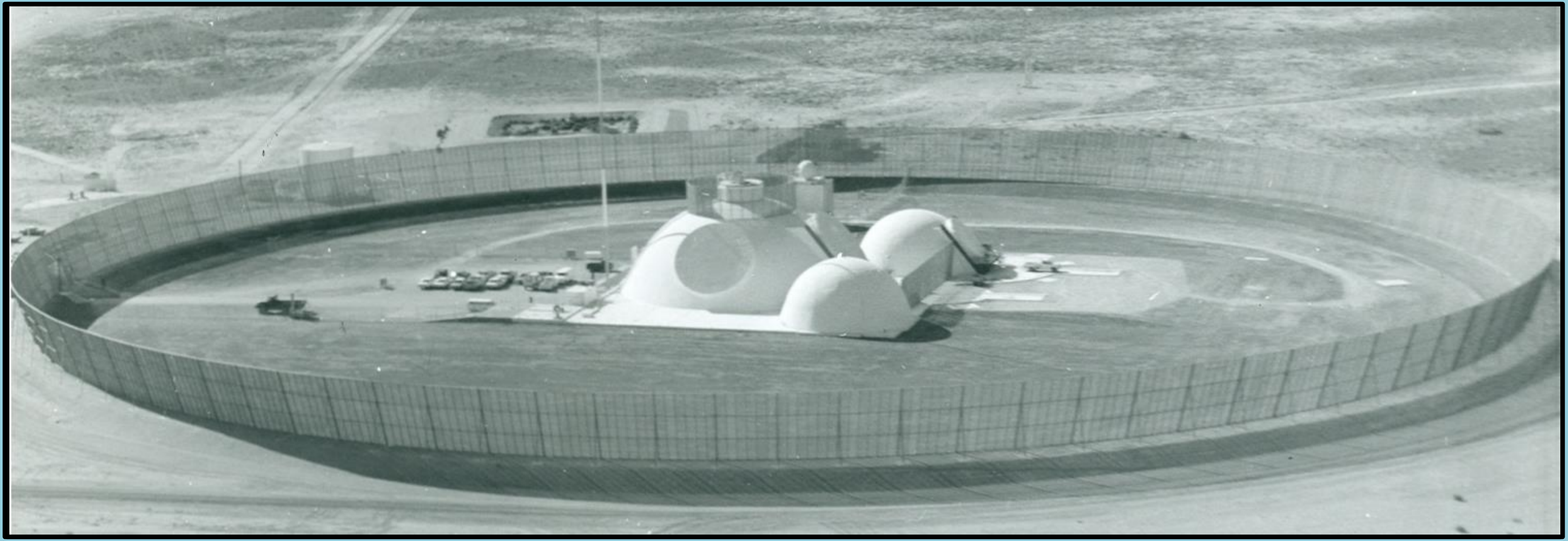
A Short History of the MAR-I



"Multifunction Array Radar"

Robert (Bob) Hayward
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Socorro, NM
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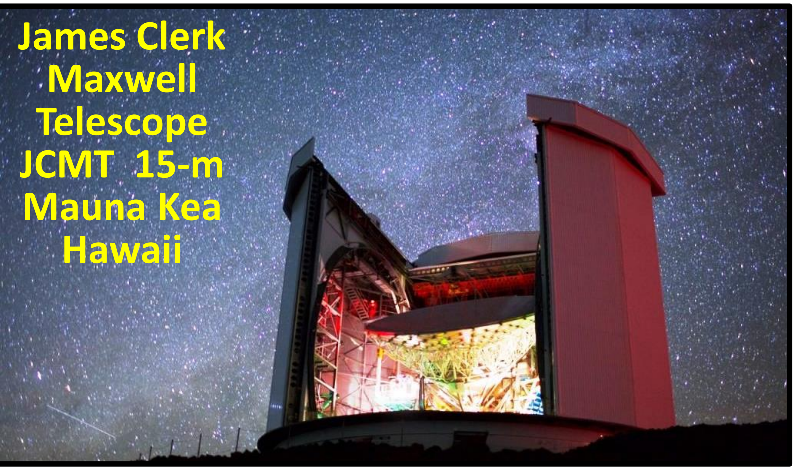
Albuquerque Chapter IEEE Dinner Talk – Wed May 22nd, 2019

https://www.army.mil/e2/c/images/2014/09/10/362075/size0.jpg

Queens University
MSc Radio Astronomy
1977-1979
&
NRC-HIA, Ottawa,
Assoc Research Officer
Astronomy Section
1979-1987

My 35 year career was in Radio Astronomy, not Radar.



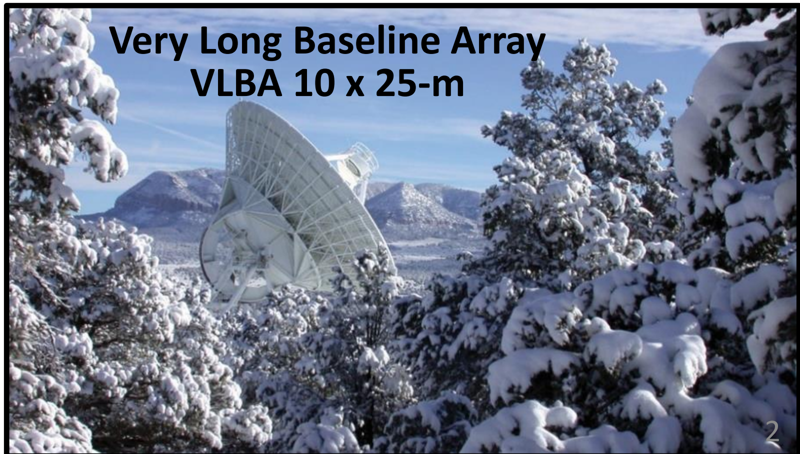
NRC-HIA, Ottawa
Senior Research Officer
JCMT Group
1987-1996

NRAO
Socorro, NM
Senior Engineer
1999-2012

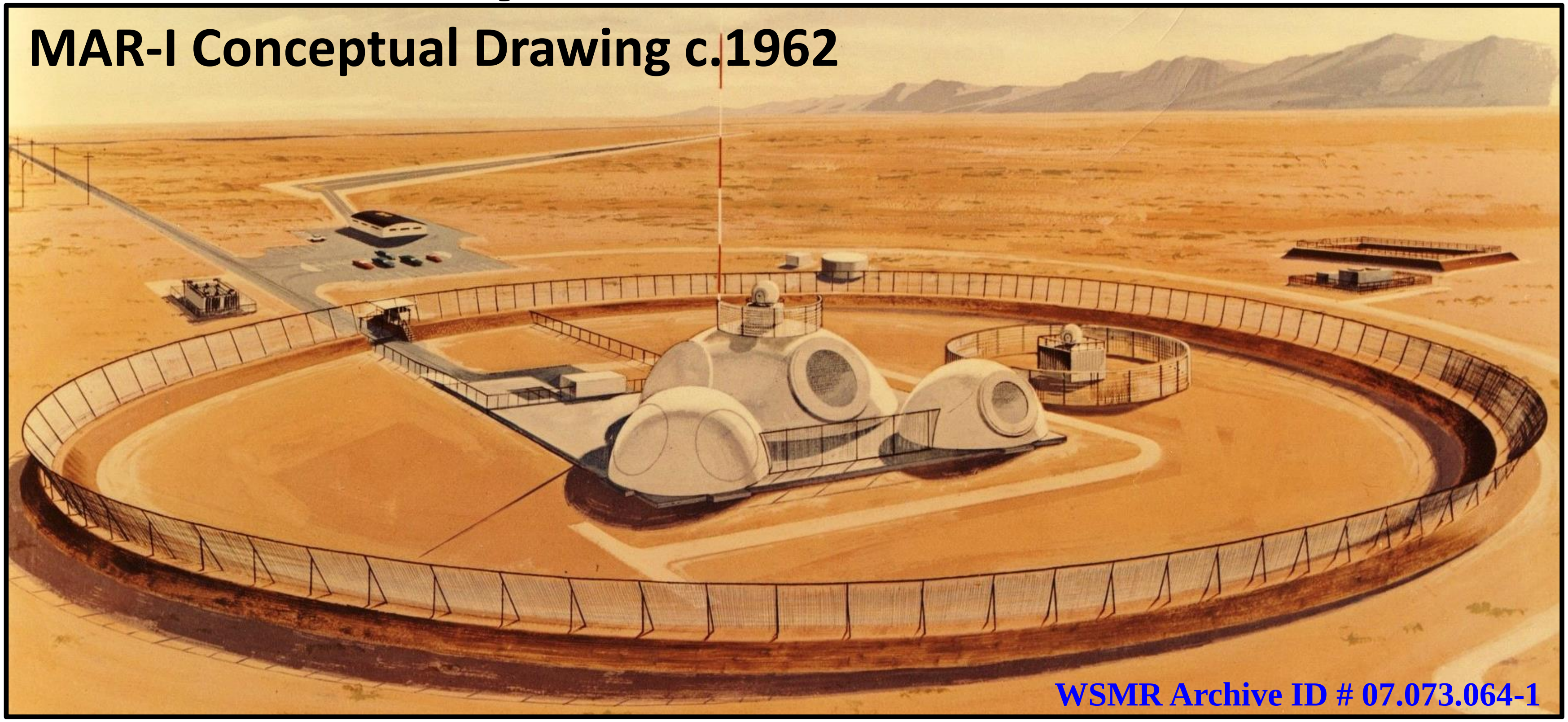
We look at radars with distain !!!

University of Arizona
Tucson, AZ
SMTO Chief Engineer
1996-1999

http://www.astro.ubc.ca/JAS/Robishaw2018_JasFest_History_of_Canadian_Radio_Astronomy_smaller.pdf
https://www.eaobservatory.org/jcmt/public/gallery/images/img_7441/
https://cdn.eso.org/images/screen/eso1229d.jpg
https://i.kinja-img.com/gawker-media/image/upload/19gdxtjn815uxjpg.jpg
http://heritage.stsci.edu/2012/47/images/VLAFox10-2009_300.jpg
http://lazytoad.com/jeep/gal-skies/toad-skies-6.jpg



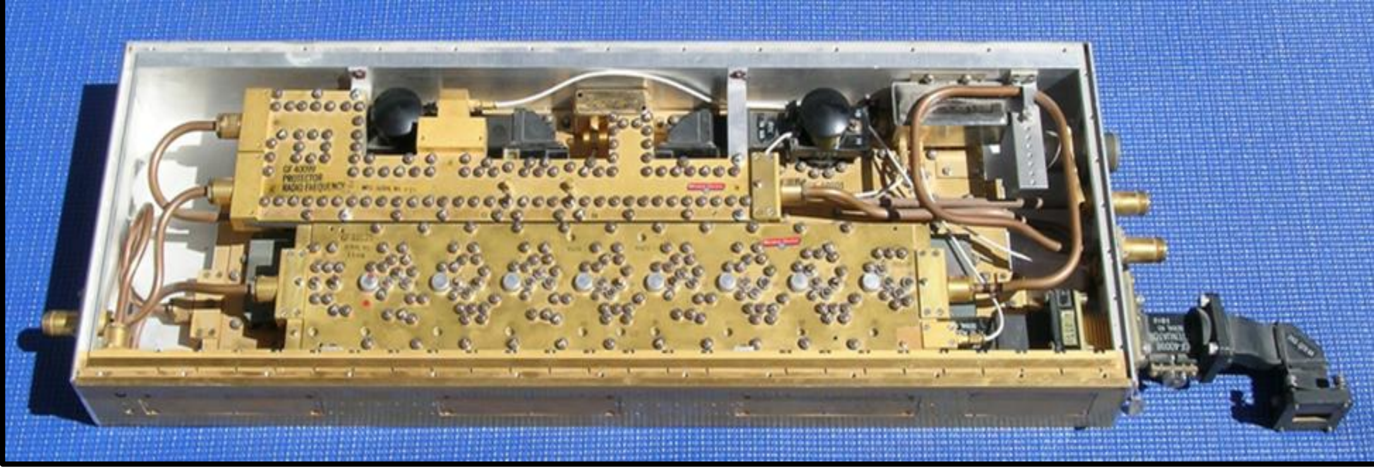
A Short History of the MAR-I : Talk Overview



- Introduction
- Cold War Radar Systems
  - ~~DEW Line~~
  - ~~BMEWS~~
  - Nike Ajax & Hercules
- Nike-Zeus
- Nike-X
  - MAR Concept
  - Multifunction Phased-Arrays
- MAR-I at WSMR
  - Construction
  - Critical Components
  - Guided Tour
  - Signal Paths & Interior Electronics
  - Timeline
  - Decommissioning & Salvage
- MAR-II, Safeguard & Soviet Don-2N
- What happened to the MAR site?
- The Colgate Paramp

There are over 600 slides in my "living document" on the MAR-I. Today's talk contains about 20% of them. Hence, this is "*a short history*"

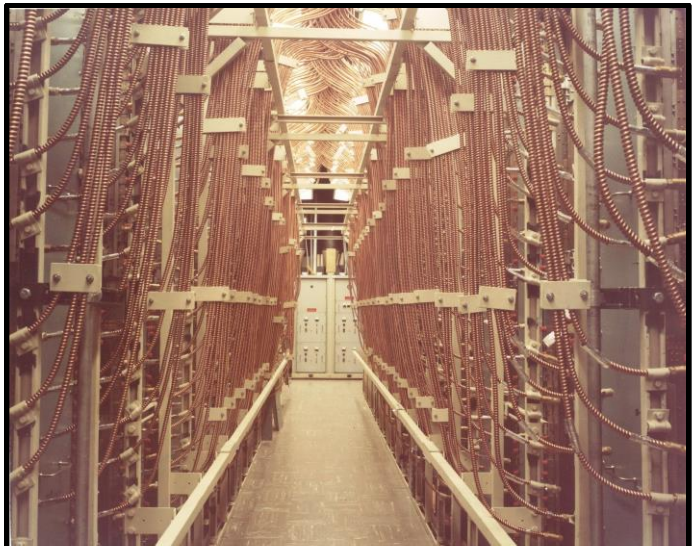
One of the over 2,000 MAR-I *Preamplifier Modules* which came to be known as "*Colgate Paramps*"



- My initial interest in the MAR-I began in 2009 when I first heard the story of how low-noise parametric amplifiers from a military radar ended up being used by radio astronomers.
- I then came across several pictures of this radar, the MAR-I, showing its triple white domes from the outside, and the endless lengths of RF cables on the inside.
- I soon became fascinated by the MAR-I itself and it's one-of-a-kind design. I have been attempting to uncover the history of this largely forgotten radar ever since.
- My journey culminated in a visit to the MAR Site (now HELSTF) in Oct 2016.
- Over the years I have presented a couple of talks about the "Colgate Paramps".

The talk tonight will emphasize the story of the MAR-I, rather than its Paramps.

Photos courtesy Doyle Piland, WSMR Archive



The Cold War
~
Living with "The Bomb" During the 1950s & 1960s

The Cold War Era & the Fear of the Bomb

"Cauliflower Clouds" over New York

Plate 32: "*Composite photograph roughly comparing the Test B cauliflower cloud with New York skyscrapers. An exact comparison would be even more extreme.*"

Perhaps the first depiction of an atom bomb attack on New York City.

From the book "*Bombs at Bikini – The Official Report of Operation Crossroads*" released by the U.S. Military in 1947.

Notice they use "*Cauliflower*" rather than "*Mushroom*" Cloud .

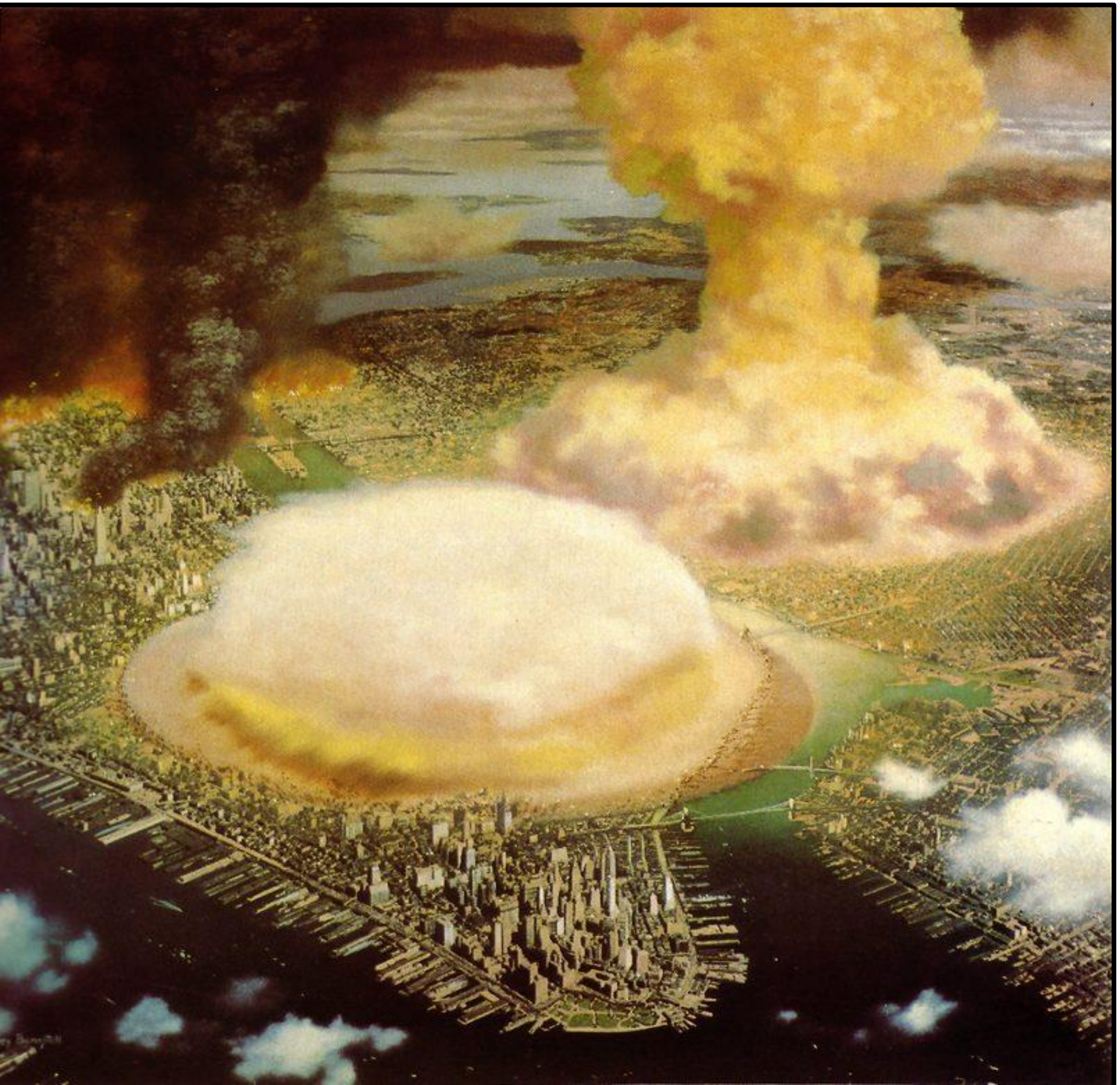
"*Operation Crossroads*" was a series of Atomic Bomb tests conducted by the U.S. at *Bikini Atoll* in July 1946 to investigate the effect of nuclear explosions on naval ships.
It was the first detonation of a nuclear device since the bombing of Hiroshima and Nagasaki in August 1945.

"*Crossroads*" consisted of two detonations, each with a yield of 23 kilotons of TNT. "*Able*" was detonated at an altitude of 520 feet on July 1st while "*Baker*" was detonated 90 feet underwater on July 25th.

Bombs at Bikini – The Official Report of Operation Crossroads, W.A. Shurcliff, Wm. H. Wise & Co., Inc., New York 1947, Plate 32

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*.

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

Gallop Poll on Nuclear War

The Lewiston Daily Sun

11 July 1956

GALLUP POLL

PUBLIC HAS NO DELUSIONS ON A NUCLEAR WAR

THE TIMID

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.

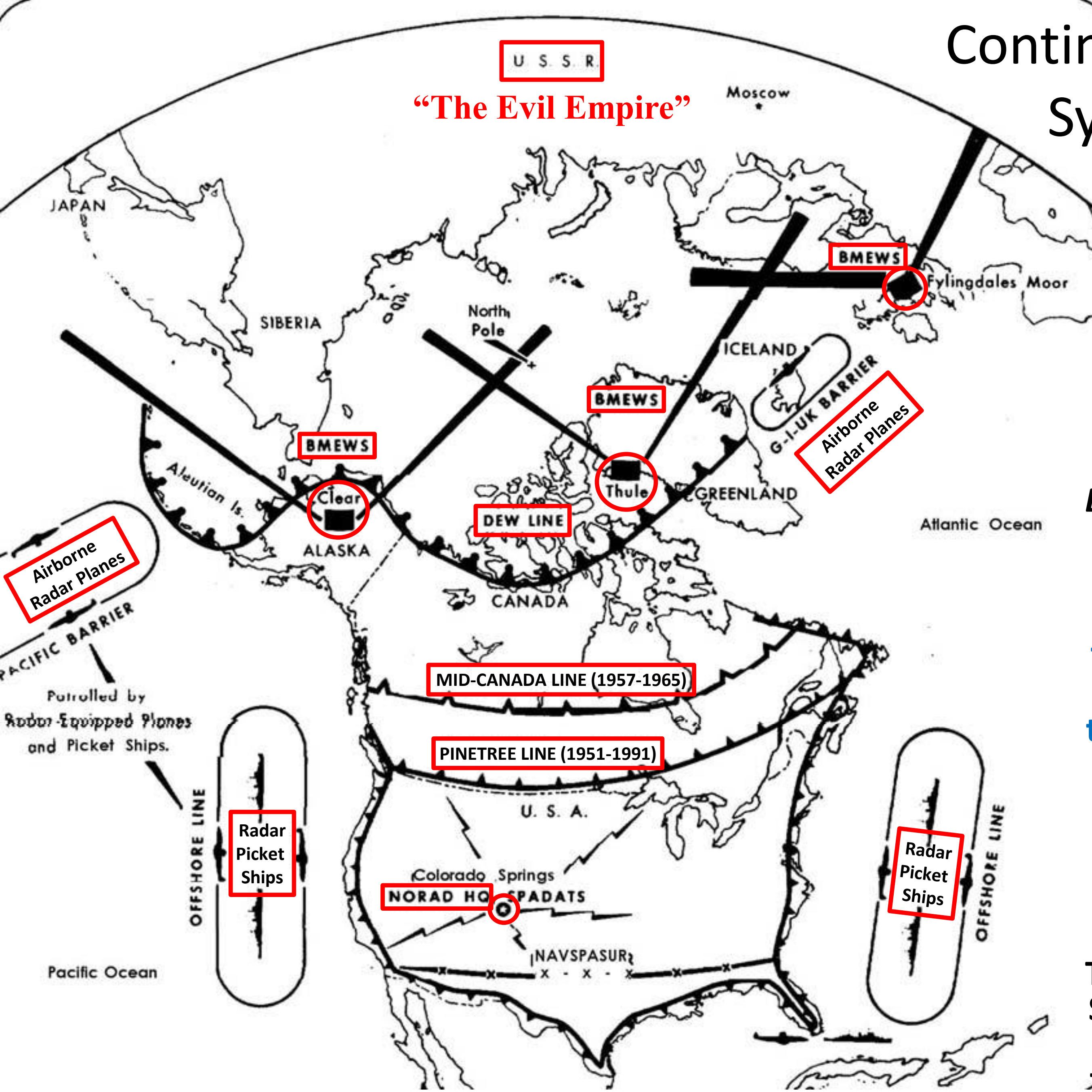
Five years ago, an Institute survey found that, in case of an all-out war with Russia, two out of every three Americans, or 66 per cent, would not be at all squeamish about using the Atom Bomb first, without waiting for it to be used on us. Nineteen per cent said it should be used only if Russia used 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

Continental Air Defense Systems c.1962



The Distant Early Warning (DEW) Line : A Bibliography and Documentary Resource List,
Prepared for the Arctic Institute of North America, P. W. Lackenbauer, M.J. Farish, J.Arthur-Lackenbauer, Oct 2005
http://pubs.aina.ucalgary.ca/aina/DEWLineBib.pdf

The U.S. implemented a layered network of *search radars* to provide early warning of any enemy nuclear attack.

To detect enemy bombers coming over the pole, the USAF requested the *Western Electric Company* to build the *Distant Early Warning* Line. The DEW Line became operational in 1957.

The DEW Line was a chain of 57 manned radar stations that stretched from Alaska to Greenland about 250 km above the Arctic Circle.

It provided up to 6 hours warning of a Soviet attack over the northern reaches.

This would allow time for the Strategic Air Command (SAC) to arm its bombers & get them into the air to deliver a retaliatory nuclear strike.

SIOP c.1964 *Single Integrated Operational Plan*

- **SIOP was the United States' general plan to wage a nuclear war.**
- **In 1963, the SAC had 1/3rd of its bombers & aerial tankers on constant alert (922 planes).**
  - **It also had 426 of its 631 ICBMs on alert in their silos.**
- **Bombers on ground alert were required to take off from their airbases in < 15 minutes.**
- **Planes sat at the end of their runways, armed with nuclear weapons, and crews stationed nearby ready to "scramble" on a moments notice when a klaxon sounded the alarm.**
- **As part of the "*Chrome Dome*" air alert, at least 12 B-52s were continuously in the air.**
  - **They would survive a first strike & could retaliate against targets deep within the Soviet Union.**
- **In 1964, the *National Security Council* estimated that if the Soviets carried out a first strike, some 400 Soviet weapons yielding about 2,500 megatons would be used, resulting in the deaths of about 93 million Americans.**
- **The American counterstrike with the forces on alert - consisting of 2,071 delivery vehicles carrying 3,976 megatons - would result in 140 million deaths in the Soviet Bloc.**
- **This was indeed the era of "*Dr. Stangelove*", where the gruesome math of World War III was calculated in terms of megatons and megadeaths.**

http://heroicrelics.org/info/b-47/b-47-jato/061024-F-1234S-011.jpg & http://av8r.yolasite.com/1969.php
From *"15 Minutes - General Curtis LeMay and the Countdown to Nuclear Annihilation"*, L.D. Keeney, St. Martin's Press, 2011

Several Notable
Cold War Defense Projects:

Nike-Ajax & Nike-Hercules
Anti-Aircraft System

Ring of Supersonic Steel

The *Nike-Ajax* Anti-Aircraft Missile System

The U.S. Army rushed the radar controlled *Nike-Ajax* system into production between 1954 & 1958.
The *Nike-Ajax* anti-missile had a range of 25 miles & a top speed of nearly 1,500 mph.

***Nike-Ajax* was designed by the *Bell Labs* while the *Western Electric* was the primary contractor.**
A total of 265 *Nike-Ajax* missile batteries were deployed around key urban, military, and industrial locations.
The Chicago area was protected by 23 sites & more than 600 missiles.
The San Francisco Bay area was protected by 12 sites, and Washington by 13. Metropolitan New York was defended by a total of 19 batteries.

The Lorton, VA, battery of 24 missiles in 1956. The group of 4 in the vertical position are in firing position.
In 1954, this base was one of the first *Nike-Ajax* installations and was known as the "*National Nike Site*".
Converted to *Nike-Hercules* missiles in 1959, it operated until 1974 before being closed.

http://wikimapia.org/495091/W-64L-Nike-Missile-launch-area-site-Cold-War-Museum
http://lortonheritagesociety.org/docs/LortonHistory-NikeSite.pdf

Nike-Hercules Anti-Aircraft Missile System

As the *Nike-Ajax* was being deployed, the Army determined that it would be inadequate to stop a massed attack of high-speed Soviet jet bombers at high altitude. Thus a faster missile with a bigger payload was developed. The *Nike-Hercules* was fitted with a nuclear warhead that offered yields of 2, 10, 20 or 30 kt.

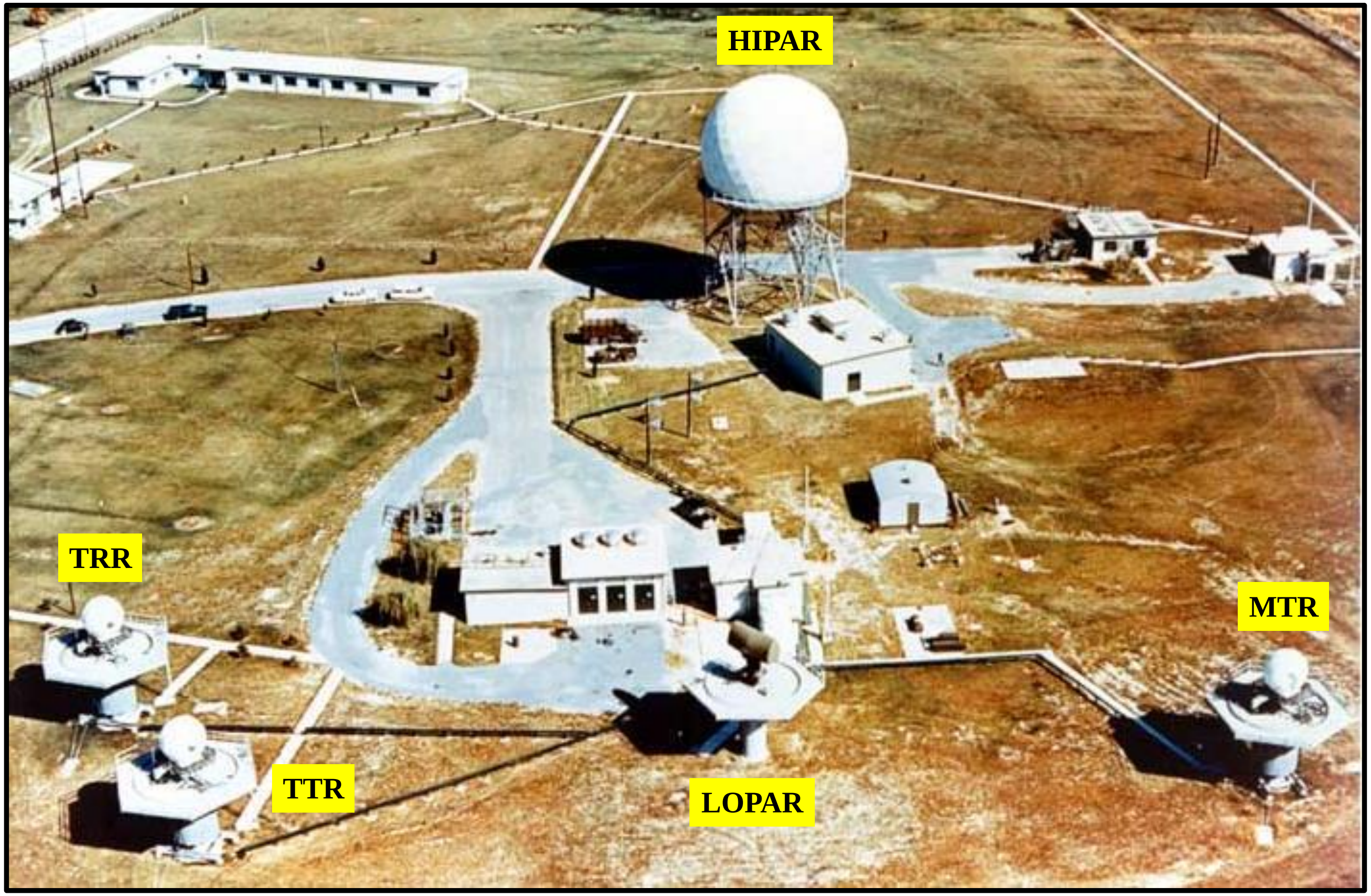
The Army deployed 145 *Nike-Hercules* batteries, 110 of which were converted *Nike-Ajax* installations.
This 2nd generation missile began to be deployed in 1958 and reached its peak in 1963.
It had a range of about 100 miles and a top speed of 3,000 mph.

***Nike-Hercules* missiles at the Sausalito SF-88 battery protecting the San Francisco Bay Area c.1959.**
The missiles are photogenically arrayed in various stages of elevation into firing position.
The site operated 12 *Nike-Hercules* missiles from 1958 to 1974.

http://nikemissile.org/ColdWar/whatwehave/

The Five Radars of the Nike-Hercules System

The *Integrated Fire Control* area contained the radars & computers for a *Nike-Hercules* battery.



The large white dome housed the early warning *High Power Acquisition Radar* (HIPAR).
At the lower center is the *Low Power Acquisition Radar* (LOPAR) originally built for *Nike-Ajax*.
The *Target Tracking Radar* (TTR) and *Target Range Radar* (TRR) followed the enemy bomber.
The *Missile Tracking Radar* (MTR) guides the missile to the interception point.
During the 1950s, over 700 *Nike-Ajax* missiles were test launched from the *White Sands Missile Range* (WSMR), and more than *400 Nike-Hercules* missiles were from 1955-1967.

http://nikemissile.org/nike_herc_46.jpg
http://en.wikipedia.org/wiki/File:Nike_Hercules_Integrated_Fire_Control_area.jpg

Nike-Zeus
Anti-Ballistic Missile System

Ballistic Missile Defense

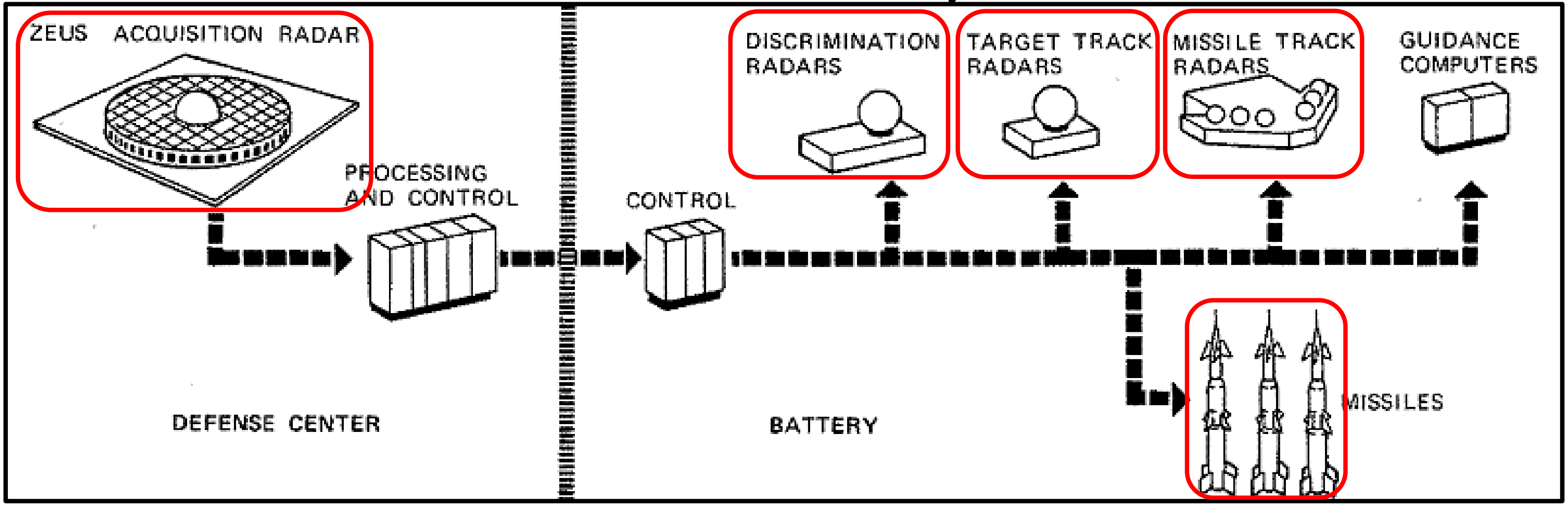
Shooting One Bullet Out of the Air with Another Bullet

- **One estimate of the total air defense expenditure over the 1945 to 1961 period (which includes the DEW Line, BMEWS, Nike, BOMARC, SAGE, etc.) was about $30 billion in then-year dollars (or about $300 billion today).**
  - **Thus the scale of the effort invested in early warning & protecting the nation from invading aircraft was comparable to the Project Apollo.**
- **However, this Cold War threat was soon replaced by the *Intercontinental Ballistic Missile* (ICBM).**
- **A warhead launched against the U.S. by an ICBM was much more difficult to detect than an enemy bomber since it was much smaller & would be travelling at nearly 16,000 mph.**
- **Launched from a Russian silo some 5,000 miles away, the total flight time to its target in the U.S. would be roughly 30 minutes.**
- **In the late 1950s & early 1960s the U.S. Army soon began development of the *Nike-Zeus Anti-Ballistic Missile* (ABM).**
  - **When deployed, it would only 4 minutes between the time the enemy warhead was first detected and the firing of the Zeus interceptor missile.**
  - **Should the intercept fail, a deadly mushroom cloud would appear over an American city.**

The Soviet SS-18 "*Satan*" is the largest ICBM in history.

