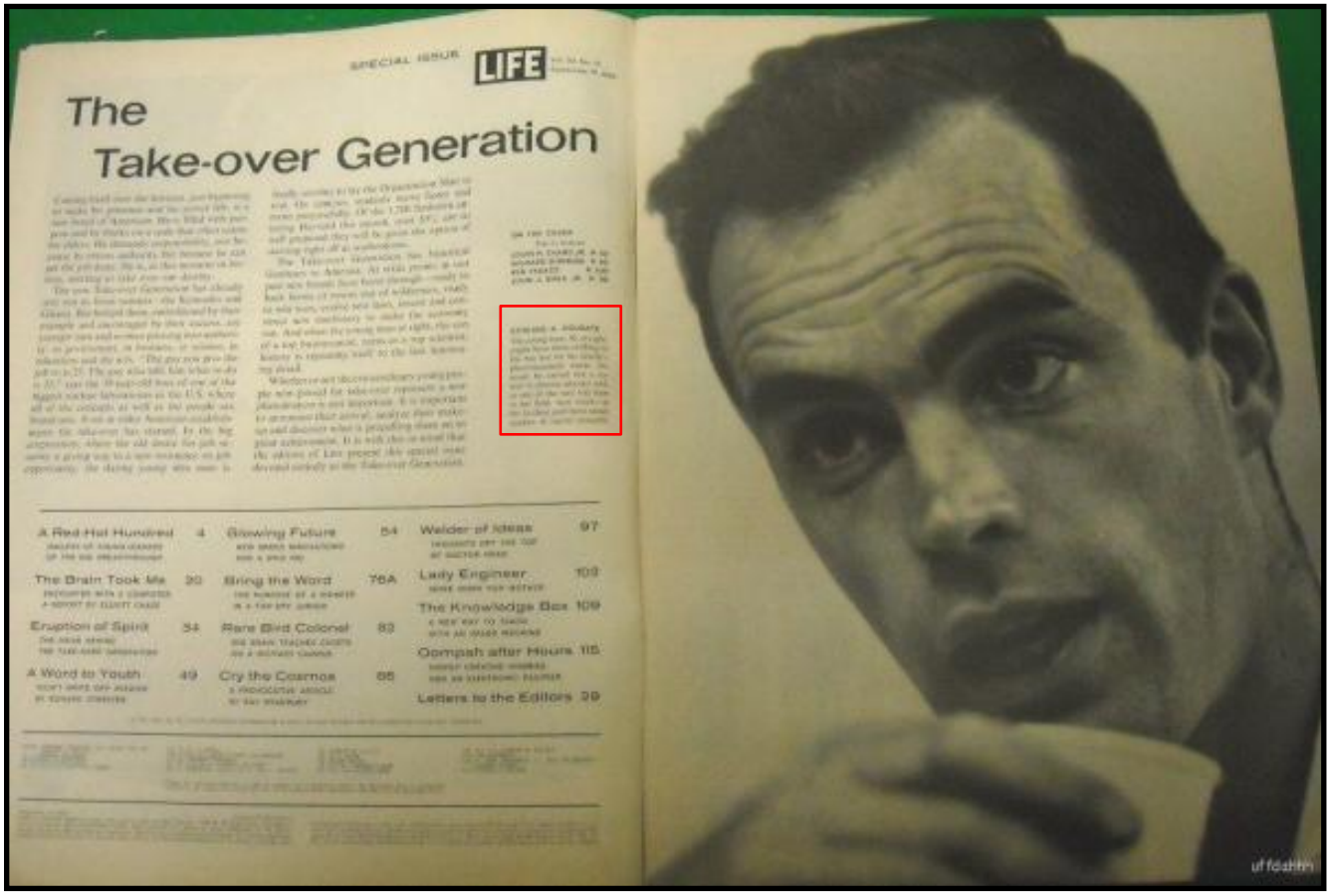
Stirling Colgate – Very Short Bio

- **Stirling Auchincloss Colgate was born in 1925.**
- **He was in last graduating class of the *Los Alamos Ranch School* before it was taken over by the US Army in 1942 for the *Manhattan Project* to develop the atomic bomb.**
- **After serving in the Merchant Marine during WWII, he received his PhD in nuclear physics from Cornell University in 1952.**
- **He joined the *Livermore National Laboratory* and worked with Edward Teller on developing diagnostic measurement techniques for nuclear explosions and was soon considered to be one of the foremost diagnosticians of thermonuclear weapons.**
- **In 1956 he investigated the theoretical radiation and debris that would be produced by a hydrogen bomb exploded in space. This study ignited in him an interest in supernovae.**
- **In 1959, the State Department recruited Colgate as a scientific consultant on nuclear test ban negotiations in Geneva. It was here that he proposed using spy satellites to detect nuclear tests. He also raised the possibility that false alarms caused by supernovae could accidently spark a third World War.**
- **He became President of the *New Mexico Institute of Mining Technology* in 1965 (now called *New Mexico Tech* or NMT or *Tech*).**
- **During his 10 year tenure, the number of students doubled. He successfully lead the college through the turbulent years of campus unrest in the late 1960's & early 1970's.**
- **He conducted numerous research programs in both astrophysics & atmospheric physics.**
- **In the late 1960's he theorized the possibility of an electromagnetic pulse arising from supernova, which led to the SNORT experiment to detect "*Extragalactic Whistlers*".**
- **He left NMT in 1975 and joined the *Los Alamos National Laboratory* (LANL) where he continued his research into supernovae. In 2006 he received the Los Alamos Medal.**
- **Stirling Colgate died on Dec 1st, 2013 at his home in Las Alamos, NM, at the age of 88.**

Stirling Colgate & LIFE Magazine 1962

Full-page photo on the Frontspiece of the Sept 14, 1962 Special Issue

"The Take-Over Generation - Its Breakthrough in Government, Science, Space, Business, Education, Religion and the Arts"



"STIRLING A. COLGATE : The young man, 36, at right, might have done nothing in life but live on his family's pharmaceutical name. Instead, he carved out a career in plasma physics and, as one of the very top men in his field, now works in the farthest and most secret reaches of fusion research."

Rumor has it, this article may have been seen by the search committee that was seeking to replace President E.J. Workman when he retired.

Also included in the *Red Hot Hundred* of the Most Important Young Men & Women in the United States:

Harold Brown
Frank Church
Thomas Eagleton
Murray Gell-Mann
Daniel Inouye
Robert Jastrow
Chris Kraft
John Lindsay
Andre Previn
Theodore Sorensen
John Updike
&
Radio Astronomers…
***Frank Drake* (NRAO)**
***Nancy Roman* (NRL)**

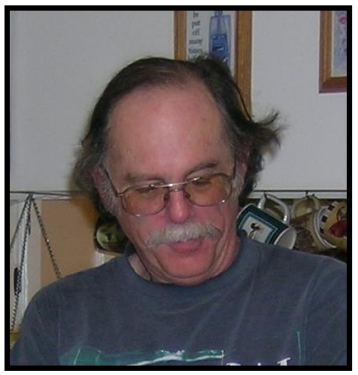
Super-Nova Observational Radio Telescope "SNORT"

Abstract for the Colgate paper presented at the Jan 1973 *Radio Astronomy Commission V* meeting of the *International Union of Radio Science* (URSI) held in Socorro

04. Supernova Observational Radio Telescope.
S. A. COLGATE and B. A. BLEVINS, New Mexico Institute of Mining & Technology, Socorro, NM. - We propose to search for dispersed electromagnetic pulses from distant supernovae with a 20-beam radio telescope at 1.4 x 10^9 Hz and antenna gain of 100 x 4 . On the basis of the expected magnetic field of pulsars and the frequency of supernova, we expect about 1 event per month from galaxies at 70 Mpc. The coordinate in the sky should be deduced to a 3-degree solid angle (10^{-2} of the array area). The expected number of galaxies that could have contained such an event at 70 Mpc is 12. The size and distance of such galaxies is roughly 1 minute of arc at 70 Mpc. This number of galaxies at this size can be searched conventionally for a supernova that would rise to optical maximum in a week to ten days. Each of the right circularly polarized feeds (7 to a parabolic dish) feeds a 2-stage parametric amplifier, 50MHz bandwidth, and then various stages of postamplification before being mixed with itself delayed by 4 meters equivalent. Dispersed pulses then appear on oscilloscopes as low frequency oscillations corresponding to the varying frequency of the signal.

Colgate's SNORT Students

~ As they look today ~



Bruce Blevins
BSc '72 & MSc '75 from NMT
PhD '78 from NMSU

Gary Schwede
BSc '73 & MSc '76 from NMT
PhD '83 from U.C. Berkeley

(Bulletin of the American Astronomical Society, Vol. 5, p. 284, 1973)
Photo by X. Kim Rubin at http://www.codeproject.com/Members/DrGary83

Super-Nova Observational Radio Telescope

A picture of SNORT from the 3rd floor of the old *Workman Research Center* building adjacent to the *Corporate Yard* on the New Mexico Tech campus in the early 1970's.

Colgate built it in the standard NMT way - with lots of surplus hardware & lots of student labor.

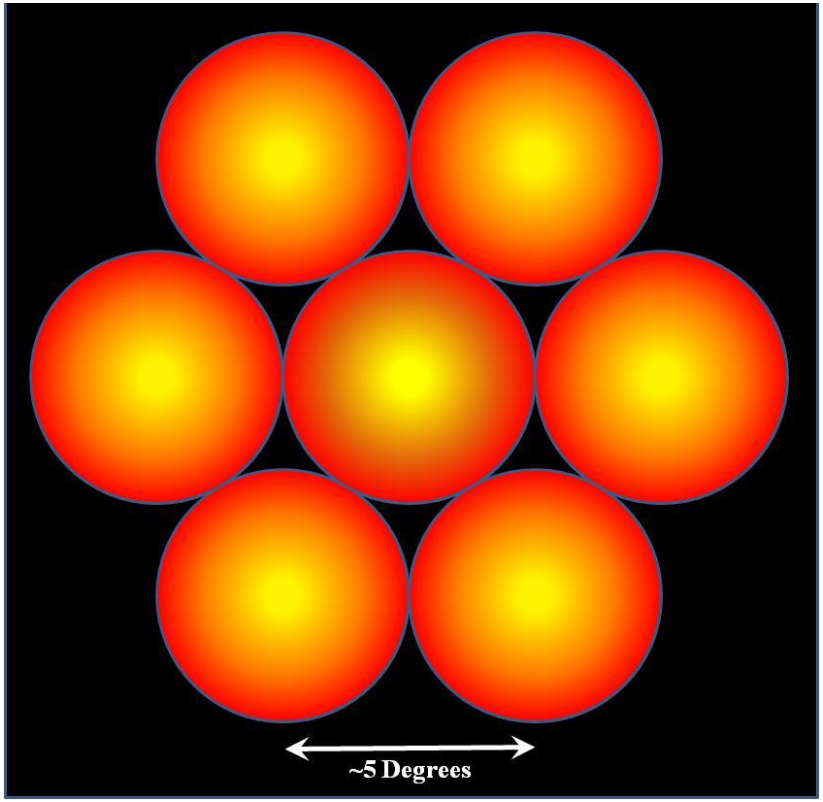
Photo courtesy of Bruce Blevins

The SNORT Experiment

Close-up picture of the SNORT trailer and its 3 telescopes, each with 7 feeds, which yielded 21 separate beams on the sky searching for a microwave pulse from an exploding star.

Photo courtesy of Bruce Blevins

More on SNORT



The reception pattern of the 7 beams of a single SNORT antenna. The 21 feeds would have a total field of view of about 420 square degrees.

A photo of most of the 11 Tektronix 551 dual-beam oscilloscopes used to display possible pulses coming from a supernova when transiting the array's field of view.

Photo courtesy of Bruce Blevins

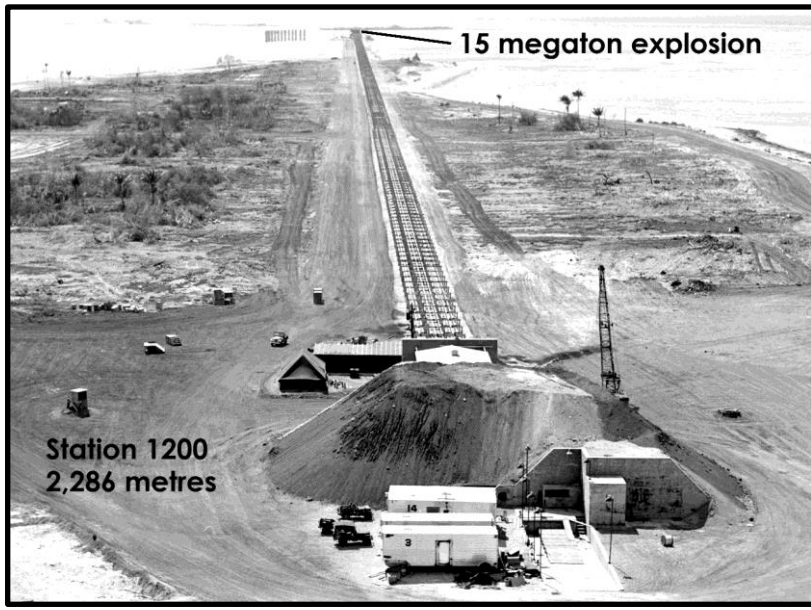
Colgate & Oscilloscopes
Castle Bravo Nuclear Test

Bravo pipeline end in shelter with 36 oscilloscope cameras to record radiation (station 1200 shelter, 11 Feb 1954)

Colgate in the diagnostics bunker during *Castle Bravo*. Banks of oscilloscopes - 36 in all - with extremely fast "streak" cameras would capture the diagnostic data. It may have been the impetus for SNORT's scopes.

In 1954, while at the *Livermore Lab*, Colgate was placed in charge of making diagnostic measurements of the *Castle Bravo* test on Bikini of the first deliverable H-Bomb.

To measure *Bravo's* thermonuclear burn rate, Colgate used evacuated pipes to collimate the neutron particles & radiation. In a heavily reinforced bunker 1.4 miles away, the time of arrival of the neutron, X-ray & gamma radiation from the bomb casing would be recorded, thus allowing energy spectrum to be determined.



***Castle Bravo* was the most powerful US nuclear detonation ever with a yield of 15 Megatons. It far exceeded the expected yield of 6 Mt by a factor of 2.5**

http://14mev.blogspot.com/search/label/bravo
http://glasstone.blogspot.com/2011/05/declassified-data-on-structures-exposed.html

The Workman Center & SNORT

- **The *Research Building* was built in 1949.**
- **The 4-story tower was added in 1962. It was topped with a cupola for atmospheric research.**
- **The name of the building was changed to "*Workman Center*" after the long-serving and respected NMT President retired in 1964.**
- **The window on the 2nd floor at the right was the NMT President's apartment residence.**
- **The smaller tower on the right was called the "*Tower of Babel*". (What was in it?)**
- **SNORT was located in the *Corporate Yard*.**
- **Blevins' picture was taken from the 3rd floor of the *Workman Tower*. Unfortunately the aerial photo was taken before SNORT was built.**

Southwest Post Card Company, Albuquerque, NM, Number 667
http://infohost.nmt.edu/~nmtlib/ARCHIVES/buildings/workman.html
http://earthexplorer.usgs.gov/
SNORT Photo courtesy of Bruce Blevins

Bruce Blevins & SNORT

- **During 1970-72, Colgate & his student, Bruce Blevins, carried out the early development work on the SNORT experiment.**
- **It used antenna elements, heliax cable, Preamplifiers & racks from the MAR-I.**
- **Bruce was the one that painted the "snort!" sign on the trailer door.**
- **The only pictures taken of SNORT that appear to have survived were those taken by Bruce and his Minolta SRT 101 camera.**
- **Colgate conceived the system to record the anticipated transients from the 21 beams encompassed by the 3 SNORT antennas.**
  - **The signal from each of the feeds went to a MAR-I *Preamplifier* where it was amplified by about 60 dB (1 million times).**
  - **With a bandwidth of more than 50 MHz bandwidth, each signal was then mixed with a version of itself time delayed by the equivalent of 4 meters.**
  - **A dispersed pulse should appear as a low-frequency oscillation with the frequency depending on the amount of dispersion encountered.**
  - **This was before analog-to-digital acquisition systems & computers were affordable.**
  - **Multiple Tektronics oscilloscopes were used to display the numerous audio signals from each feed. These Tek 551 scopes had a dual-beam capability.**
- **Colgate came up with a novel idea to use mirrors to bring the images of all the traces from the scopes to converge on to a 2D grid which could be recorded by an oscilloscope camera on one photograph. A circuit devised to detect a voltage transient on any one of the signals was used to trigger the camera.**
- **Bruce left in Dec 1972 for the *University of Arizona* to begin his MSc degree.**

Gary Schwede & SNORT - 1

- **Gary took over the student effort when Bruce left in Dec 1972. While Bruce had worked on the front-end system, he worked on the back-end.**
- **Gary recalled that Colgate had made vast contributions to the understanding of supernovae, "*the biggest bangs of all*".**
  - **The purpose of the SNORT : "*If there was a pulse, and if there was enough matter between the galaxies, and if we happened to be gathering radio waves when the pulse arrived here, we MIGHT catch a dispersed pulse*."**
  - **Gary coined the terms "*Intergalactic Whistler*" and "*Meta-galactic Whistler*" for the dispersed EMP, similar to the radio whistlers coming from Jupiter.**
- **Gary recalls spending a frustrating few months trying to tweak the paramps so that they yielded a more uniform performance.**
  - **They were "*beautiful, shining, overbuilt, and expensive (at least to the taxpayers), but I had no clue how to make any sort of repeatable changes. I do not recall ever seeing a manual for tuning them*."**
- **Colgate would occasionally fiddle with one to his satisfaction while Gary watched. But when he tried, "*the next one refused to play along*".**
- **While the complete mirror and camera system remained largely notional, its framework was eventually roughed in.**
  - **The best description Gary could provide was "*think 'Erector Set'...*"**
  - **However, there was no point in completing its full implementation until the rest of the SNORT system had been proven to work.**