***Atomic Audit - The Costs & Consequences of US Nuclear Weapons Since 1940*, Editor, S. Schuartz, Brookings Institution1 Press, 1998**
http://en.wikipedia.org/wiki/File:Dnepr_rocket_lift-off_1.jpg

The *Nike-Zeus* System



In 1956, the US Army initiated work on the *Nike-Zeus* ABM to protect large urban areas. *Western Electric* was the prime contractor while *Bell Labs* was in charge of its overall design.

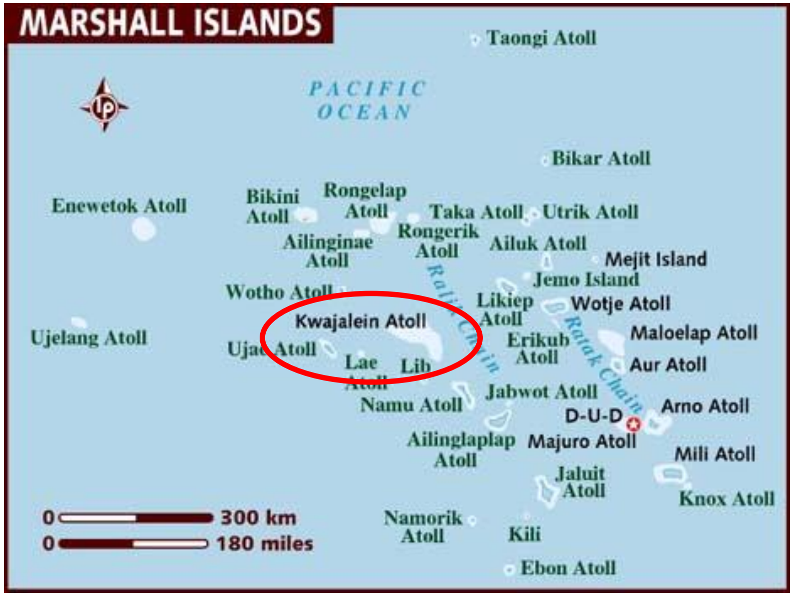
The long-range *Zeus Acquisition Radar* (ZAR) would search for incoming ICBMs at distances of up to 1,500 miles and provide advance warning of which regions were under attack. The ZAR was the biggest, most expensive, and most critical element of the Zeus ABM system.

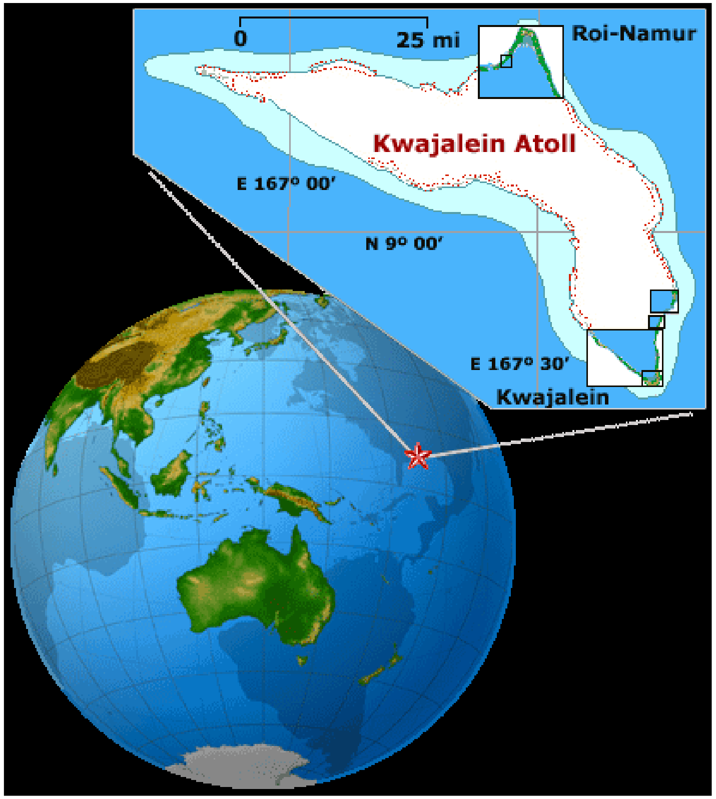
The incoming warheads were then tracked by the *Discrimination Radar* (DR) and it would sort out which of the targets were warheads & which were decoys or debris.

Once identified, *Target Track Radars* (TTRs) would lock on to the enemy warheads. *Nike-Zeus* missiles, carrying 400 Kiloton warheads, would be launched to intercept them. They were guided to their targets by the *Missile Track Radars* (MTRs) over a radio link.

ABM Research &Development at Bell Laboratories – Project History, Oct 1975, pg. 1-3 at http://www.alternatewars.com/WW3/WW3_Documents/ABM_Bell/ABM_Ch1.htm
A History Of Missile Defense at http://www.vectorsite.net/twabm_1.html#m1

Kwajalein Atoll





http://ournutshelllife.blogspot.com/2009/03/kwajalein-quadulan-kwaj.html
http://en.wikipedia.org/wiki/Kwajalein_Atoll
Google Earth

Nike-Zeus on Kwajalein

The second *Nike-Zeus* prototype was constructed on Kwajalein Island in the middle of the Pacific Ocean.

The huge ZAR *Transmitter* and *Receiver* can be seen to the left of the runway towards the top end.

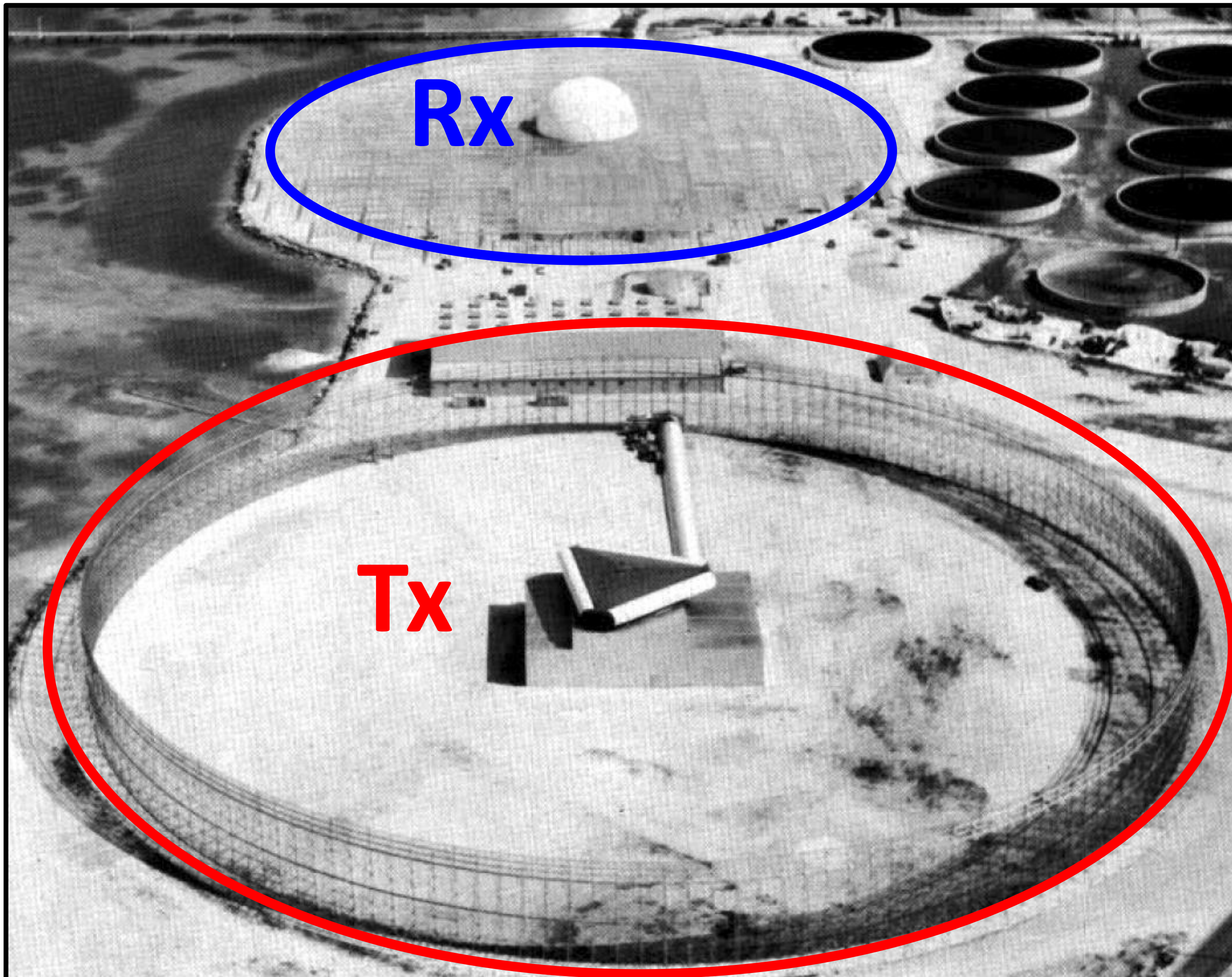
The *Discrimination Radar* (DR), inside its double layered clutter fence, is at the lower center, with the smaller *Target & Missile Track Radars (*TTR & MTR) to its right.

The Kwajalein ZAR received its first radar signal returns from an ICBM test firing in January 1962.

http://www.williamson-labs.com/kwaja.htm

Zeus Acquisition Radar (ZAR) - Kwajalein, c.1962

The *ZAR Receiver* consisted of a rotating hemispherical 80-ft diameter Luneburg Lens inside a 120-ft radome with a 600-ft wide ground plane.

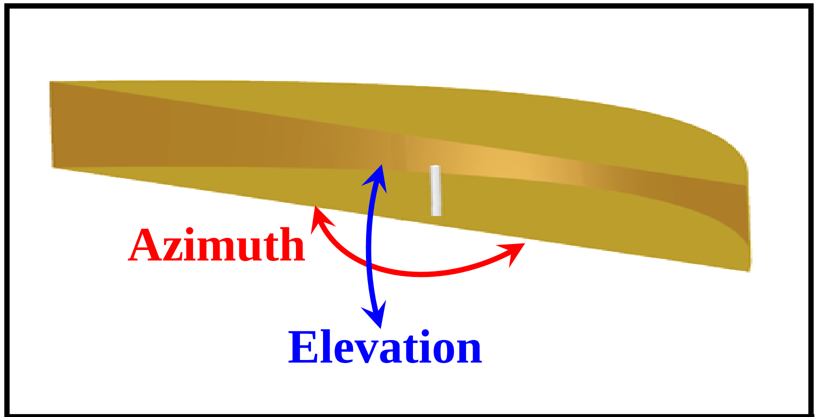


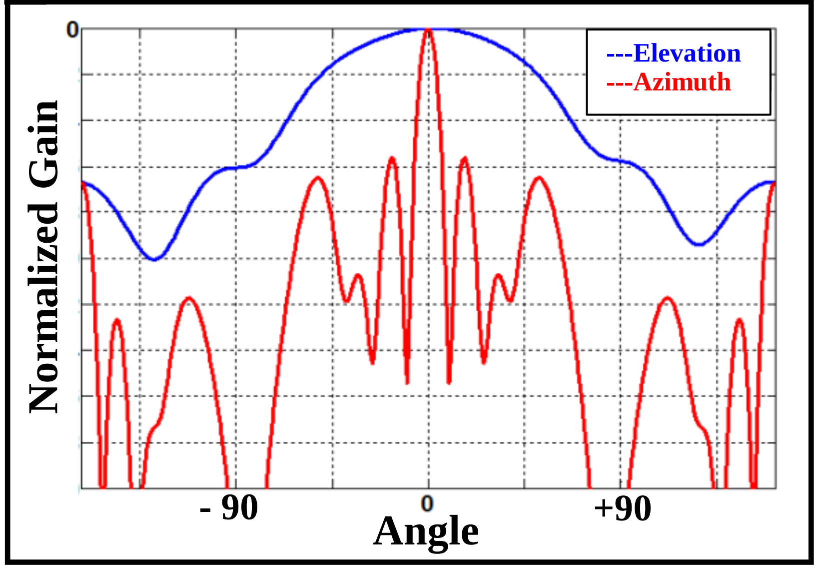
The ZAR swept the sky with 3 radar beams spaced in azimuth by 120 degrees apart, covering the entire sky every 6 seconds.

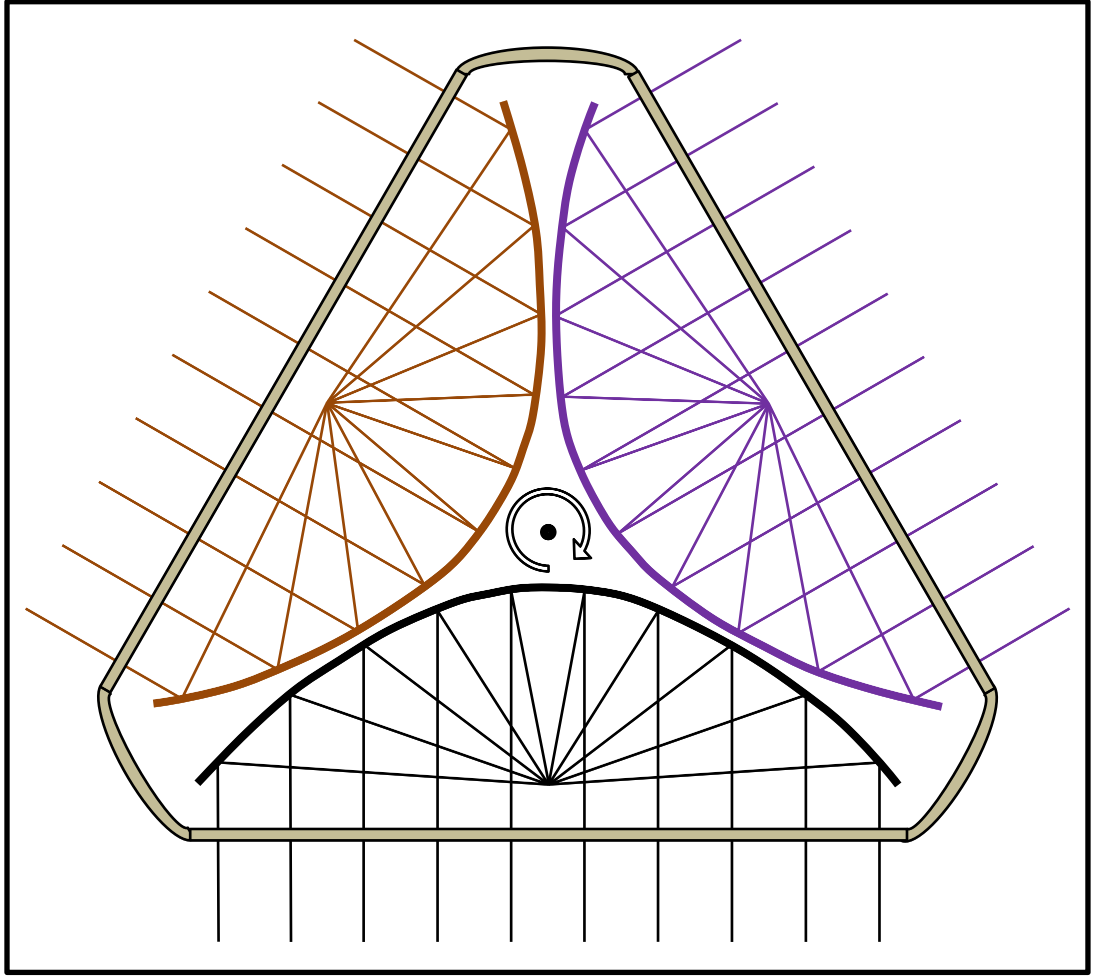
The ZAR *Transmitter (*Tx) was enclosed by a 90-ft high, 660-ft wide *Beam Forming Fence* to reduce radar "*clutter*" returns, and to protect staff from the high-power megawatt emissions. The triangular Tx had 3 x 80-ft long antennas which co-rotated with the ZAR Rx.

http://www.freerepublic.com/focus/f-news/1561713/posts

The ZAR Transmitting Antenna







The ZAR Transmitter consisted of 3 "*pillbox*" antennas.
The 3D model at the upper left shows why it is often referred to as a "*cheese*" antenna.

Since this type of antenna aperture is much longer than it is high, it has a very narrow beam in azimuth while the beam in elevation is considerably broader, as shown in the graph of a representative pillbox beam profile.
Each ZAR pillbox was 80-ft long by 2.5-ft high with a beamwidth of 0.9º in azimuth and 70º in elevation.

The Transmitter had a peak output power of 10 MW.
With 3 tightly packed pillboxes, the ZAR Transmitter radiated 3 beams separated in azimuth by 120 degrees.

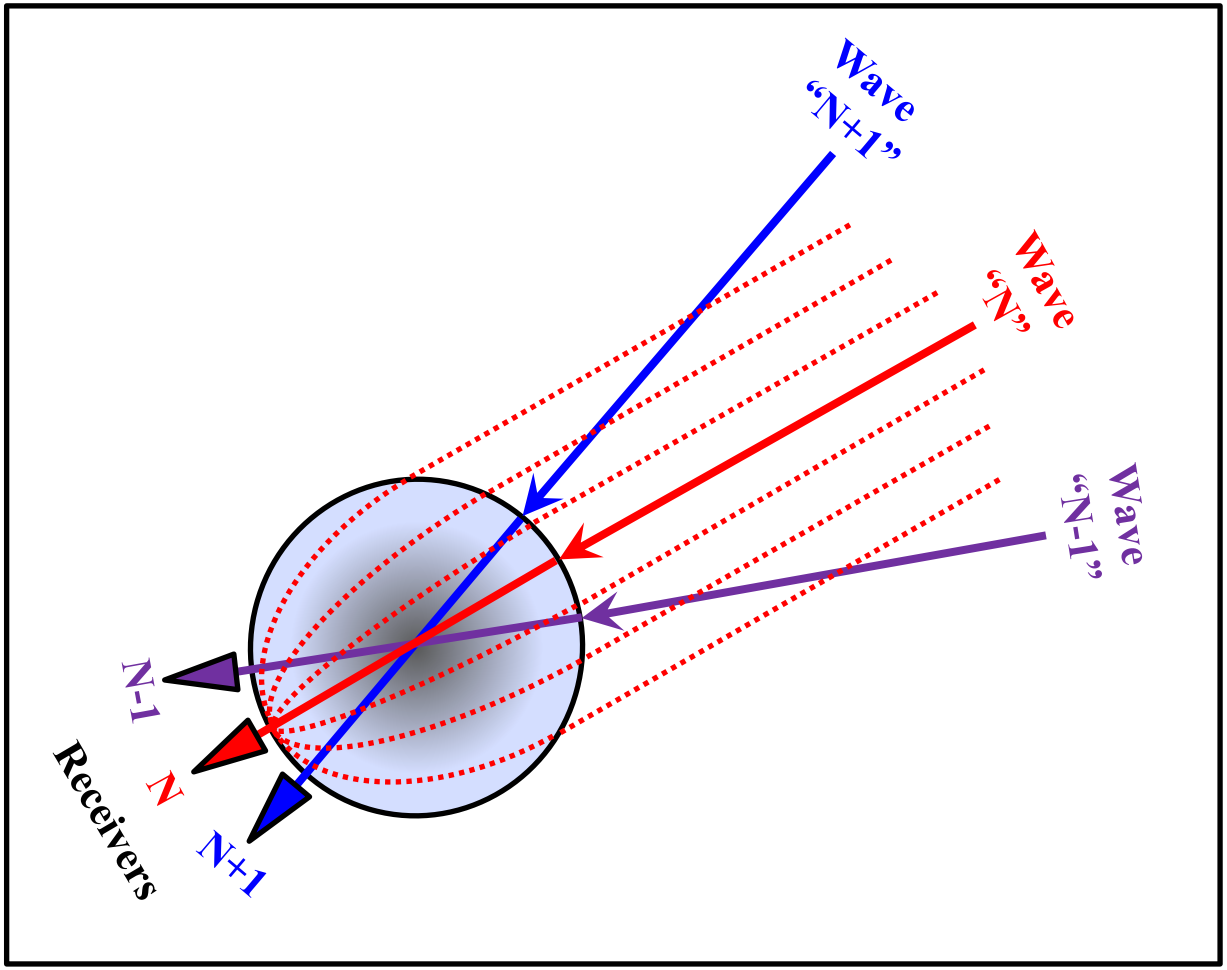
http://www.patternmagus.com/database/patterns/pattern_page.php?dir=19

21

The Spherical Luneburg Lens

The *Luneburg Lens* has the property that a plane wave will be focused at a point on the opposite side the sphere.

The basic principle of the "*variable dielectric spherical lens*" is credited to Rudolf Luneburg in 1944.
Ideally, the dielectric constant of the lens material must increase from 1 at its surface to 2 at its center.



Thus it is possible for multiple signals to be received simply by placing more receivers on the sphere's periphery.

The ZAR exploited this concept with 3 stacks of 77 receivers, for a total of 231 receivers.
Used in a radar, an array of vertically stacked receivers can determine a target's position in both elevation (depending on which horn in the vertical fan beam sees the echo) and in azimuth (by rotating the antenna).

Introduction to Radar Systems, M. Skolnik, McGraw-Hill 1963

ZAR Beam Patterns

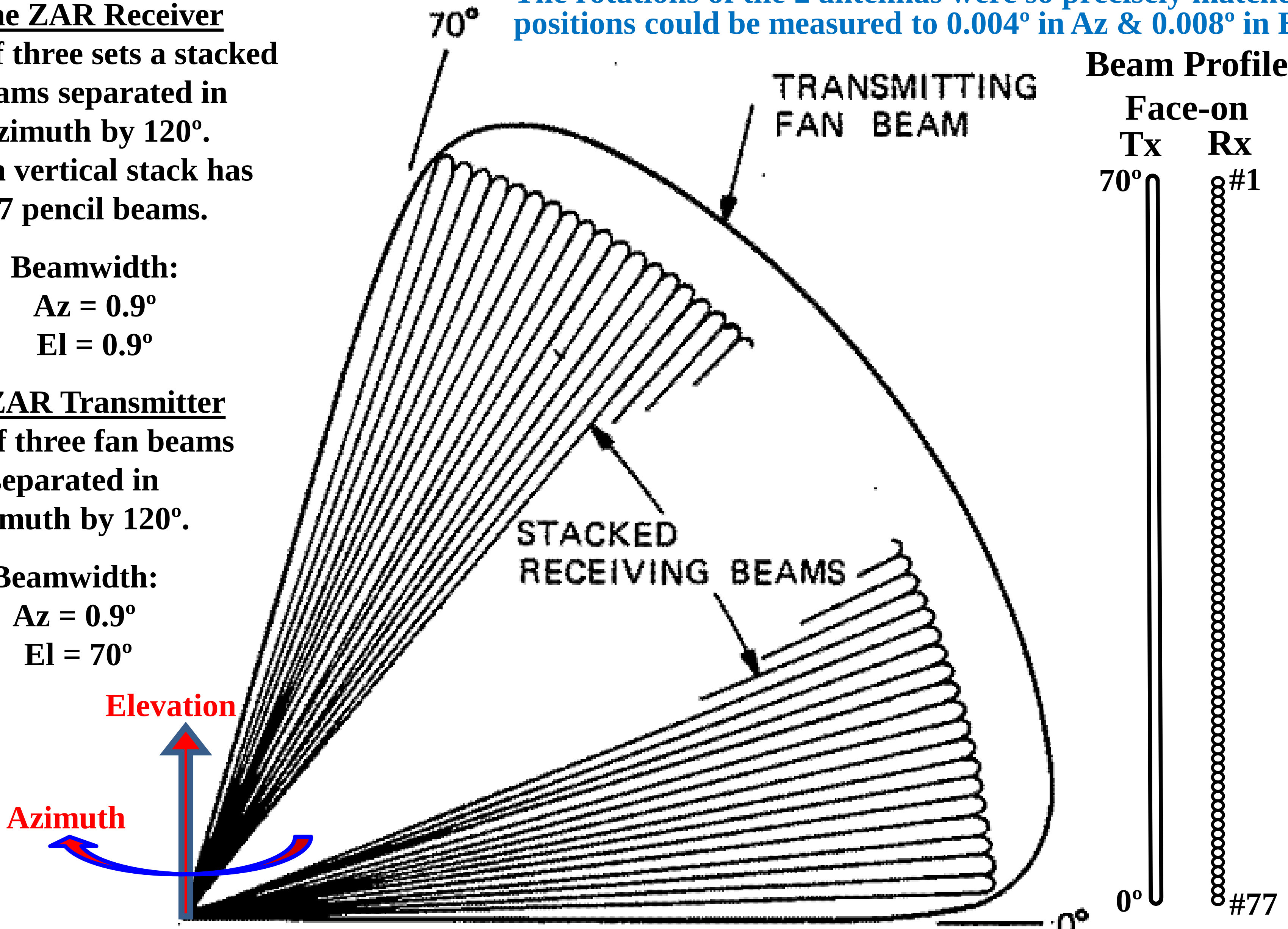
Since the Rx antenna was slaved to the 3⅓ rpm rotation of the Tx antenna, it swept the sky with essentially full hemispherical coverage once every 6 seconds.
The rotations of the 2 antennas were so precisely matched, positions could be measured to 0.004º in Az & 0.008º in El.

The ZAR Receiver
One of three sets a stacked beams separated in azimuth by 120º.
Each vertical stack has 77 pencil beams.

Beamwidth:
Az = 0.9º
El = 0.9º

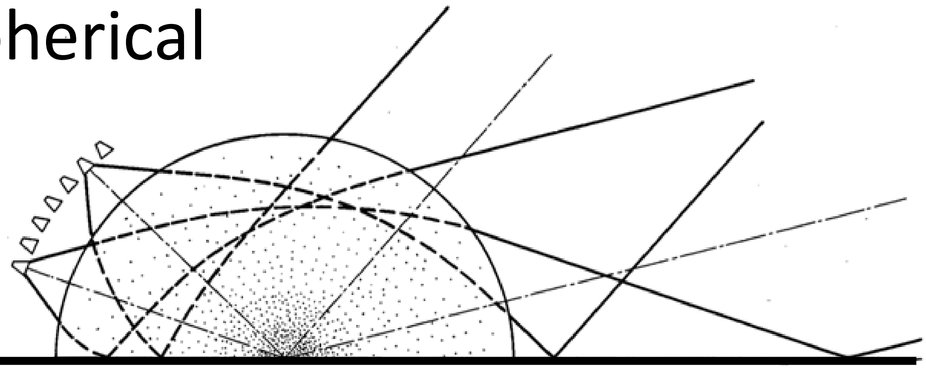
The ZAR Transmitter
One of three fan beams separated in azimuth by 120º.

Beamwidth:
Az = 0.9º
El = 70º



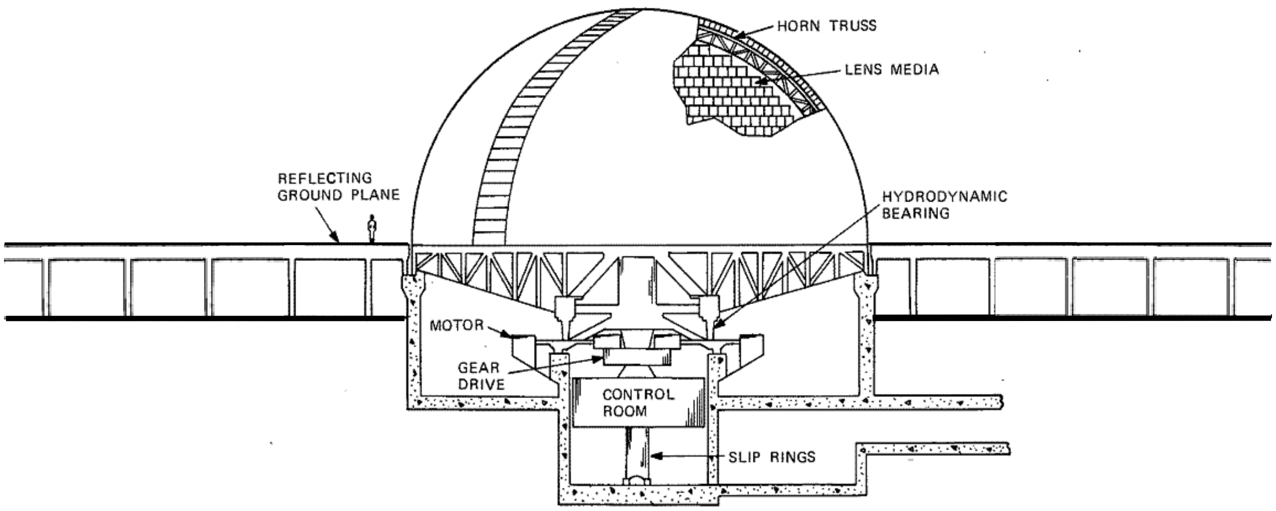
ABM Research &Development at Bell Laboratories – Project History, Oct 1975, pg. I-8 & 1-8

The Hemispherical *Luneburg Lens* at Kwajalein



Incoming signals are reflected by the ground plane & focused by the dielectric lens to horns on the opposite side of the lens.

The horns look down, rather than up. This scheme eliminated the bottom half of the lens, thus reducing the amount of costly dielectric material needed.



Cutaway view of the ZAR Rx antenna built showing the reflecting ground plane, and one of the three horn trusses.

There were 77 vertically stacked horns mounted on 3 trusses spaced 120º apart producing 231 pencil beams on the sky.

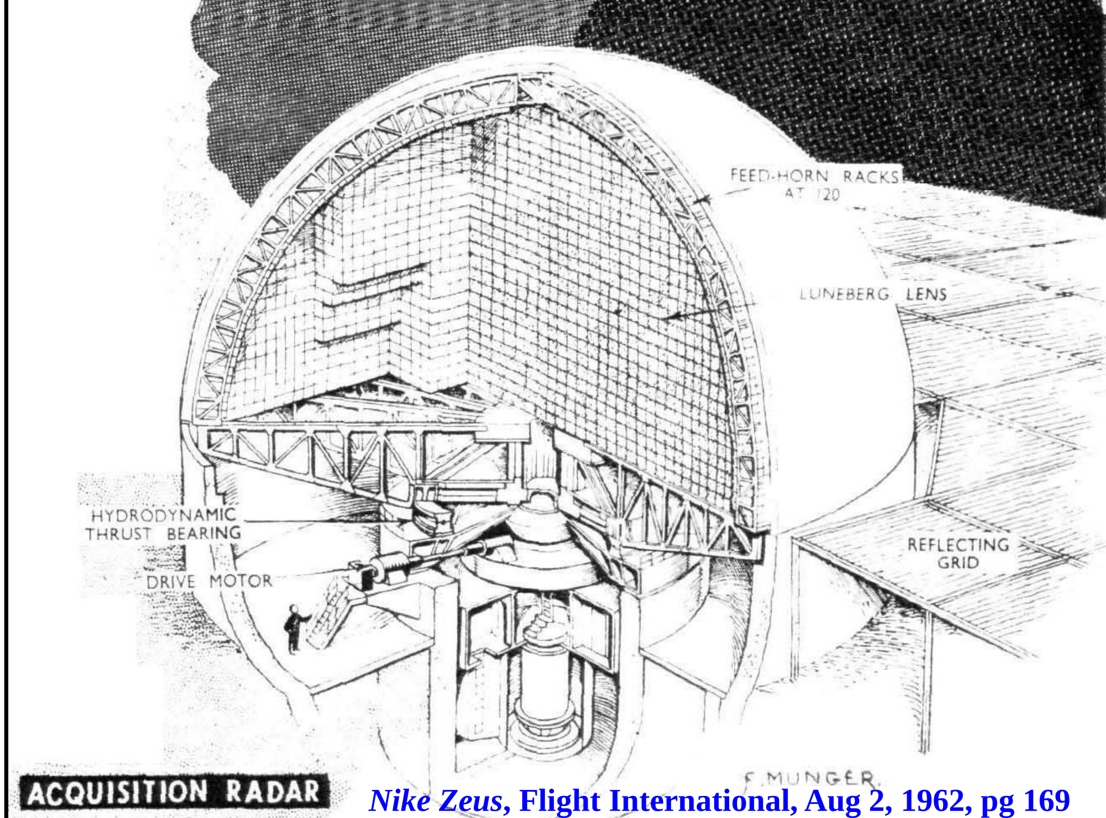
Each beam had a system noise temperature of about 720°K.

The profile view of the entire ZAR Receiver antenna showing the 120-ft white radome enclosing the 80-ft hemispherical Luneburg Lens, as well as the 600-ft diameter elevated reflecting ground plan.

The Kwajalein ZAR Receiver

The lens consisted of 34,484 expanded-beam polystyrene foam blocks, molded into 18”x18”x18” cubes, weighing 2,800,000 lbs.

Each block was impregnated with a precisely controlled amount of 3/8” long randomly oriented aluminum slivers. Varying the concentration allowed the dielectric constant of the foam lens to be changed from unity at the surface to 2 at its center.



Nike Zeus, Flight International, Aug 2, 1962, pg 169

Nike-Zeus Summary:

- **The first successful interception of an ICBM launched from California occurred in Dec 1962. The Zeus missile came within 600 ft of the Atlas nosecone – an acceptable “miss distance”.**
  - **There were 13 live-intercept tests - 9 were successful, 3 were partially successful.**
- **Deploying Nike-Zeus would have cost \$10 to \$15 billion (\$80 B to \$120B today).**
- **In January 1963, the high projected cost, among other concerns, led to the decision by Secretary of Defense, Robert McNamara, to cancel the *Nike-Zeus* project.**
- **However, the ZAR is still considered a high-performance radar with an unprecedented search capability. As summarized in the project history “*ABM R&D at Bell Laboratories*”…**
  - **“the ZAR represented the most efficient wired-logic system for detection…ever developed. Its stacked-array receivers on three rotating arms also provided the highest data rate…yet achieved, and is not matched even by today's phased-array systems.”**

The Nike-X "MAR-I"

Multifunction Array Radar

at the *White Sands Missile Range*

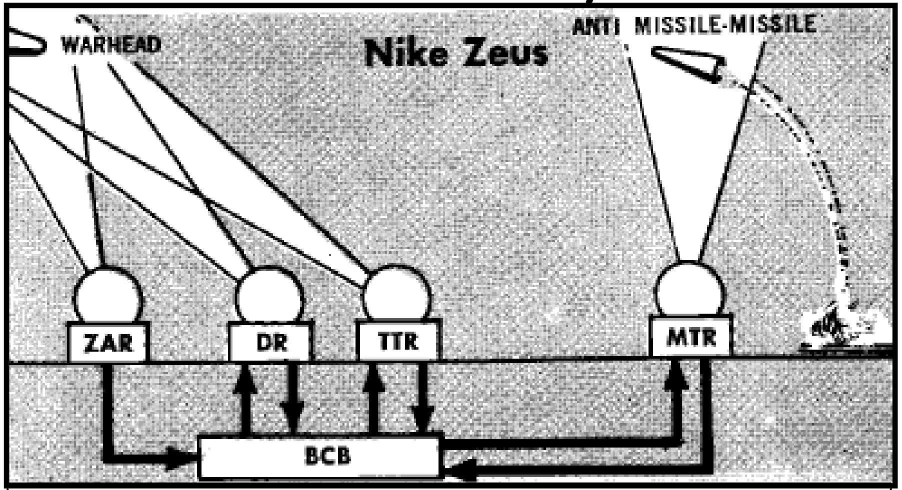
Introduction

&

How was this radar so different from earlier long-range radars?

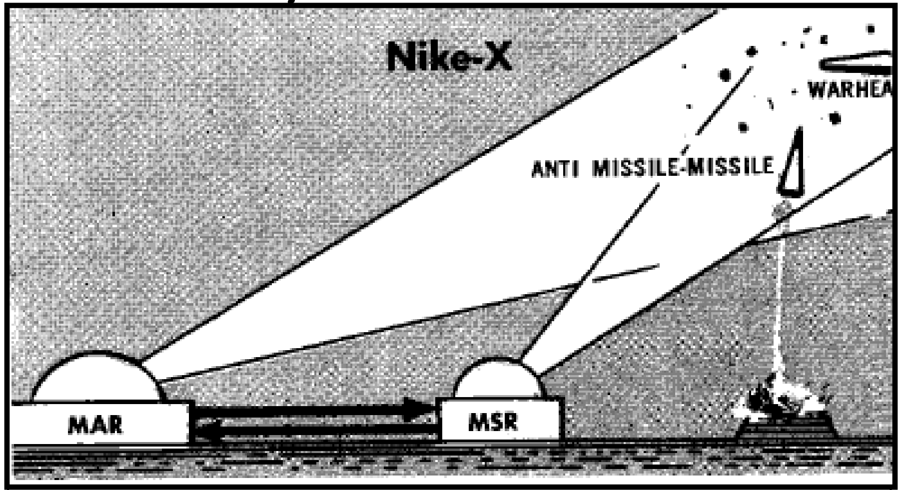
Nike-Zeus vs. Nike-X ABM Concepts

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
The less capable MSR would augment the more powerful & costly MAR.