Gary Schwede & SNORT - 2

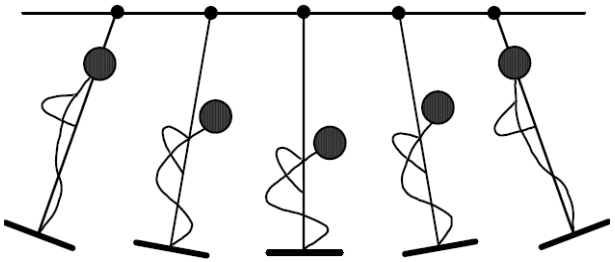
- **As it turns out, the SNORT never did reach a fully functional state.**
  - **Gary did do some limited tests using a single beam on the sky.**
  - **Unfortunately, all that was seen was radio interference.**
  - **The worst of the interference seemed to be coming from the trucks in the *Corporate Yard* where the SNORT trailer and telescopes lived.**
  - **He tried it at night but still saw lots of interference, perhaps from aircraft.**
- **Gary laments, "*It was honestly an anticlimax when I finally fired up a channel or two and discovered that we had an interference problem so overwhelming that I had no idea how to resolve it.*"**
  - **Given the level of RFI, it was hard to believe any simple analog circuit could discriminate a supernova EMP from it.**
- **At about this time, President Colgate was having problems with the Regents at NMT and Gary didn't see him too often.**
  - **Gary "*dimly remembers Stirling saying that the math he and Albert Petschek were doing had been discouraging*."**
- **As 1974 was ending, Gary had become interested in signal processing & the emergence of microprocessors, so switched to *Computer Science*.**
- **In 1975, Colgate resigned and accepted a position at LANL.**
- **And thus the SNORT project came, more or less, to an ignominious end.**

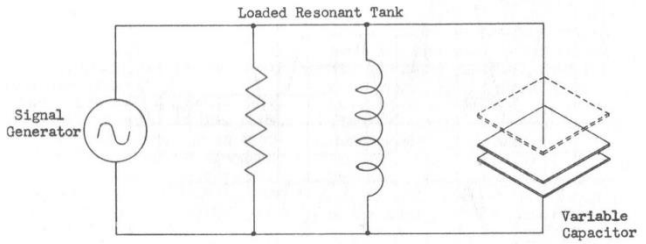
Gary Schwede & SNORT - 3

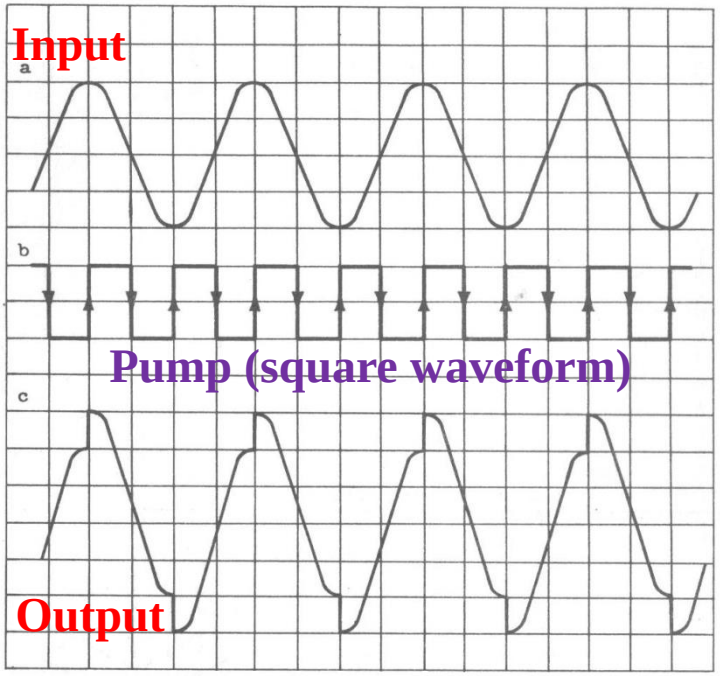
- **On reflection, Gary says these types of projects needed well resourced engineering.**
  - **At this time, "*NMT was a Science school, not really an Engineering school.*"**
  - **"*Colgate was a high-concept, really-big-idea guy, who really needed a staff to fill in the practice.*"**
  - **"*He didn't always hire enough of an engineering and technical staff to turn his cutting-edge concepts into reality.*"**
- **Gary on Stirling Colgate and his time at NMT:**
  - **"*Stirling, for all his intelligence, ego, & drives, always put Tech's students first. This is so unusual and such a marker of a great mentor! I was privileged to sweat it out in the SNORT trailer, and to tag along when Stir was about.*"**
  - **"*My mentors at Tech, including C.B. Moore, Bill Winn, and Stirling Colgate, taught me more life-lessons for a young physicist, engineer, and man, than I could have imagined, and was certainly not restricted to just academics!*"**

How a Paramp Works

A Mechanical Parametric Amplifier





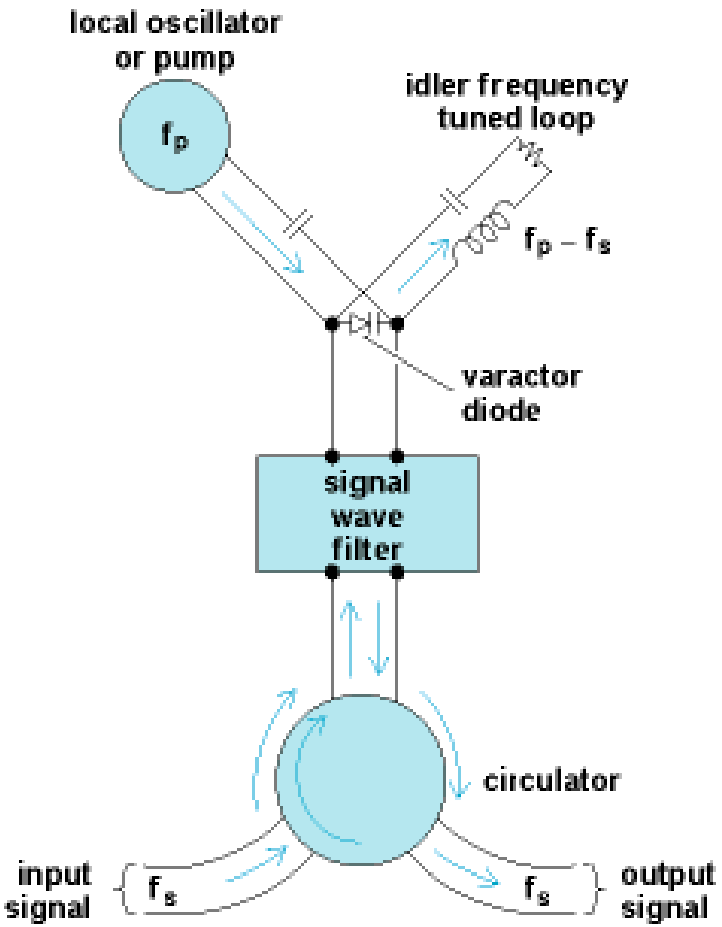


Parametric Amplifiers, J. Fisk,73 Inc., 1964
1964http://www.stanford.edu/~rsasaki/EEAP248/slide11

- **An everyday example of the process of parametric amplification is a child on a swing:**
  - **A child maintains the oscillation by "*pumping*". He lowers his center of gravity on the downswing & raises it on the upswing. Pumping thus takes place at twice the swing frequency.**
  - **Energy is continually fed by the child into the swing and its initial motion is amplified. There needs to be some oscillation to begin with – the first external push is the "input".**
- **In a *varactor* diode paramp, the parameter that is being "*pumped*" is a variable capacitance.**
  - **The *varactor* is a reverse-biased *p-n* diode that has been doped to maximize the change of its junction capacitive from a change in the applied bias voltage, which comes from the *Pump*.**
  - **Since the *Pump* causes the capacitance to change, electrical energy is transferred to the *RF Input Signal*.**
- **A *Degenerate* paramp uses a *Pump* that is twice the frequency of the *Input Signal*.**
  - **In practice, it is difficult to maintain this frequency and its phase relationship with the *RF Signal*.**
- **In a *Non-degenerate* paramp, the *Pump* has a frequency other than twice the *RF Input*.**
  - **Because the *varactor* is non-linear, a 3rd frequency is produced – the difference between the *Pump* & *RF Signal*. This intermodulation signal is called the *Idler* because it is considered a useless by-product.**

Practical Parametric Amplifiers

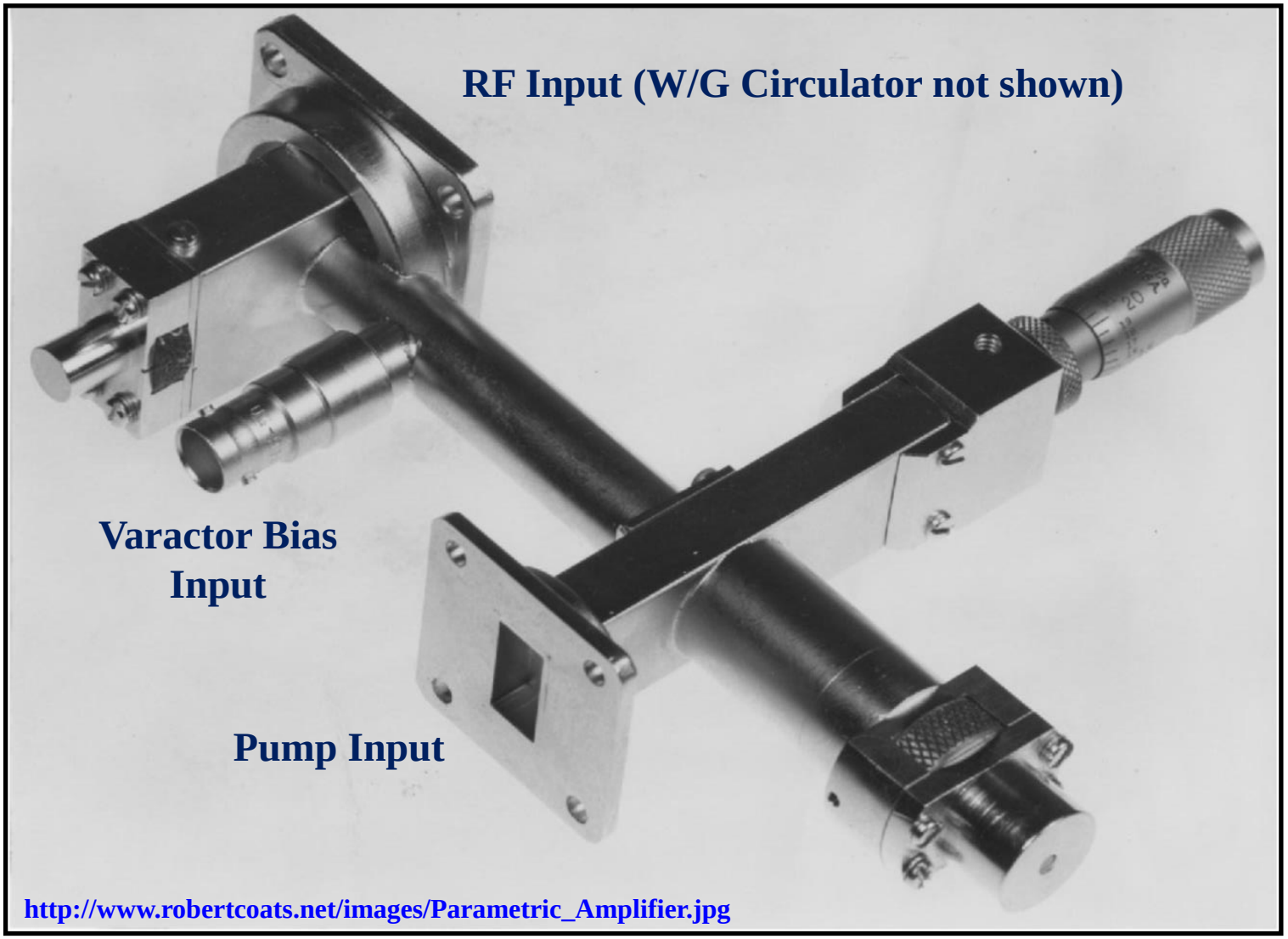
- **The *Non-degenerative* design is slightly less sensitive than a *Degenerative* paramp but has better stability.**
- **The *Paramp* is called a reflection amplifier. The voltage wave entering the negative resistance device is reflected back out the same port. Amplification occurs because the reflected wave is stronger than the incident wave. A 3-port ferrite *Circulator* is typically used to separate the input & output signals.**
- **As only resistances in an amplifier produces thermal noise while capacitances produces none, the paramp is theoretically devoid of internal noise. In practice, however, semiconductor varactor diodes are not entirely devoid of internal resistance.**
- **The *paramp* is somewhat similar to a more conventional amplifier, like the *Field Effect Transistor* (FET) which transfers energy from its DC Bias to amplify the RF Signal. A *paramp* steals RF power from the *Pump* and transfers it to the input signal.**
- **Room temperature *Paramps* can achieve noise temperatures as low as 100°K. The gain & bandwidth depend on the design. Typical gains of 10 to 30 dB (i.e., factors of 10 to 1000) have been achieved with bandwidths of 5 to 20% of the center frequency.**
- **In order to achieve the best noise temperatures (say 10-20°K or less), paramps must be cooled to cryogenic temperatures, perhaps with liquid nitrogen (77°K) or liquid helium (4.2°K).**



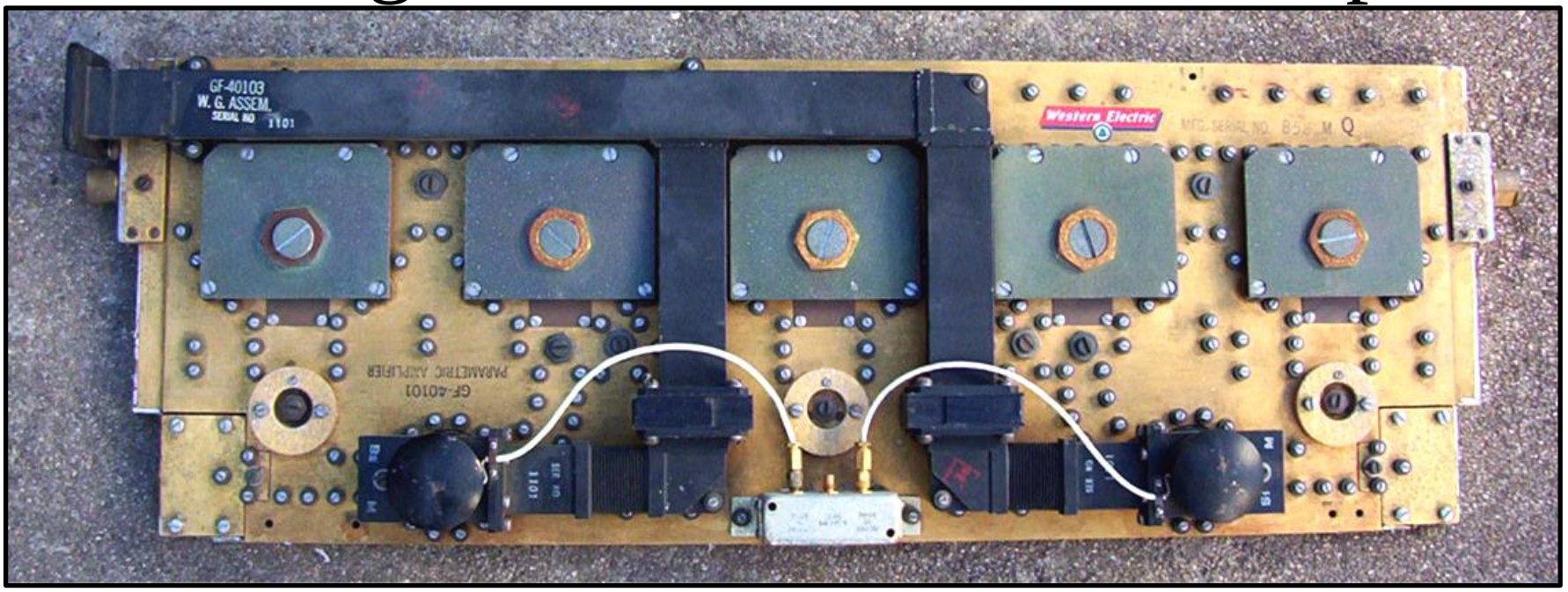
Two resonant circuits are needed. One is for the *RF Signal*, which rejects both the *Pump* & *Idler* frequencies. The 2nd is for the I*dler* which acts as an energy reservoir for the *Pump* & *RF Signals.*

http://www.accessscience.com/popup.aspx?figID=487800FG0010&id=487800&name=figure

Typical Single-Stage Waveguide Paramp from the Late 1950s and Early 1960s



The 2-Stage MAR-I Parametric Amplifier



The first "*stripline*" implementation of a paramp.
Note the extensive use of gold-plating.