Tests of the *Nike-Zeus* system had shown that it would have been impractical for it to track a large number of separate targets because of its mechanically steered radars.
If the USSR launched enough ICBMs, their simultaneous arrival would saturate the system.

Nike-Zeus

After *Nike-Zeus* was cancelled in January 1963, work began on a greatly improved system, called *Nike-X,* that utilized an electronically-steered radar that could replace all 4 of the mechanically-steered radar systems used in *Nike-Zeus.*

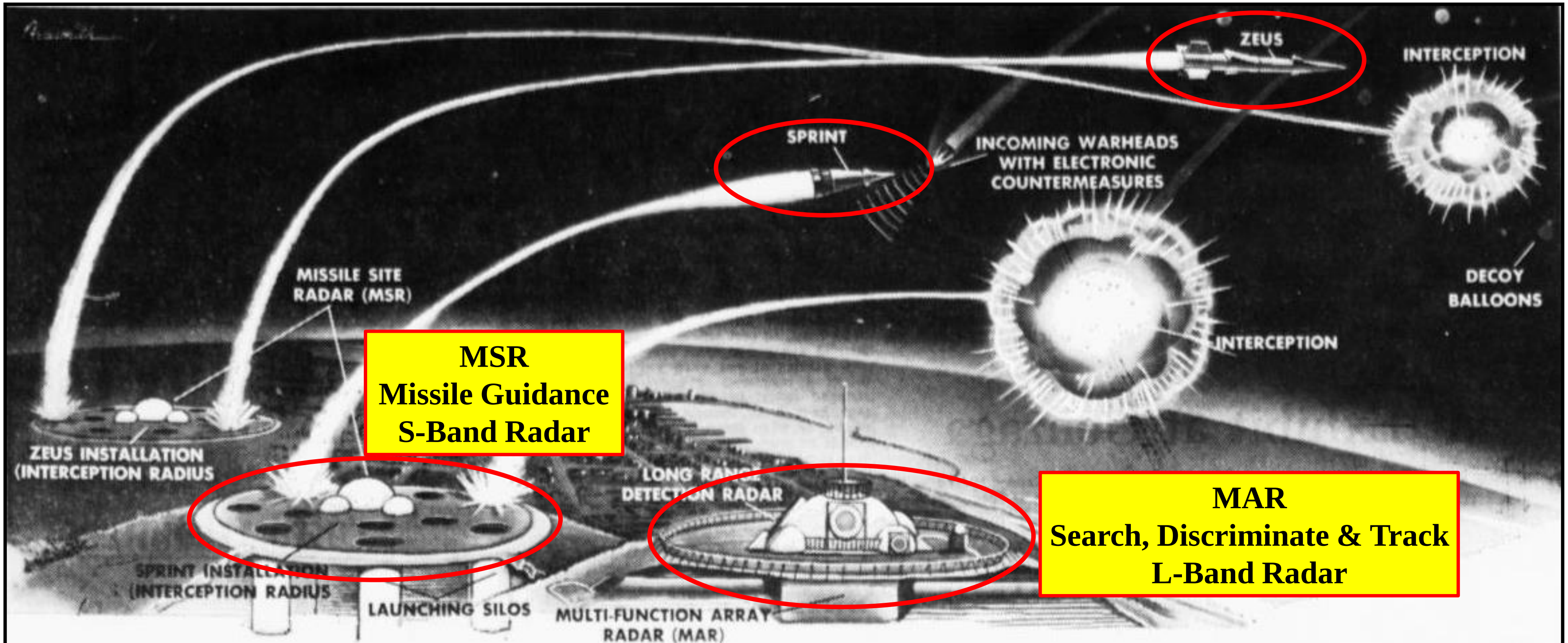
It would be able to track many more targets and it would be able to withstand the blast of a nuclear explosion.

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

Nike-X

The *Nike-X* Anti-Ballistic Missile (ABM) Defense Concept of the Mid 1960s

"*Nike*" was the Greek Goddess of Victory.



The long-range *Zeus* (later *Spartan*) missile had a range of over 700 km & carried a W-71 thermonuclear weapon with a 5 megaton yield.

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

The terminal defense *Sprint* missile had a range of 40 km and was armed with a W-66 enhanced radiation nuclear warhead with a yield of a few kilotons.

It accelerated at over 100 G's, reaching a speed of 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

The *Multifunction Array Radar* (MAR-I) at WSMR

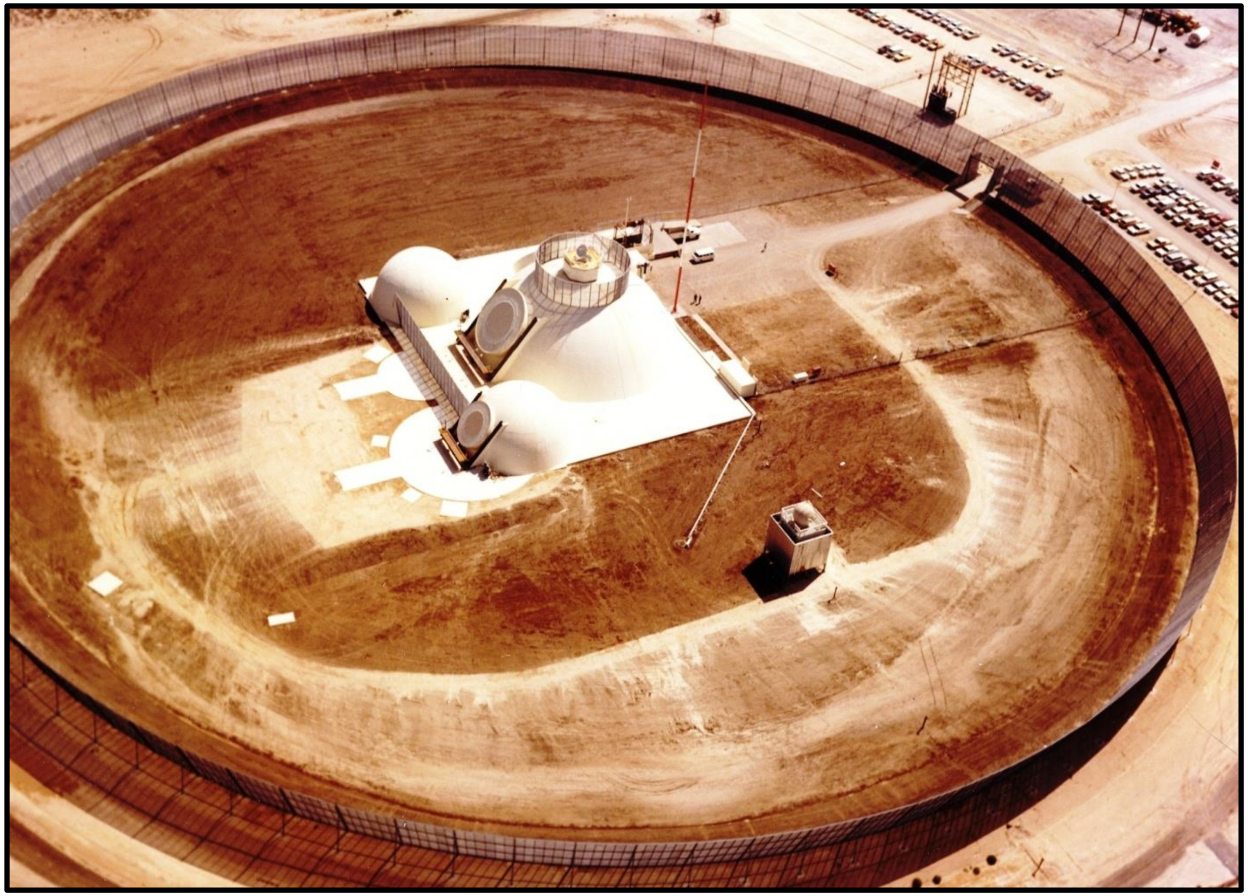
This novel radar was a test-bed for evaluating the electronically steered radar developed for the US Army's Nike-X *Anti-Ballistic Missile* (ABM) defense program and was the first "hardened" phased-array ever built.

- ***Western Electric Company* (WECo) was the prime contractor.**
- ***Bell Telephone Laboratories* (BTL) was responsible for the overall system design.**
- ***Sylvania Electronic Systems East* (SES-East) was the subcontractor responsible for the detailed design and fabrication of the facility.**

Built at the *White Sands Missile Range* with an extraordinary 15 month construction schedule:

<u>Groundbreaking</u>
15 March 1963
<u>Powered Up</u>
15 June 1964

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



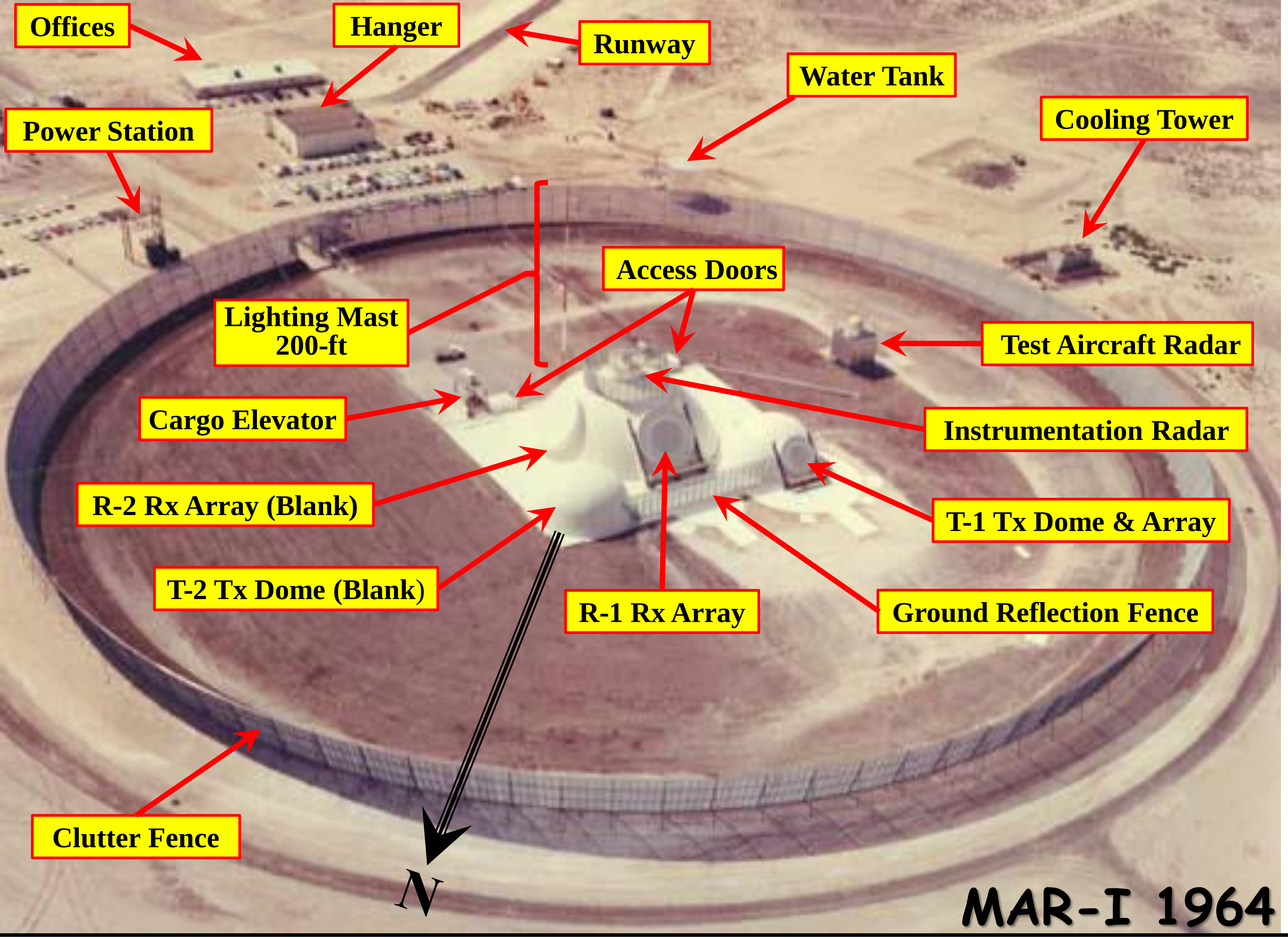
Most of the 195 x 155 ft structure is underground and extends 42 ft below surface grade.

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

WSMR Archive ID # 97.180-.96-7

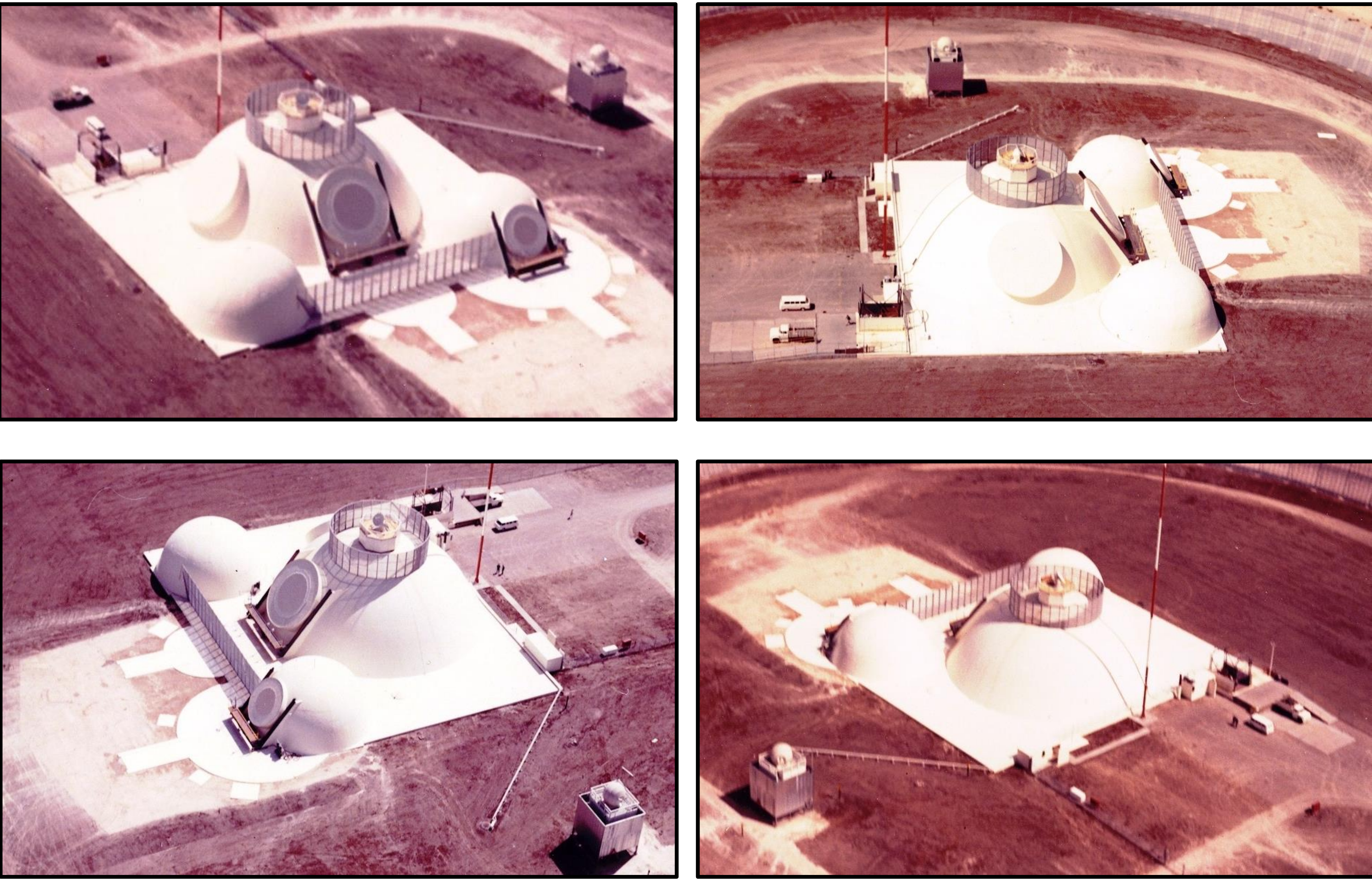
Where was the MAR-I Site at WSMR?

GoogleEarth



WSMR Archive ID # 97.180.196-6

MAR-I : 4 Aerial Close Ups – 17 Aug 1964



Clockwise : WSMR Archive ID # 97.180.196-3, -4, -5 & -6

MAR-I from Beaver Aircraft used in Pattern Measurement Tests - Late 1964

Image from the collection at the USASMDC/ARSTRAT Historical Office, Redstone Arsenal

Quotes about the MAR-I in the Media

"Igloo-Shaped Structures Hide Advanced Antimissile System"

- From : *The Christian Science Monitor*, Boston, MA, Dec 15, 1964

"At the heart of the Nike-X antimissile system is a huge steel-and-concrete device called MAR. A briefing officer showed us a picture of it and remarked that archeologists of the future, finding MAR there in the desert, might think it a monument something like the Egyptian Sphinx."

- From : *On the Political Front,* The Reading Eagle, Reading, PA, May 28, 1965

"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."

- From : *Army Research and Development Newsmagazine, Aug 1964* (Vol. 5, No. 8, p.23)

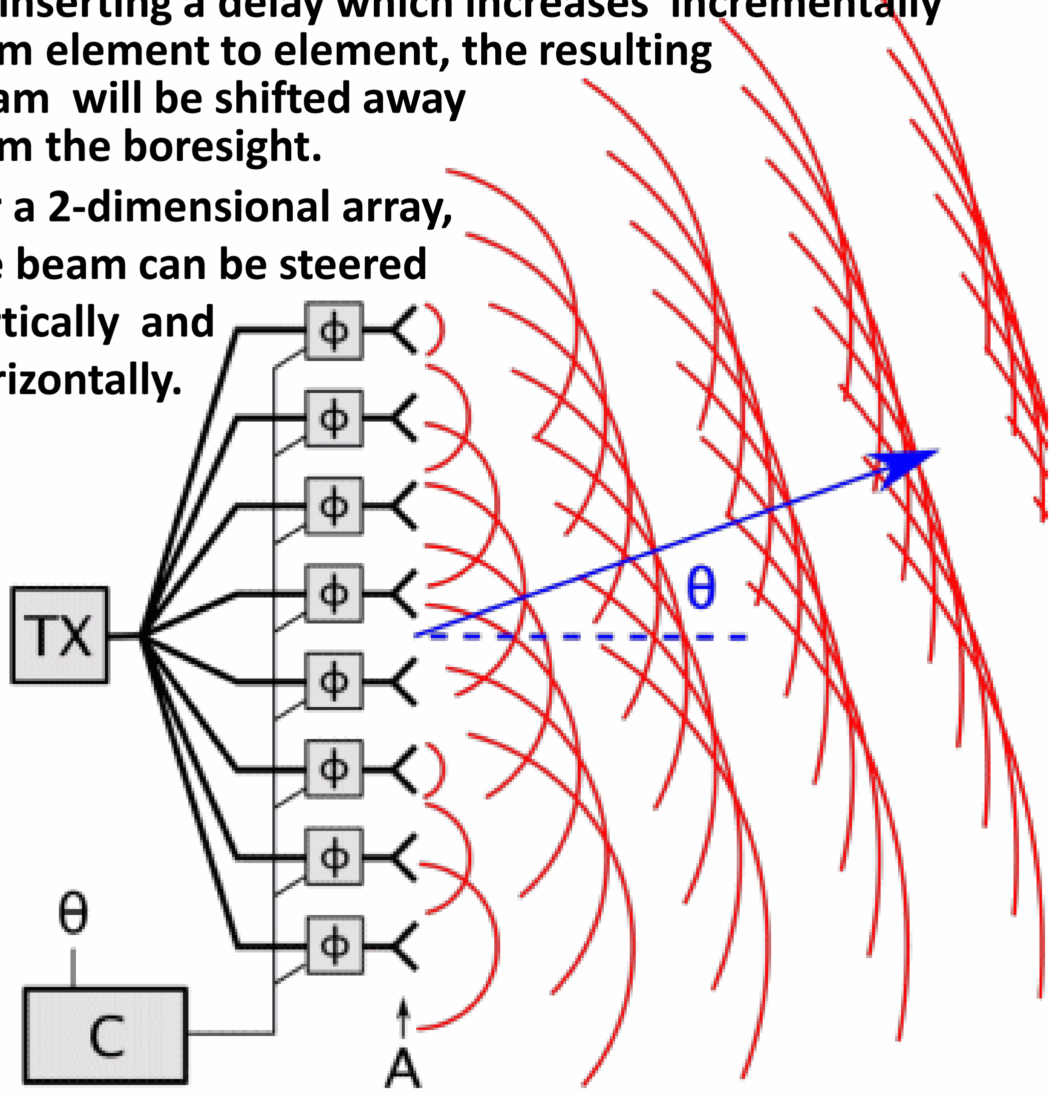
WSMR Archive ID # 12.007.783

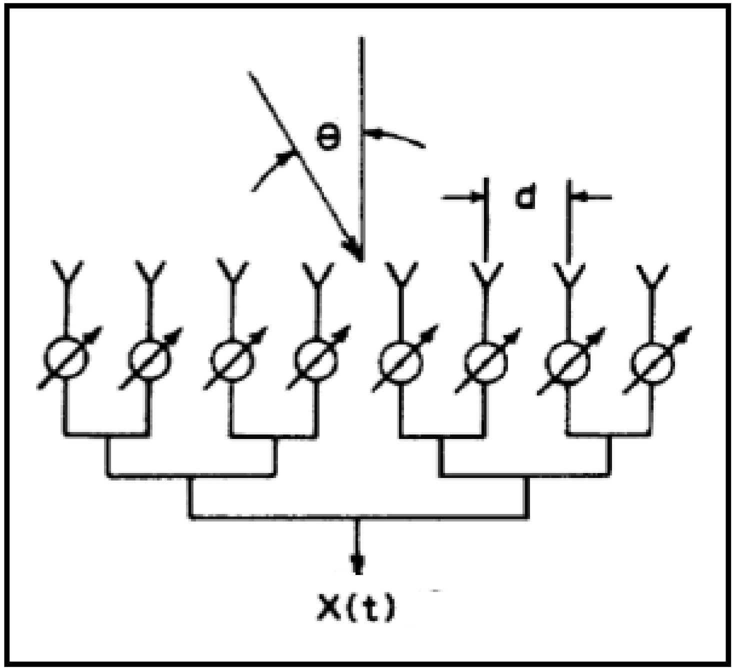
Electronically Steered Phased-Array Radar

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 which increases incrementally from element to element, the resulting beam will be shifted away from the boresight.

For a 2-dimensional array, the beam can be steered vertically and horizontally.





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.

https://en.wikipedia.org/wiki/Passive_electronically_scanned_array#/media/File:Phased_array_animation_with_arrow_10frames_371x400px_100ms.gif
http://www.fotoimage.org/beam-steering-phased-array/ http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4101595

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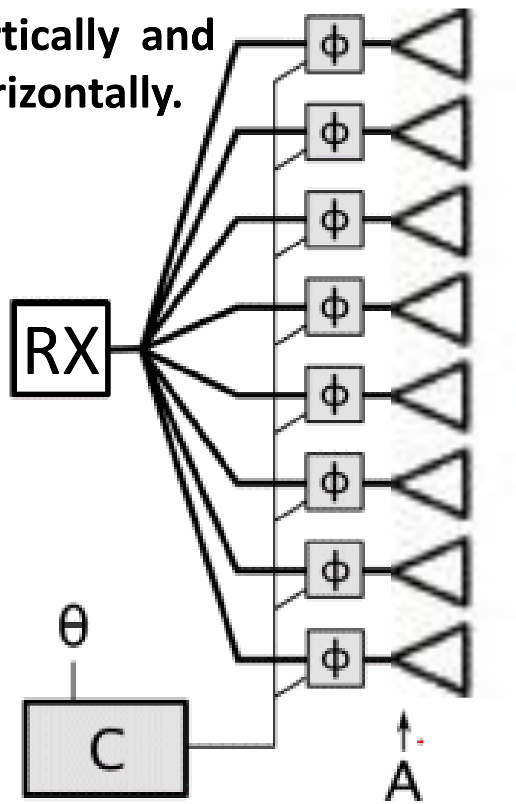
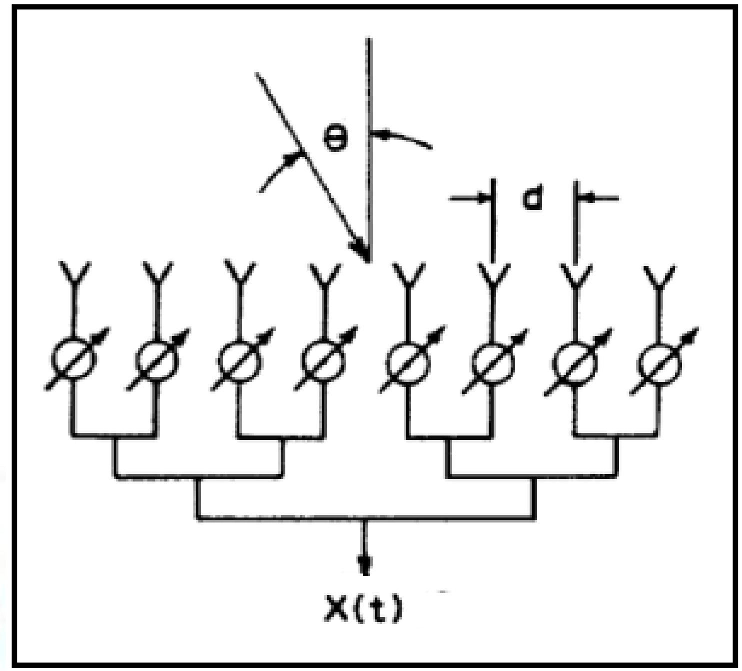


The more elements, the wider the aperture, and the narrower the beam.



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https://en.wikipedia.org/wiki/Passive_electronically_scanned_array#/media/File:Phased_array_animation_with_arrow_10frames_371x400px_100ms.gif
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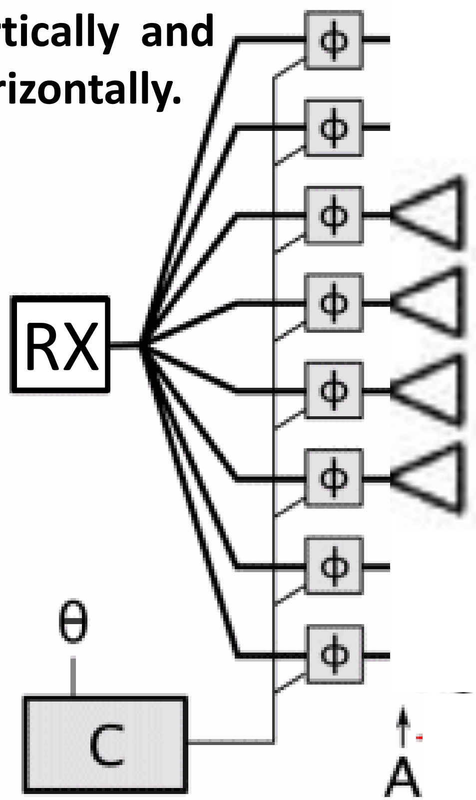
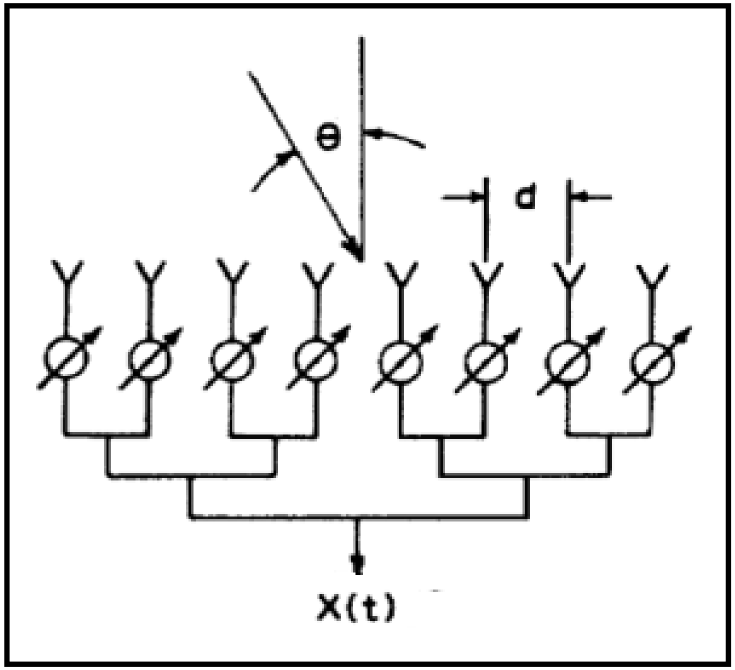


Dropping elements at the edge, decreases the aperture and widens the beam.



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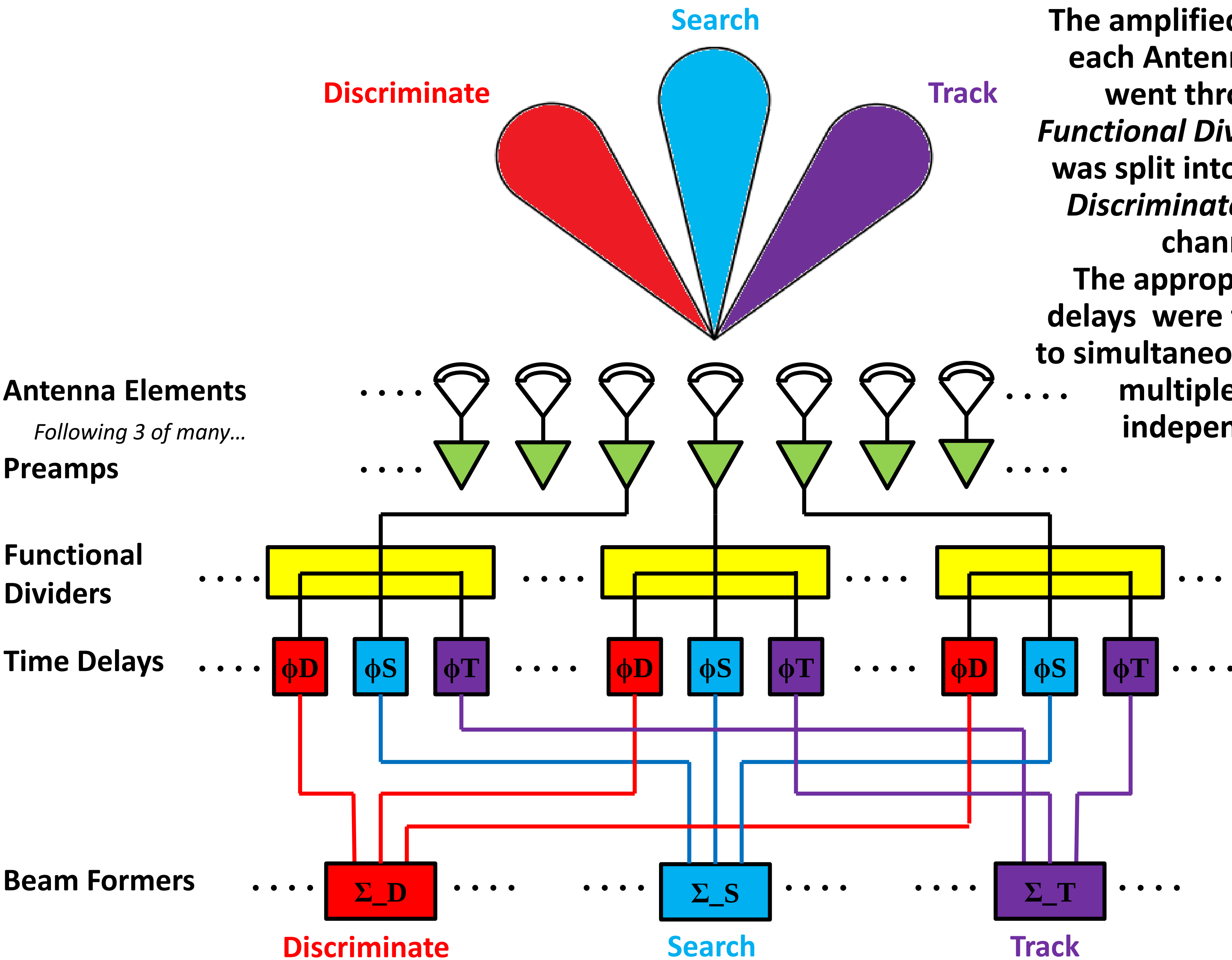
https://en.wikipedia.org/wiki/Passive_electronically_scanned_array#/media/File:Phased_array_animation_with_arrow_10frames_371x400px_100ms.gif
http://www.fotoimage.org/beam-steering-phased-array/ http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4101595

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.

MAR-I Ground Level Views

MAR-I from the Front - c.1965

WSMR Archive ID # 97.180.205-1

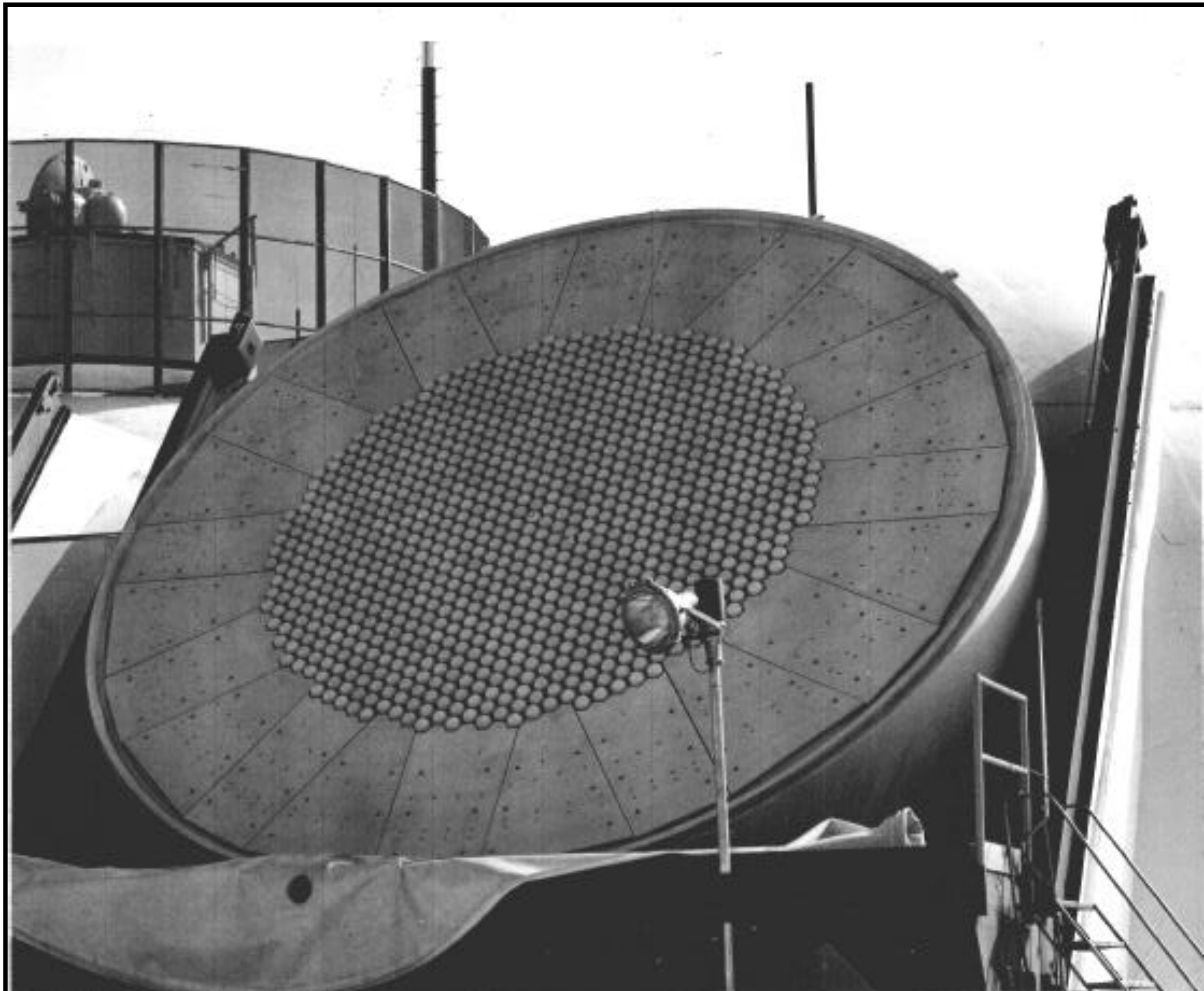
MAR-I Transmitter Face – 21 Dec 1965

Diameter:
~15 ft

Number of Antenna Elements:
Active = 805
Passive = 108
Total = 913

The peak output power from the Transmitter was in the megawatt range.

Its large steel antenna support structure weighed 30 tons.



Courtesy Bob Gamboa, who worked for WECo at the MAR-I in the Public Relations department

MAR-I Receiver Array Face - Dec 1965

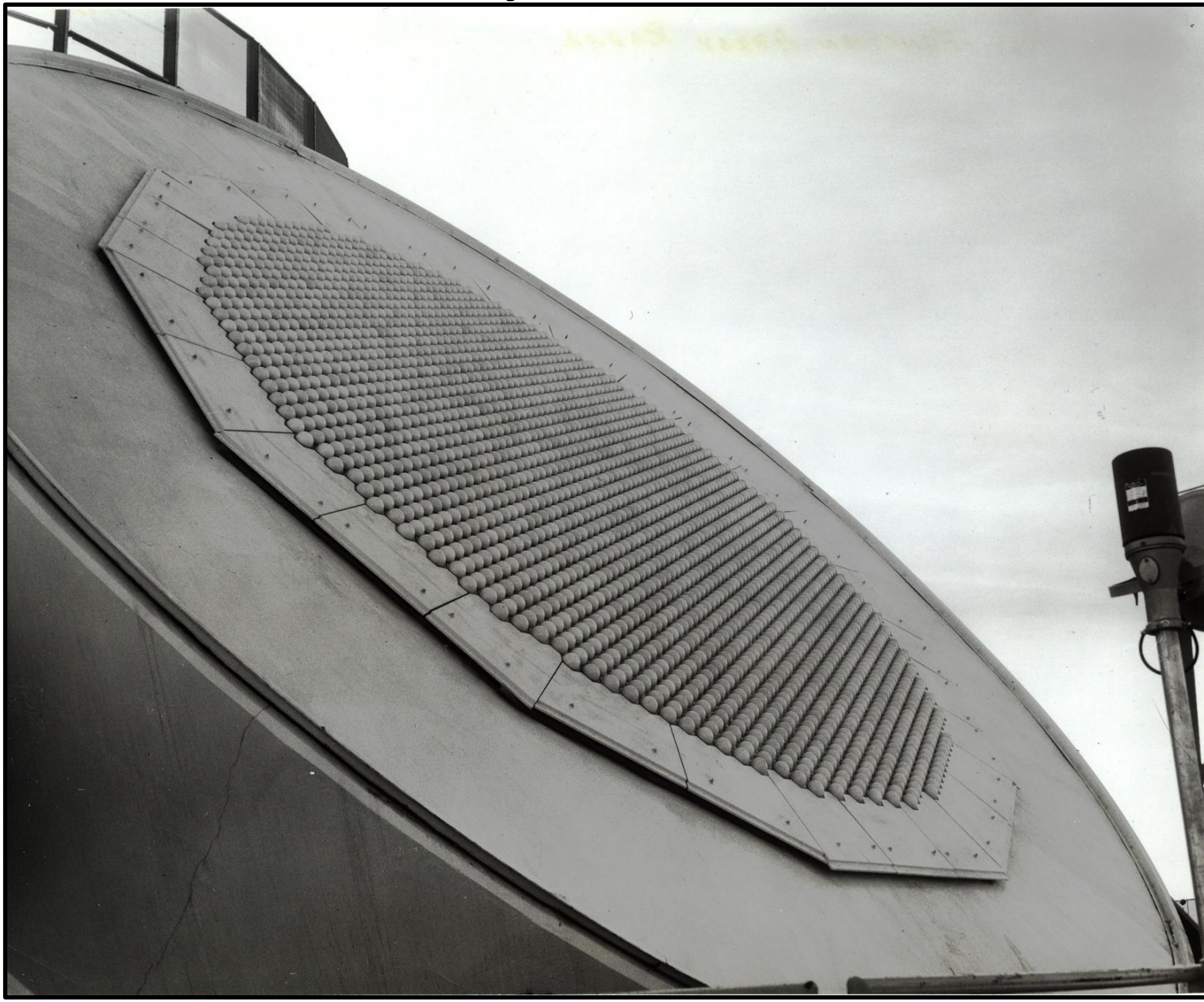
Diameter ~25 ft

Number of Antenna Elements:
Active = 2077
Passive = 168
Total = 2245

Antenna Element Field of View > 90°

Phased-Array Beamwidth ~1.8°

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



WSMR Archive ID # 97.180.205-3

MAR-I Style Planar Array

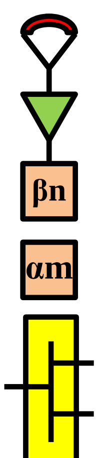
The MAR-I Transmit & Receive arrays used a 2D *Triangular* grid.

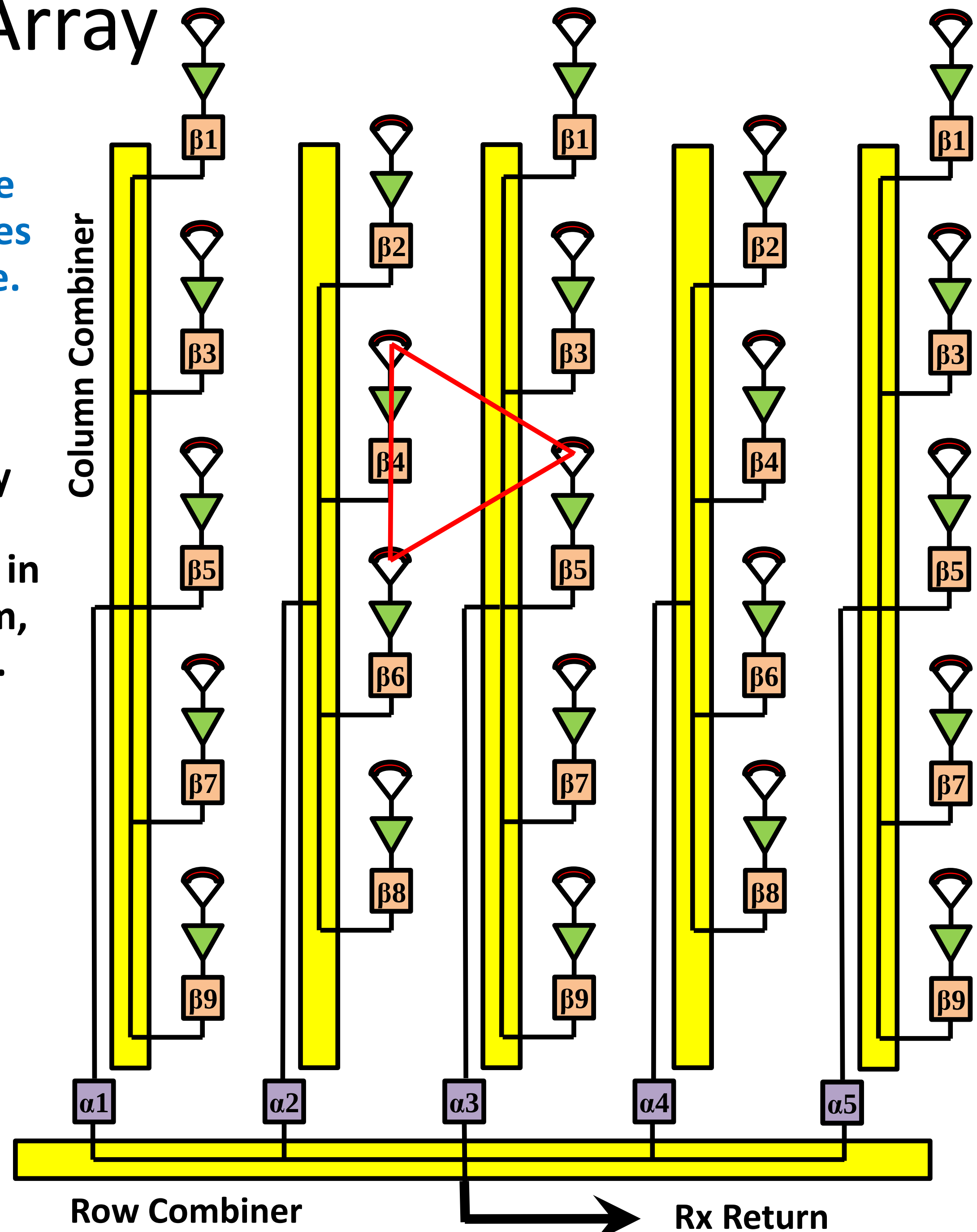
It is more efficient for suppressing side lobes than a *Rectangular* grid & requires 16% less elements for a given aperture.

***(Radar Handbook*, M.S. Skolnik, 1970)**

A 23 element Triangular grid Receiver Array example is shown. There are 4 or 5 Elevation (Beta) delay units for each antenna in a column, and 5 Azimuth (Alpha) time delay units in a single row required to steer the beam, for a total 28 delay units (i.e., not 46).

Each of the MAR-I's Receiver beams have a total of 2077 Beta delay units and 55 Alpha delay units.





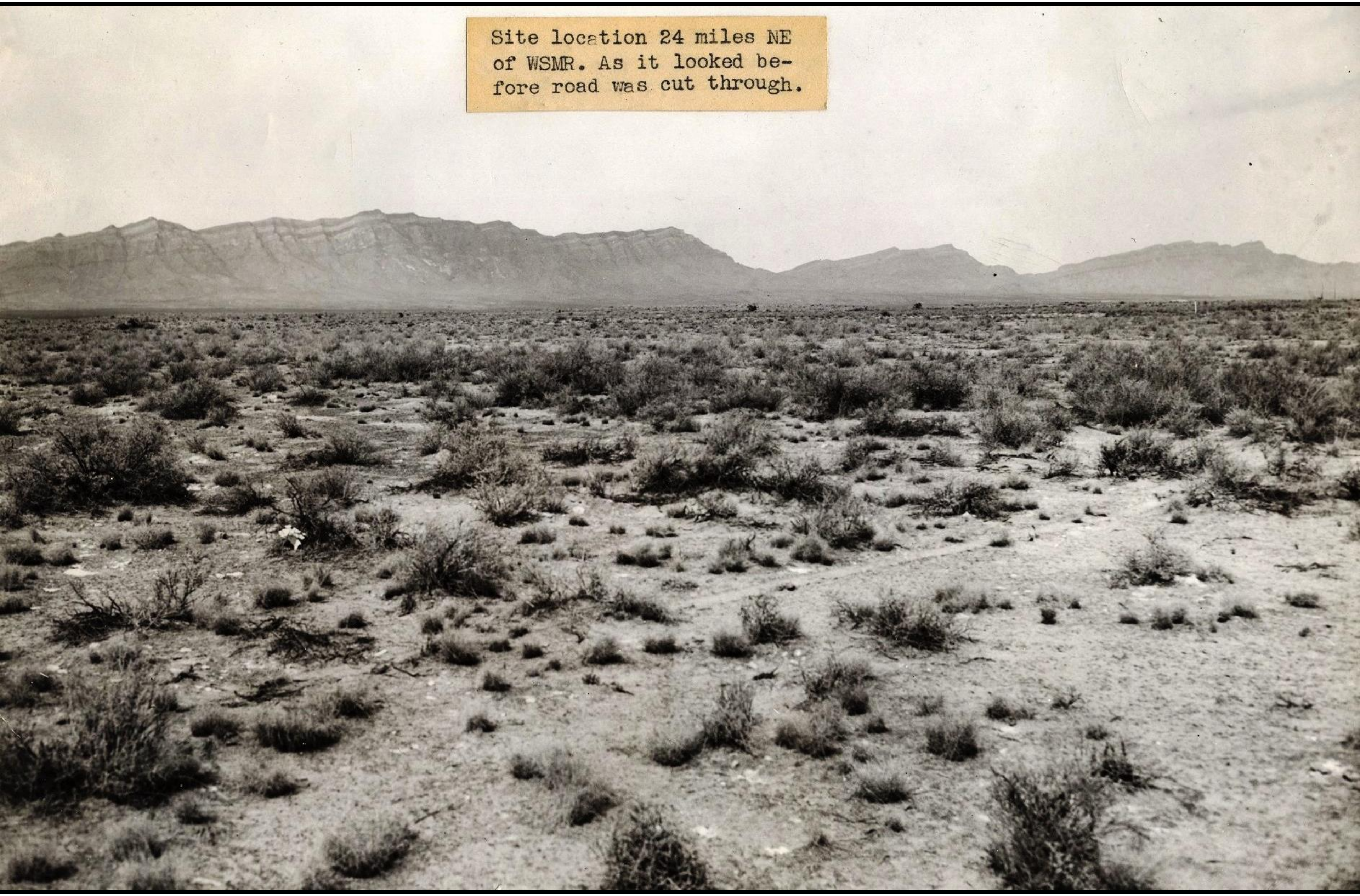
The MAR-I Construction Album

There were 285 photographs collected in a 3-ring binder showing the construction of the site that were donated to the *WSMR Archive* by the widow of George Sharpe, BTL's second-in-command at WSMR during the MAR-I project.