Western Electric Co., Model GF-40101, Serial No. 858
Designed at *Bell Labs*, Murray Hill, NJ
Manufactured, *WECo*, Laureldale, PA

Advantages of Stripline (versus Microstrip):
- **Wider bandwidth**
- **Better isolation between adjacent traces**

Disadvantages of Stripline (versus Microstrip):
- **Harder to fabricate**
- **More expensive.**
- **Thicker traces (typically four times)**

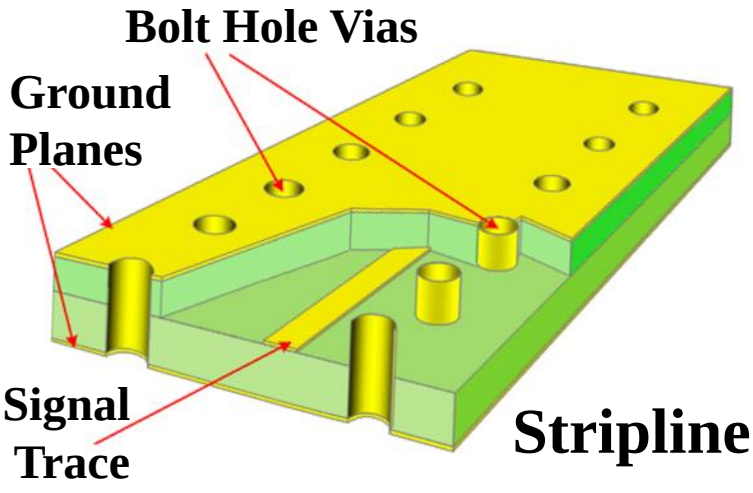
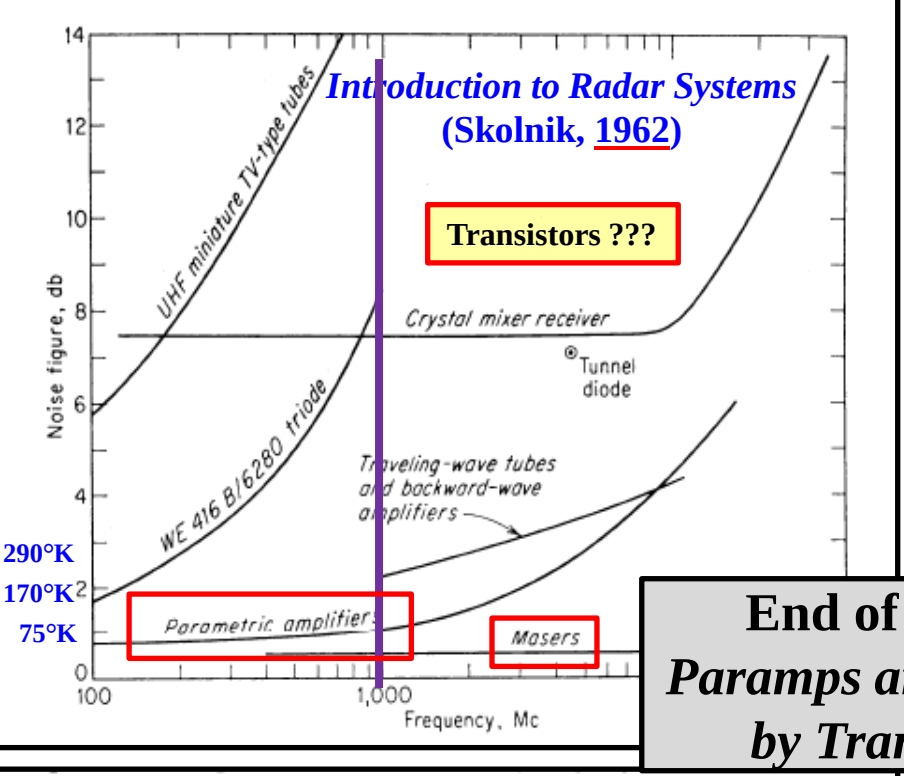
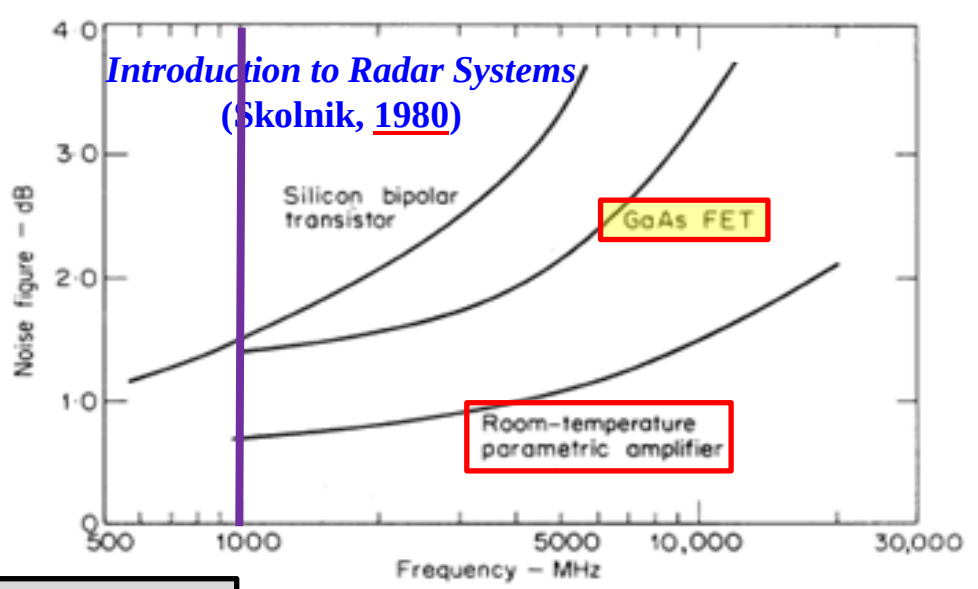
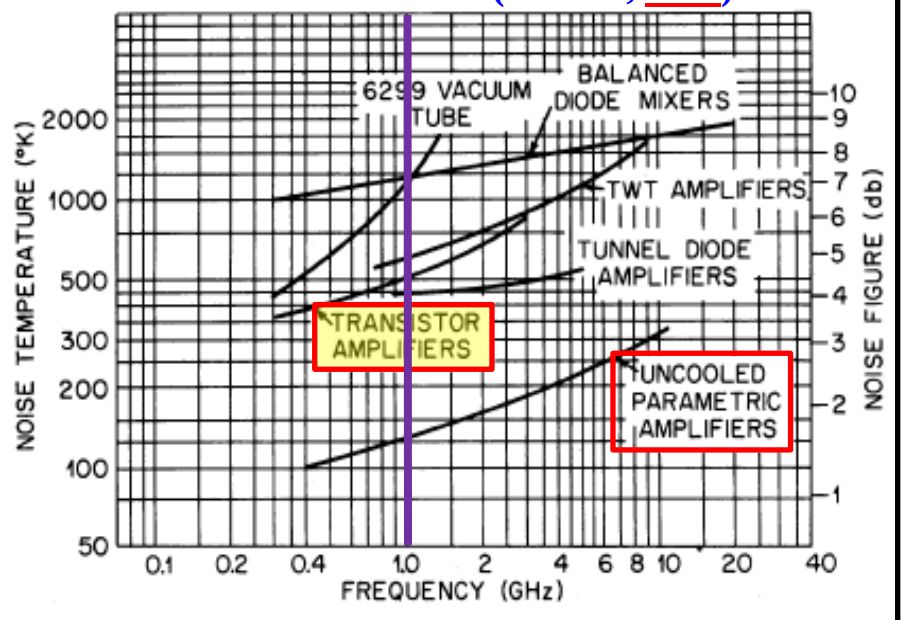


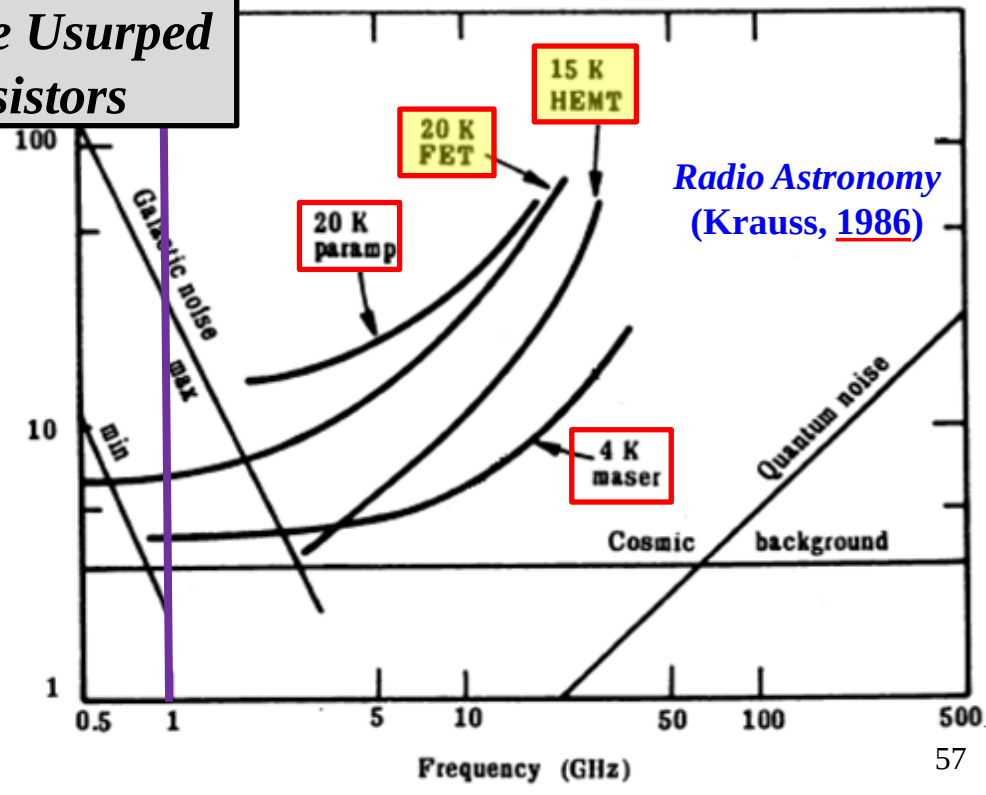
Photo courtesy of Gloria Dubner & Juan Carlos Olalde
http://www.ami.ac.uk/courses/topics/0006_emcpcb/





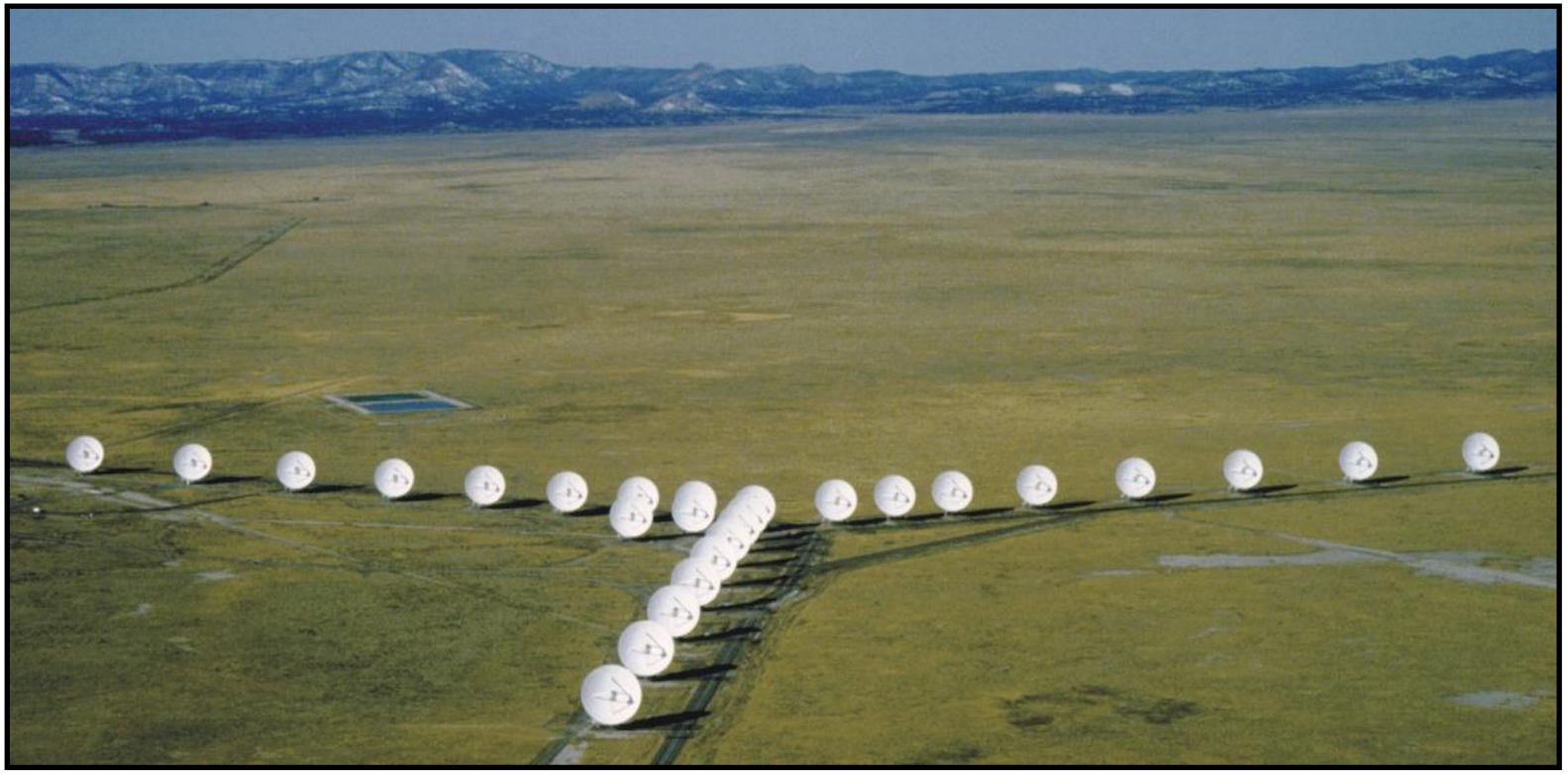
End of an Era
Paramps are Usurped by Transistors





Paramps on the *Very Large Array*

- **Original VLA design, carried out in the mid 1970's, called for:**
  - **28 cooled "L-Band" (1.3-1.7 GHz) parametric up-converters.**
  - **28 cooled "C-Band" (4.5-5.0 GHz) three-stage parametric amplifiers.**
  - **For a total of 112 cryogenic operational paramp stages !!**
  - **The MAR-I had 4490 room temperature paramp stages !!!!!**
- **Until the mid 1980's, Paramps were more sensitive than transistor amps - albeit less stable and much more difficult to work with.**
- **All of the VLA's Paramps were subsequently replaced with cryogenic GAsFET amplifiers by the late 1980's. New EVLA receivers use the latest InP amplifiers.**



http://images.nrao.edu/object/index.php?id=307

First Mention of *Bell Lab's* Stripline Integrated Parametric Amplifier at the *International Solid State Circuits Conference* - 19 Feb 1964 held at the *University of Pennsylvania*

WPM 3.2: A Low-Noise, Wideband, L-Band Parametric Amplifier

C. E. Barnes, W. J. Bertram and M. J. Cowan

Bell Telephone Laboratories, Inc.

Murray Hill, N. Y.

BOTH THE THEORETICAL and experimental aspects of broadband parametric amplifiers have been considered in the past [1-4], but only relatively recently have attempts been made to integrate the design and construction of the essential components to achieve precise amplifier performance. Theoretical and experimental work[5] on L-band parametric amplifiers served as a guide for the development of this particular amplifier.

For the case being discussed, the objectives we set were for 19.0-db flat gain and linear phase with a better than 2.0-db noise figure over a 15% bandwidth in the L-band frequency region (1.0-2.0 Gc). This indicated the use of at least two cascaded stages, each stage being a circulator type nondegenerate reflection type amplifier. Input and output match requirements led to the incorporation of isolators at each port, and an interstage isolator was also indicated to eliminate coupling between the stages at signal frequencies. The construction of these isolators is similar to the two circulators, differing only in that the isolators have the third port loaded with a broadband resistive termination while the third ports of the circulators are designed to provide a specific admittance to the diodes. The basic Y-junction circulator configuration and associated transmission lines are constructed as a photoetched microwave printed circuit on irradiated polyethylene.

Gain	19.0 ± 0.2 db over 20% band
Phase	±7° over 15% band
Noise Figure	1.5 db over 15% band
Input Return Loss	30 db over 15% band
Output Return Loss	30 db over 15% band
Pump Power	+20 dbm

T_N = 120°K

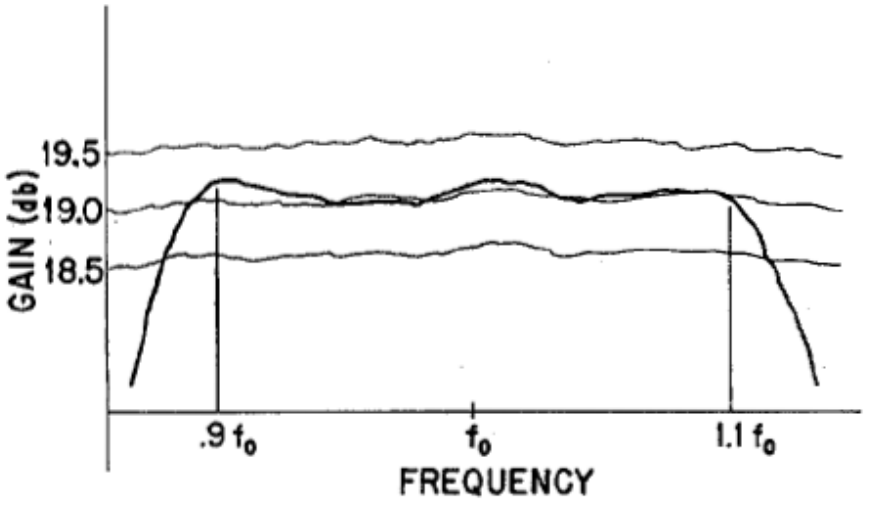


***FIGURE 1*—Amplifier gain versus frequency.**

No where in the paper does it mention the Nike-X project or the MAR.
While it was remarkably devoid of technical details, it won the ISSCC *Outstanding Paper Award* for 1964

Mention of *Bell Lab's* Stripline Paramp Design in an IEEE Paper on *Paramps & Receivers* in 1964

IEEE TRANSACTIONS ON MILITARY ELECTRONICS July-October

Parametric Amplifiers for High Sensitivity Receivers

M. UENOHARA, MEMBER, IEEE, AND J. P. ELWARD, JR.

Manuscript received May 13, 1964.
The authors are with Bell Telephone Laboratories, Inc., Murray Hill, N. J.

TABLE I

SINGLE-DIODE AMPLIFIER

f_s	Gain	Per Cent Bandwidth (3 db)	Note
L band	19 db	26 per cent	Two stages, triple-tuned signal circuits [13]
C band	19 db	4.6 per cent	Single stage, double-tuned idler circuit [14]
X band	19 db	4.6 per cent	Single stage, double-tuned idler circuit [15]

Refers to Barnes et al ISSCC Paper

5 x larger bandwidth

John Ondria & the MAR-I Paramp

- **John Ondria was employed by *Western Electric* from 1960-1964.**
- **He was reassigned to *Bell Labs* to work on the parametric amplifier for the MAR-I system.**
- **In 1967 he joined the facility of the *Department of Electrical Engineering* at *Lehigh University*.**
- **He worked with Clare Barnes, who was based at the *Bell Labs* Murray Hill, NJ, facility.**
- **While he had not contributed to the early prototype work, which was largely done by Barnes, he did become involved in the design of the stripline circuits that *"ended up on the MAR-I.***
- **The novel stripline design it used "*was mainly developed to minimize the size and weight of the paramps*."**
- **On why the paramps had so much gold plating in them, he indicated "*the thickness of the gold was to wipe out irregularities in the plating. The units were plated three times making the surface smooth and reducing the mass production plating problem inherent in most other designs*."**
- **As to how well they performed, "*Actually the initial test results were better than anticipated, and the bandwidth achieved was better than expected. Since paramps are normally narrow band devices, it was a surprise that the bandwidth turned out so good*."**

Mail exchange with John Ondria, Dec 5, 2013

Tracking Down Where the MAR-I Paramps were Built & Tested…

It was assumed the MAR-I Paramps were secret until this article was uncovered in Oct 2013.

READING EAGLE

READING, PA., SUNDAY, JANUARY 31, 1965

Laureldale Lab Employes Develop New Products

The past year was one of accomplishment for Bell Telephone laboratories as its engineers and scientists continued to make significant contributions to communications technology.

At Bell labs' local branch laboratory, located at the Western Electric Co. Laureldale plant, the year's efforts were highlighted by:

A solid-state pre-amplifier was developed at the Laureldale Laboratory and more than 2,000 were manufactured for use in the receiver of an experimental model of the Nike X phased array radar. The pre-amplifiers are characterized by exceptional sensitivity as well as extreme uniformity of gain and phase performance throughout their operating band of frequencies. Each pre-amplifier included a self-triggering microwave switch to protect the rest of the microwave components from damage when the radar transmitter is operated. Each pre-amplifier actually consisted of a low noise parametric amplifier as well as a high gain microwave transistor amplifier. The Nike X radar is the first to take advantage of the excellent noise characteristics of parametric amplifiers using solid-state microwave diodes.

c.1962

So, we now know the MAR-I *Preamplifiers* & *Paramps* were manufactured at the WECo plant in Laureldale, PA

Laureldale Lab Employes Develop New Products, Reading Eagle, 31 Jan 1965, p.24
http://news.google.com/newspapers?nid=ZuSUVyMx-TgC&dat=19650130&printsec=frontpage&hl=en
http://rhodyman.net/WesternElectric.pdf

The Seeger Letter

- **As there was no documentation on the MAR-I Paramp found at the site, Colgate asked Charles Seeger to try and decode its secrets.**
- **Born in Berkeley in 1912, he was the older brother of famed folk singer Pete Seeger.**
- **During the time period that NMT was salvaging the MAR-I site, Seeger was working at nearby *New Mexico State University* (NMSU) from 1969-1974.**
- **He disassembled one of the paramps so he could better understand its stripline design.**
- **He sent Colgate a report in April 1971. Here are some excerpts …**

April 30, 1971

Stir, this is the information I have on the parametric amplifier at the moment.

The array used crossed dipoles or the equivalent. The next section is a balun; this is followed by a polarization switch. The polarization switch is activated via the single coax output line by superimposing a dc signal or low frequency signal for the switching operation between left and right circular. Next in line comes the parametric amplifier. We disassembled completely the unit you gave me and I have here a photograph in front of me labelled, "Top" in two main sections. The top photograph merely shows the power amps as you see them when you look at a complete unit. The top adjustments, the five in a row, are nothing

bottom picture, are the tuners for the power amp, idler, etc. The circuitry should be perfectly clear with the possible exception of two 3 cm stops which are down and to the right of or the left as the case may be of circulators 3 and 5. These merely stop pump signal from getting into the circulator and otherwise overloading the circuits. A little quarter wave stub tuner. The simplest way of dealing with adjusting one of these units is with a sweep oscillator. Have the input properly attenuated so as not to overload the system and then just take the umpteen adjustments and tune them to your own satisfaction. With a bit of judgment it shoudn't be an endless non-converging operation.

If Pierce will only come through life will be simple for all the users. I strongly recommend that no one disassemble one and then reassemble it unless they are exceedingly skillful and have already worked with a properly operating one. There are so many screws in this operation and they are so critical it must be taught just so that it takes real skill to assemble a unit such as this, so the one that you gave me I assume is permanently disassembled.

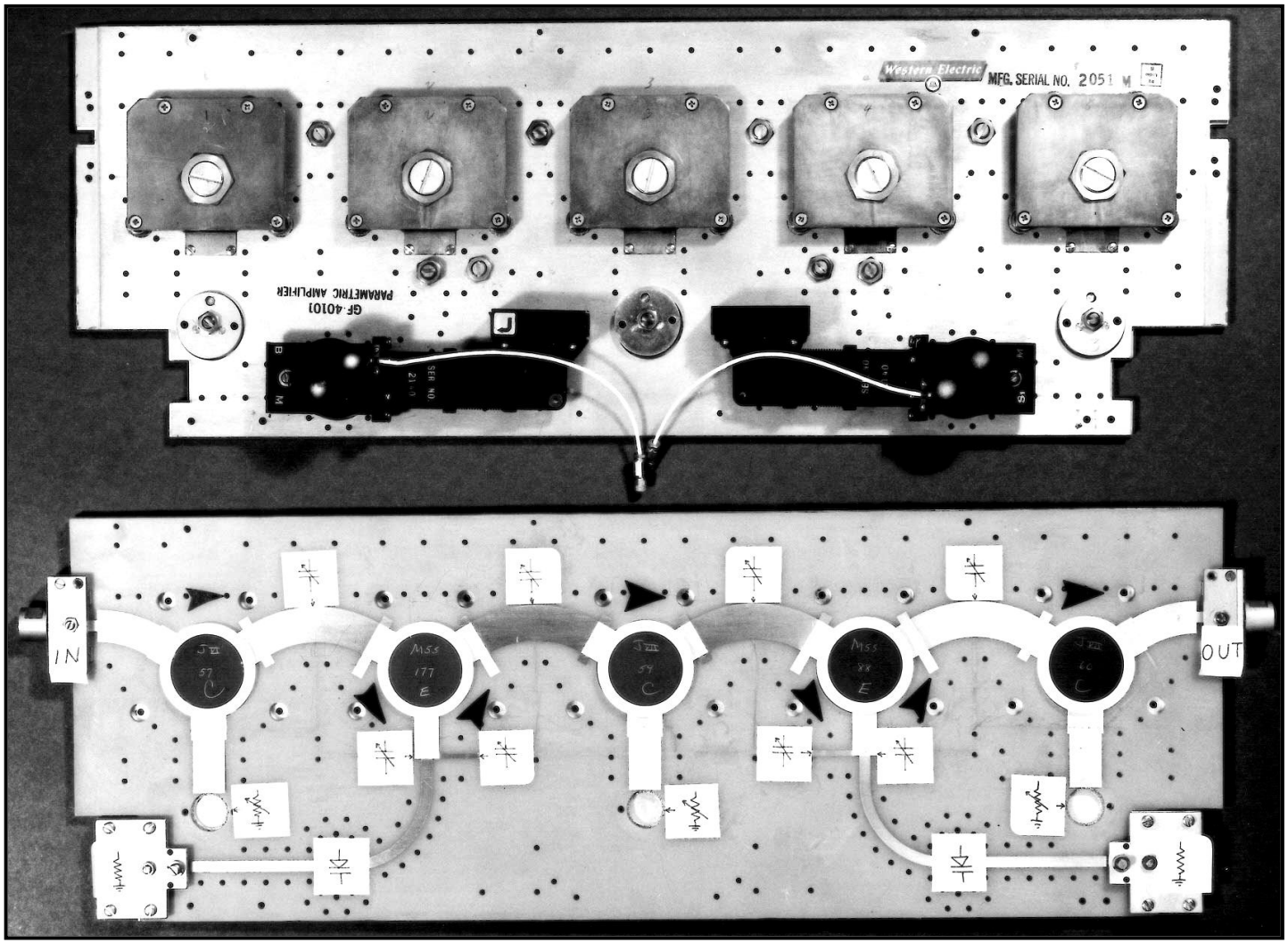
I am taking back 6 power amps because we have a project going in electrical engineering which can definitely use them in a justifiable manner as a radiometer. I have no particular project in mind at the moment simply because to get the power amps would require spending a lot more money which we don't have as yet. However, keep a couple of thousand for me.

At this point I would think the delay tuning filter that is plastered and bolted up against one side of the whole assembly is probably worth preserving for tuning purposes. If you don't use that you will have to use something else. This connects between the power amp and the transistor amplifier.

If I hear from J. R. Pierce, I'll let you know immediately, but I'll probably see you before then. I don't know whether he is in the country or out or which government committees he is occupying himself with these days. I don't happen to know of any other particular "in" there, but the information should be perfectly free to everybody at this stage.

Dr. Charles Seeger

Seeger's Dissection of a Colgate Paramp



The "*umpteen adjustments*" needed to tune the WECo Parametric Amplifier:

---

5 x Circ. Mag Field screws
6 x Signal Tuner screws
2 x Pump Tuner screws
2 x Idler Tuner screws
3 x Termination screws
2 x Bias Volt adjustments

From Stirling Colgate's January 1972 Letter to *Science* Magazine…

- ***"Fortunately, 2000 parametric amplifiers were salvaged, and 280 have been presented for use by telescopes throughout the world. These alone significantly improve the quality of many instruments."***
- **Colgate used 21 of them on SNORT.**
- **Where did the rest of the 280 amplifiers end up?**
- **How were they put to use?**
- **What role did the *Colgate Paramps* play in the field of radio astronomy?**
- **Here are a some of the places that the *Colgate Paramp* travelled to…**

The Colgate Paramp & NMT – 1

Early Attempt to Map Lightning

- **Bill Winn is a atmospheric scientist in the Physics Dept at NMT who was interested in lightning. He is now the Chair of the *Langmuir Laboratory* at NMT.**
  - **In the early 1970's he conceived a scheme for locating the source of microwave emission from lightning discharges.**
  - **He developed a 3-element "*time of arrival*" array at ~1400 MHz using *Colgate Paramps* fed by conical horns.**
  - **By measuring the delays between the 3 elements, the position of the lightning radiation might be determined.**
  - **It was soon realized, however, that this technique would be better done at lower frequencies and the *Colgate Paramp* system was abandoned.**

- **Years later, a team which included Paul Krehbiel developed the *Lightning Mapping Array* (LMA) at the *Langmuir Lab* which operates at 60 MHz and produces spectacular 3-D maps of total lightning activity in near real-time.**

http://physics.nmt.edu/Department/faculty.html

The Colgate Paramp & NMT - 2

RF Emissions from Lightning at L-Band

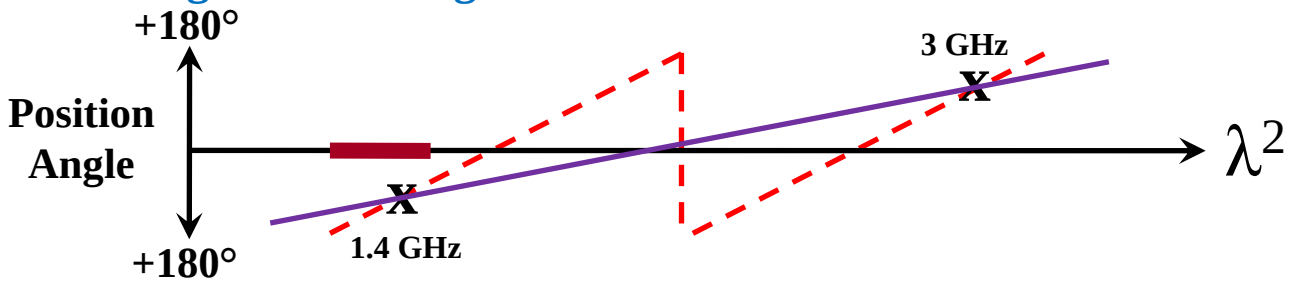
- **<u>Charley Rhodes</u> came to NMT in 1976 and received a BSc, MSc (1985) and PhD (1989).**
- **He worked at the *Los Alamos Nuclear Laboratory* (LANL) from 1990 to 2005.**
- **Charley was familiar with the *Colgate Paramp* as it had been considered for use in his master's research project, "*Some Properties of Radio Emissions from Lightning in the Frequency Range 30 to 3000 MHz*".**
- **In the summer of 1980, he characterized a *Colgate Paramp* for use as a low-noise amplifier at 1414 MHz.**
- **By the time of he started his Masters project, he "*had graduated to a Trontech low-noise amplifier*". Low-noise transistor amplifiers were now available commercially.**

Private communication with Charley Rhodes – Jan 2013
http://www.linkedin.com/pub/charley-rhodes/b/829/623

The Colgate Paramp & Green Bank

Its Most Significant Astronomical Result

- **NRAO obtained ~10 of the paramps from Stirling Colgate and while they were no where near as sensitive as the cryogenically-cooled paramps which were being used on the Green Bank 140 foot telescope, the room-temperature 2-stage amplifier had a much wider bandwidth.**
  - **Over 200 MHz compared to a few 10's of MHz for the existing receivers.**
- **In 1972 NRAO built a receiver using the *Colgate Paramp* for S. J. Goldstein and F. S. Gauss that exploited its unusually wide bandwidth to study the effect of *Faraday Rotation* on several extragalactic sources.**
  - ***Faraday Rotation* arises when electromagnetic waves propagate through a medium in the presence of a strong magnetic field. Such an interaction will rotate the plane of linear polarization. By measuring the polarization angle at a number of wavelengths, the *Rotation Measure* can be determined which then allows one to estimate the average magnetic field along the line of sight.**



- **In the early days of linear polarization measurements relatively widely spaced frequencies between 1 and 3 GHz were looked at. There was some concern that the values of the *Rotation Measure* could be in error because an integral number of "half-turns" in the rotation angle might have been missed. This would mean that the RM might have been underestimated.**
  - **Since radio telescopes in those days were rarely outfitted with more than one low-noise receiver at a time and since the front-end could usually only be tuned across a narrow range, these observations at different frequencies were often made months apart. As many extragalactic sources have time variable emission, and time-varying polarization, the previous observations could be prone to error.**

The Goldstein Rx

MULTIFREQUENCY POLARIZATION OBSERVATIONS
OF EIGHT EXTRAGALACTIC SOURCES

F. Stephen Gauss* and Samuel J. Goldstein, Jr.
Department of Astronomy, University of Virginia
Received 1972 July 20; revised 1972 August 14

ABSTRACT

Observations of linear polarization in forty 5-MHz bands between 1250.4 and 1445.4 MHz show the expected linear relation between position angle of the polarized vector and wavelength squared for eight sources. Seven of the sources have Faraday rotations in agreement with values in the literature obtained at higher frequencies. Upper limits to the difference in Faraday rotation of the two components of five double sources are derived.

We acknowledge with thanks the skilled assistance of the staff of the National Radio Astronomy Observatory. We thank R. J. O'Connell for reading a preliminary manuscript, and S. A. Colgate for arranging the transfer of the surplus military parametric amplifier that was the first stage in our receiver.

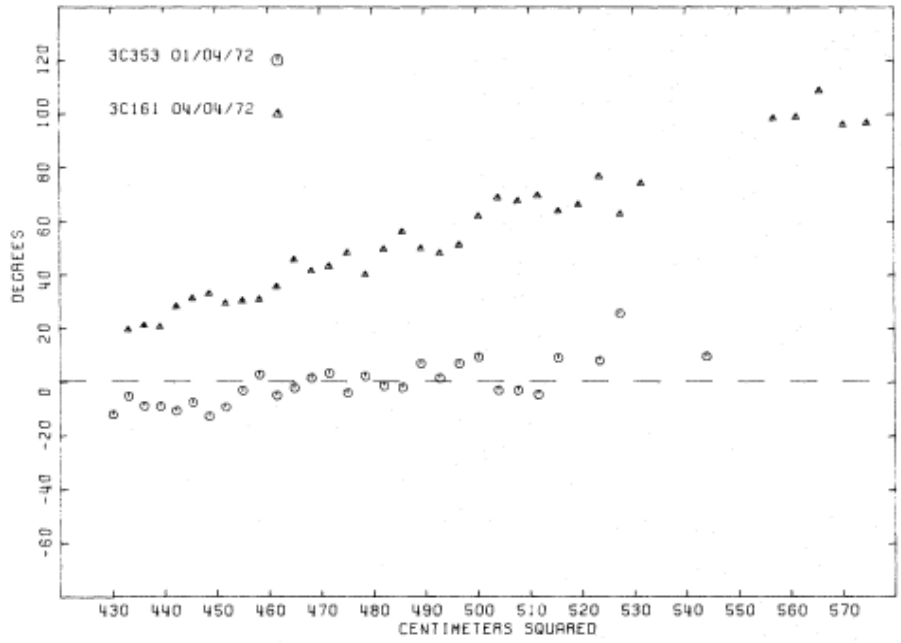
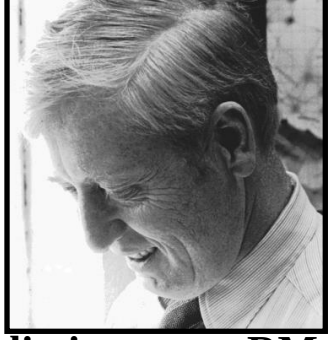


FIG. 1.—Position angle of the linearly polarized radiation from 3C 161 and 3C 353 plotted against wavelength squared. The estimated angular error for each point is about 6°.