Here are a few of them…

WSMR Archive ID # 03.013.001

MAR-I Construction – 25 Mar 1963



WSMR Archive ID # 03.013.001-001

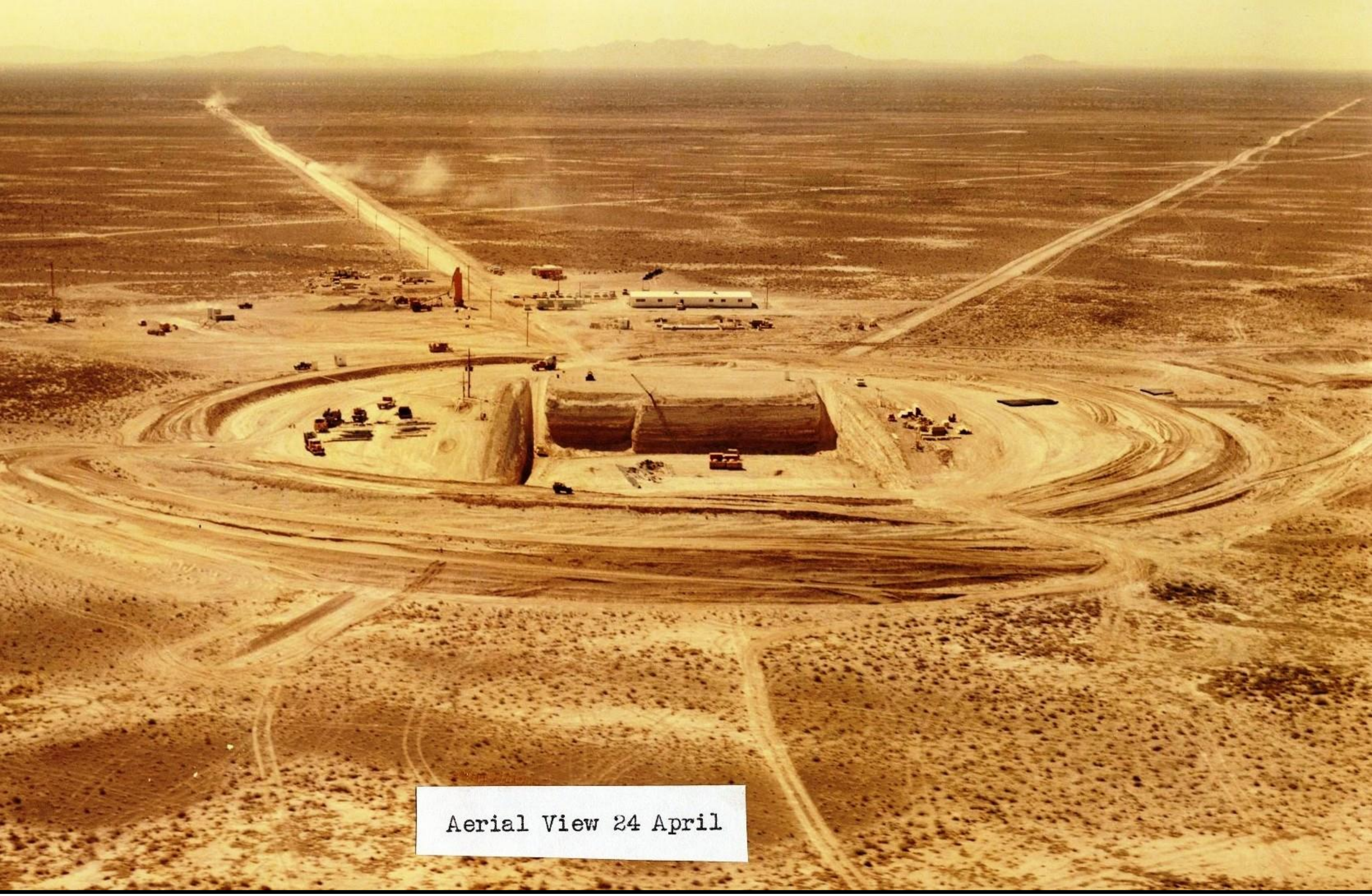
MAR-I Construction – 2 Apr 1963

WSMR Archive ID # 03.013.001-006

MAR-I Construction – 9 Apr 1963

WSMR Archive ID # 03.013.001-019

MAR-I Construction – 24 Apr 1963

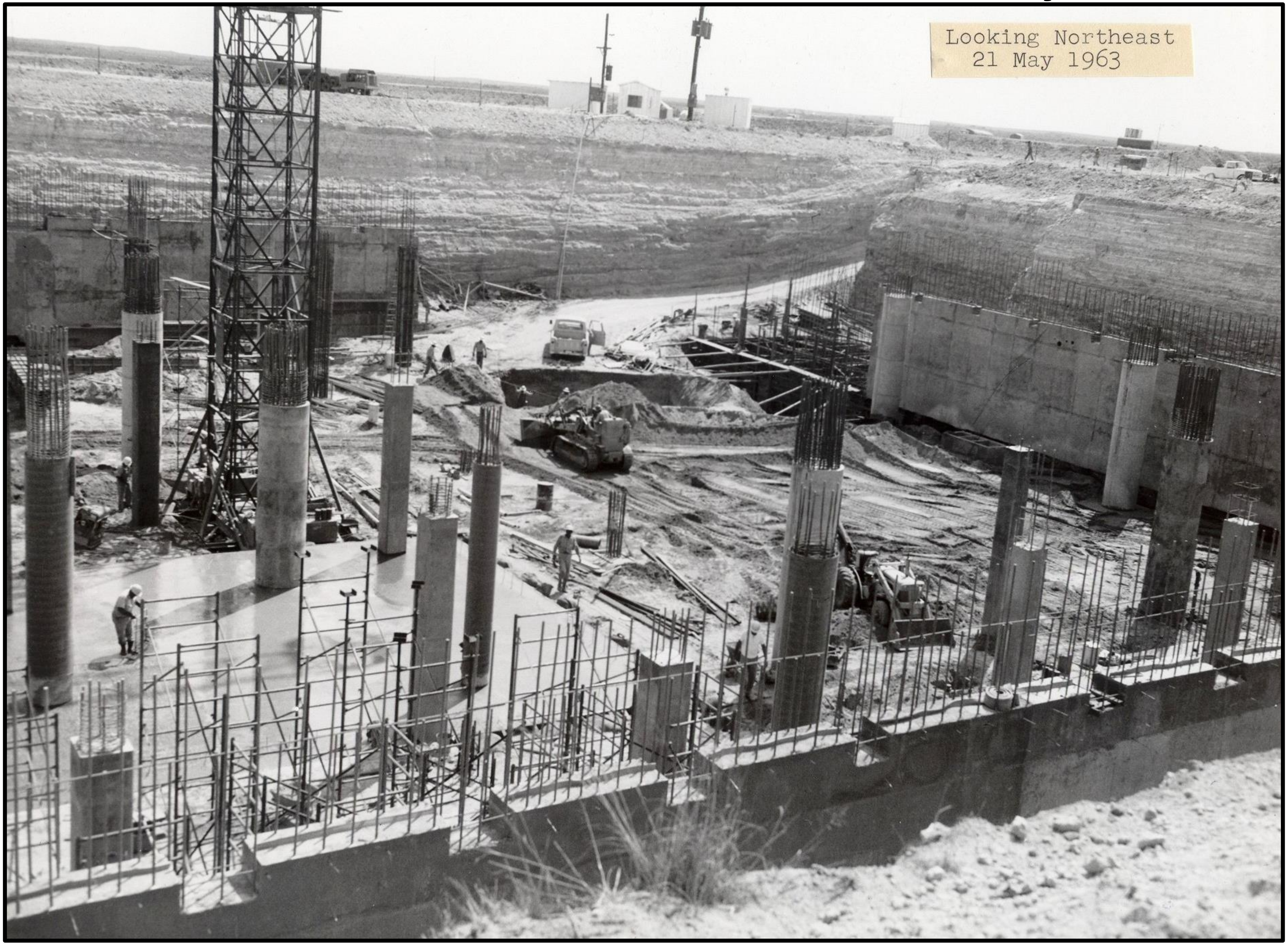


WSMR Archive ID # 03.013.001-029

MAR-I Construction – 7 May 1963

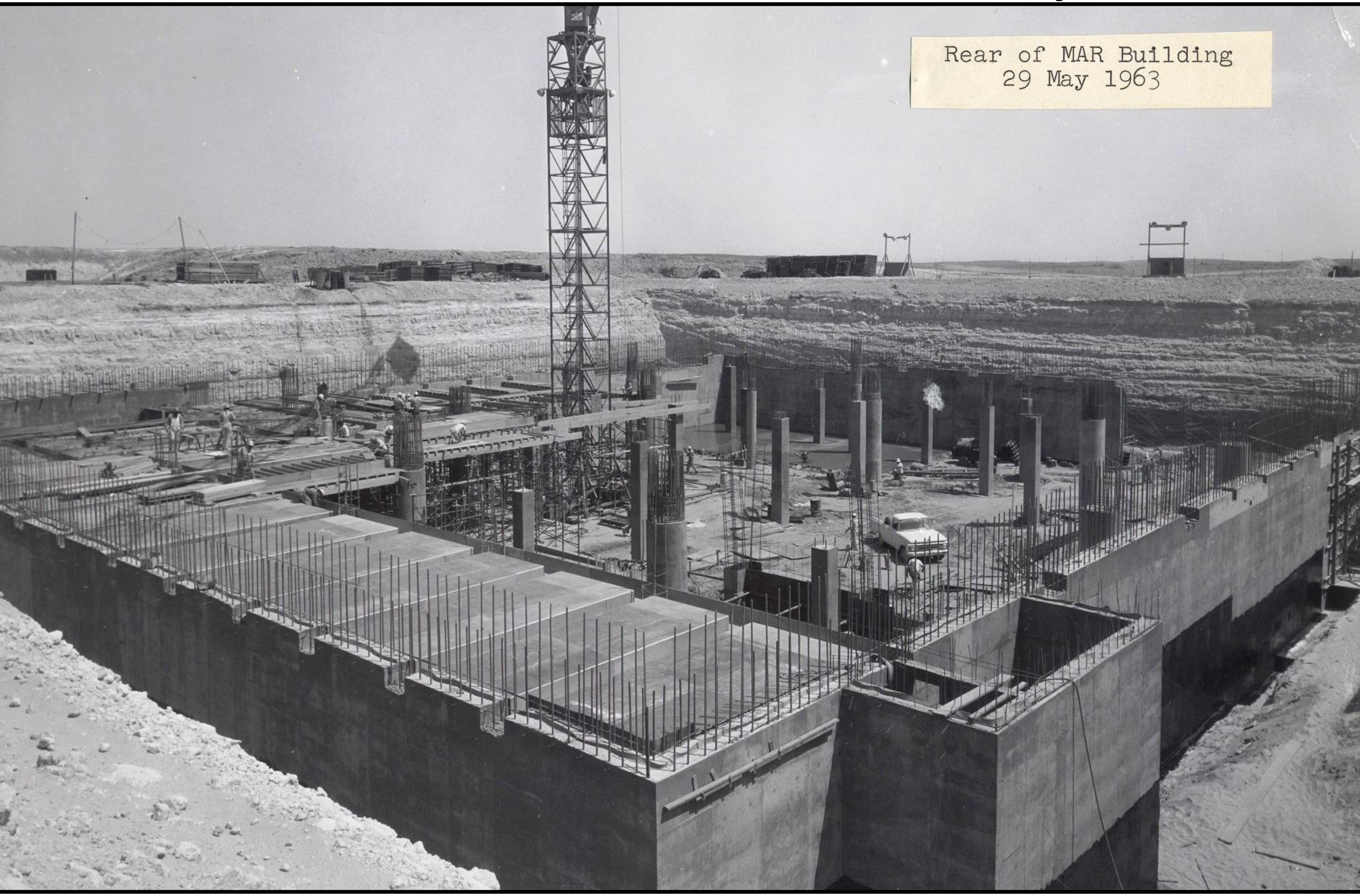
WSMR Archive ID # 03.013.001-036

MAR-I Construction – 21 May 1963



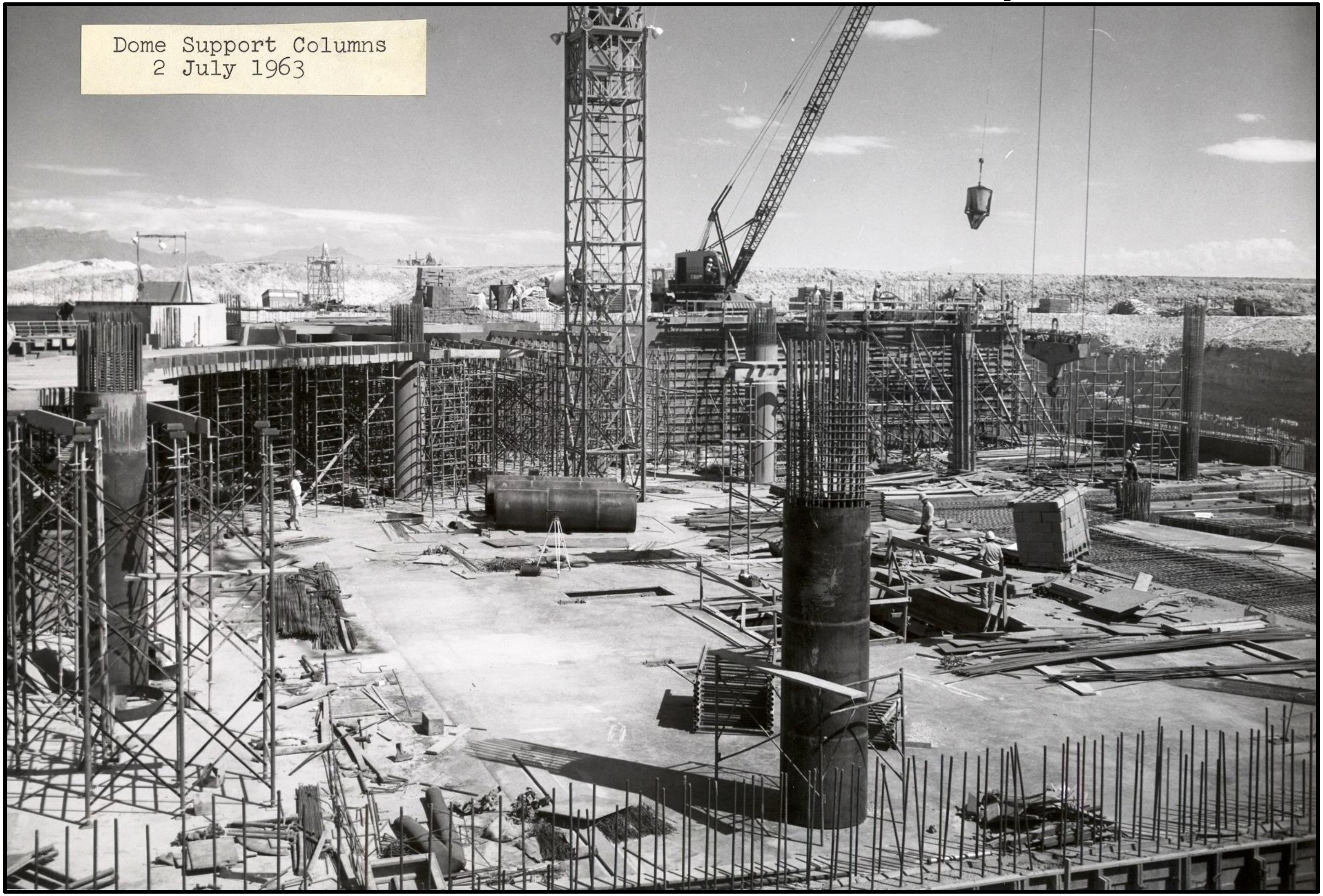
WSMR Archive ID # 03.013.001-048

MAR-I Construction – 29 May 1963



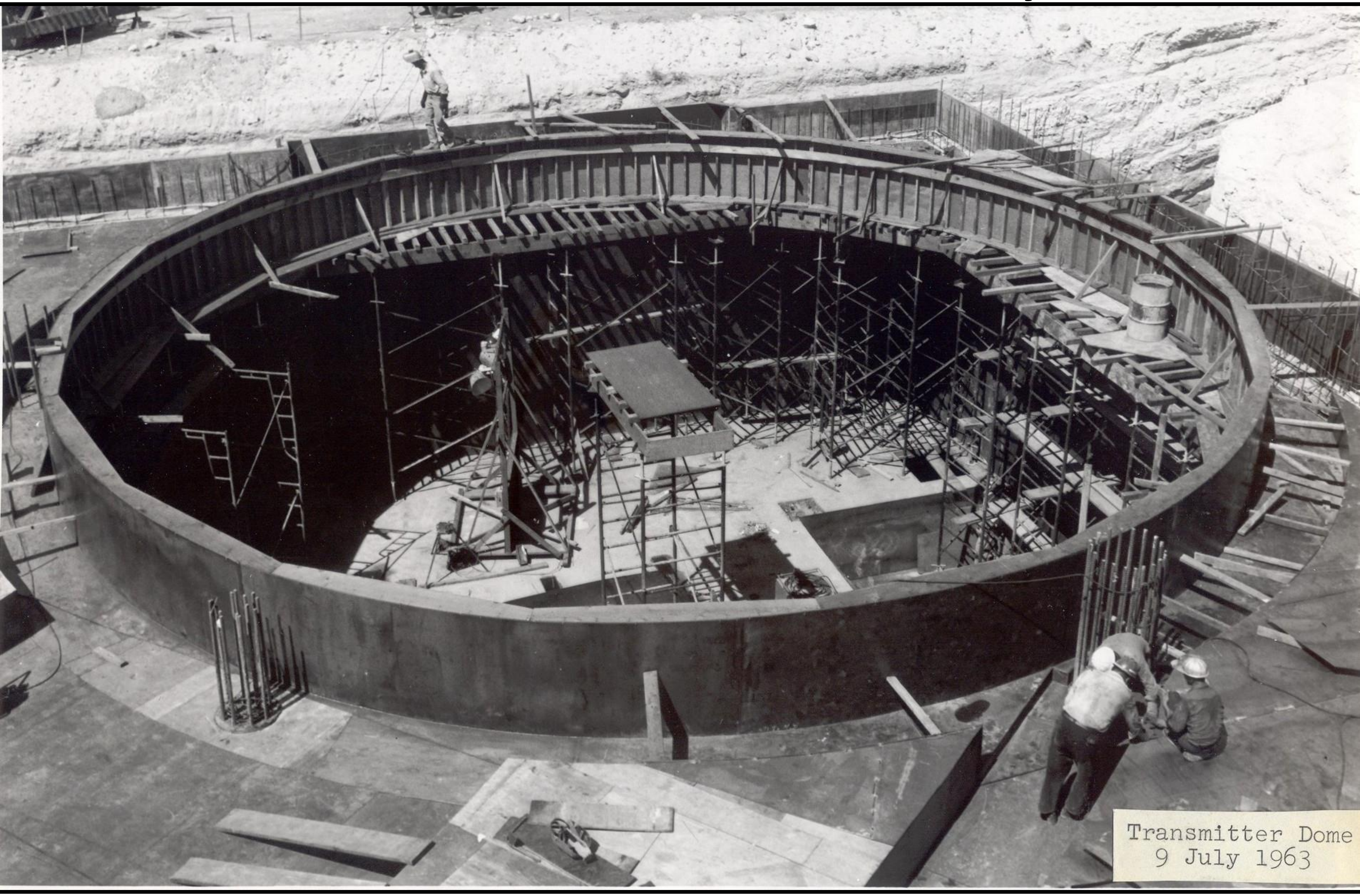
WSMR Archive ID # 03.013.001-054

MAR-I Construction – 2 July 1963



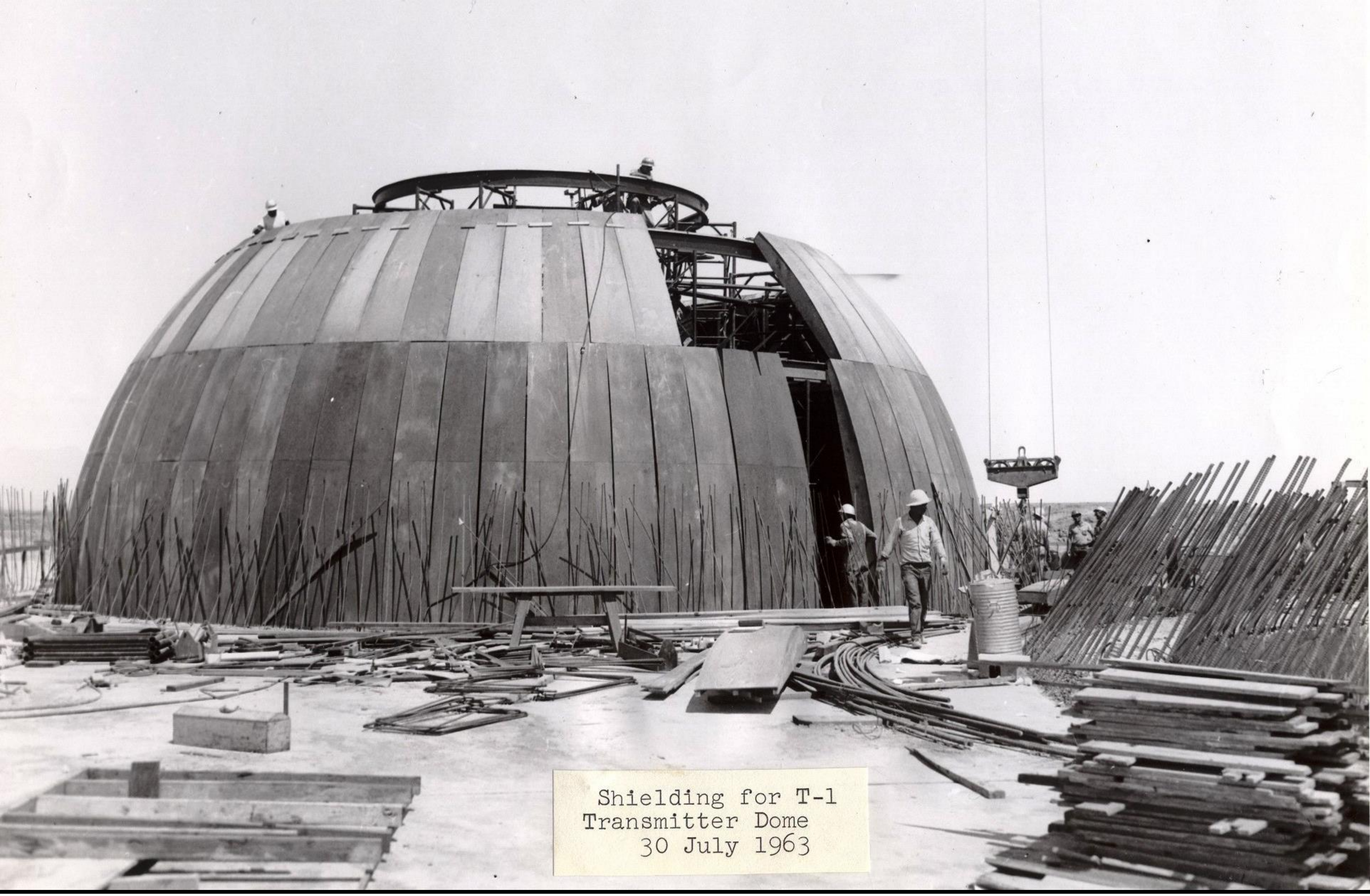
WSMR Archive ID # 03.013.001-086

MAR-I Construction – 9 July 1963



WSMR Archive ID # 03.013.001-097

MAR-I Construction – 30 July 1963

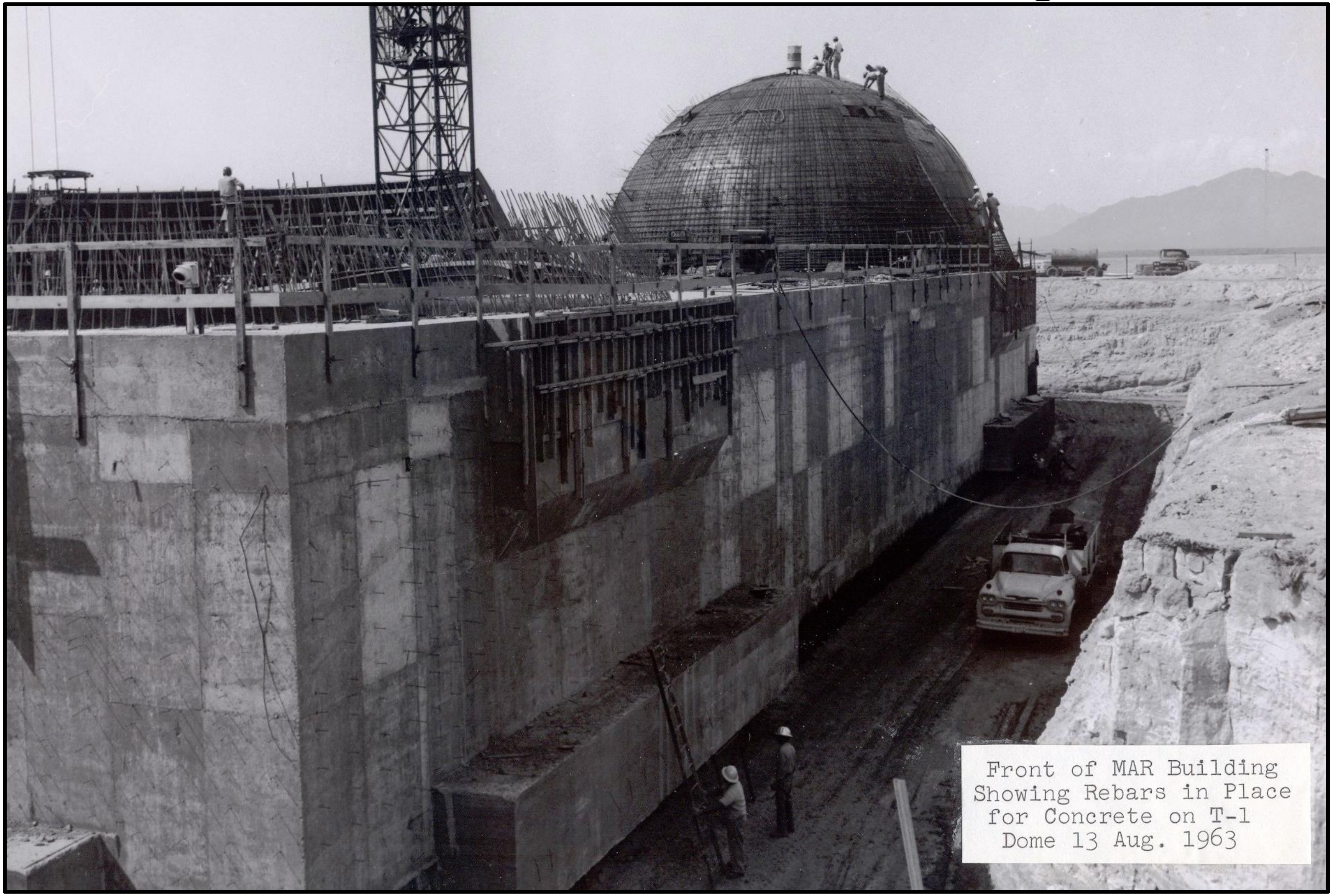


WSMR Archive ID # 03.013.001-117

MAR-I Construction – 3 Aug 1963

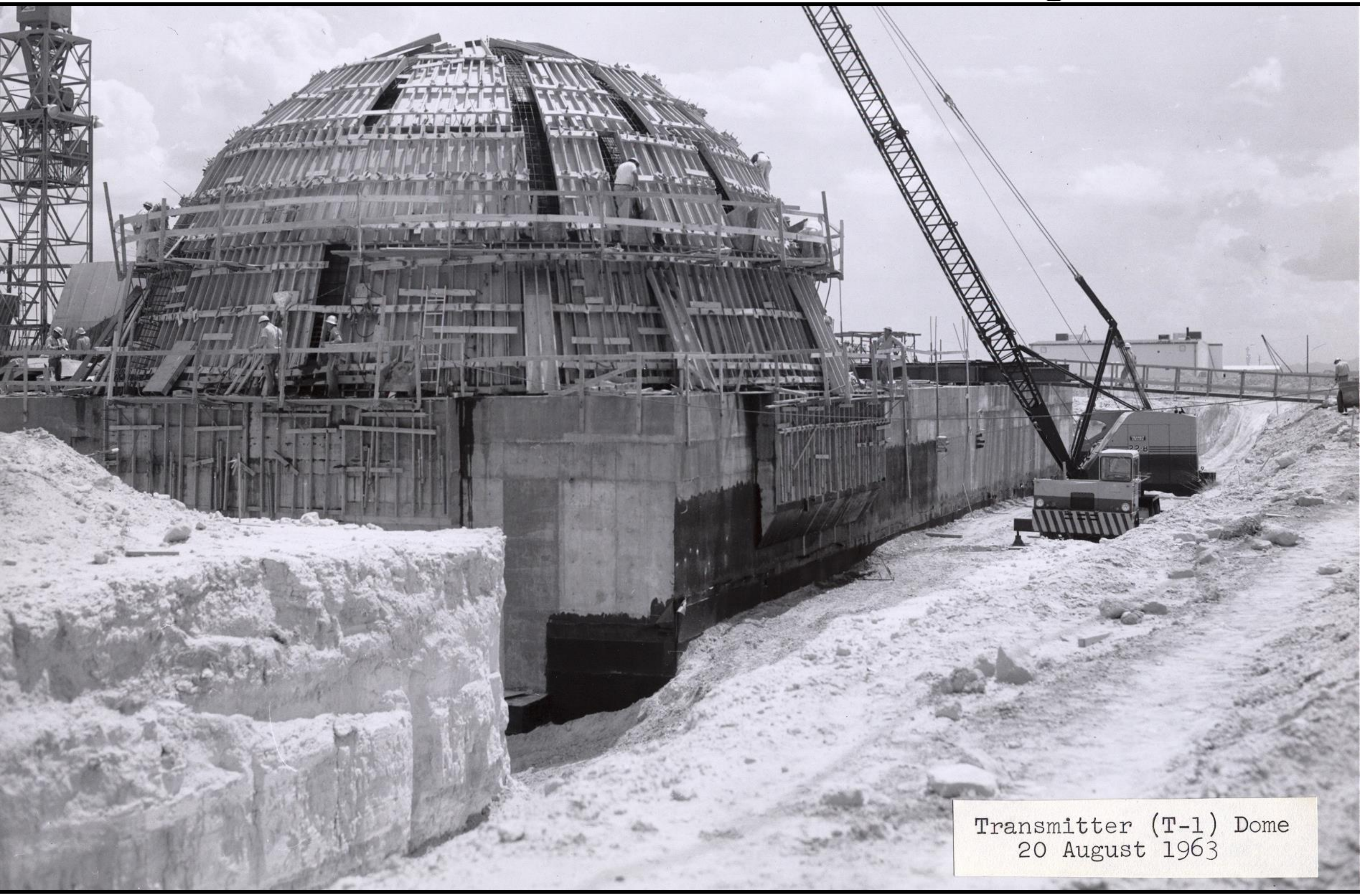
WSMR Archive ID # 03.013.001-120

MAR-I Construction – 13 Aug 1963



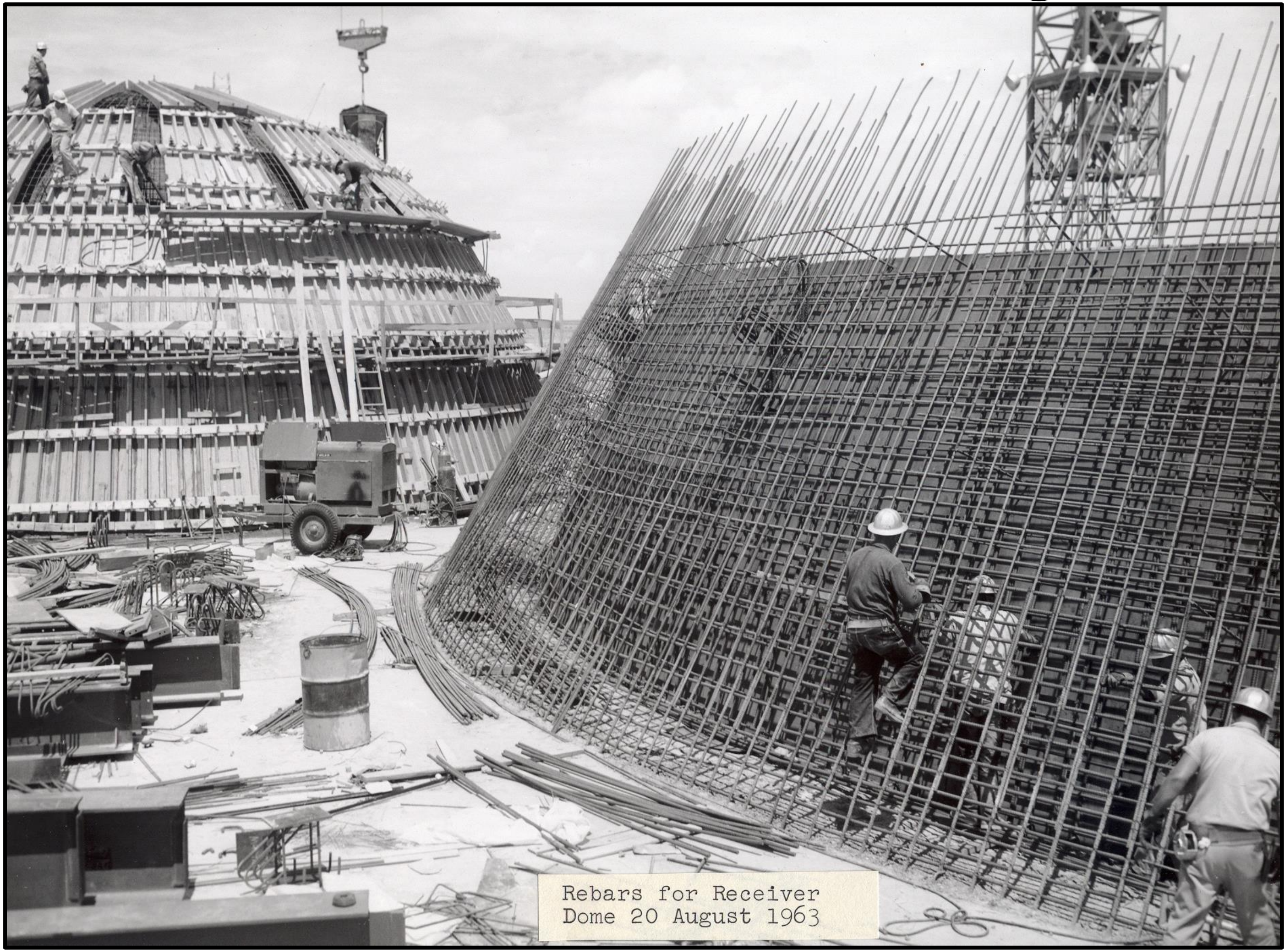
WSMR Archive ID # 03.013.001-132

MAR-I Construction – 20 Aug 1963



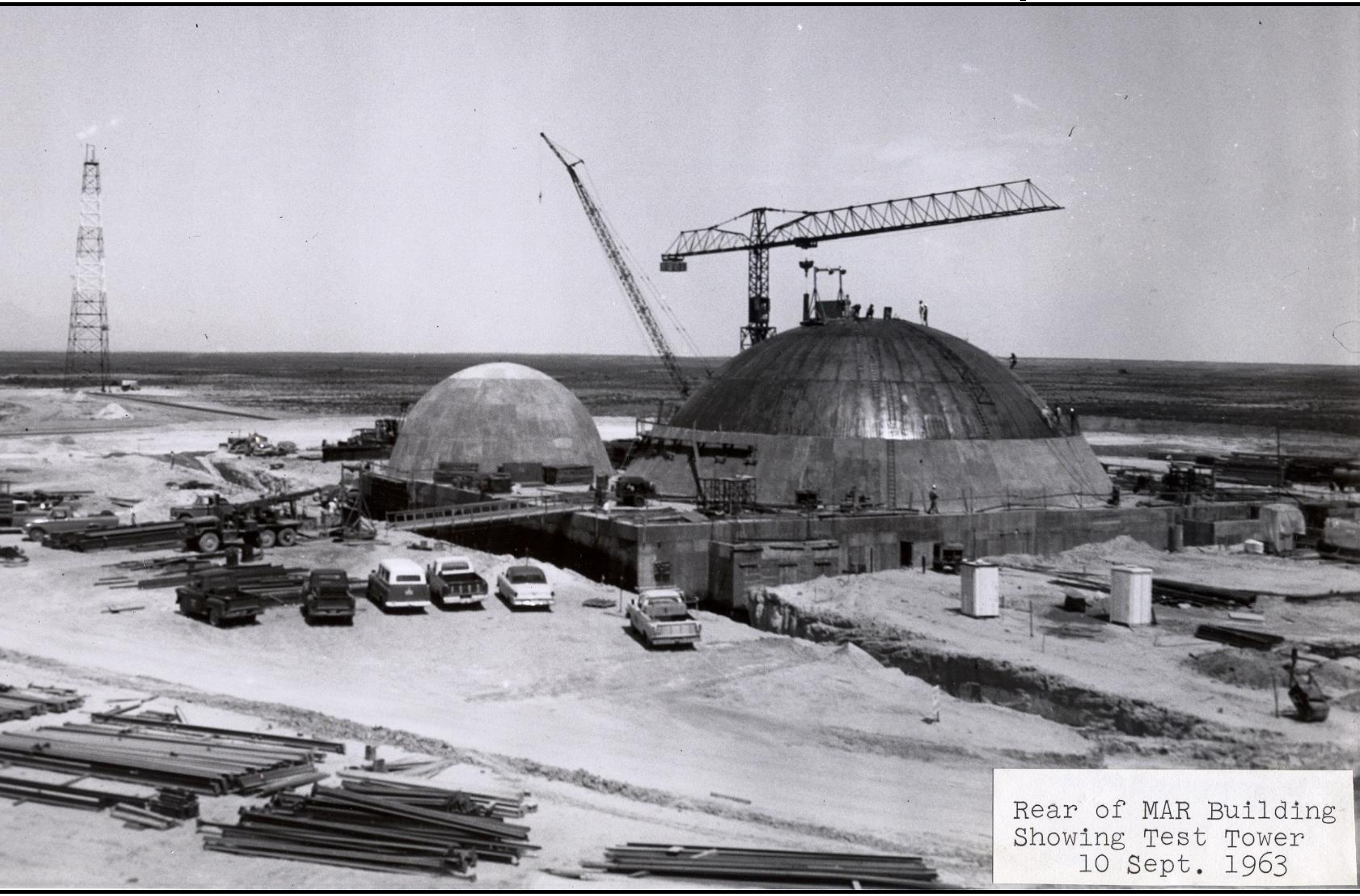
WSMR Archive ID # 03.013.001-145

MAR-I Construction – 20 Aug 1963



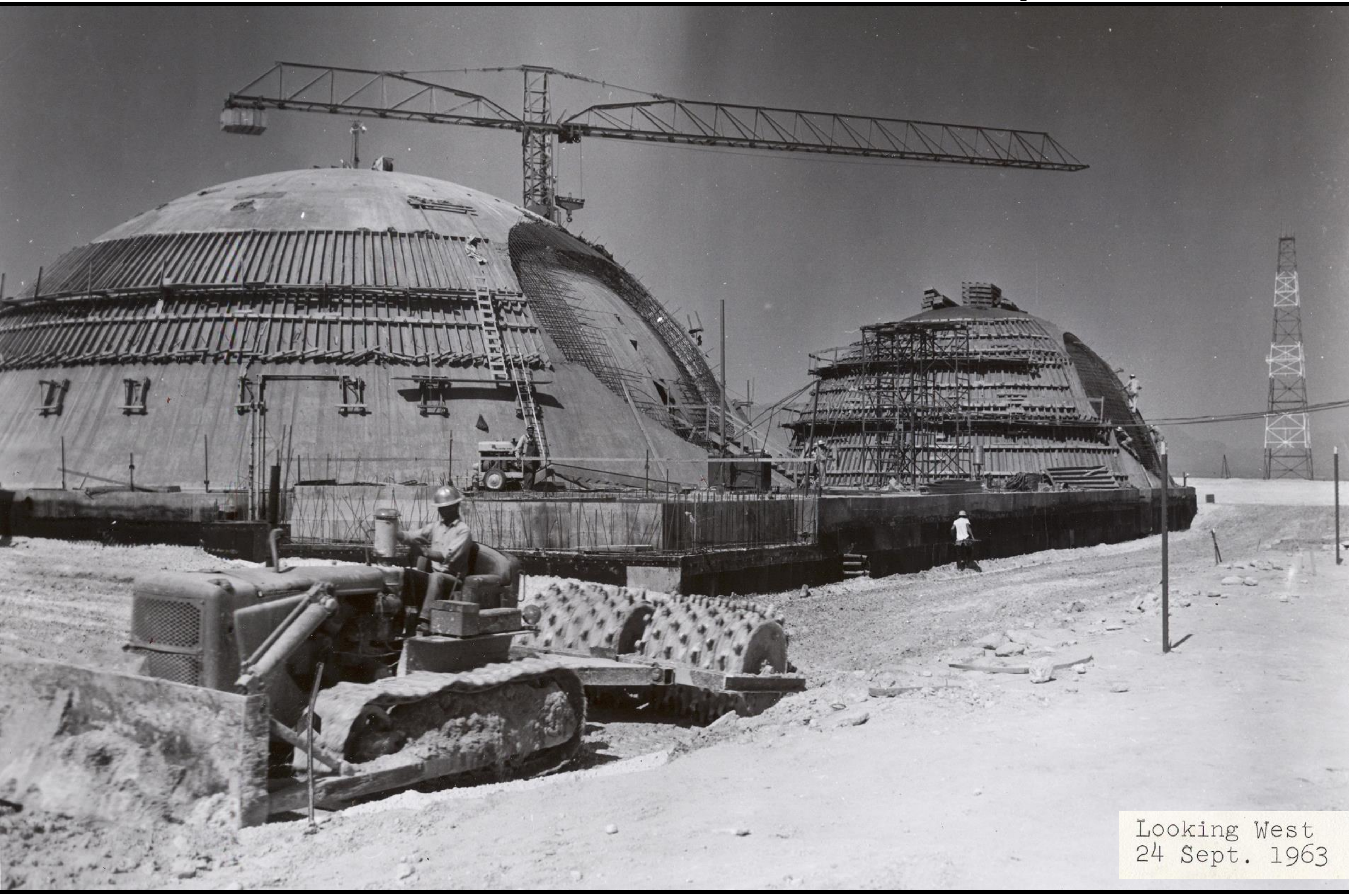
WSMR Archive ID # 03.013.001-

MAR-I Construction – 10 Sept 1963



WSMR Archive ID # 03.013.001-154

MAR-I Construction – 24 Sept 1963

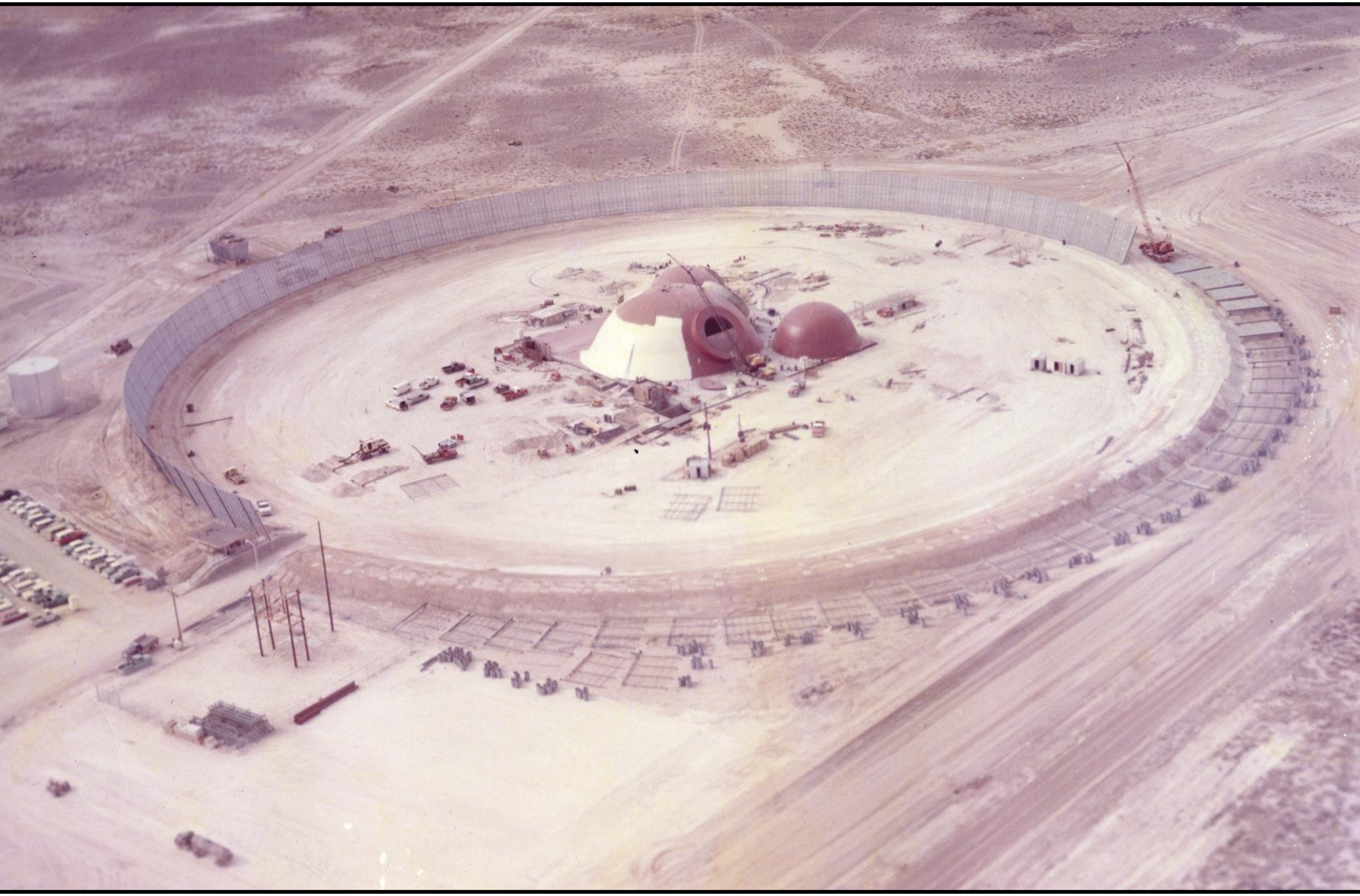


WSMR Archive ID # 03.013.001-169

MAR-I Construction – 22 Oct 1963

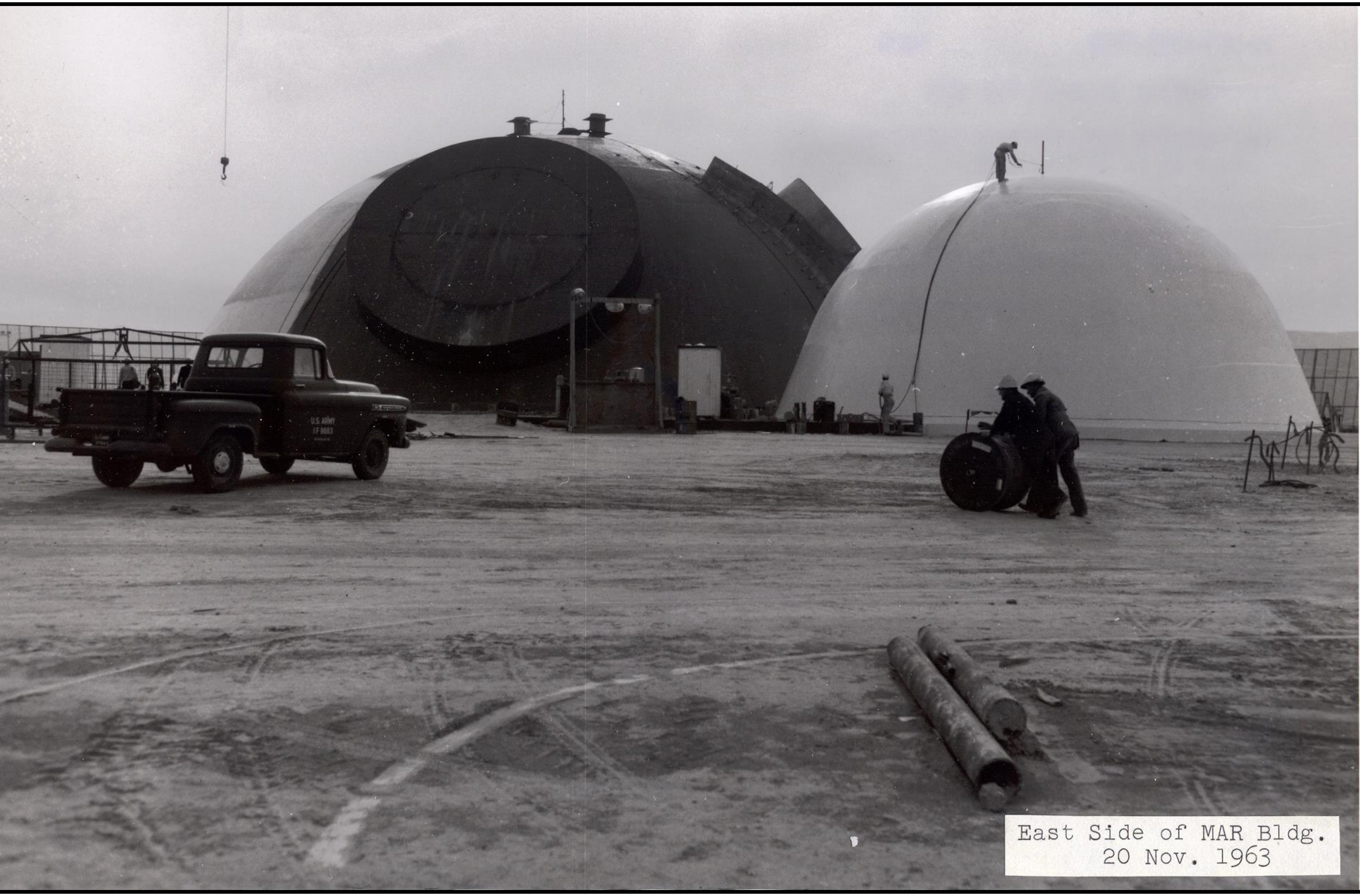
WSMR Archive ID # 03.013.001-194

MAR-I Construction – Mid 1963



WSMR Archive ID # 03.013.001-215

MAR-I Construction – 20 Nov 1963

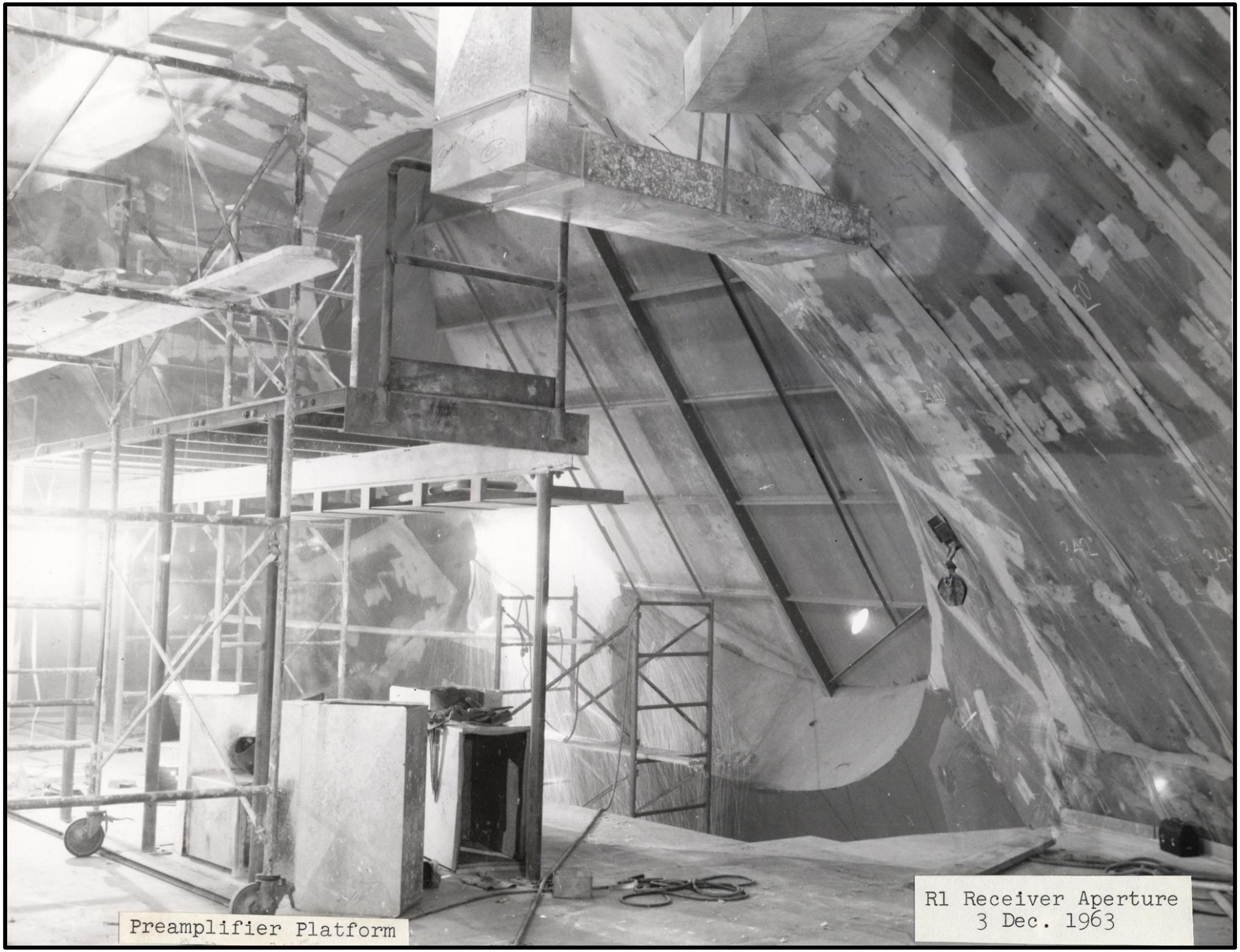


WSMR Archive ID # 03.013.001-218

MAR-I Construction – 3 Dec 1963

WSMR Archive ID # 03.013.001-234

MAR-I Construction – 3 Dec 1963



WSMR Archive ID # 03.013.001-

MAR-I Construction – 17 Dec 1963

WSMR Archive ID # 03.013.001-255

MAR-I Construction – 17 Dec 1963

WSMR Archive ID # 03.013.001-260

MAR-I Construction – 4 Feb 1964

WSMR Archive ID # 03.013.001-282

MAR-I Completed, circa mid 1964

Rare picture of the MAR-I with radomes covering the Tx & Rx Array Faces

Unfortunately the photos in the *MAR-I Construction Album* ends in Feb of 1964.
Construction, outfitting & installation of its electronics continued for several months.

The radar was ready to be powered up in June 1964.
It tracked its first target - a balloon - in September.

***MAR Introduced 50 Years Ago*, US Army Space & Missile Defense Command SMDC History, 14 Sept 2014**
http://www.army.mil/e2/c/images/2014/09/10/362074/original.jpg

MAR-I Critical Microwave Components

Antenna Element,

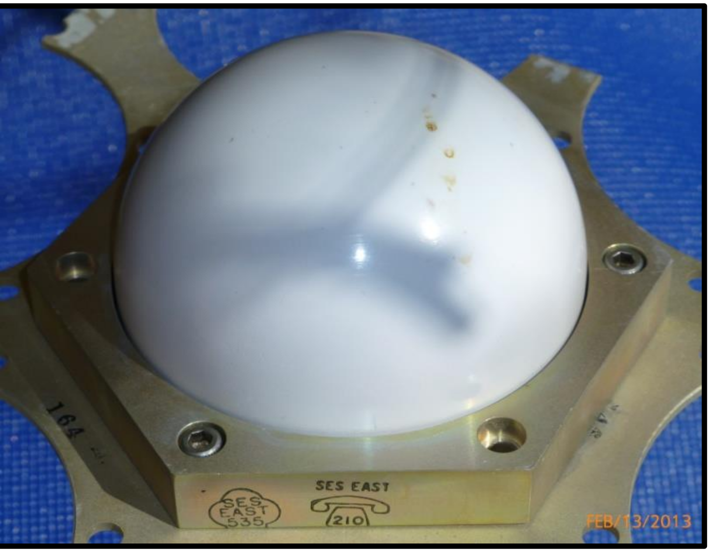
Driver Power Amplifier,

Pre-amplifier,

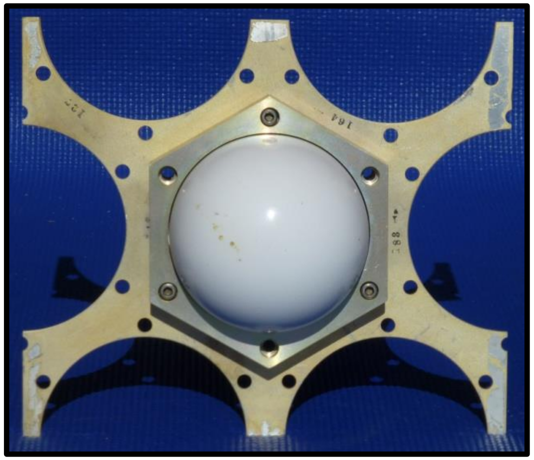
Digital Delay

MAR-I Antenna Element

The *Antenna Element* had a ceramic window which kept the weather out of the internal waveguide structure. It could withstand the blast from a nuclear explosion.

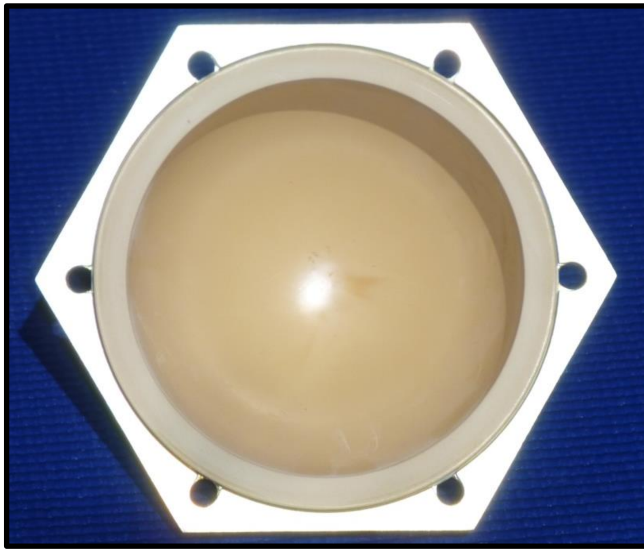


Ceramic Window - Exterior



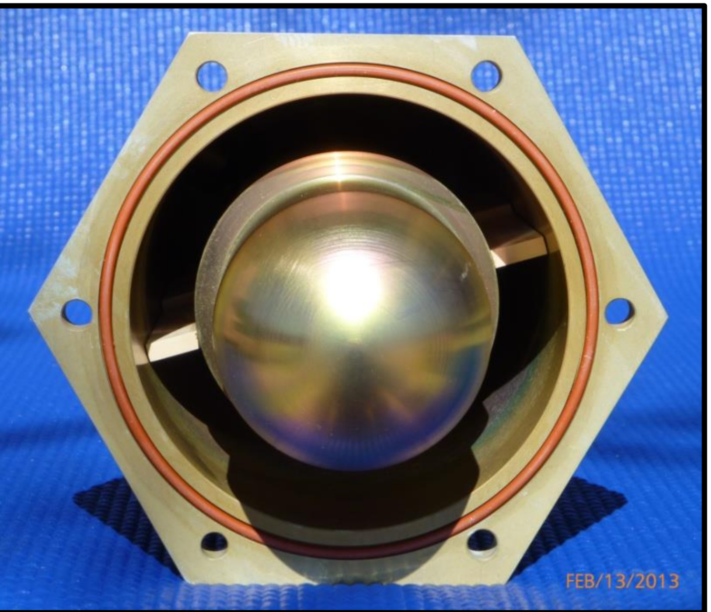
SES-E Model 9845973

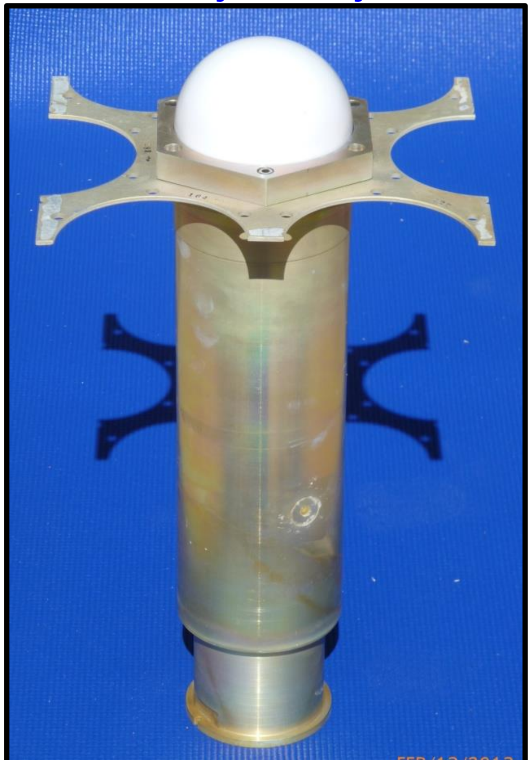
Photos by R. Hayward



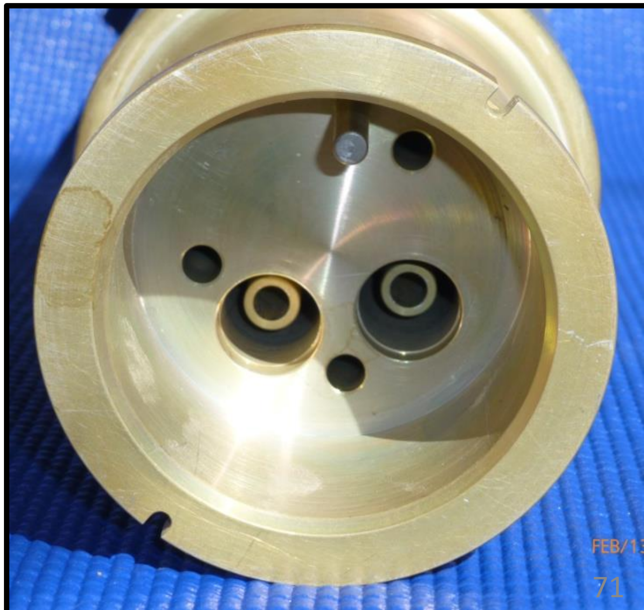
Ceramic Window - Interior

Mouth of Feed with no Window





H&V-Pol Coaxial Ports



Dietrich Alsberg on the MAR-I Windows

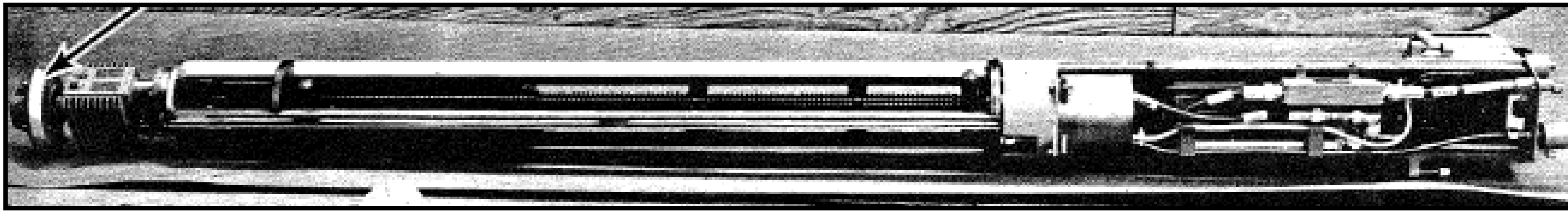
Dietrich A. Alsberg was a Bell Labs microwave engineer who worked on the MAR-I.

In his memoir, *A Witness to a Century* (2000), he relates the story about a nuclear blast test carried out to test potential types of windows for covering the MAR-I Antenna Elements…

In later tests for the MAR I project we designed individual antenna elements we believed combined the needed electrical characteristics with survival near or in a nuclear fire ball. The most promising designs had a quartz or ceramic window at the end of the circular waveguide radiator. The windows were to be flush with the antenna. If the building were covered with debris from an explosion, a mechanical device would remove the debris like a windshield wiper. Now we needed to verify the antenna designs in a live nuclear test

A relatively "small" tactical nuclear device was mounted on a wooden pole a few feet above the ground. We mounted our antenna samples close by on heavy wooden posts, whose faces were directed towards the bomb. Although we tried our best to convince the range officer, that the post was not strong enough he prevailed. Unfortunately we were right. After the blast we found our samples about two miles from ground zero. The quartz antenna windows fared badly: molten glassy sand had fused to the quartz and rendered the antenna useless. Our ceramic windows came through with flying colors, which we would never have known without a live test. The soil immediately around ground zero had melted and fused like glass. Strangely, contrary to any intuition, the wooden pole supporting the bomb still stood; it barely splintered and hardly scorched. What goes on at the center of an exploding nuclear device is a mystery

***A Witness to a Century – A Memoir*, D. Alsberg, 2002**



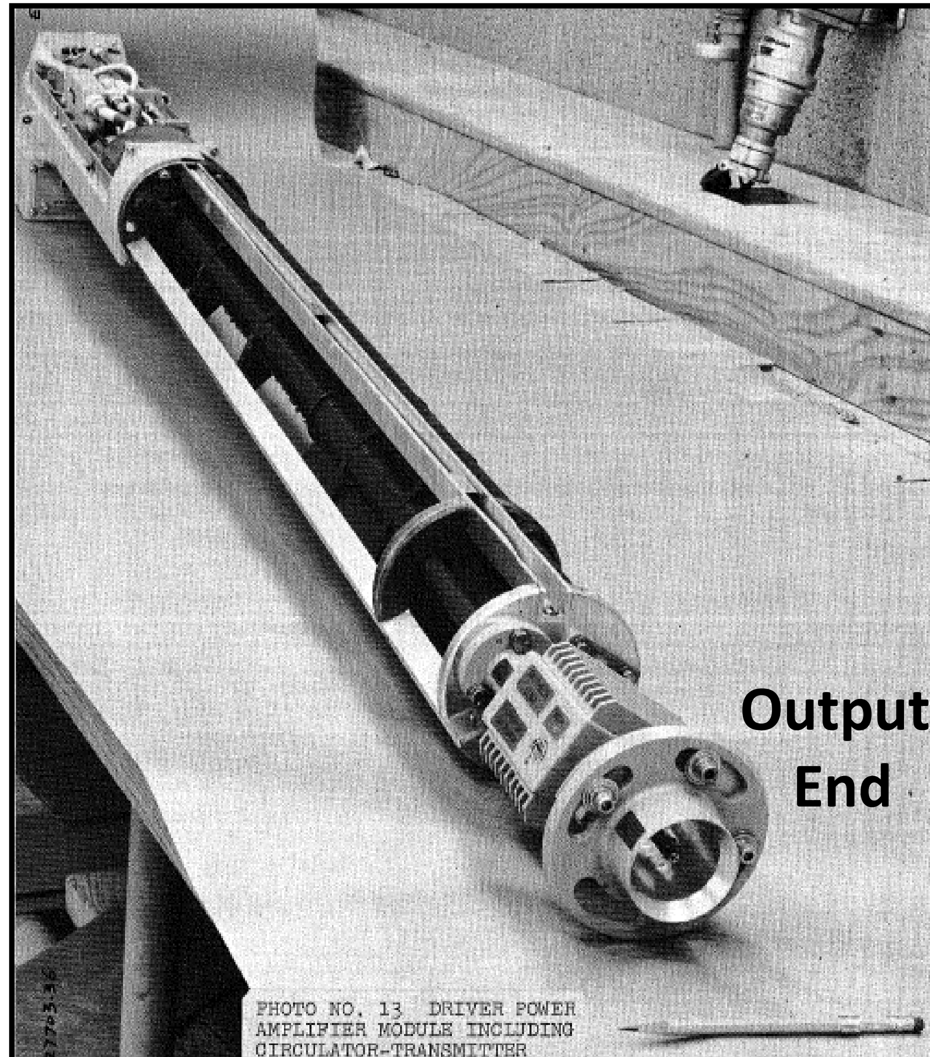
MAR-I Transmitter
Driver Power Amplifier (DPA) Module

Each of the 805 active Transmitter *Antenna Elements* was driven with a *Driver Power Amplifier*.

The DPA was nearly 5½ ft long and contained a *Traveling Wave Tube* (TWT) supplied by Raytheon Corporation.

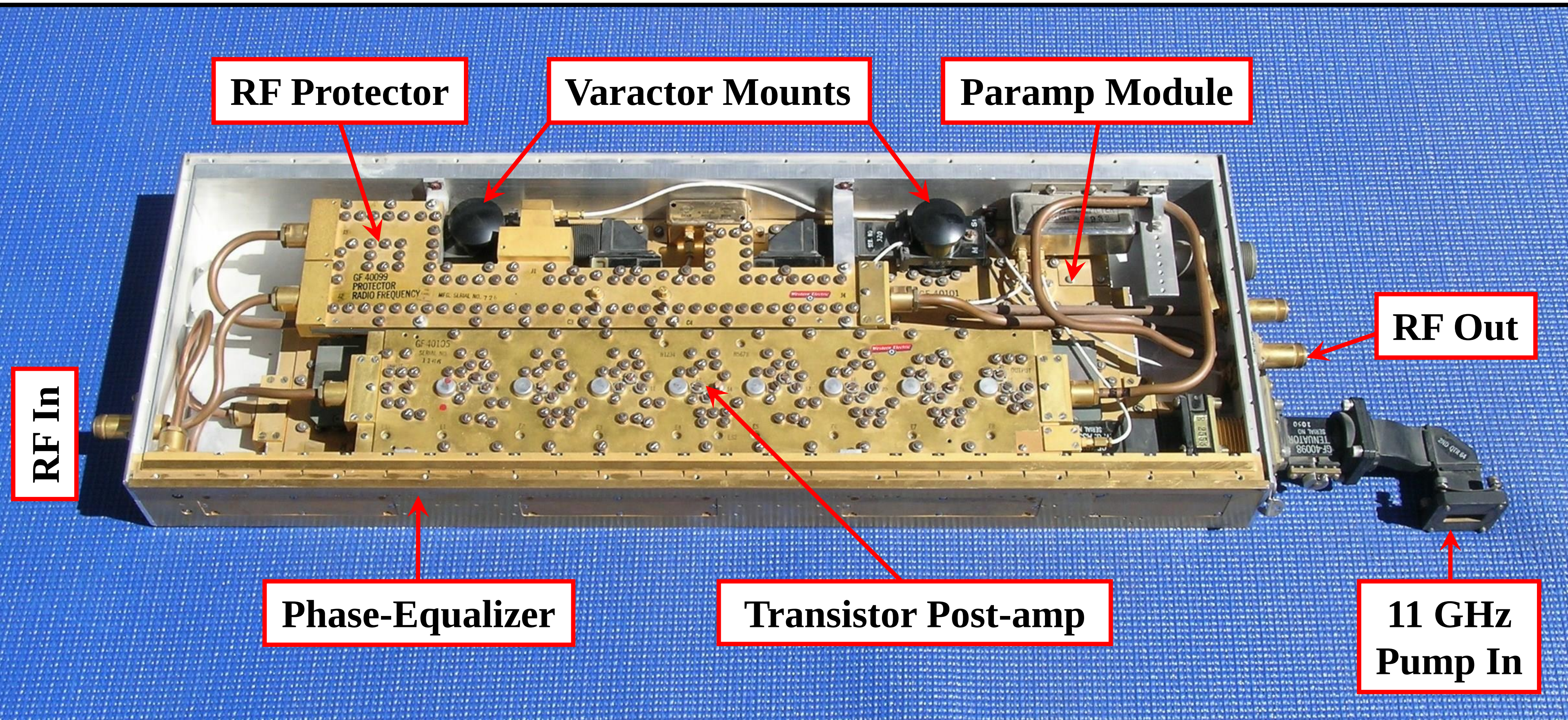
Each TWT had a peak output power of about 5 kilowatts and was cooled with distilled water.

This implies the MAR-I Tx had an output power of nearly 4 Megawatts.



WSMR Archive ID # 10-010-001, *MAR I Critique (Preliminary)*, 1964-06-15, Figure 6.2.3.1
WSMR Archive ID # 10-010-001, *Review of Mechanical Problems Associated with the MAR-I*, 1964-06-05, Photo 13

MAR-I WECo *Preamplifier* (WECo Model GF-40096-L2, S/N 930)



The unit contained several additional modules and was obviously built to take a beating (or a nuclear strike).

The MAR-I *Preamplifier* unit consisted of a
2-stage *paramp* with…
Gain = 16 dB
Noise Temp = 110°K.

Dimensions (inches)
L x H x W =
26” x 9⅛” x 2⅝”
Weight = 32 lbs

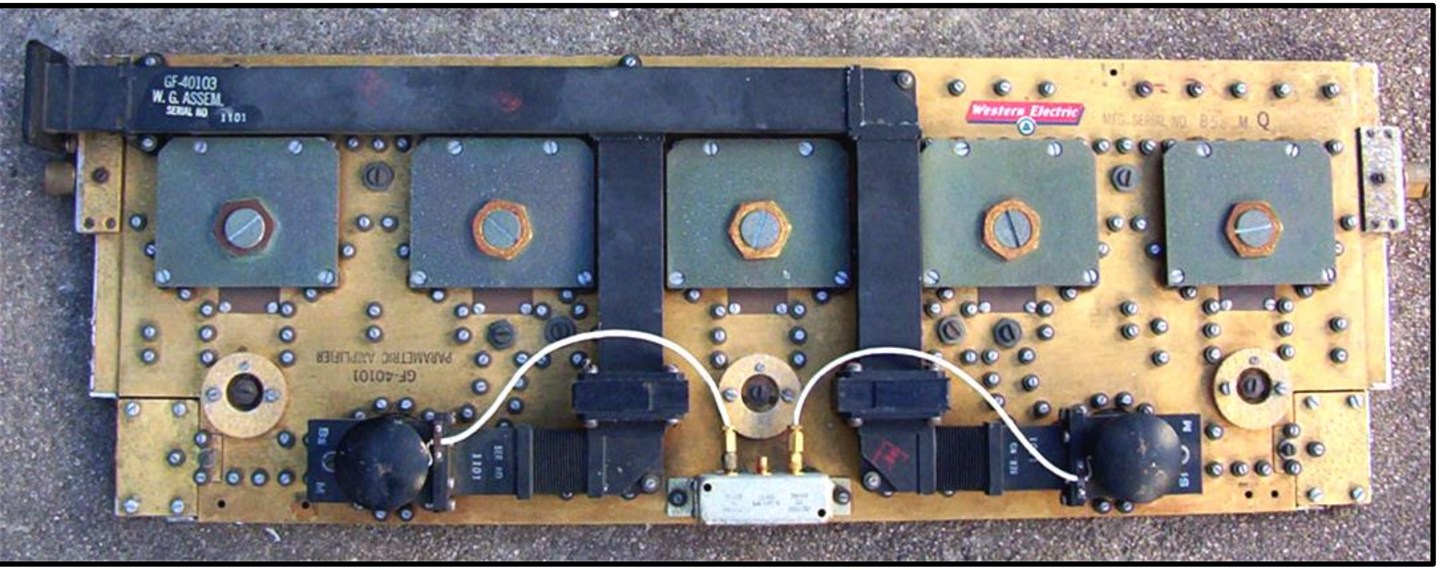
On the MAR-I, the 2077 preamps would weigh 33.2 tons.

Photo by R. Hayward

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

Today’s version of this 56 dB *Preamplifier* would require 4 or 5 gain stages and wpuld have a noise temperature < 100°K in a package about 1/100th the size.

The 2-Stage MAR-I Parametric Amplifier



Numerous adjustments were needed to tune the WECo Paramp:

- 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

The first ever "*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)

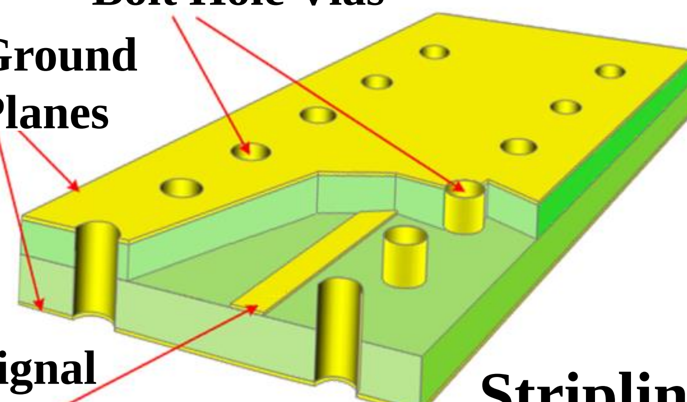
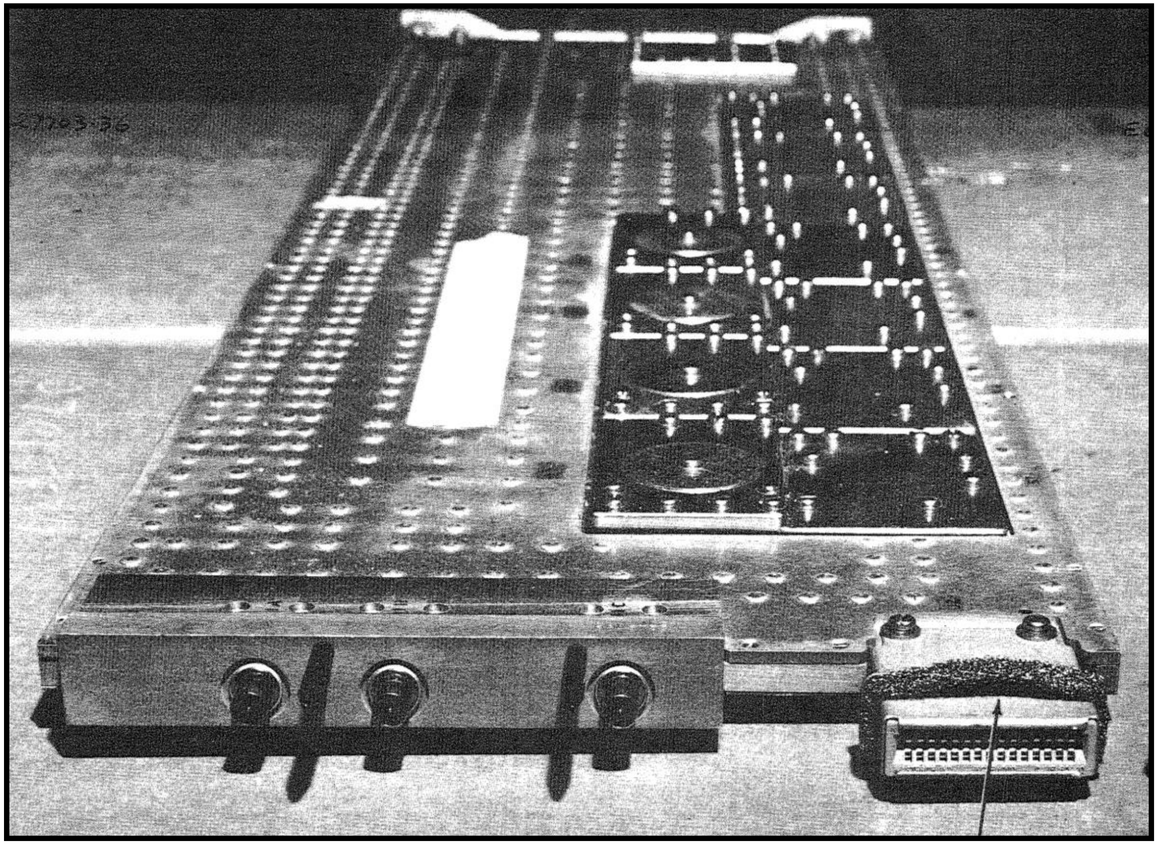


Photo courtesy of Gloria Dubner & Juan Carlos Olalde
http://www.ami.ac.uk/courses/topics/0006_emcpcb/

MAR-I Digital Delay Stripline Board

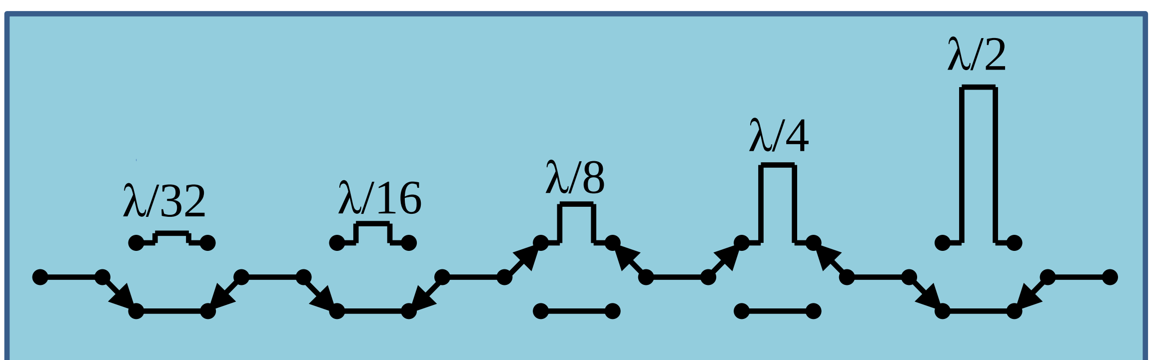


A programmable time delay was applied to the signal from each *Antenna Element* to steer the beam.

This was done with a *Digital Delay Board*. For example, over 10,000 *Delay Boards were used to* steer the *Search*, *Discriminate* & *Track* beams in Elevation.

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

From the *Beta Racks*, the signals went to the *Alpha Racks* where a smaller number of *Delay Boards* steered the beam in Azimuth.



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

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

For the large 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

Display Boards & Block Diagrams

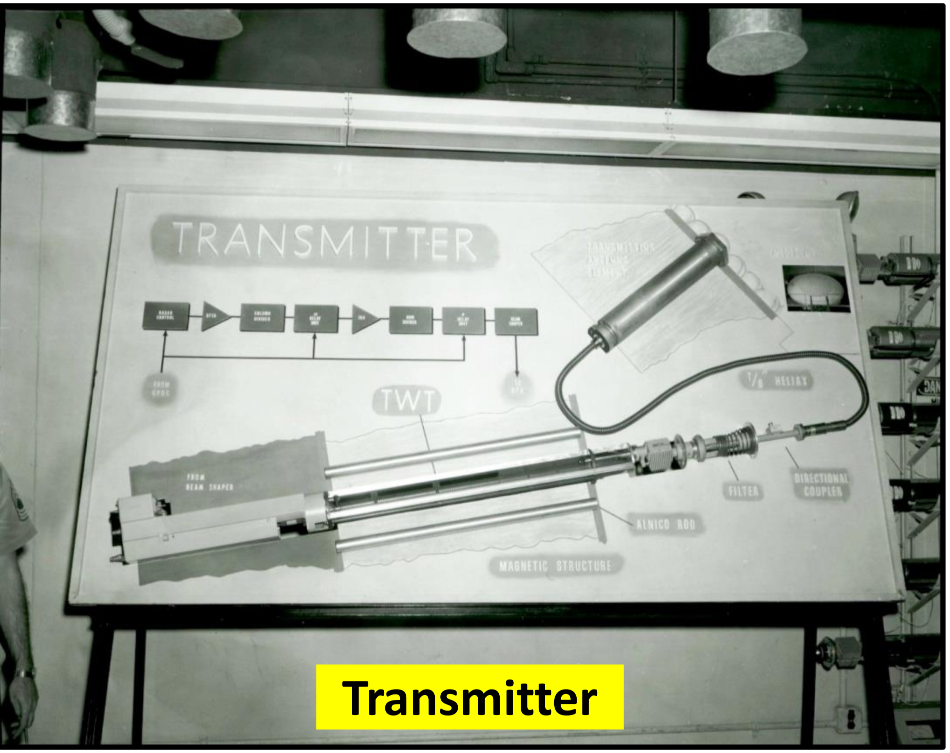
(used during guided tours of the facility)

Bob Gamboa & the *Tour Guide "Crib Notes"*

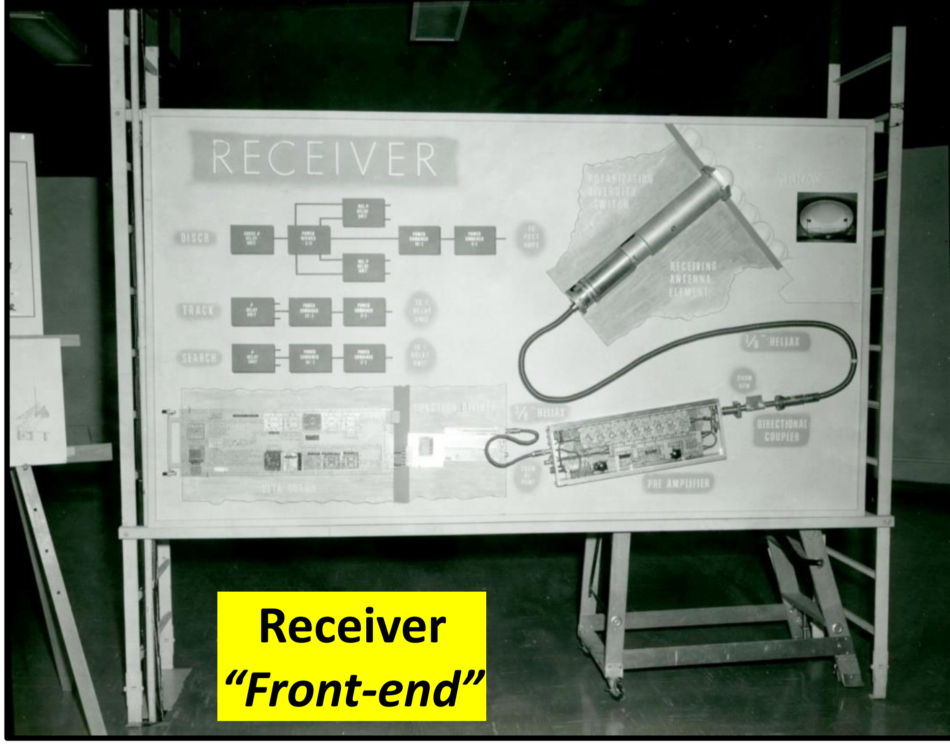
- <u>**Bob Gamboa**</u> **worked for *Western Electric,* the prime contractor for the Nike-X project, at WSMR from 1960 to 1966 as an Electronic Buyer and later in the Nike-X Public Relations office.**

- **In 2010 Bob sent me MAR-I related material from his personal collection. He had found 2 sets of briefing notes from 1965 written for Col. Ivey Drewry, the Nike-X program manager, which were used when he was conducting guided tours of the MAR-I to visiting VIPs.**
- **One 7 page document was an introductory overview presentation of the radar, providing information on the general layout of the MAR-I.**
- **The second 15-page document was a real show stopper as it was essentially the "crib notes" for a walk-through of the MAR-I facility and contained detailed descriptions of the Tx Array, the Rx Array, and the Radar Control Room**
- **The document also made references to 3 different "*display boards*" at various locations during the tour. Alas, no pictures were preserved with the document.**
- **But several pictures of the MAR-I sent to me in 2016 by Sharon Watkins-Lang of the *Redstone Arsenal Historical Office* showed all 3 of the display boards.**
- **It was finally great to actually see what the tour guide had been pointing at as he had read from his crib notes. Reading them now with the newly discovered pictures adds much to our understanding of the MAR-I.**

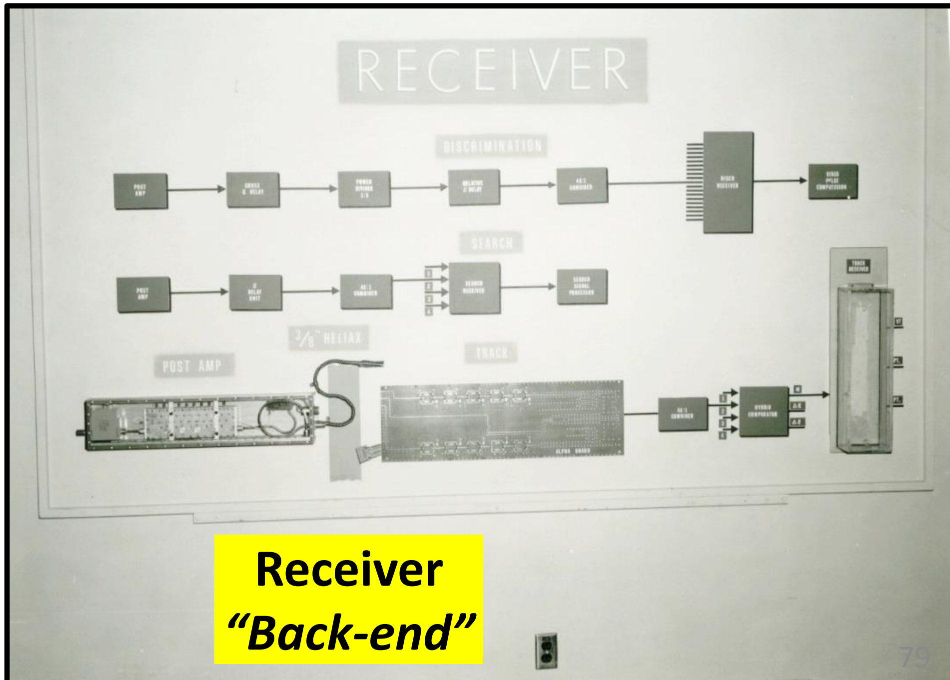
MAR-I Display Boards
29 July 1964



Transmitter



Receiver *"Front-end"*



Receiver *"Back-end"*

During guided tours of the MAR-I, these 3 display boards were used to explain how the complex phased-array worked.

Several critical components were actually mounted on the boards as visual aids, such as *Antenna Elements, TWT, Preamplifier, Functional Divider, Postamp & Delay Boards.*

Images from the collection at the USASMDC/ARSTRAT Historical Office, Redstone Arsenal
Courtesy Sharon Watkins-Lang

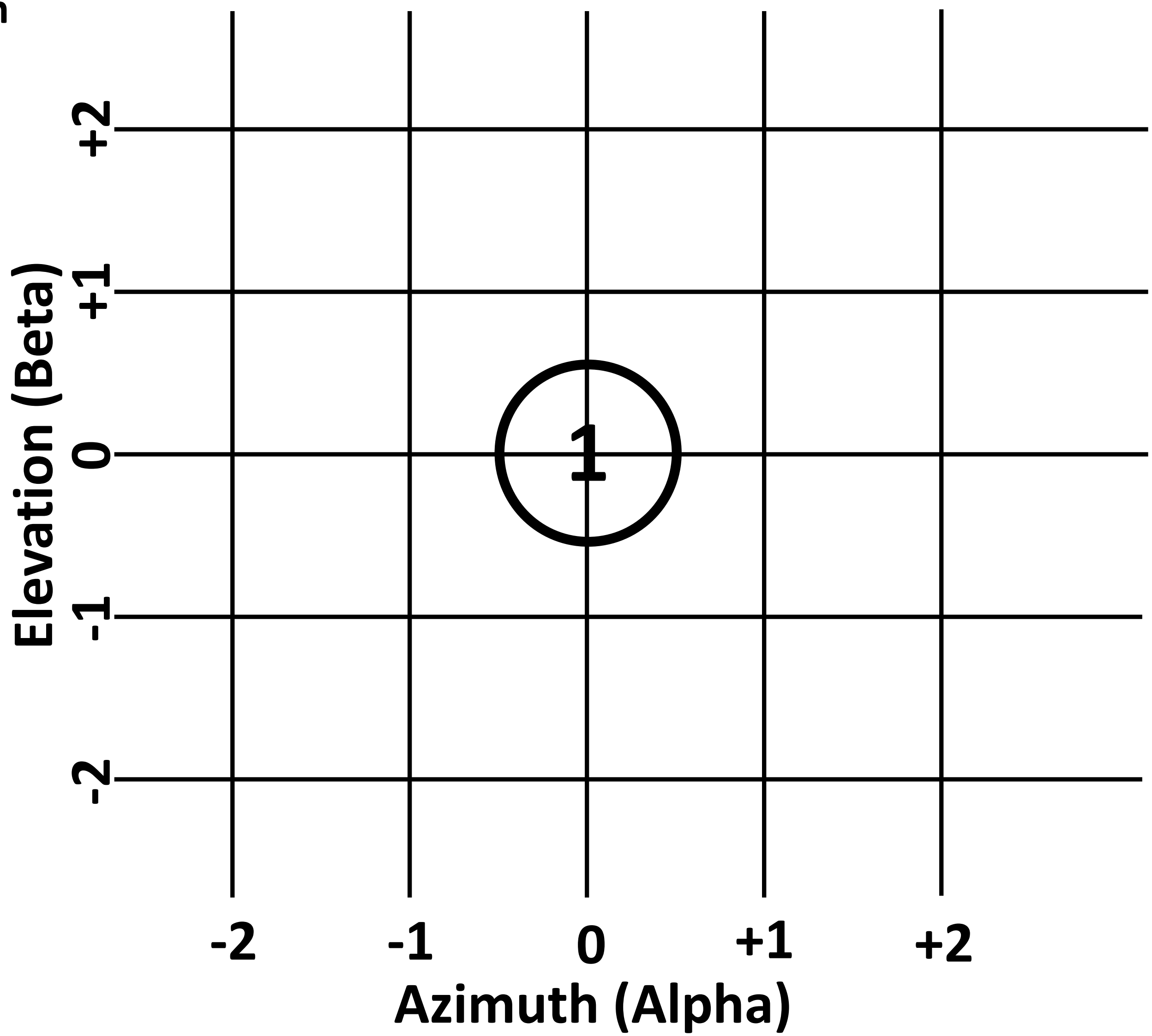
Forming the MAR-I's 19 Concentrically Packed Discrimination Beams or "*Threat Tubes*"

One surprising feature of the MAR-I that was discovered from the Display Boards was that the radar had a cluster of 19 Beams when it was in Discrimination Mode.

These were formed with each of the 2077 antenna elements forming a central Discrimination Beam along with 4 Relative Offsets in Beta and 4 Relative Offsets in Alpha

Both the offset & the width of the beams could be controlled.

Changing the offset would be done by changing the relative Beta & Alpha delays.