What was needed to eliminate any RM ambiguity was observations done with a receiver that had much wider bandwidth than had ever been used before.

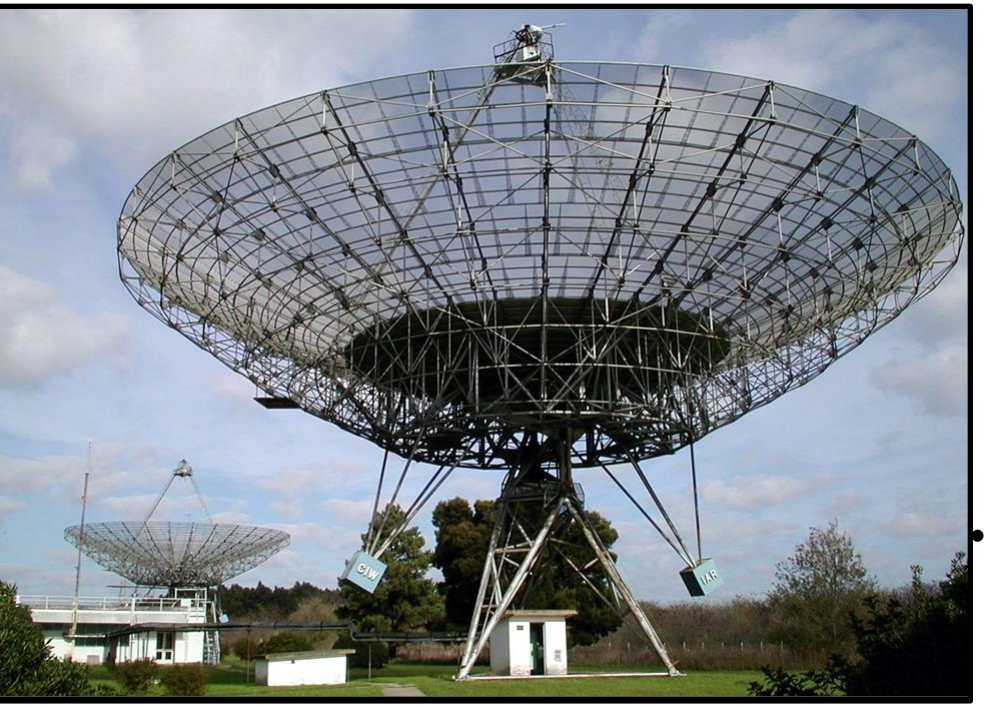
This was a perfect role for the *Colgate Paramp*, as it covered the 1250-1445 MHz band and perfectly matched to the 200 MHz wide spectrometer on the 140-ft telescope (40 x 5 MHz filter bank).

The *Goldstein Receiver* observed 8 extragalactic sources in 1972.
By analyzing the slope of the RM curve, Goldstein & Gauss were able to confirm that the previous polarization measurements did agree, thus removing all questions about half-turn ambiguities.

While not an earth-shattering result, it was an important one, and at the time, could only have been done with a *Colgate Paramp*.

The Colgate Paramp & Argentina

Its Longest Astronomical Mission



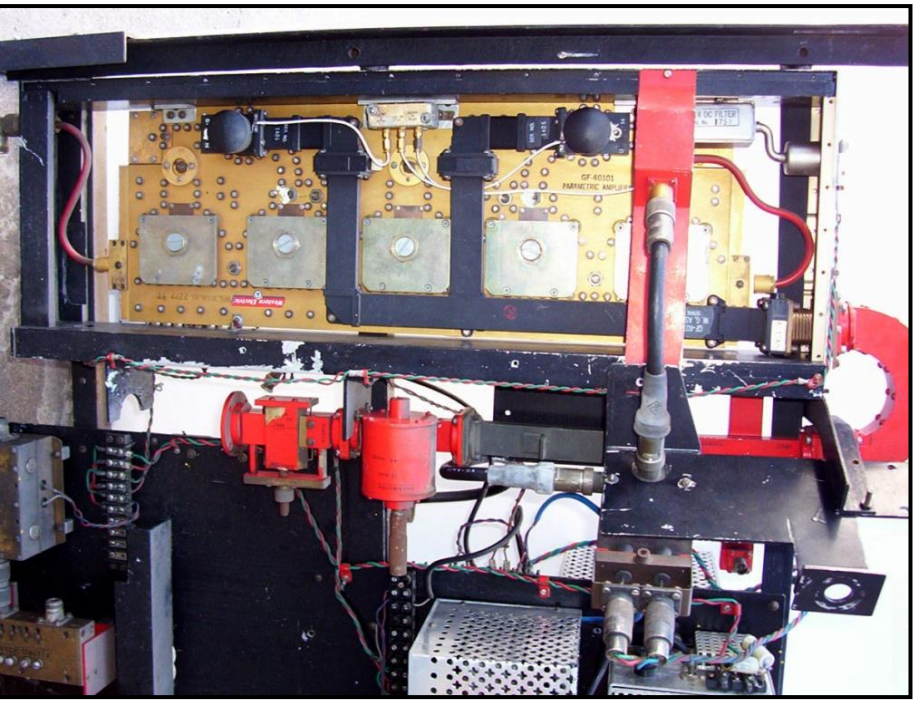
The IAR 30-meter Antenna-I near La Plata, Argentina

http://www.iar.unlp.edu.ar/images/imagenes/a-034.jpgevins)

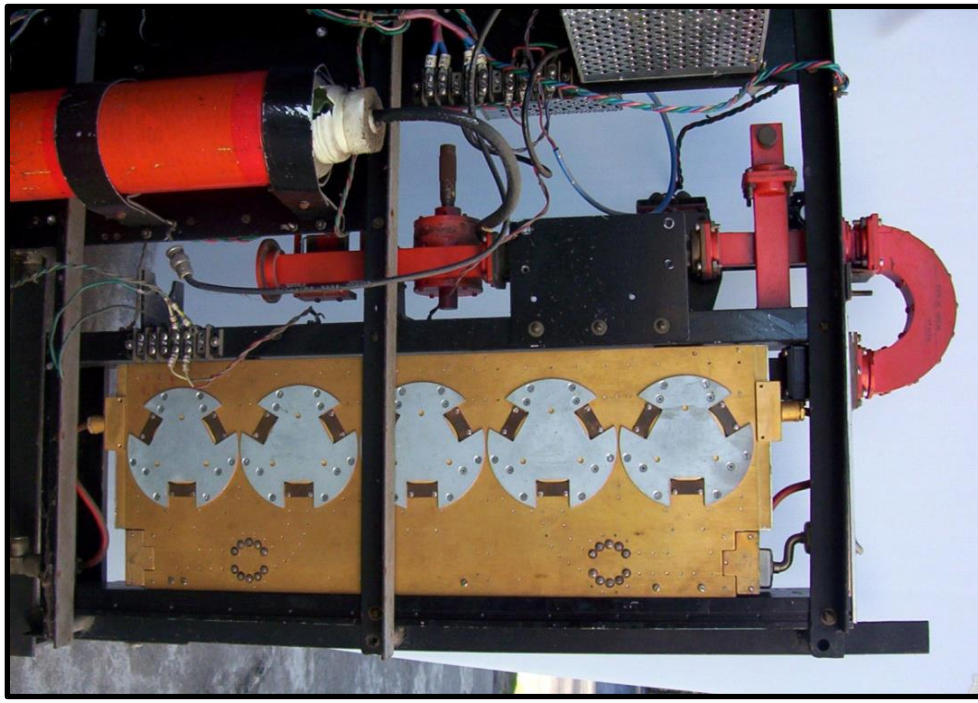
- **In 1962, the *Instituto Argentino de Radioastronomia* (IAR) was created.**
- **Its primary purpose was to coordinate scientific research & technical development in the field of radio astronomy.**
- **In 1963, with funds from the *Carnegie Institution of Washington* (CIW) and the *National Science Foundation*, construction began on a 30-m antenna located 20 km from the city of La Plata.**
  - **The CIW collaboration included the provision of a 21 cm receiver.**
  - **On 11 April 1965, *Antenna-I* detected its first line of neutral hydrogen emission.**
  - **A few years later, construction started on the 2nd 30-meter telescope, *Antenna-II*.**
  - **The original receiver on *Antenna-I* was also replaced by a more modern system utilizing a paramp, also provided by CIW, dropping the system temperature from 800°K to 300°K.**
- **In 1972, a receiver utilizing a *Colgate Paramp* was installed on *Antenna-I* which resulted in a T(sys) of 200°K.**
  - **It stayed in use until about 1980 when it was replaced with a receiver that used a paramp from WRST.**
  - **In 1992, a new receiver was installed on *Antenna-I* which was built at the MPIfR by engineers from IAR. This system was cryogenically cooled to reduce internal noise."**

The Colgate Paramp & the IAR 21-cm Rx

Front



Back



Front and back views of the receiver showing the bright gold stripline circuit board paramp that had been removed from the WECo *Preamplifier* used on the MAR-I and donated to the IAR by Stirling Colgate.

Photos courtesy of Gloria Dubner & Juan Carlos Olalde

The IAR 30-Meter L-Band Receiver

- **Recollections from Tomas Gergely, who in the 1970's worked at the IAR 30-m (he recently retired after 27 years at the NSF, where he spent many years as head of the *Electromagnetic Spectrum Management Unit*):**
  - ***"I do remember at about that time the engineers were quite excited about receiving what they called the "parametricos".***

- **Recollections from Gloria Dubner, who as a graduate student used the IAR 30m L-Band receiver in the 1970's (she is currently the head of the *Radio Astronomy Group* at the *Institute of Space Research*, Argentina):**
  - **"*When I worked with the 30m dish, I was a student that, I must admit, was little concerned with most of the technical details of the telescope, being focused on the astronomical subjects.*"**
  - **"*What I remember from those years is that I was impressed with the handsome appearance of Stirling Colgate!*"**
  - **"*It seems that my thesis, and many more, were carried out using those amplifiers.*"**

List of IAR 30-m papers which specifically acknowledge the *Colgate Paramp*

1) ***A Search for Neutral Hydrogen Remnants of Strong Tidal Disruption of the Small Magellanic Cloud***
   Mirabel & K.C. Turner, Astron. Astrophys., Vol 22, pg 437-440, 1973
2) ***Study of the Outer Galactic Structure for 288° ≤ l ≤ 310°, -7° ≤ b≤ 2°***
   S.L. Garzoli& I.F. Mirabel, Astrophysics & Space Science, Vol 25, Issue 1, pg 207-216, 1973
3) ***An Anomalous Velocity Neutral Hydrogen Structure Near the Galactic Center***
   I.F. Mirabel & K.C. Turner, Astrophysics and Space Science, Vol 3, pg 381-394, 1975
4) ***Observations of the 21-cm Hydrogen Emission Line in the Direction of 23 Southern Pulsars***
   F.R. Colomb & I.F. Mirabel, Astron. Astrophys., Vol 47, No. 1, pg 157-159, 1976
5) ***A Peculiar HI Feature at l = 285°, b = ~18°***
   E. Bajaja, F.R. Colomb & M. Gil, Astron. Astrophys., Vol 49, pg 259-262, 1976
6) ***A Survey of Neutral Hydrogen in the Region 290° ≤ l ≤ 314° -32° ≤ b ≤ -17°***
   F.R. Colomb, M. Gil & R. Morras, Astron. Astrophys Suppl Series, Vol 26, pg 195-206, 1976
7) ***21cm Line Observations in the Region 348° ≤ l ≤ 360°, -22° ≤ b ≤ -1°***
   I.F. Mirabel, Astronomy & Astrophysics Supplement Series, Vol 28, pg 327, 1977
8) ***Galactic HI at |b|>=10 - I. Preliminary Presentation of Part of the Southern Sky Area***
   F.R. Colomb, W.G.L. Poppel and C. Heiles, Astron. Astrophys. Sup., Vol 29, pg 89-101, 1977
9) ***Neutral Hydrogen Associated with Southern Supernovae Remnants***
   F.R. Colomb & G.M Dubner, Astron. Astrophys., Vol 82, pg 244-248, 1980)
10) ***HI 21 cm Line Observations at Low Galactic Latitudes in the Southern Hemisphere***
    E. Bajaja & R. Morras, Astrophysics and Space Science, Vol 41, pg 121-128, 1980

The Colgate Paramp & Japan

Radio Brightness Distribution of M 17 and Orion A at 3.5-mm Wavelength

Yasuo FUKUI

Department of Astronomy, University of Tokyo, Bunkyo-ku, Tokyo 113

and

Tetsuo IGUCHI†

Tokyo Astronomical Observatory, University of Tokyo, Mitaka, Tokyo 181

Publ. Astron. Soc. Japan **29**, 63–73 (1977)

Observations were made from December 1974 to March 1975 by using the 6-m millimeter-wave telescope at Tokyo Astronomical Observatory, Mitaka. This telescope has a shaped Cassegrain system with a dual-mode primary horn and is on an azimuth-elevation mount. The half-power beamwidth and the beam and aperture efficiencies were measured to be 2′, 0.38, and 0.35, respectively at 3.5 mm from the observations of Jupiter whose disk brightness temperature was assumed to be 140 K. The front end is a GaAs Schottky barrier diode mixer followed by an uncooled parametric amplifier (supplied by the courtesy of New Mexico Institute of Mining and Technology). The I.F. frequency was 1.25 GHz with a 3-db bandwidth of 300 MHz. The center frequency was 86.75 GHz during the observations. The double sideband noise temperature was around 2000 K and the r.m.s. noise fluctuations were 0.3 K with one-second integration time.

From later papers, it seems the *Colgate Paramp* was in use on the TAO 6-meter for at least 3 years (between Dec 1974 & Mar 1977, and perhaps longer).

***Radio Brightness Distribution of M 17 and Orion A at 3.5-mm Wavelength*, Y.Fukui & T.Iguchi, PASJ, Vol. 29, p. 63-74 (1977)**
http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1977PASJ...29...63F&defaultprint=YES&filetype=.pdf
http://alma-intweb.mtk.nao.ac.jp/~kt/morimoto/morimoto-san-no-uchu.pdf

The Colgate Paramp & the Molonglo Cross

Trip Report by Kelvin Wellington, Aug-Sept 1973

NETHERLANDS FOUNDATION FOR RADIO ASTRONOMY

AUSTRALIAN TRIP REPORT.

K.J. Wellington.

4.1. The Molonglo Cross Observatory. Instead there has been some development work done towards converting the telescope to 1400 MHz operation. A novel feed-phase shifter has been tested and a large number of "Colgate" paramps acquired (although transistor preamps with N.F. < 3 dB would probably be used).

The first written reference of the unit as the "*Colgate Paramp*".

There wasn't enough funds to upgrade MOST from 408 to 1420 MHz, and they settled on 843 MHz. So there never was an opportunity to use the *Colgate Paramp* on MOST.

The Molonglo Observatory Synthesis Telescope

B. Y. Mills *School of Physics, University of Sydney* *Proc. ASA* 4(2) 1981

Indeed, the specifications for the original instrument were chosen to permit a subsequent conversion from 408 MHz to 1420 MHz with little extra expenditure on the reflector

Australia Telescope Compact Array (ATCA) opened 1988

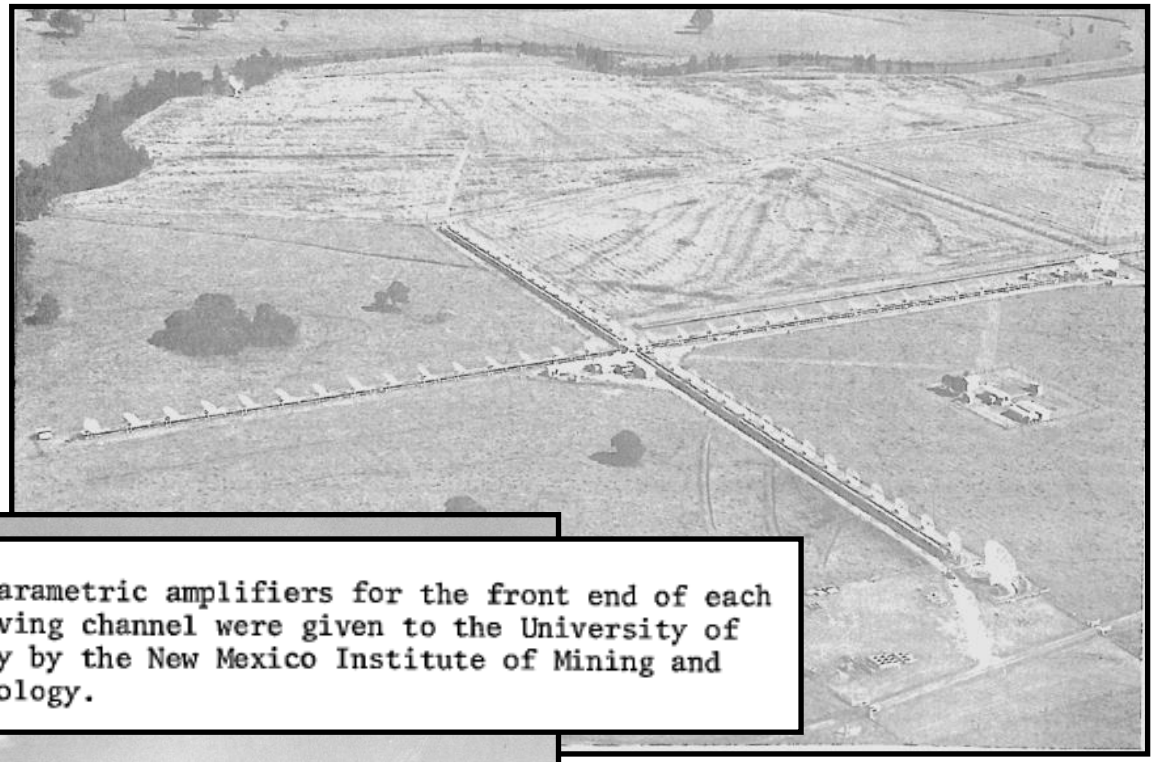
Further consideration indicated that the cost of a system of this type, operating at 1420 MHz, would require special Commonwealth funding, and this possibility was virtually eliminated by the CSIRO and ANU push for a synthesis telescope which would operate at 1420 MHz and higher frequencies. Accordingly, we settled for a rather less useful lower frequency which would enable the existing waveguide feed structures to be used and require little or no upgrading of the mechanical structure, resulting in very substantial savings. The frequency initially chosen was 803.5 MHz, but, after discussions with Telecom, this was raised to 843 MHz for greater protection from possible interfering transmissions.