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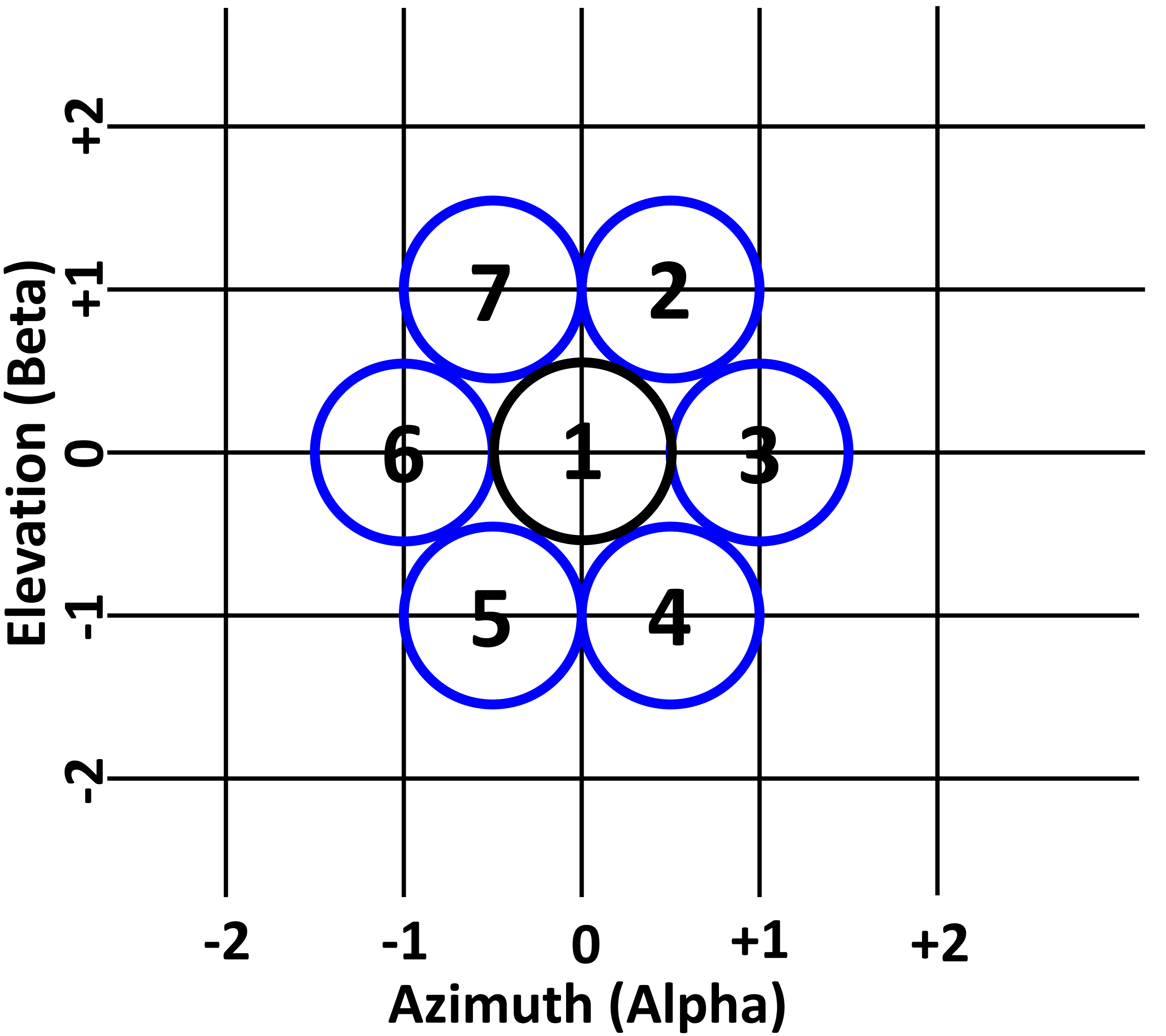

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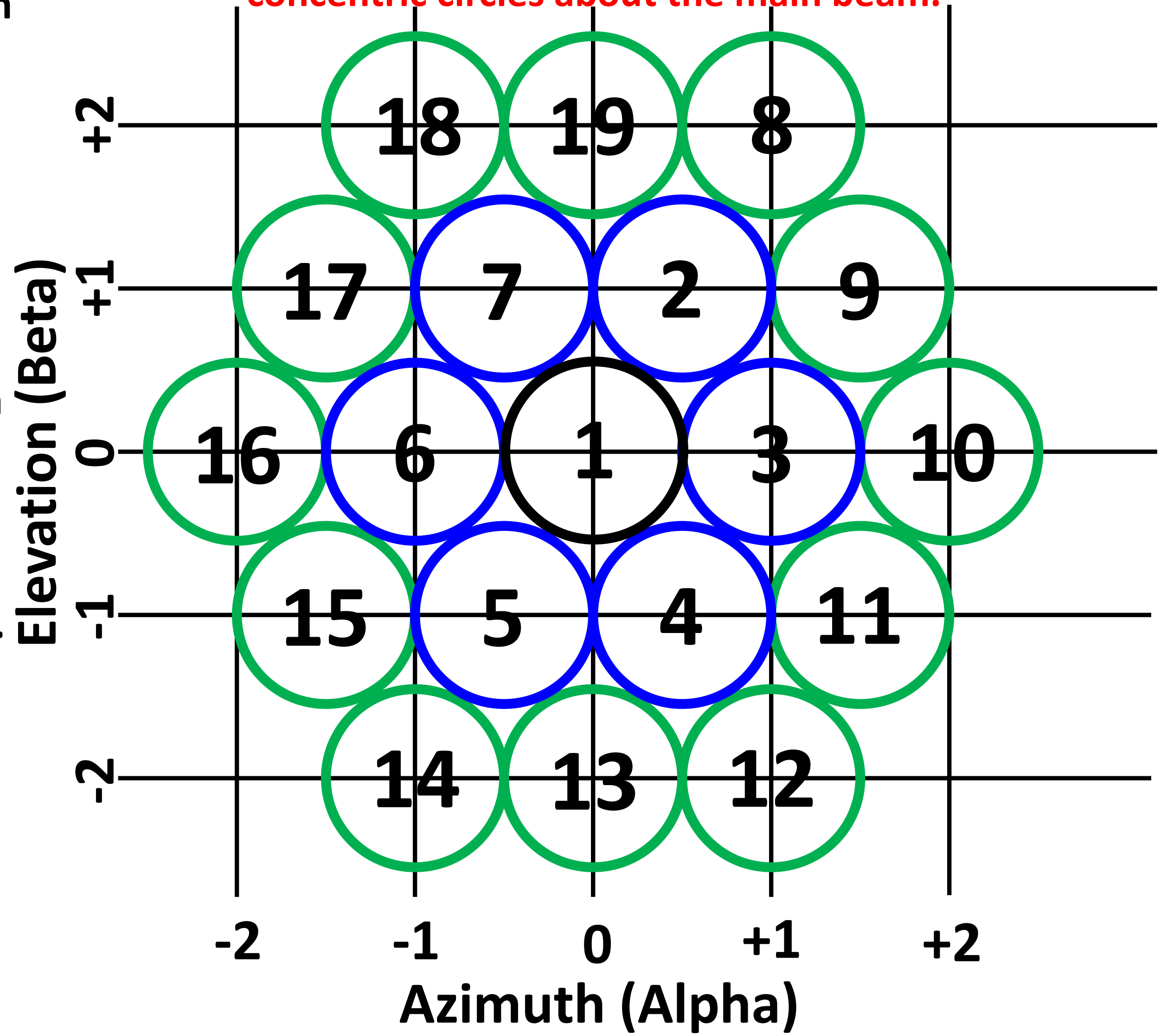
Changing the offset would be done by changing the relative Beta & Alpha delays.

Generating 19 beams would form 2 concentric circles about the main beam.



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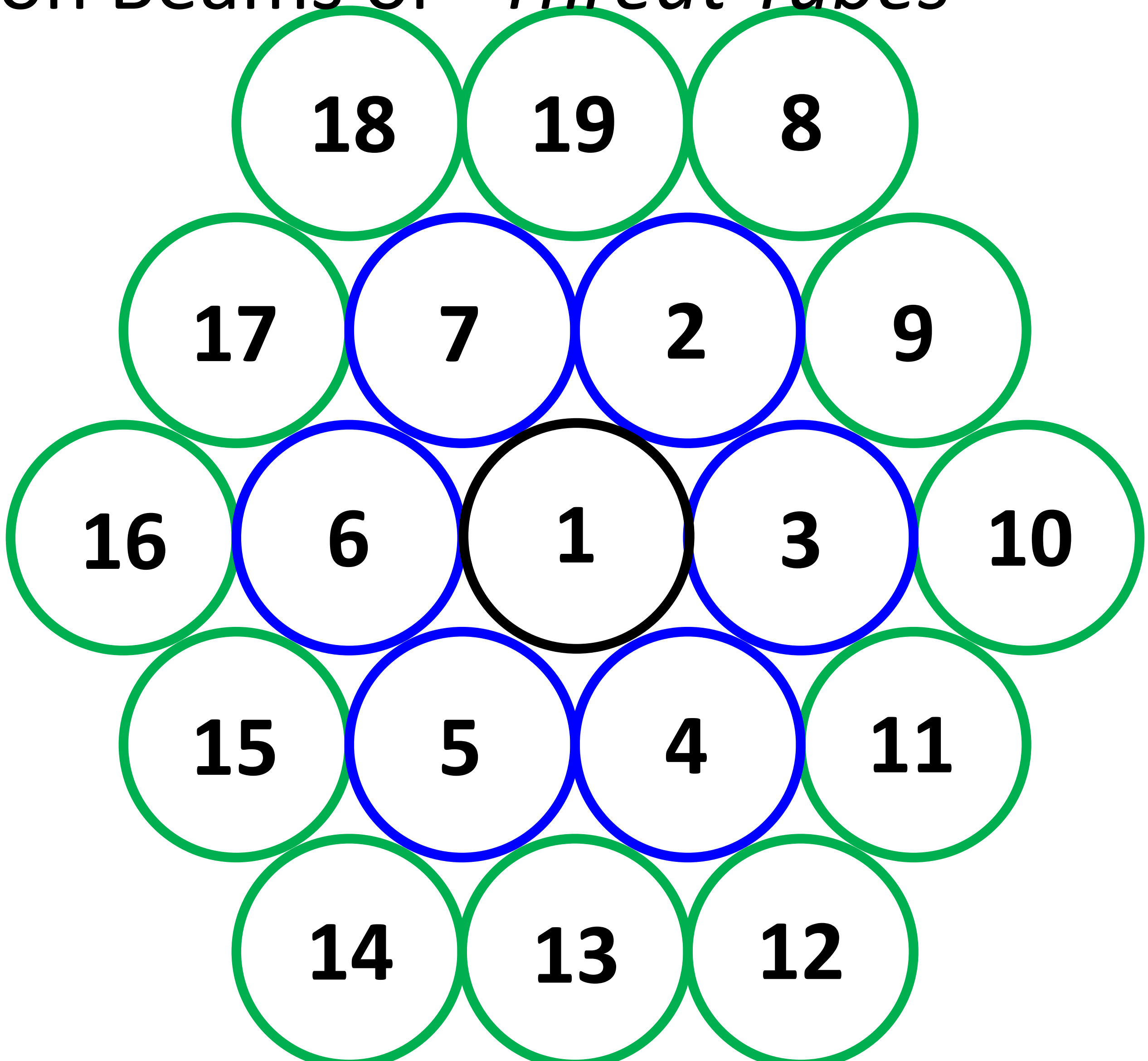
Both the offset & the width of the beams could be controlled

Changing the offset would be done by changing the relative Beta & Alpha delays.

Making the beamwidth larger would require dropping antenn elements along the perimeter s that the effective diameter of tl array was less.

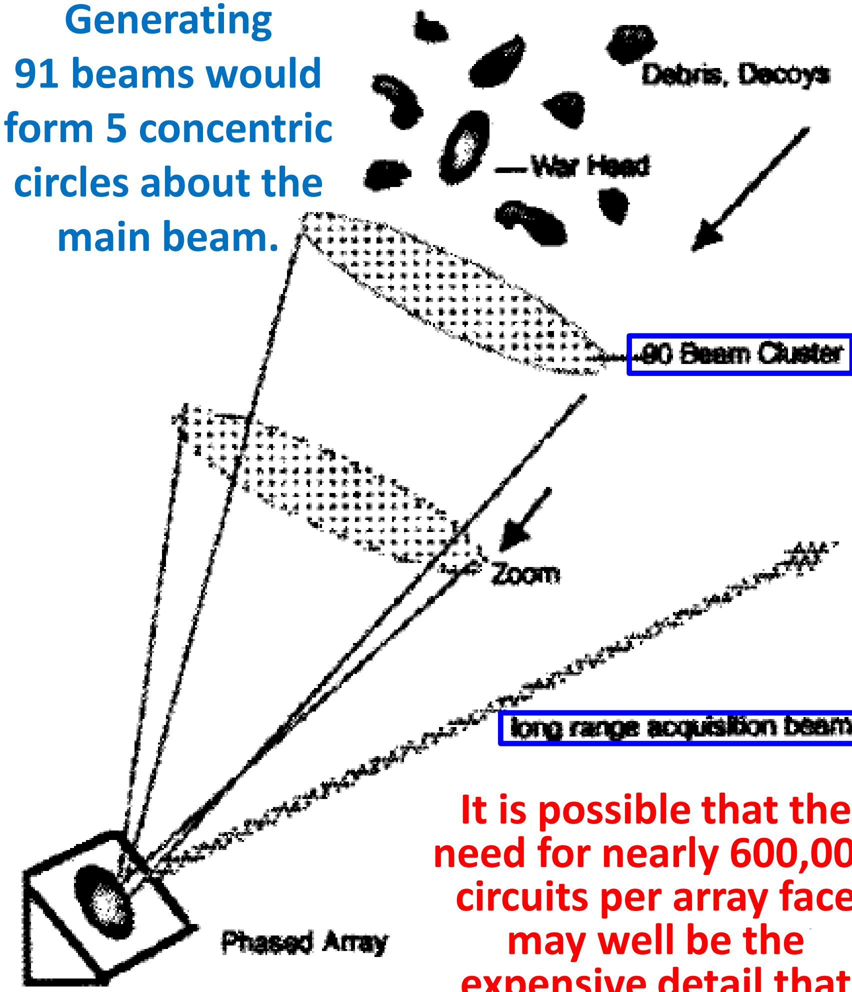


This allowed the Threat Tubes to "zoom out" as the target cloud got closer.

Dietrich Alsberg on the Operational MAR

The MAR-I prototype had 2,077 elements in its Receiver array face & 19 Discrimination Beams.
An operational MAR would have had 6,405 elements (on each of its 4 array faces), and would have formed 91 Discrimination Beams which could be zoomed in & out.

Generating 91 beams would form 5 concentric circles about the main beam.



It is possible that the need for nearly 600,000 circuits per array face may well be the expensive detail that would kill the MAR .

Fig. 11.1 Multi Function Phased Array Radar

Since the receiver antenna had to track individual pieces of the threat cloud, antenna beams had to be narrow. The receiver antenna therefore had 6,400 antenna elements. A single tracking beam was required in the receiver during the target acquisition mode. Once the target cloud reentered the atmosphere, the receiver switched to a zooming cluster of 90 individual beams that sorted out the war heads from the surrounding decoys and tank debris.

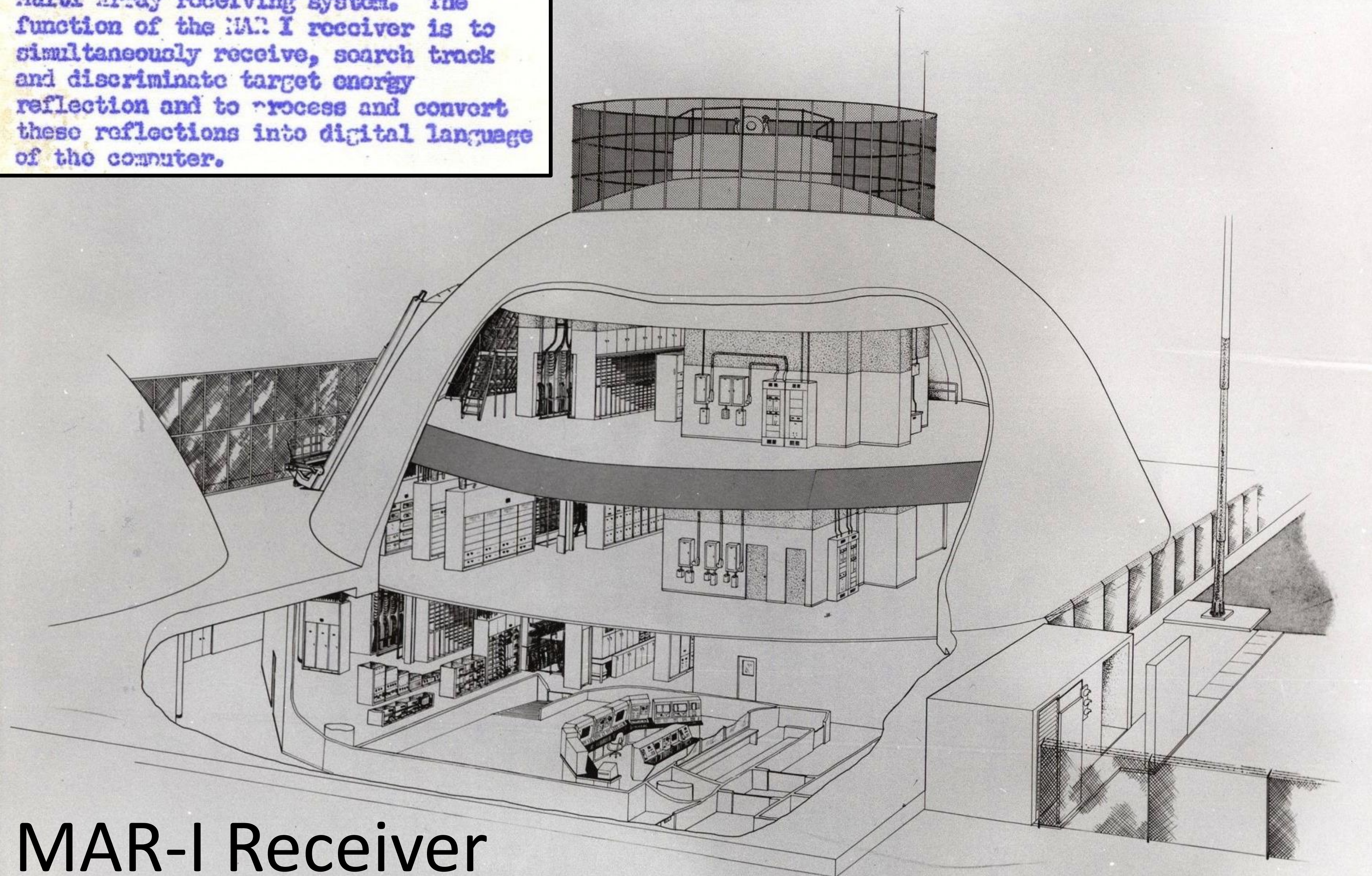
Immediately at the output of each antenna element was a low noise amplifier. The amplifier output was split and connected to individual phase shift and amplitude control circuits for each of the ninety beams. Each of the 6,400 antenna elements had their own ninety phase and amplitude control circuits, totaling 600,000 circuits and their associated wiring. From the rear the antenna array looked like tubes arranged in honeycomb fashion. There was little space between the tubes to accommodate the massive control wiring. We ended up with 9 feet deep cable beams that had to fit into the narrow spaces between the individual antenna elements.

In a phased array, the number of antenna elements used determines the size of the beam. The fewer elements, the broader the beam. As the number of elements increases, the beam narrows like a well-focused flashlight. When the threat cloud is first detected, it is far distant and appears very small. As it approaches the target, it looks larger and larger. The ability of the phased array to go from a narrow to a broad beam makes it possible to "zoom" it like an optical zoom lens. At the farthest distance, the antenna can concentrate its power on the small "dot." As the cloud comes closer and closer, it appears larger and larger, and the transmitter antenna beam is zoomed to illuminate the entire cloud. When the cloud enters the atmosphere, the receiver operation switches to 90 independent beams that can track and examine each piece in the cloud. A sophisticated computer program analyzes the "signature" of each object and identifies which object is a war head and a real threat.

A Witness to a Century – A Memoir, D. Alsberg, 2002, p.249-252

Multifunction Array Radar (MAR-I) Drawings

This is a cutaway diagram of the Multi Array receiving system. The function of the MAR I receiver is to simultaneously receive, search track and discriminate target energy reflection and to process and convert these reflections into digital language of the computer.

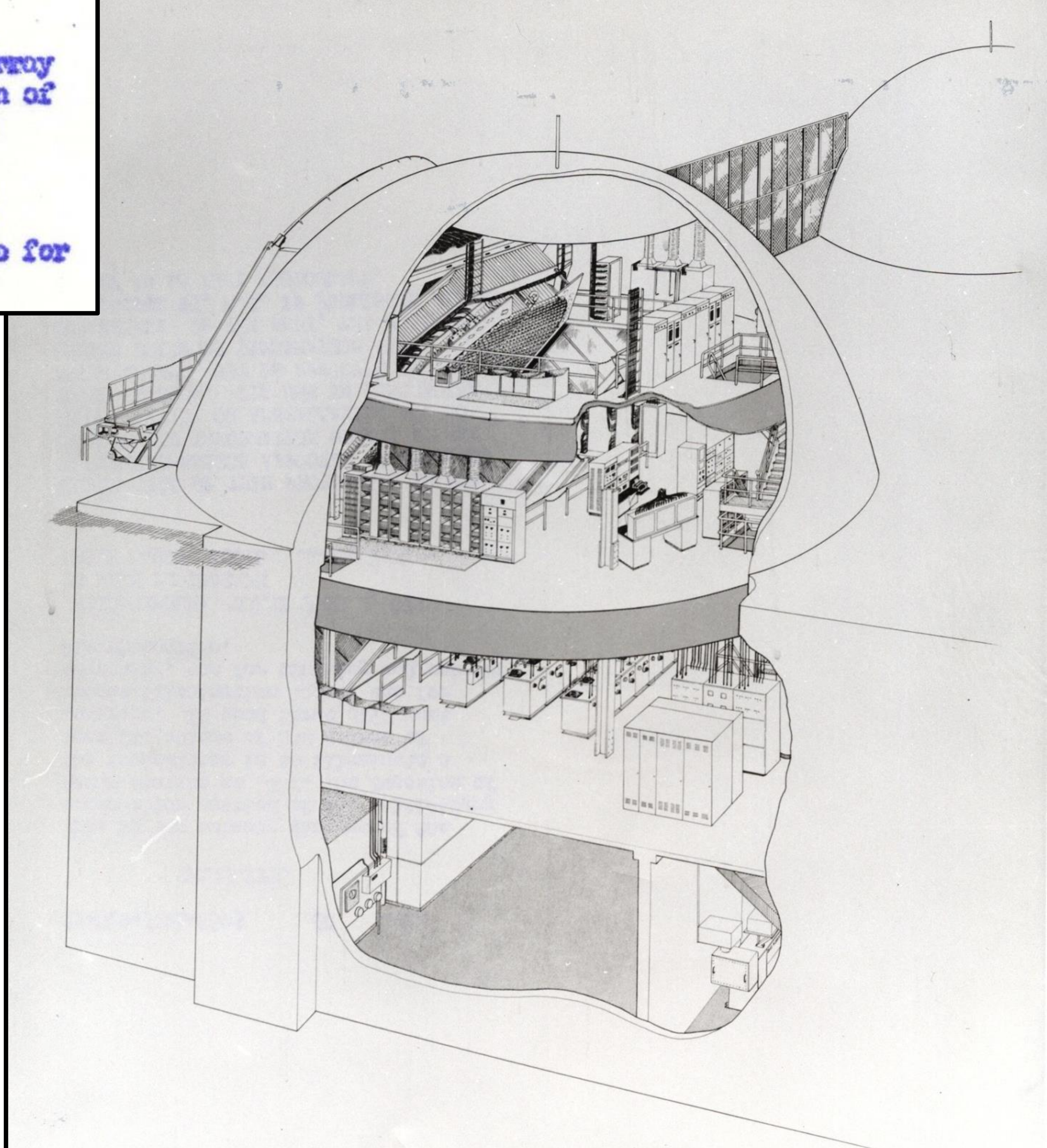


MAR-I Receiver Cutaway Drawing, c.1963

WSMR Archive ID # 12.007.784

This is the cutaway diagram of the transmitter section of the Multi-Array Radar station at WSMR. The function of the transmitter is to illuminate a specific volume of MAR volume of coverage. It used three different shaped illumination beams: one for searching, one for tracking and one for discrimination.

MAR-I Transmitter Cutaway Drawing c.1963



WSMR Archive ID # 12.007.785

MAR-I "As-Built" Drawings (c.1963)

ZEUS MULTIFUNCTION ARRAY RADAR FACILITIES

DEFINITIVE DRAWINGS
FOR
WHITE SANDS MISSILE RANGE – NEW MEXICO

PREPARED FOR
BELL TELEPHONE LABORATORIES INC.
WHIPPANY, NEW JERSEY

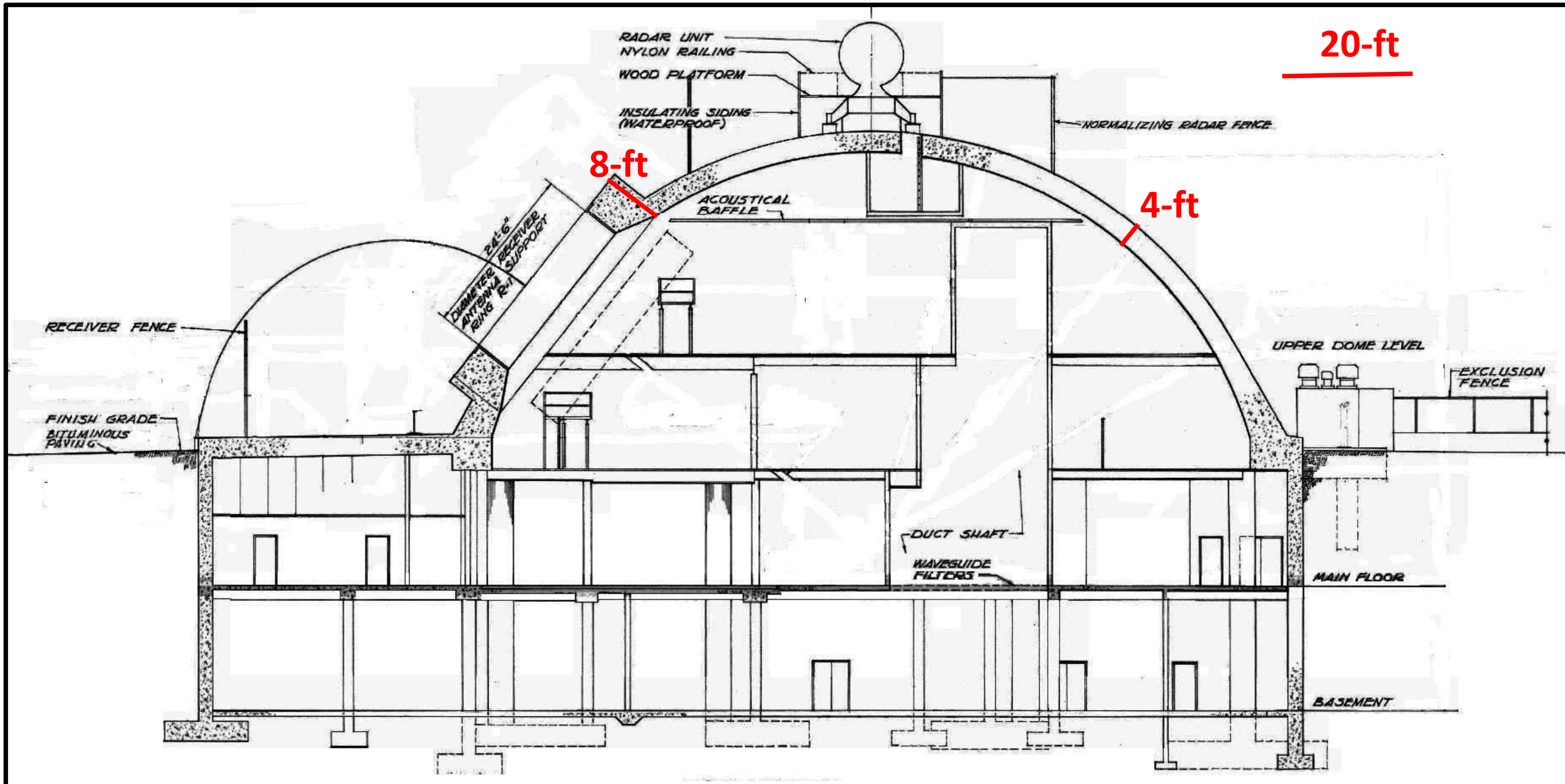
BY
THE RALPH M. PARSONS COMPANY
LOS ANGELES, CALIFORNIA

UNDER SUPERVISION OF
CORPS OF ENGINEERS
OFFICE OF THE DISTRICT ENGINEER
MOBILE, ALABAMA

In 2016, while clearing out a large number of filing cabinets that were in storage at the Tech Support Area at HELSTF, a 16-page set of architectural drawings from 1963 were found that showed the "as-built" configuration of the MAR-I Site.
Exquisite in detail, the drawings show everything from dimensions to how many electronic racks there were, and what their functions were.
Dated : 21 Aug 1962 & 2 May 1963 (with revisions from as late as 17 Jan 1964)
The drawings all date from the early days when the test-bed facility was known as the *Zeus Multifunction Array Radar* (ZMAR).

Zeus Multifunction Array Radar Facilities – Definite Drawings for White Sands Missile Range – NM, 1963, p.1

Sample MAR-I Drawing – Dome Section

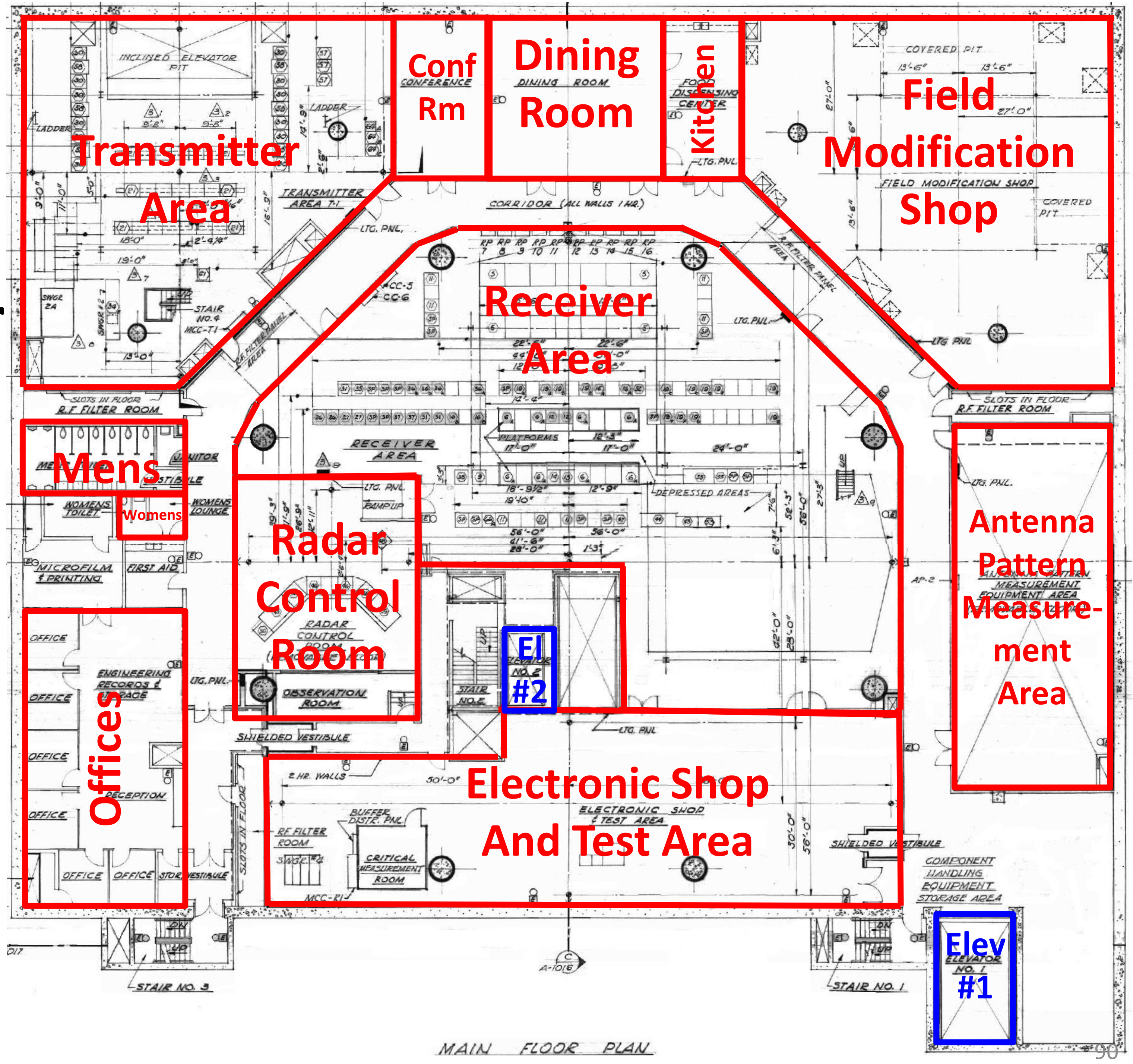


Zeus Multifunction Array Radar Facilities – Definite Drawings for White Sands Missile Range – NM, 1963, p.10

Sample MAR-I Drawing

Main Floor Plan View

All of the numerous electronic racks were numbered and identified on separate equipment lists.



Zeus Multifunction Array Radar Facilities – Definite Drawings for White Sands Missile Range – NM, 1963, p.6

MAR-I Equipment List (1/5) - Transmitter

TRANSMITTER EQUIPMENT

ITEM NO.	COMPONENT NOMENCLATURE	TASK NO.	NO. STD. RACKS	SPECIAL RACKS NO.	SPECIAL RACKS SIZE W×D×H	COOLING TYPE	COOLING WATTS/RACK	WEIGHT # PER RACK	REMARKS
20	TRANSMITTER POWER TRAIN (DPA EGG CRATE)	3.1	NONE	1	21'×11½'×24'	WATER AIR	2.2×10^6 120×10^3	263,000	ITEM 20 INCL. SUPPORT & MAGNETIC STRUCT., DPA MOD. CIRCULATORS, VACUUM RELAYS, FILTERS, DIRECT'L. COUPLERS, INTERNAL AIR COOLING DUCTS & LIQUID COOL'G. LINES & FITTINGS
21	H.V.P.S.	3.1	NONE	20	33"×24½"×46"	WATER	5000	5000	
23	BETA STEERING	4.4	NONE	8	40"×46.31"×80"	AIR	SEE NOTE 1.		INCL. SW. DRIVER UNITS
24	A. PS B. IDA & BFIA C. IDA D. PS	3.2	4	NONE		AIR	A&D 1100 B&C 1850	A&D 700 B&C 300	
25	ALPHA STEERING	4.4	NONE	1	40"×46.31"×80"	AIR	SEE NOTE 1.		
26	PULSE CODING	5.1	2	NONE		AIR	600	1000	BTL SUPPLIED EQUIPMENT
29	POWER SUPPY STEERING SWITCH DRIVERS	7.4	5	NONE		AIR	700 TO 1000	1000	AIR SUPPLY TO EACH RACK AT AVERAGE OF 360 CFM
30	MODULATOR ASSY. (INCLUDING REGULATOR)	3.1	NONE	20	29"×32"×84"	AIR	4700	600	
32	DPA RF MON. PWR COMBINER & SW MATRIX	8.0	NONE	4	40"×27"×65"	NONE		300	2 ON UPPER DOME LEVEL 2 ON LOWER DOME LEVEL
57	RF MON. CROSSBAR SWITCHES, DRIVERS & POWER SUPPLIES	8.2	3	NONE		AIR	800 500	500 400	
58	ENERGY STORAGE CAPACITOR	3.1	NONE	10	29"×36"×84"	AIR WATER	2200 6000	1900	NO DIRECT PIPE CONNECTION
61	TRANSMITTER HV ON-OFF CONTROL	3.1	1	NONE		AIR	900		
63	TRANSMITTER MAINT. CONTROL CONSOLE	8.0	NONE	1	72"×30"×54"	NONE		600	
64	MAGNETIZER A. CONTROL RACK B. CAPACITOR RACK	3.1	NONE NONE	1 1	17"×32"×50" 26½"×31⅜"×50"	NONE			NO SPECIFIC BUILDING REQUIREMENTS - WELDING OUTLETS USED FOR POWER

MAR-I Equip List (2/5) - Receiver

RECEIVER EQUIPMENT

ITEM NO.	COMPONENT NOMENCLATURE	TASK NO.	NO. STD. RACKS	SPECIAL RACKS NO.	SPECIAL RACKS SIZE W×D×H	COOLING TYPE	COOLING WATTS/RACK	WEIGHT # PER RACK	REMARKS
1	PREAMP "EGG CRATE"	4.1	NONE	1	35'×3'×30'	AIR	A. 4150 B. 2,700 C. 9,000		A. PREAMP HEAT LOAD B. PWR SUPPLY HEAT LOAD C. WAVE GUIDE HEAT LOAD
2	RF PUMP & POWER SUPPLY	4.1	NONE	1	7'×4'×6'	WATER AIR	40,000 40,000	5000	6 GPM PRESSURE DROP ACROSS UNIT @ 20 PSI
4	PWR. SUPPLY, PREAMPLIFIER	4.1	NONE	NONE		AIR			SEE ITEM #1 (B.)
5	BETA STEERING	4.4	NONE	41	53"×48"×126"	AIR	SEE NOTE 1.		
6	A. ALPHA STEERING	4.4	NONE	14	33.12"×43.56"×112.5"	AIR	SEE NOTE 1.		
	B. POST AMPLIFIER MODULE DISK	4.1	NONE	14	20.5"×26"×22"	AIR	SEE NOTE 1.		
	C. POST AMPLIFIER TRACK & SEARCH	4.1	NONE	280	1"×13"×4"	AIR	1	2	
9	POST AMP. POWER SUPPLY	4.2	1	NONE		AIR	200	500	
11	PWR. SUPPLY, STEERING SWITCH DRIVERS	7.4	32	NONE		AIR	1200 TO 2900	1000	AIR SUPPLY TO EACH RACK AT AVERAGE OF 350 CFM.
12	TRACK RECEIVER	4.2 - 3	2	NONE		AIR	400,650	428	
13	SEARCH RECEIVER	4.2 - 3	1	NONE		AIR	240	616	
14	DISCRIMINATION RECEIVER	4.2 - 3	1	NONE		AIR	140	588	
16	PULSE CODING A. TRACK	6.1	3	NONE		AIR	600	1200	
	B. DISC.		3			AIR	600	1200	
17	RF MON. CROSSBAR SWITCHES DRIVERS & POWER SUPPLIES	8.2	3	NONE		AIR	1000	500	
18	RF MON. LOGIC		1	NONE		AIR	600	1200	BTL SUPPLIED EQUIPMENT
19	A. SEARCH SIGNAL PROCESSOR	6.4	3	NONE	28"×33"×72"	AIR	900	1200	
	B. VIDEO PULSE CONVERTER	6.3	3	NONE		AIR	600	1200	
	C. TAPE BUFFER	NONE	3	NONE		AIR	900	1200	
	D. COMPUTER (G.P.D.C.)	NONE	7	NONE		AIR	540	1200	
	E. TAPE UNIT	NONE	NONE	6			2500	800	SEE NOTE 2.
	F. COMPUTER SW. BUFFER (CSB)	NONE	2	NONE		AIR	800	1200	
	G. TYPEWRITER UNIT (FLEXOWRITER)	NONE	1	NONE		AIR	450	1200	
40	RECEIVER COMBINER	4.2	NONE	1	66"×36"×42"	NONE		2400	
41	RECEIVER SWITCHING MATRIX	4.2	NONE	1	57"×20"×10"	NONE		60	
43	RECEIVER MAINT. CONTROL FLEXOWRITER		NONE	1	2'×2'×4'	NONE			BTL SUPPLIED EQUIPMENT
44	RECEIVER MAINT. CONTROL CONSOLE		NONE	1	72"×30"×54"	NONE		600	
65	D-UNIT CABINET		NONE	1	93"×46"×80"	AIR	1000		BTL SUPPLIED EQUIPMENT

MAR-I Cabling

A Groundbreaking Computer Program

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

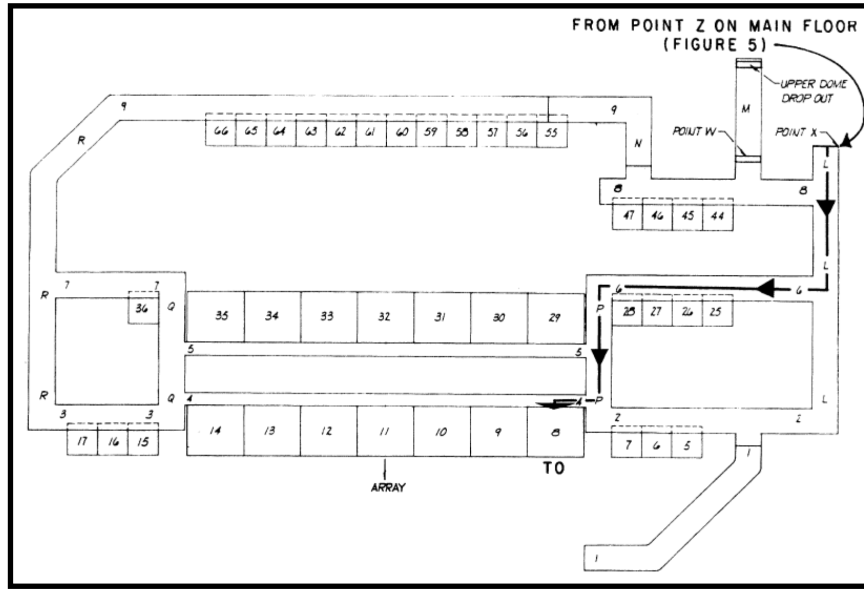
The use of computer techniques to perform moderately complex highly repetitive processes accurately for equipment integration on large scale systems has resulted in a considerable time and cost reduction as well as freeing skilled people for functions requiring human judgment.