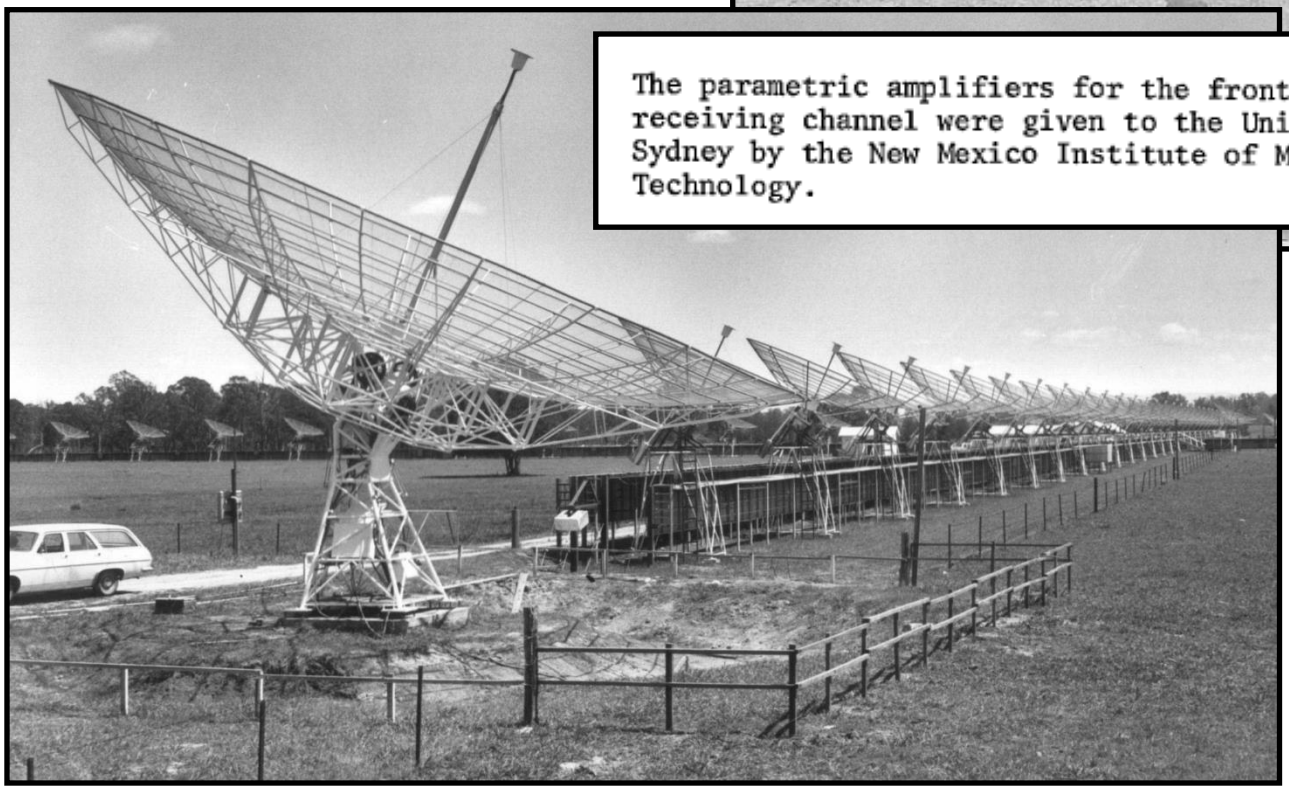
The Fleurs Synthesis Telescope *(University of Sydney)*

W. N. CHRISTIANSEN*
Fellow, I R E E

Proceedings of the I R E E
September 1973

The FST operated at 21-cm and had a resolving power of 20".





The parametric amplifiers for the front end of each receiving channel were given to the University of Sydney by the New Mexico Institute of Mining and Technology.

East-West array of 32 x 5.7-m dishes

North-South array of 32 x 5.7-m dishes

Beyond the ends of the E-W & N-S arrays were 4 x 13.7-m dishes

Max Baseline of 1.6 km

The Colgate Paramp & the FST

Recollections

- **Kelvin Wellington, a radio astronomer/engineer helped design the FST.**
  - **"*I'm pretty sure they were never used in anger at Fleurs. They didn't come with a pump oscillator which would have been a pretty expensive addition.*"**

Bob Frater was a Professor of EE at the Univ. of Sydney (1968-80), Director of FST (1980) and Chief of the CSIRO Division of Radiophysics (1981–1988).

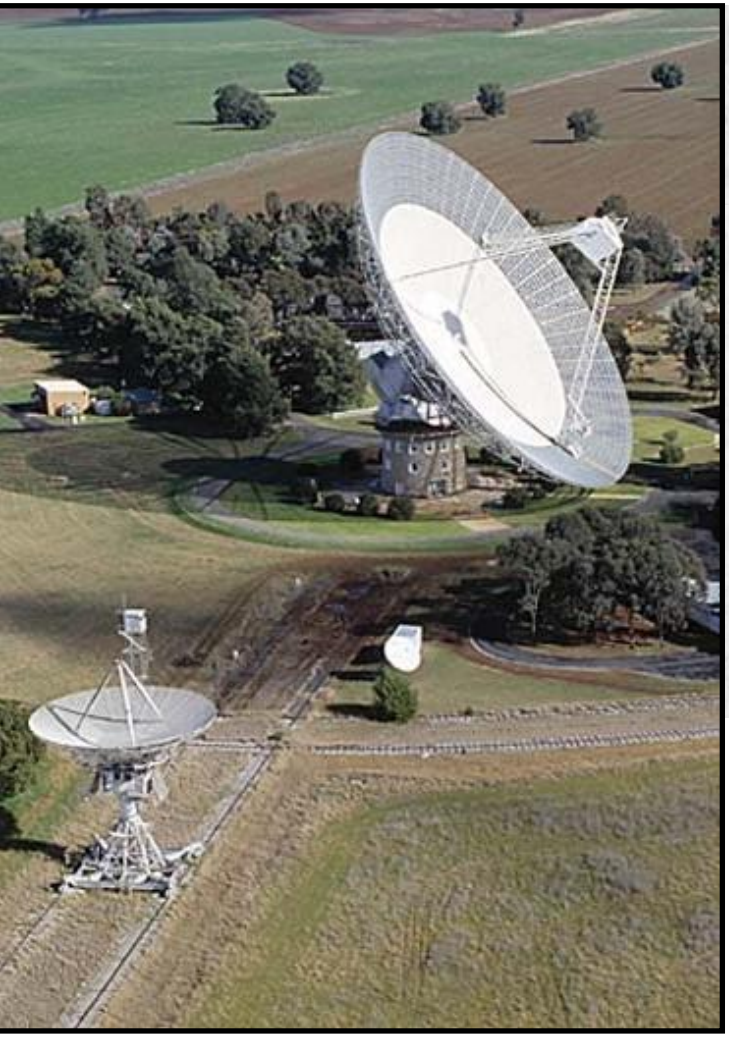
- **"*I really only remember the big load of boxes arriving and wondering what we were going to do with them.*"**
- **"*I'm fairly sure the number was large – 68 plus.*"**
- **"*We did have a lot of them and when we decided that they were not going to be used, I found myself calculating the value of the gold!*"**

John Bunton joined the FST in 1983. Between 1986-88 he was the Engineer-in-Charge with responsibility for all aspects of telescope operation.

- **"*They use to live under the stairs down to the courtyard*" at the EE School."**
- **"*No one ever figured out how to tune them to 1.4 GHz..*"**
- **"*Eventually they were scavenged for parts, the most useful being the coax cables that supplied power. The connectors and cables were use for the outputs from the LNAs on the 13.7m dishes.*"**
- **Finally, he recalled, "*They were beautifully made with lots of gold plating.*"**

The Colgate Paramp & Parkes

Letter Discovered by Miller Goss in the CSIRO Archives



http://2.bp.blogspot.com/_9vpCpphdcSI/TKNIMfih0hI/AAAAAAAAAW0/K0vAChTDw7E/s1600/Parkes_arp_750pix.jpg

Dr B.J. Robinson,
Max-Planck Institut fur Radioastronomie,
Argelanderstrasse 3,
53 BONN, West Germany

18th May 1973

Dear Brian,

Mal Sinclair, later head of the Receiver Group, indicated they had gotten several from the Univ of Sydney but he didn't think they were ever used.

Re the Stirling Colgate paramps none of these have ever turned up at Radiophysics and I wondered if in fact you had written to Stirling after we discussed the paramps. There seems to be a definite need for them as low-noise IF's and I thought we should see if any are still available. To save some three-cornered correspondence, John Bolton will write Stirling, as he knows him personally, but if you have anything more on the paramps please let me know.

Yours sincerely,
(B.F.C. Cooper)

Brian Cooper **helped pioneered the manufacture of first transistors in Australia. He was placed in charge of the group developing receivers for the Parkes telescope in the late 1950s. He died in 1999.**

Brian Robinson **was the resident paramp expert in *Radio Physics* who was spending a year away from Australia as a visiting professor at the MPIfR in Germany. He was the first to detect the maser radiation from hydroxyl molecules. Became the Deputy Director of the ANTF (1968–1970) and the Director of Research (1971–1979). He retired as a Chief Research Scientist in 1992 and died in 2004.**

John Bolton **was the first Director of *Owens Valley Radio Observatory*, Caltech (1955-60). He returned to Australia to become the first Director of the *Parkes Radio Observatory* (1960-1972). After stepping down he remained at Parkes as *Astronomer at Large* until 1981. He died in 1993.**

Distribution of the 280 Colgate Paramps

What we have been able to track down so far…

Organization	Min	Max	Used	Contact
New Mexico Tech (NMT)	21	24	SNORT	S. Colgate, B. Blevins, G. Schwede
	3	5	3-element lightening array	B. Winn
	1	2	Lightning RF emission development	C. Rhodes
California Institute of Technology	1	2	Laboratory evaluation	A. Moffet (1971 letter)
CSIRO	2	6	Several obtained from Univ. of Sydney, never used	M. Sinclair, B. Cooper (1973 letter)
Five Colleges Radio Observatory	2	4	Unknown (a few)	N. Erickson
Goddard Institute for Space Studies	2	6	Unknown (a few)	A. Kerr
Instituto Argentino	1	1	Disassembled to see how it worked	G. Dubner, J.Olalde,
de Radioastronomia	1	1	Used on 30-meter Antenna I	E.Filloy, T. Gergely
(IAR)	2	2	Unknown	
Massachusetts Institute of Technology	6	10	Perhaps used in Microwave Thermography	P. Crane, P. Myers, J. Barrett
National Radio Astronomy	1	1	Polarization observation on Green Bank 140 ft	M. Ballister
Observatory (NRAO)	9	9	Never used	
National Research Council of Canada	2	2	Ottawa - Never used	K. Tapping, T. Legg, R. Hayward
	1	2	Penticton - Never used	T. Landecker
New Mexico State University (NMSU)	1	1	Disassembled	C. Seeger (1971 letter)
	6	6	Unknown	
Ohio State University	2	3	Never used on the "Big Ear"	R. Dixon
Rutherford Appleton Laboratory, UK	1	2	Unknown	K. Tapping
Tokyo Astronomical Observatory,	2	4	IF amp for mm-wave Schottky diode mixer	Y. Fukui, T. Iguchi (1977 paper)
University of California, Berkeley	2	4	Early IF amp for mm-wave Schottky mixer	N. Erickson
University of Groningen, Netherlands	2	4	Planned for a Student Telescope, never used	R. Allen, M. Goss
University of Sydney, Australia	68	80	Considered for the Fleurs Synth Telescope (2 of the 13.7m antennas may have used them)	C. Christiansen (1973 paper) R. Frater & K. Wellington
University of Virginia	0	2	Unknown (could be from NRAO)	GovDeals Auction - 23 Aug 2012
Others to England & Sweden	?	?	Unknown	According to J. Reiche
Sub-totals	139	183		

We have determined where at least half of the 280 ended up…

…what about the rest of the 2000 salvaged from the MAR-I in 1970 ?

"The Rest of the Story"

The Story of the Remaining Paramps

- **The *Colgate Paramps* that weren't used – probably close 2000 - were stored away in the NMT corporate "*Bone Yard*" for the next 10 years.**
- **It was known that the paramp components where heavily gold plated.**
  - **When the MAR-I was salvaged in 1970, the price of gold was only ~$50/oz.**
  - **The price of gold would climb through the rest of the 70's and would peak at about $850/oz in 1980.**
- **John Reiche, the *NMT Instrumentation Manager* at the time, did the first assay of the paramps himself and was flabbergasted to find that there was well over 1 ounce of gold in each paramp module.**
- **At that point they realized they literally had a goldmine on their hands.**
- **So late in 1980, almost exactly a decade after the MAR-I site had been salvaged, Marx Brook, the Director of NMT's *Research & Development Division*, decided to sell the remaining MAR-I paramps & gold-plated components. They were driven in two trucks to the *Sabin Metal Corp* in NY where the gold was reclaimed and, amazingly, netted the university…**

$941,966 → ~$2.5M today

- **The proceeds of the reclaimed gold were used to construct a new wing on the *Workman Center* building.**
- **Although the official name was the "*Workman Addition*", it has since become known as the *Gold Building*.**

The *Gold Building* on the NMT Campus

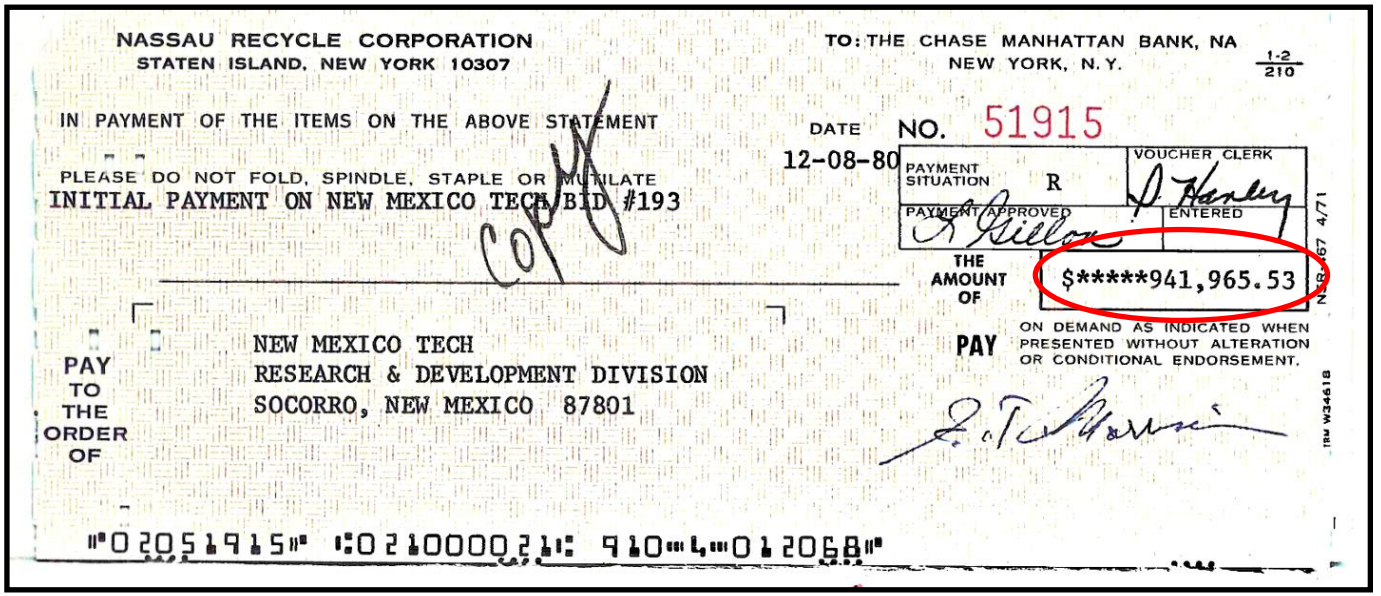
Now the Bureau of Geology "Mineral Museum"

Photo by R. Hayward

The "Gold Check"

The Gold Check

Courtesy of Paul Krehbiel



NASSAU RECYCLE CORPORATION
STATEN ISLAND, NEW YORK 10307

TO: THE CHASE MANHATTAN BANK, NA
NEW YORK, N.Y.

1-2
210

IN PAYMENT OF THE ITEMS ON THE ABOVE STATEMENT

PLEASE DO NOT FOLD, SPINDLE, STAPLE OR MUTILATE

INITIAL PAYMENT ON NEW MEXICO TECH BID #193

DATE 12-08-80

NO. 51915

PAYMENT SITUATION R

VOUCHER CLERK

PAYMENT APPROVED

ENTERED

THE AMOUNT OF $*****941,965.53

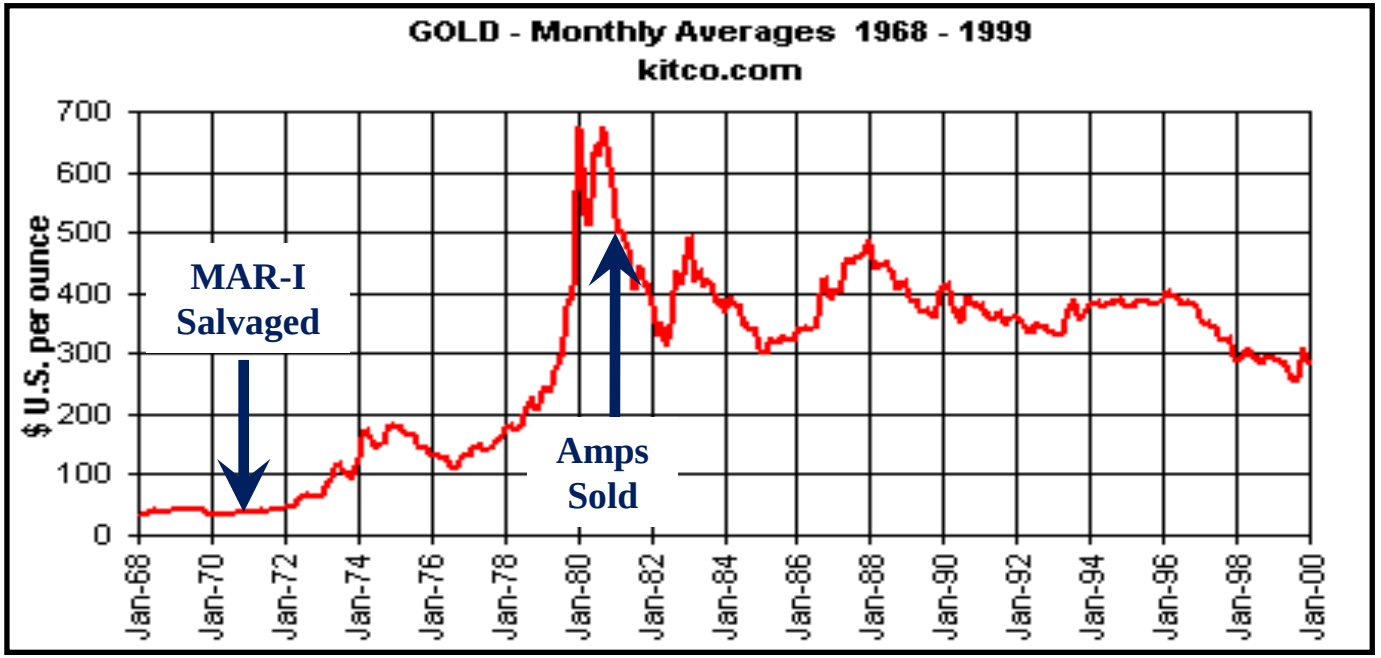
PAY TO THE ORDER OF

NEW MEXICO TECH
RESEARCH & DEVELOPMENT DIVISION
SOCORRO, NEW MEXICO 87801

PAY ON DEMAND AS INDICATED WHEN PRESENTED WITHOUT ALTERATION OR CONDITIONAL ENDORSEMENT.

"02051915" :021000021: 910-4-012068"

Monthly gold prices from Jan 1968 to Jan 2000



More on the "Gold Building"

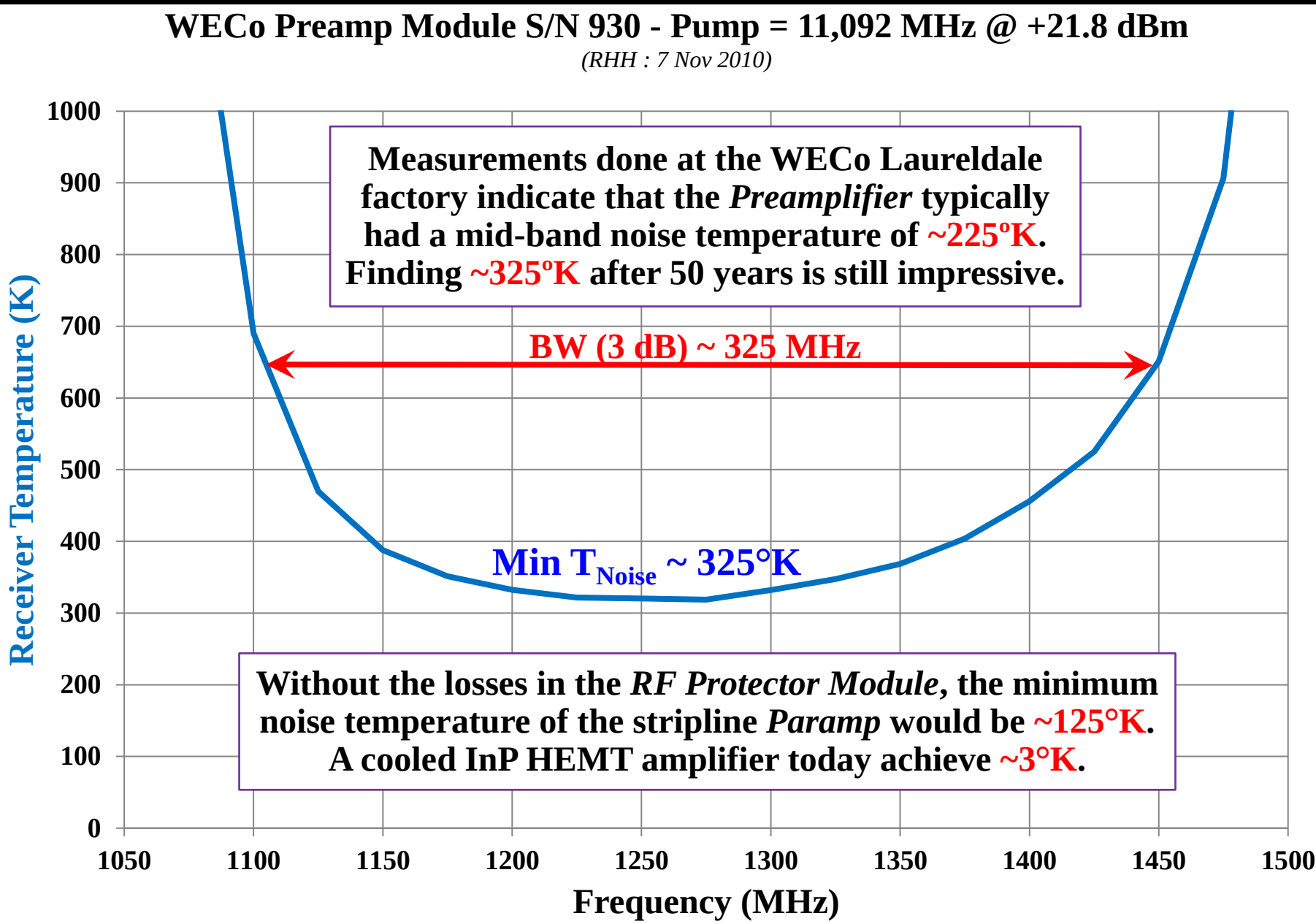
- **Although the material saved from the MAR-I had been officially transferred from the US government to NMT by the *Office of Naval Research* (ONR), there were accusations that the paramps had been improperly disposed of.**
- **Three separate agencies – the *Office of Naval Research* (ONR), the *Air Force* and the *FBI* -- investigated the gold recycling episode to determine if NMT had sold government property improperly. All three reviews gave the university a clean bill of health.**
- **Being able to argue that NMT was not trying to profit from the paramps and had attempted to help the scientific community by giving many of them away years earlier was "*a big hammer*" for the university during their defense.**
- **John Reiche had wanted to commemorate the role the paramps had played in the *Gold Building* by embedding one behind plastic in the wall next to the lobby stairway. Alas, Marx Brook wouldn't let him.**
- **In 1995, the *New Mexico Bureau of Geology and Mineral Resources* (NMBGMR) relocated its *Mineral Museum* to the *Gold Building*. This collection has more than 12,000 specimens with an estimated 10,000 visitors annually.**

Finding a Colgate Paramp

- **After spending much of 2009 researching the *Colgate Paramp*, we hoped to find one of the units to look at but had met with little success.**
  - **Upon hearing that John Reiche would be passing through Socorro, Paul Krehbiel arranged for a lunch time meeting in Sept 2009 where John described the MAR-I salvage & the *Gold Building* story.**
  - **As luck would have it, Paul told his wife, Kay, about the upcoming lunch. She said, "*By the way, you know that we have one of these things in Archive at the Tech Library*". She had retired as the its Director Of the Library in 2003.**
- **In lower left photo, Bob and Paul examine the Colgate Paramp in the *Skeen Library*.**
- **And so, we were able to sign out a *Colgate Paramp* on a 6 month loan.**

Pictures by Miller Goss, 1 Sept 2009

RF Tests on the NMT Library Colgate Paramp



Proof that you can find just about anything on eBay…

Click to view larger image and other views

Western Electric GF-40096-L2 Preamplifier

Like | Want | Own

Item condition: **Used**

Ended: Sep 24, 2012 14:21:10 PDT

Starting bid: **US $19.99** [0 bids]

Add to list

Shipping: **$50.44** Standard Shipping | See details

Item location: **Woodbridge, Virginia, United States**

Ships to: **United States**

Delivery: Estimated within 3-7 business days

Payments: PayPal | See details

Returns: 14 days money back, buyer pays return shipping | Read details

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Seller information
dlinventory (4051 ★)
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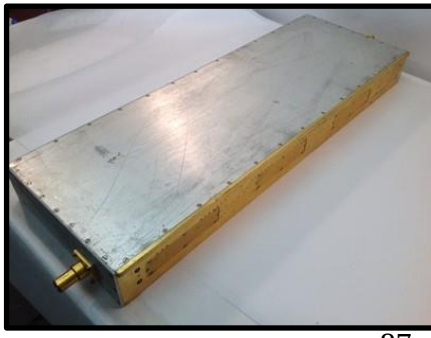

Item specifics

Condition: Used: An item that has been used previously. The item may have some signs of cosmetic wear, but is fully operational and functions as intended. This item may be a floor model or store return that has been used. See the seller's listing for full details and description of any imperfections. See all condition definitions

- This unit is in good used physical condition with a few minor cosmetic markings present
- Unit is in great working order
- Email us with any questions
- Auction includes exactly what you see pictured

Good Luck Bidding!

http://www.ebay.com/itm/Western-Electric-GF-40096-L2-Preamplifier-/261099839842?nma=true&si=qeWQfSOJw%2BZGpBd0fVVdfbs6Wi0%3D&orig_cvip=true&rt=nc&_trksid=p2047675.l2557

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3 Pallets of Various Types of Old Lab Machines, & 1 Box of Garden Lights.

Quantity	Condition	Category	Inventory ID

1 Box of Low Voltage Garden Lights - Working condition.

1 American Instruments Laboratory noise generator 7010 - Good

1 Hewlett Packard Model 805C Slotted Line - Good

1 Western Electric GF40096 L2 Preamplifier - Unknown

1 Western Electric GF 40096 L2 Preamplifier - Unknown

Auction Closed

High Bidder:	K******2
Sold Amount:	$104.50
Tax (5.0000%):	$5.22
Buyer's Premium (5.00%):	$5.22
Total Price:	$114.95

View Bid History

Terms and Conditions

Bid History for 3 Pallets of Various Types of Old Lab Machines, & 1 Box of Garden Lights.
Auction Start Date: 08/17/12 11:24 AM ET
Auction End Date: 08/23/12 6:55 PM ET
Asset ID: 5219 Number of Bids: 16

Seller Information

Seller Name: University of Virginia, VA [view seller's other assets]

Asset Contact: Vu Nguyen (Phone: 434-243-6092)

Asset Location: 1101 Millmont St
P.O. Box 400102 (Zip: 22904-4102)
Charlottesville, Virginia 22903-4868
Map to this location

Over Here

http://www.govdeals.com/index.cfm?fa=Main.Item&itemid=5219&acctid=1858

While the SNORT Trailer has vanished, surprisingly all three SNORT Antennas can still be found in the NMT *Bone Yard*

In Oct 2009, Bruce Blevins inspected his handwork from when he was a student. After a 40 year career designing antennas, he's wondering just how well the MAR-I elements actually illuminated the 10 foot dishes and what kind of return loss they achieved.

The 2nd SNORT antenna with its prime focus no longer in an optimally located position.

Photos by R. Hayward

The 3rd antenna appears to be looking for EM pulses from the Earth's core.

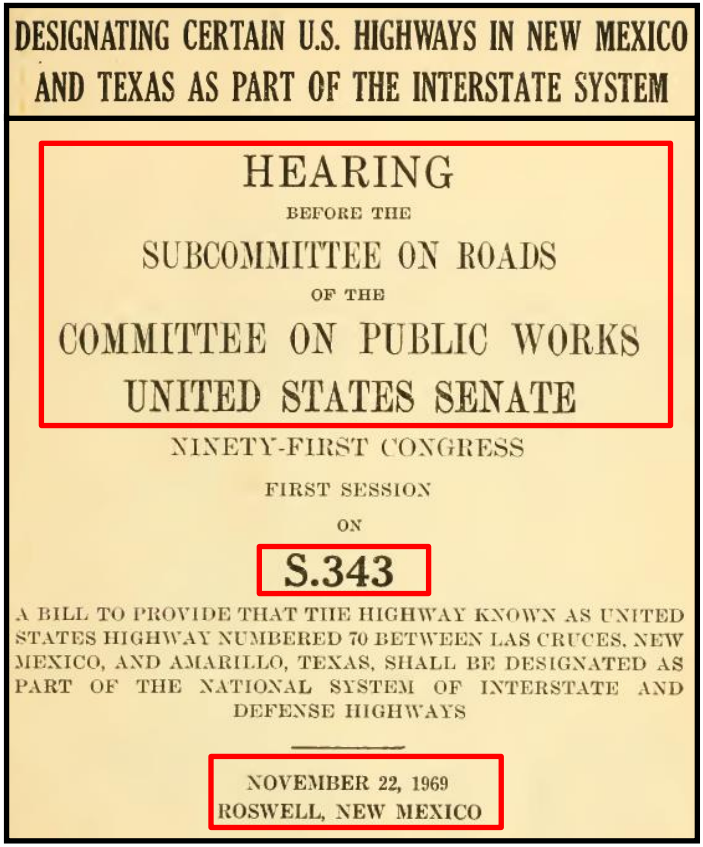
Whatever Happened to the MAR-I…

A more recent picture of the MAR-I.
No longer used as a radar, its Array Faces have been permanently sealed.

http://www.smdc.army.mil/SMDCPhoto_Gallery/Facilities/HELSTF/Img21.jpg

The MAR-I Becomes a Fallout Shelter (?)

- **In Nov 1969 *Senate Bill S.343* sought to designate *Highway 70*, between Las Cruces & Amarillo, as part of the *Dwight D. Eisenhower National System of Interstate& Defense Highways*.**
- **While the primary purpose behind the *Interstate Highway System* was to link most of the major cities, a not so widely known function of *the Interstate Highway* system was that it would provide crucial transport routes for troops & supplies in case of a military emergency, which is why the federal government provides ~90% share of the cost.**
- **One of the reasons presented in the Bill was to help speed up the evacuation of dependents at the *Holloman Air Force Base* (HAFB) to a nearby fallout shelter at the MAR-I.**
- ***Bill S.334* must not have succeeded as *Highway 70* has never been designated as an Interstate route, although the portion south of the MAR-I site is indeed a 4-lane divided highway and looks very much like an *Interstate Highway*.**
- **We're not sure if the MAR-I was ever really intended to be a fallout shelter. In 1969, the site had not yet been salvaged - could it really hold 5000 people?**
- **Perhaps it was just an excuse to get a better highway to access WSMR & HAFB.**



DESIGNATING CERTAIN U.S. HIGHWAYS IN NEW MEXICO AND TEXAS AS PART OF THE INTERSTATE SYSTEM

HEARING

BEFORE THE

SUBCOMMITTEE ON ROADS

OF THE

COMMITTEE ON PUBLIC WORKS

UNITED STATES SENATE

NINETY-FIRST CONGRESS

FIRST SESSION

ON

S.343

A BILL TO PROVIDE THAT THE HIGHWAY KNOWN AS UNITED STATES HIGHWAY NUMBERED 70 BETWEEN LAS CRUCES, NEW MEXICO, AND AMARILLO, TEXAS, SHALL BE DESIGNATED AS PART OF THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

NOVEMBER 22, 1969
ROSWELL, NEW MEXICO

5. The main fallout shelter area for all dependents at HAFB is the hardened facilities which were originally constructed for Research and Development of to Multi-Function Array Radar, an early element of the Research and Development of the Safeguard project. The now unused facility has a capacity of approximately 5,700 persons for shelter space. In the event of a national emergency, which would require evacuation of HAFB dependents, the entire group must be transported over the present narrow two-lane road to Mar Site which is shown on the map (inclosure 1). Evacuation time will be substantially reduced and the probability of serious accidents significantly reduced if the 24 mile stretch of two-lane road was rebuilt as a four-lane highway.

The MAR-I & HELSTF

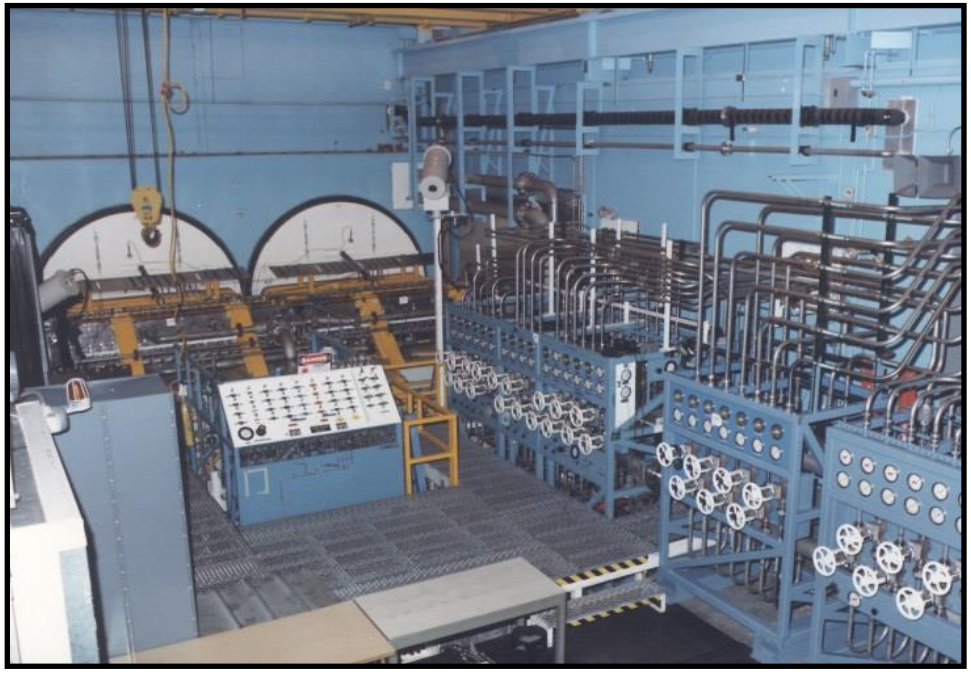
In 1974, the DOD to created a tri-service (Army, Navy and Air Force) *High Energy Laser Systems Test Facility.*

HELSTF was established at the old MAR-I site. Its 90,000 sq ft of concrete-reinforced space was advantageous for safety & security. Offices are located inside the main dome. Other facilities, such as the cafeteria and the laser test control room, are in the underground levels.

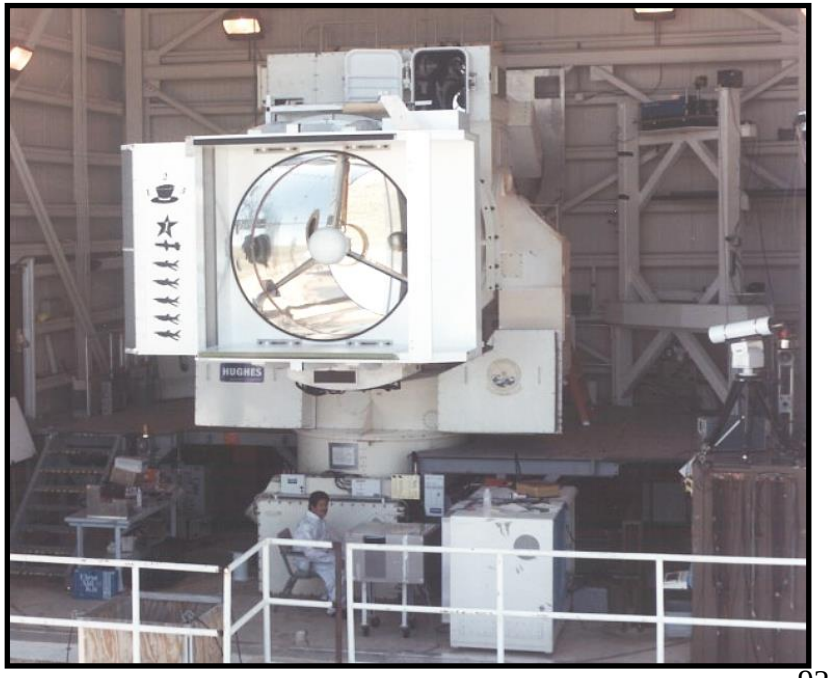
HELSTF became operational on September 6, 1985. Over several decades it represents a ~$800 million investment.

The *Mid Infrared Advanced Chemical Laser* (MIRACL), the U.S.'s most powerful laser, is shown in the lower left photo. The SLBD *Beam Director* is at the lower right.

http://www.jpesten.com/SLBD.html



http://www.fas.org/spp/military/program/asat/miracl.htm



www.ausairpower.net/APA-DEW-HEL-Analysis.html

The MAR-I Site Today…HELSTF

Google Earth

Conclusions

- **Of the over 2,000 paramps that NMT had harvested from the MAR-I in 1970, we know where most of them ended up…**
- **Thanks to the efforts of Stirling Colgate, NMT donated some 280 of the paramps to observatories & science organizations around the world.**
  - **We've managed to track down where over half of them went.**
- **Several were used to do interesting or unique radio astronomy projects:**
  - **Colgate's SNORT experiment**
  - **Polarization studies on the Green Bank 140-ft**
  - **HI observations of the southern sky with the Argentinean IAR 30-m**
  - **Millimeter-wave observations on the Tokyo 6-m**
- **Several observatories acquired them with specific plans for their use which, alas, never panned out (MOST, FST & Parkes)**
- **Numerous institutions acquired small quantities of the paramps but they never ended up putting them to use.**
- **Unlike other amplifiers that have been pushed aside by obsolescence, the *Colgate Paramp* still had one last, if somewhat unusual, role to play…**
  - **After sitting in the NMT *Bone Yard* for nearly a decade, the gold in at least 1,700 surviving paramps was reclaimed in 1980, providing NMT with a $1M windfall.**
  - **Thus the contribution of the *Colgate Paramp* to science & technology continues to live on some 45 years later in the *Gold Building* on the Tech Campus.**
- **And, finally, one can truthfully say that the *Skeen Library* at NM Tech is probably the only library in the world where you can sign out a 50 year old fully functional parametric amplifier on-loan.**

Stirling Colgate
~ *Kudos* ~

LANL researchers Hui Li of *Plasma Physics*, Philipp Kronberg of the *Institute of Geophysics and Planetary Physics* and Stirling Colgate of *Theoretical Astrophysics* standing outside the Los Alamos radio antenna of the VLBA.

http://www.lanl.gov/news/index.php/fuseaction/nb.story/story_id/%20521

Vic Gaizauskas - a Canadian astronomer who has studied the Sun for nearly 50 years. He was the Director of the *Ottawa River Solar Observatory* from its creation in 1970 until its closing in 1992.

"He is an admirable example of an extremely wealthy man who has used his fortune to indulge his passion for science and, most importantly, to impart that passion to others. A very rare breed."

Colgate & the "*Relevance of Research to Students*"

- **When Colgate became president of NMT in 1965, the university had 479 students. When he left in 1975, it had risen to 918.**
- **Twenty-one new degree programs were added to the curriculum during his tenure, 7 of which were in engineering and 14 in science.**
- **Not only did he work to improve the quality of the S&E programs but he was a strong advocate of students participating in university research.**
- **In June 1969 he wrote a letter to *Science* Magazine to express his views...**

The tragedy and mistake is that universities have allowed research to grow without demanding and ensuring continuing undergraduate student involvement.

This involvement should take the form of part-time jobs.

Undergraduate student employment in research at NMT, currently at 60 percent of all undergraduate students, goes a long way toward achieving the student-faculty involvement that is so desperately needed at this time.

***College on the Rio Grande – The Story of a Small School*, Paige Christiansen (1989)**

***Science* Magazine, 20 June 1969 (Vol 164, pg. 1342-1343) ; http://www.chinamyopia.org/Colgateenglish01.htm**

Extra Slides

Unanswered Questions in the *Colgate Paramp Saga*

- **What were the terms & conditions of NMT's contract at WSMR to salvage the MAR-I?**
- **Did NMT salvage any of the MAR-I's *Transmitter, Signal Processing & Computer* systems? And if not, what happened to them?**
- **Did NMT get all the MAR-I's *Preamplifiers* (2000 vs. 2500)?**
- **How did Colgate spread the word to the radio astronomy community about the availability of the surplused MAR-I *parametric amplifiers*?**
- **Did he send out a letter? Does a copy of it still exist?**
- **Is there a file buried away in the NMT *Archives* that details where the 280 *Colgate Paramps* were sent?**
- **How many *Preamplifiers* were actually sold to *Sabin Metals* for their gold?**

The MAR-I as an Astronomical Instrument ?

The MAR radar was dismantled before a proper evaluation could be made of its astronomical capability.

It is a tragedy indeed that such a short-term military experiment could not have been made available to astronomers who could have made measurements that now may not be made for many decades.

It was an incomparable instrument, operating near the 21-centimeter line for beam-switched observations of distant radio sources and possibly even of supernovas in distant galaxies.

- **Stirling Colgate, in his 1972 letter to *Science*, suggested the MAR-I would have made a great astronomical telescope.**
  - **Pro's: - With retuning, it could access the 21-cm Hydrogen Line.**
    - Field of View > 90° with a phased-array beamwidth of ~1.8°
  - **Con's: - Smallish Aperture of about 25 ft.**
    - System Temperature of Antenna Element & Paramp > 300°K
    - Its single Receiving Array Face points to the Northwest.
    - The maintenance of over 2000 paramps is more than scary.
- **So it was probably rather marginal as an astronomical instrument.**
  - **Except, perhaps, for surveying the Northern Sky for Supernovae.**
- **The astronomical community certainly wouldn't say no to a portion of its cost ($160M or $1.1B today ≈ ALMA) nor the speed of its construction (groundbreaking to turn-on took only 15 months).**

Colgate & the Tornado

Pampa, Texas
19 May 1982

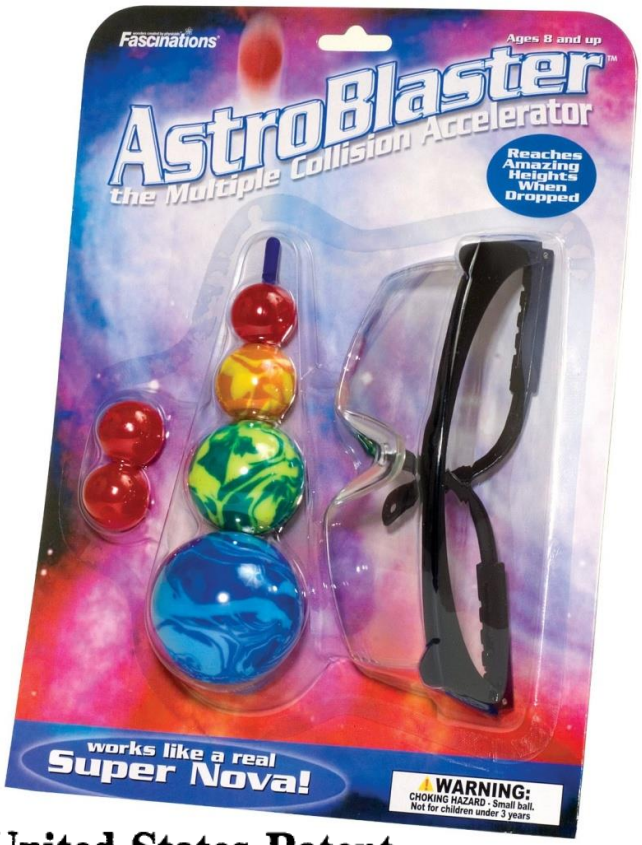
Stirling Colgate approached the storm in an attempt to fly his Cessna 210 close enough to fire small instrumentation rockets into the vortex to record pressure, temperature, electrical fields & ionization data.

Flying alone, at about 2,000 ft and to within about one mile of the tornado, Stirling fired two rockets (near misses), and suddenly found himself caught in a powerful inflow wind that was beginning to pull him backwards, tail first, into the tornado.

Luckily, he was able to drop to a lower elevation and into a weaker inflow. Suspecting tail damage, he managed to make an emergency landing. Neither pilot, nor plane, suffered structural damage.

http://www.stormtrack.org/archive/0565.htm

Stirling Colgate & the *AstroBlaster* Toy



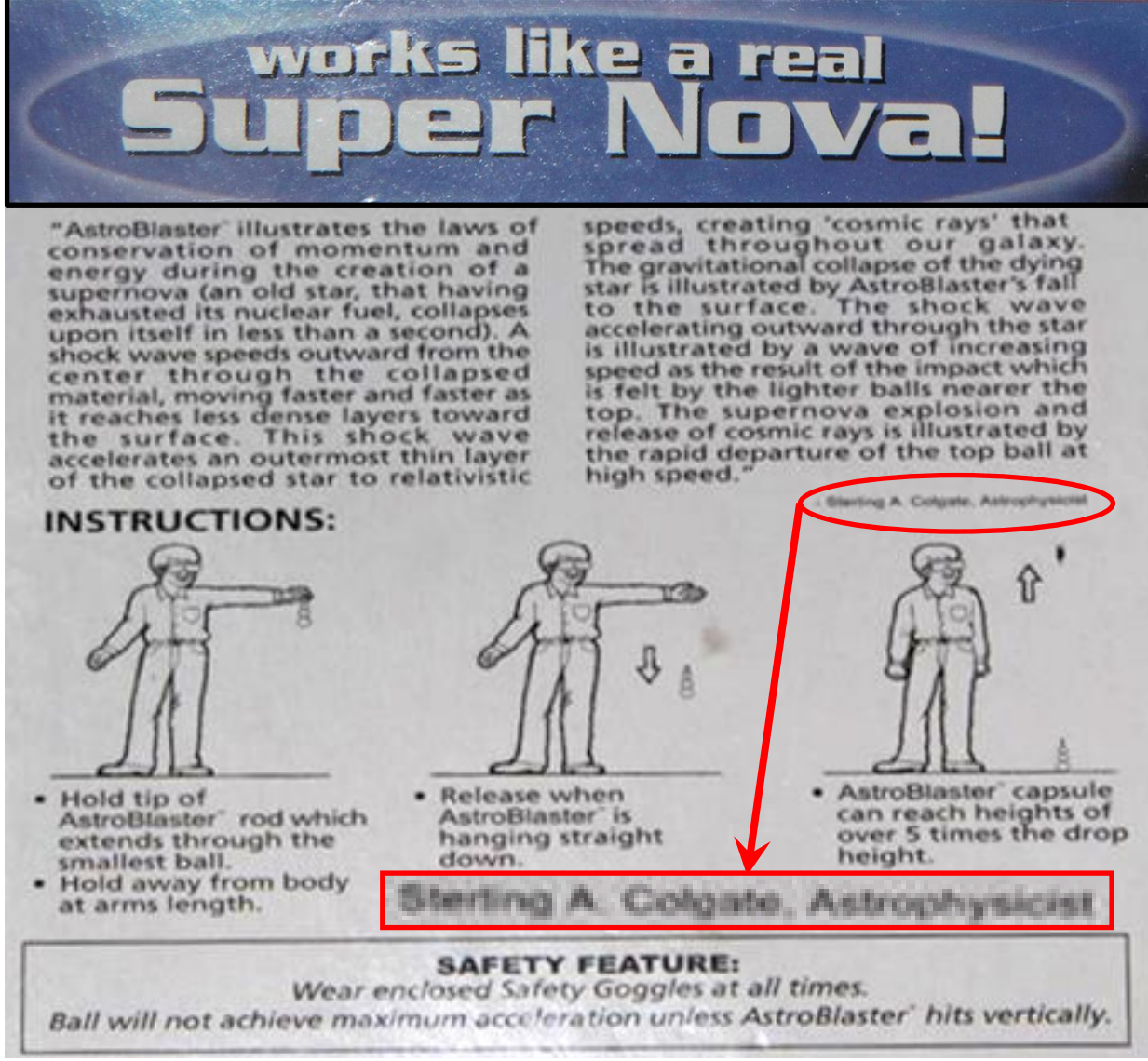
United States Patent

Hones et al. **Patent Number: 5,256,071**

Date of Patent: Oct. 26, 1993

MULTIPLE-COLLISION ACCELERATOR ASSEMBLY

Inventors: **Edward W. Hones**, 129 Monte Rey Dr., Los Alamos, N. Mex. 87544; **William G. Hones**, 17953 Marine View Dr., Seattle, Wash. 98166; **Stirling A. Colgate**, 422 Estante Way, Los Alamos, N. Mex. 87544



The idea for the *AstroBlaster* toy arose during a cocktail party discussion between Colgate and a father & son pair of physicists. They filed for a "*Multiple-Collision Accelerator Assembly*" patent in 1991 and the *AstroBlaster* appeared for sale soon after.

Colgate indicated that the toy was modeled on the dynamics of an exploding supernova and demonstrated the gravitational collapse and remarkable kinetic power associated of a dying star.

Since the top *AstroBlaster* ball is capable of rebounding over 5 times the height from which it was dropped, it was one of the first toys for children that came with a pair of safety glasses.

http://www.ebay.com/itm/Fascinations-Astro-Blaster-The-Multiple-Collision-Accelerator-Age-8-Super-Nova-/321278451047?pt=Educational_Toys_US&hash=item4acdb01d67