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.

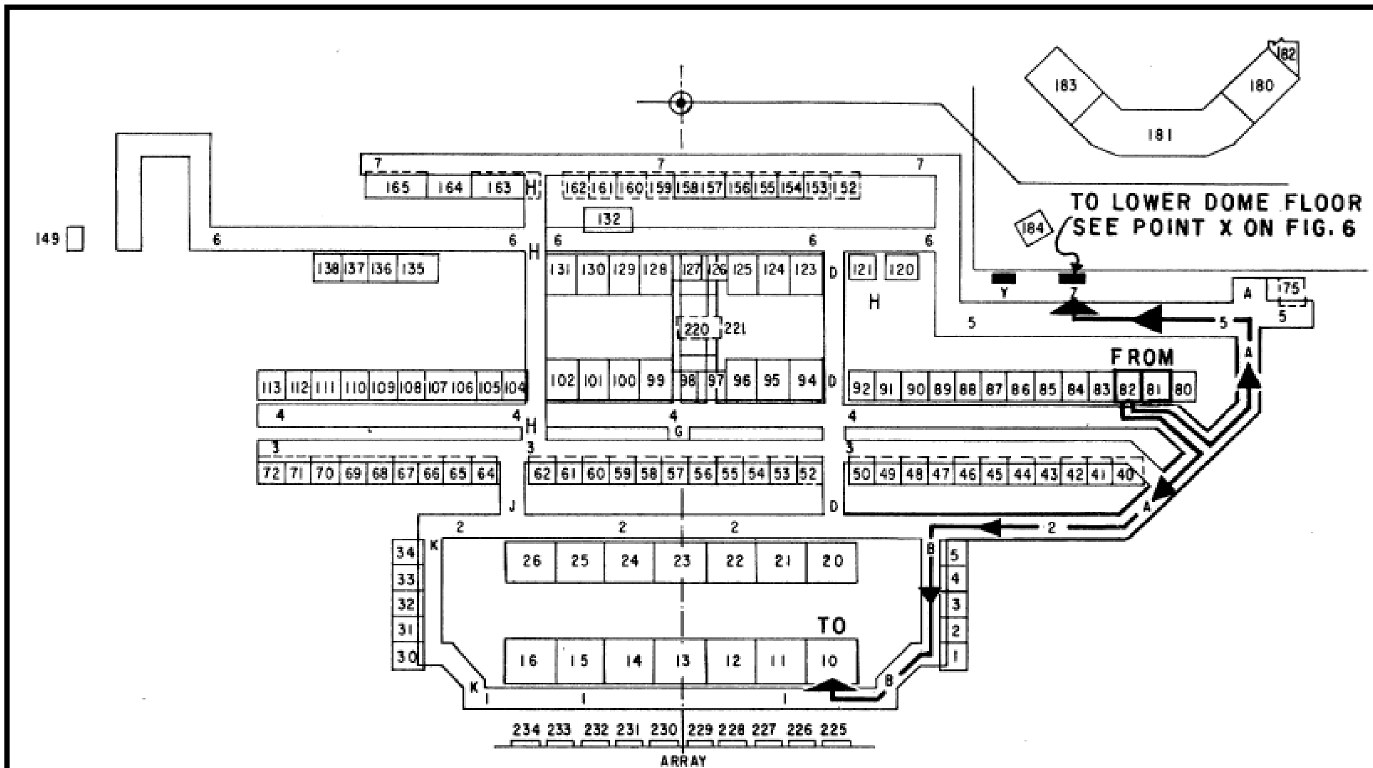
A New Approach to Equipment Interconnection

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 Receiver Dome <u>Lower Level</u> of the MAR-I



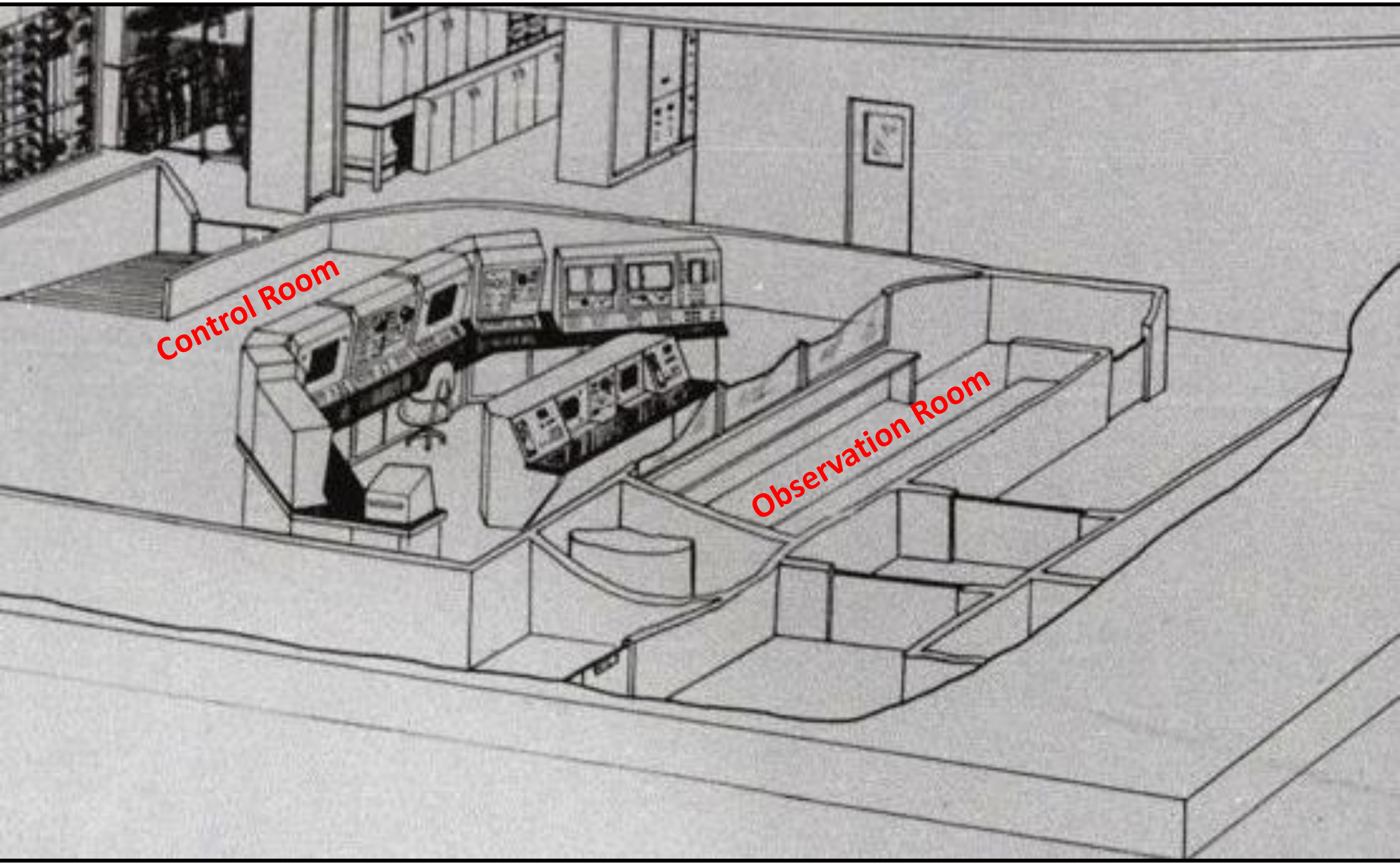
"Street map" of the numerous electronic racks on the Receiver Dome <u>Main Floor</u> of the MAR-I



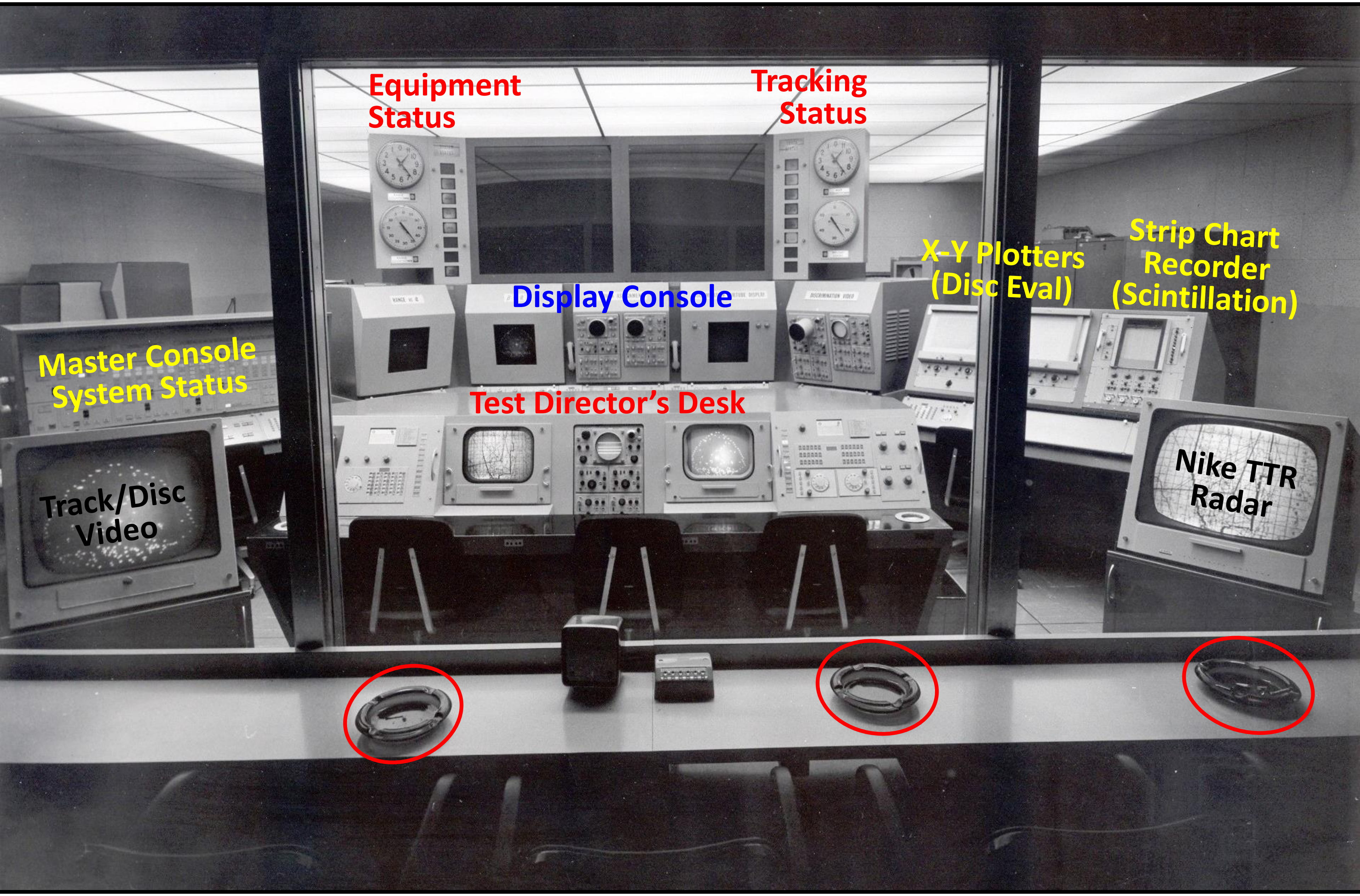
A New Approach to Equipment Interconnection, N. Christopher, IEEE Trans Aerospace & Elect Systems, p.259-271

MAR-I Radar Control Room

MAR-I Cutaway – Control Room

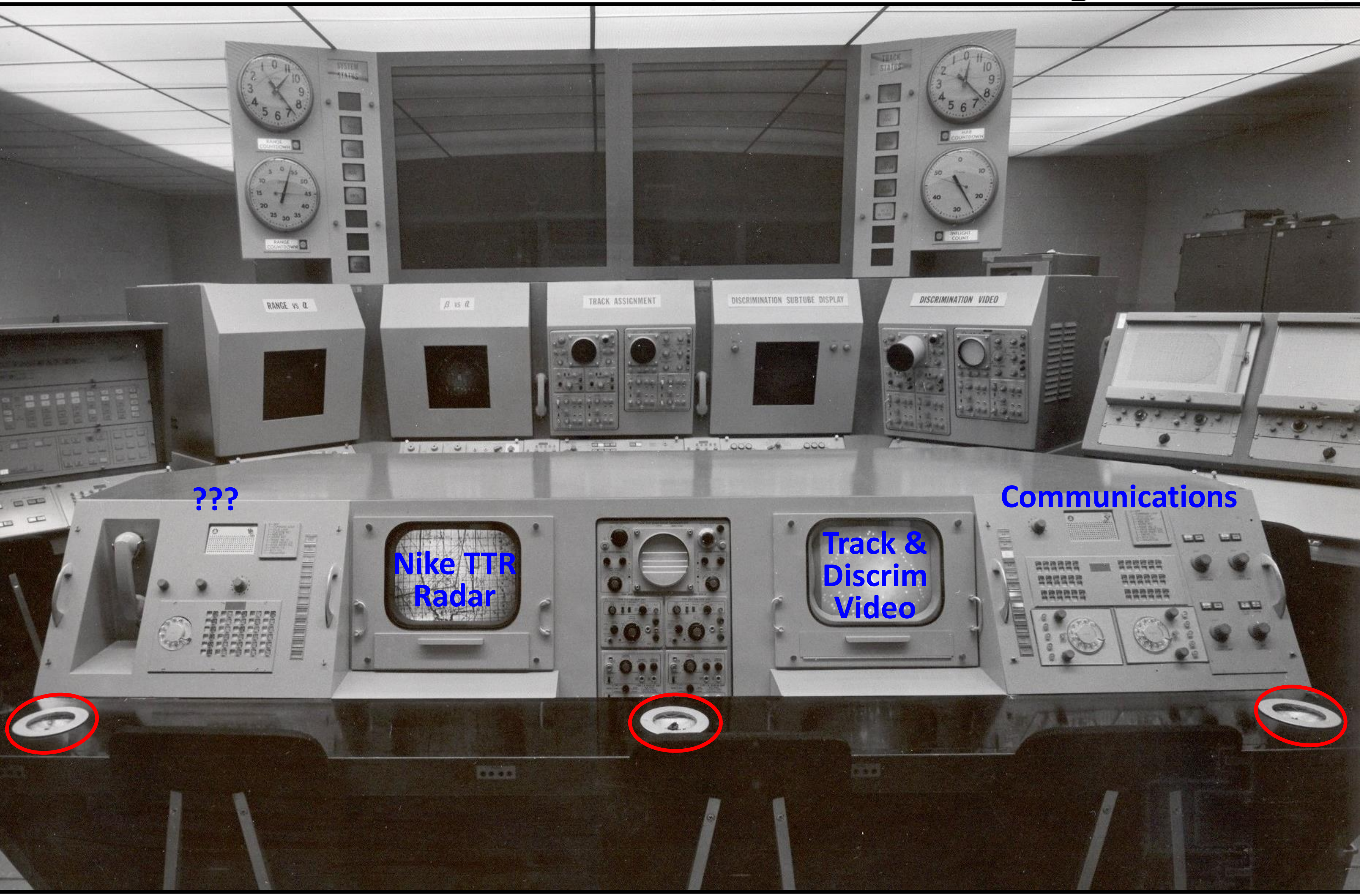


Radar Control Room



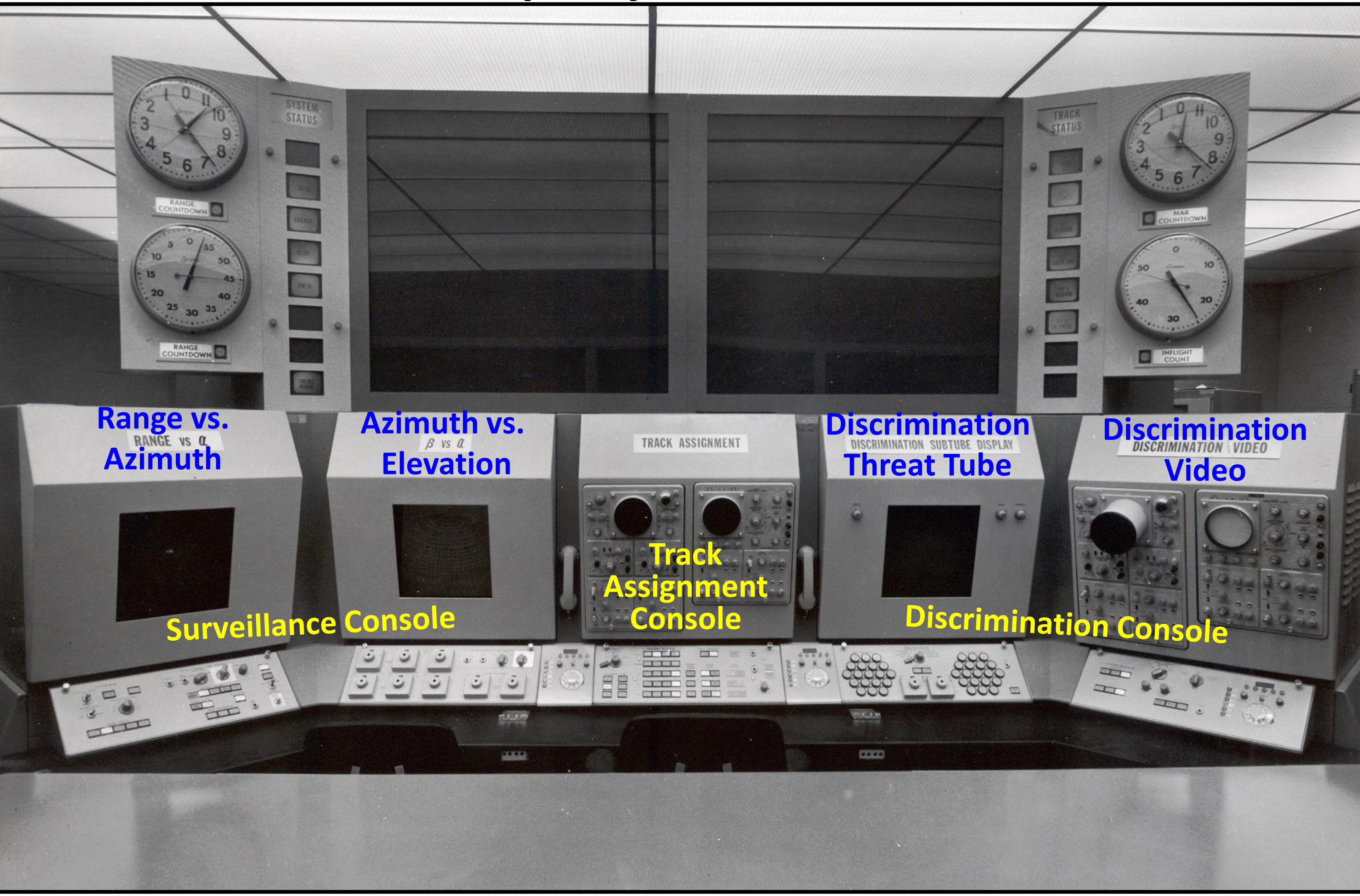
WSMR Archive ID # 97.180.204-19

Test Director's Desk (i.e., Testing Phase)



WSMR Archive ID # 97.180.204-18

Display Console



WSMR Archive ID # 97.180.204-17

Display & Control Desk – Right View

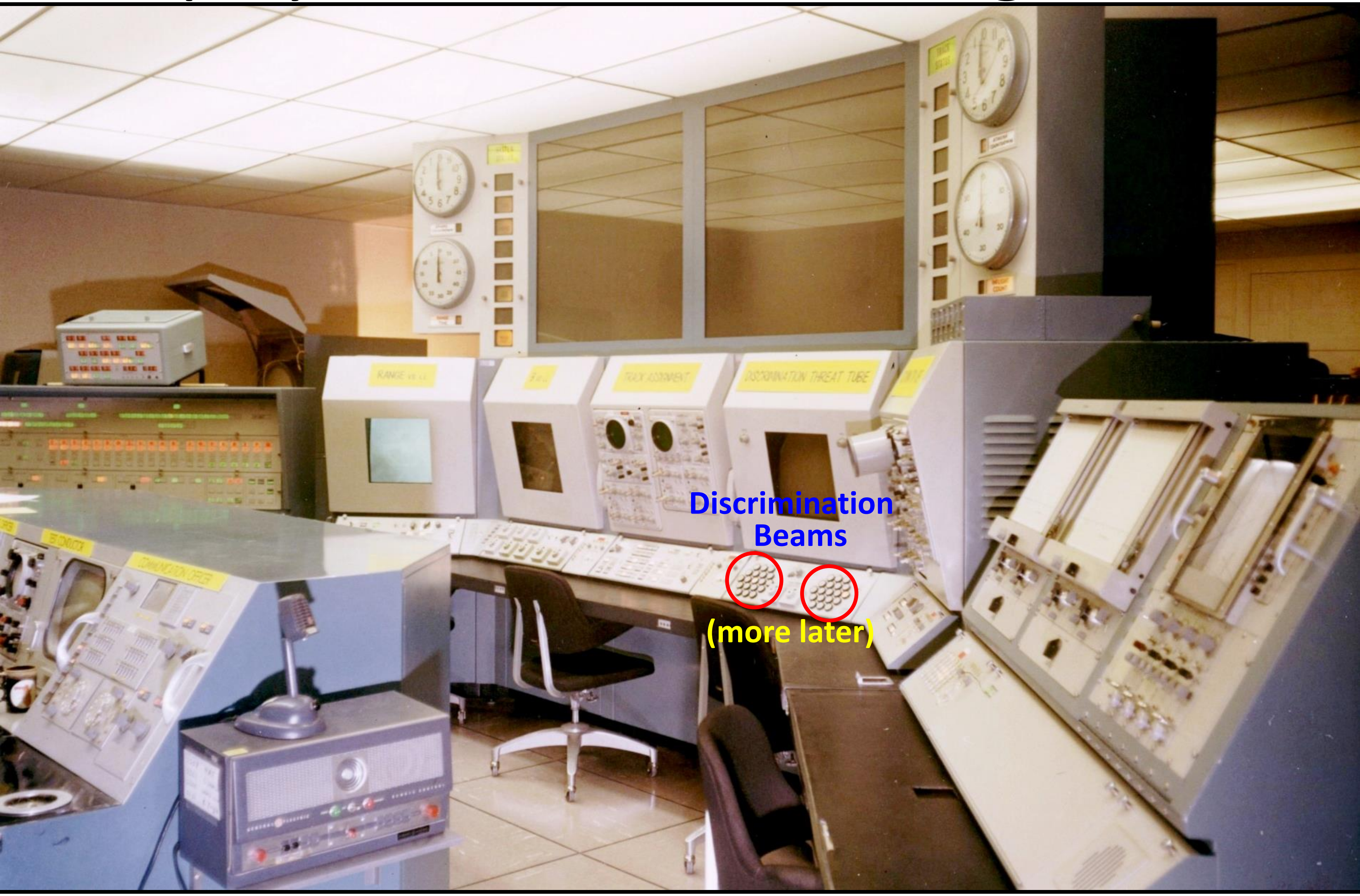
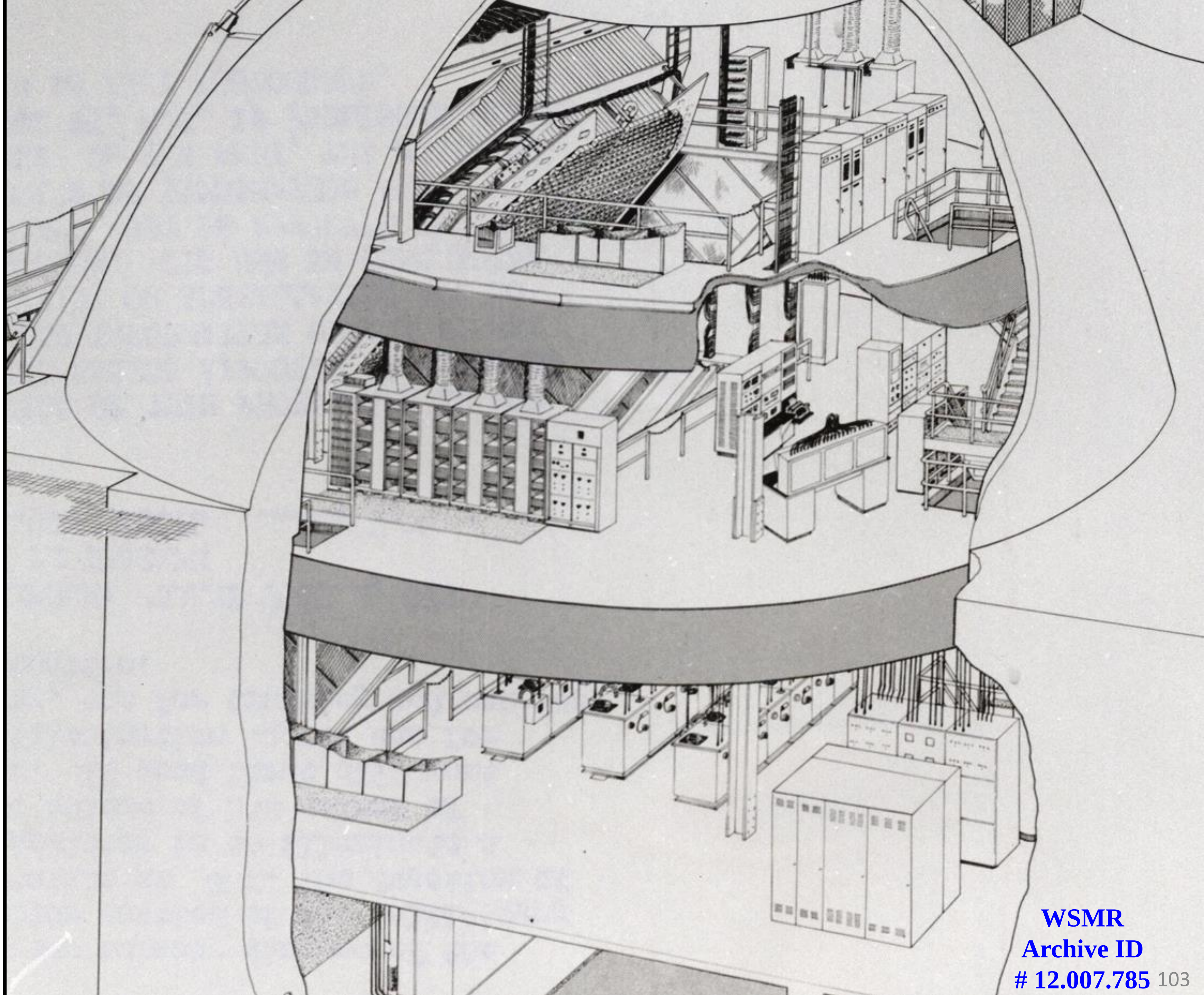


Image from the collection at the USASMDC/ARSTRAT Historical Office, Redstone Arsenal

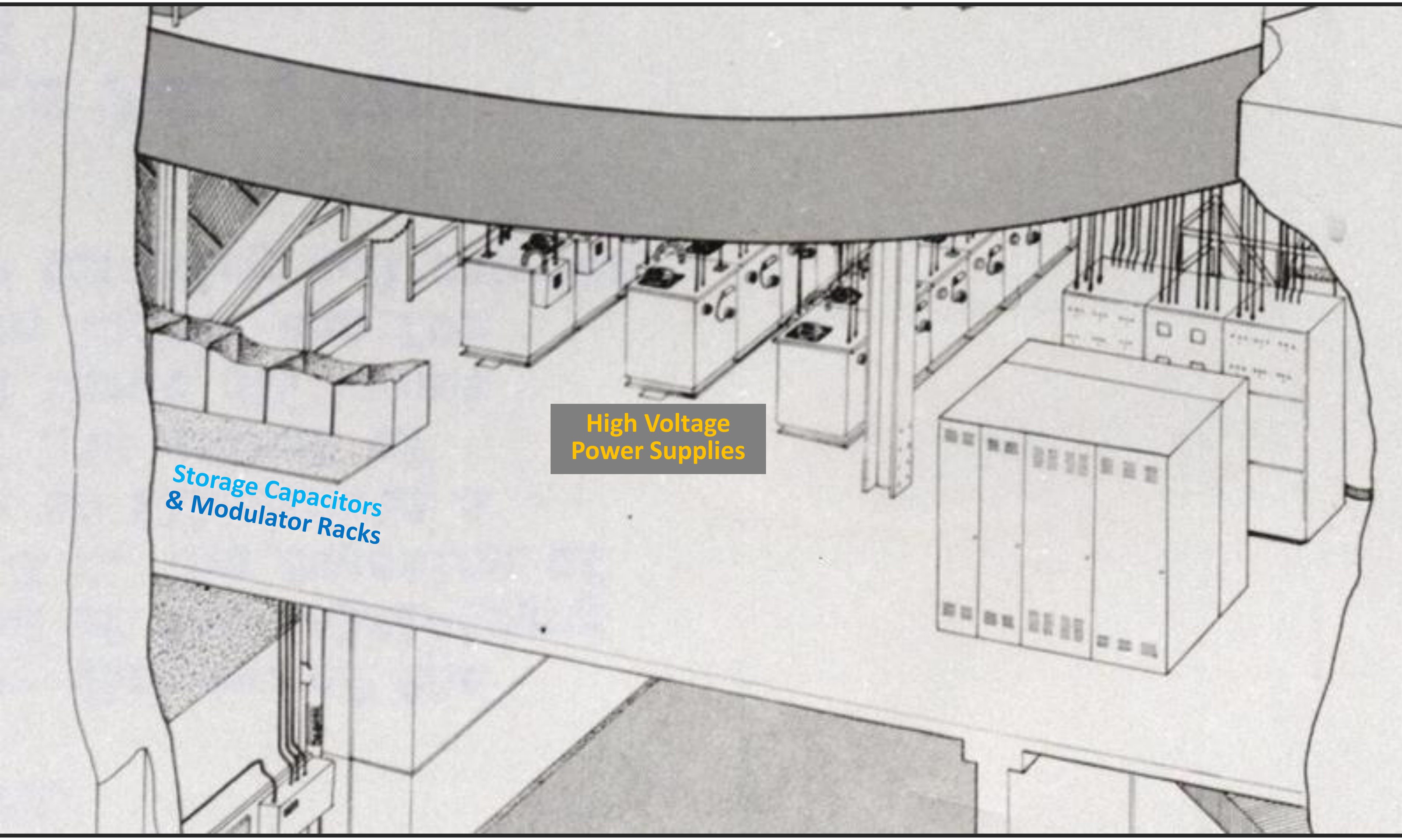
MAR-I Transmitter Dome

MAR-I Transmitter Cutaway Drawing

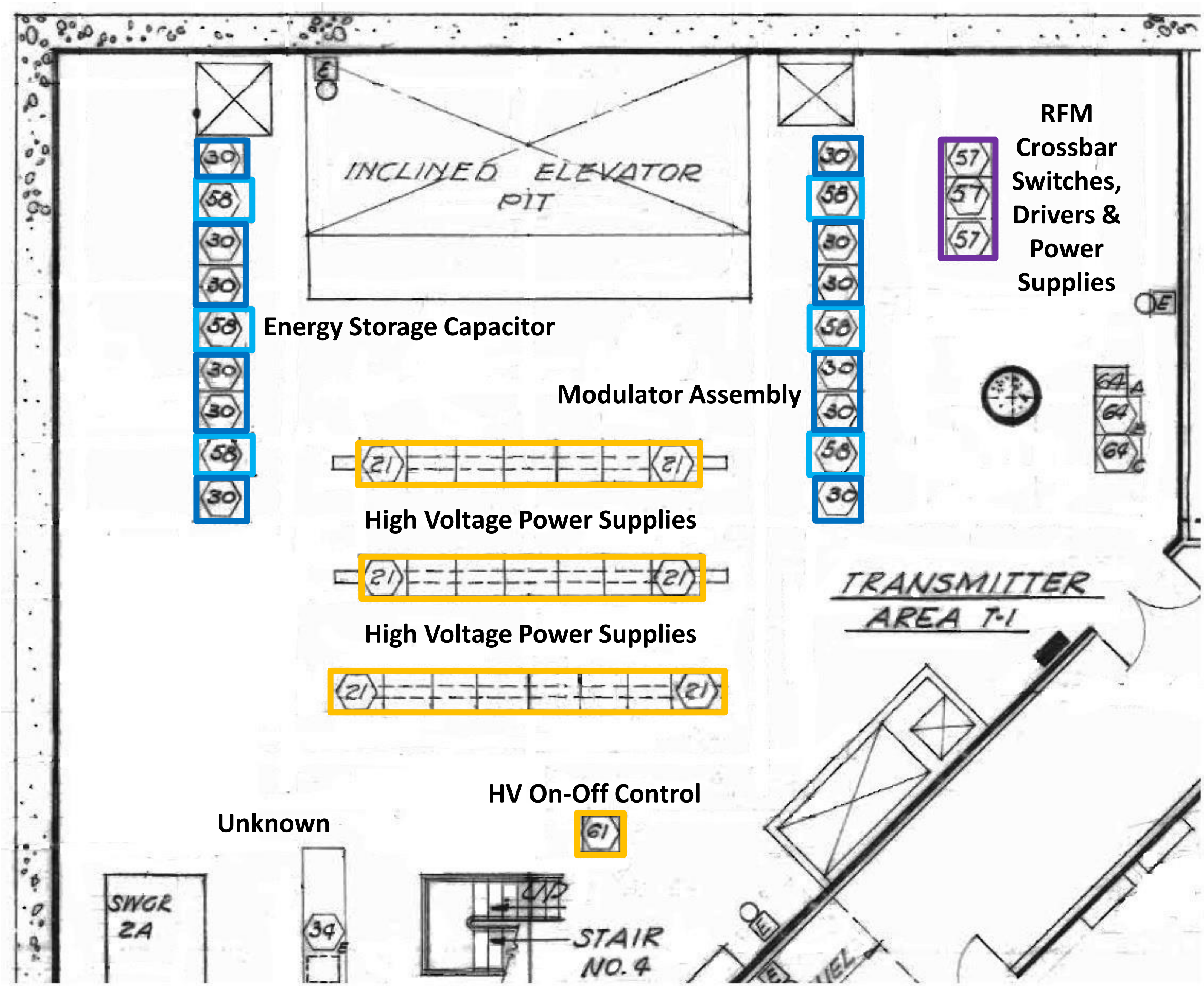


WSMR Archive ID # 12.007.785

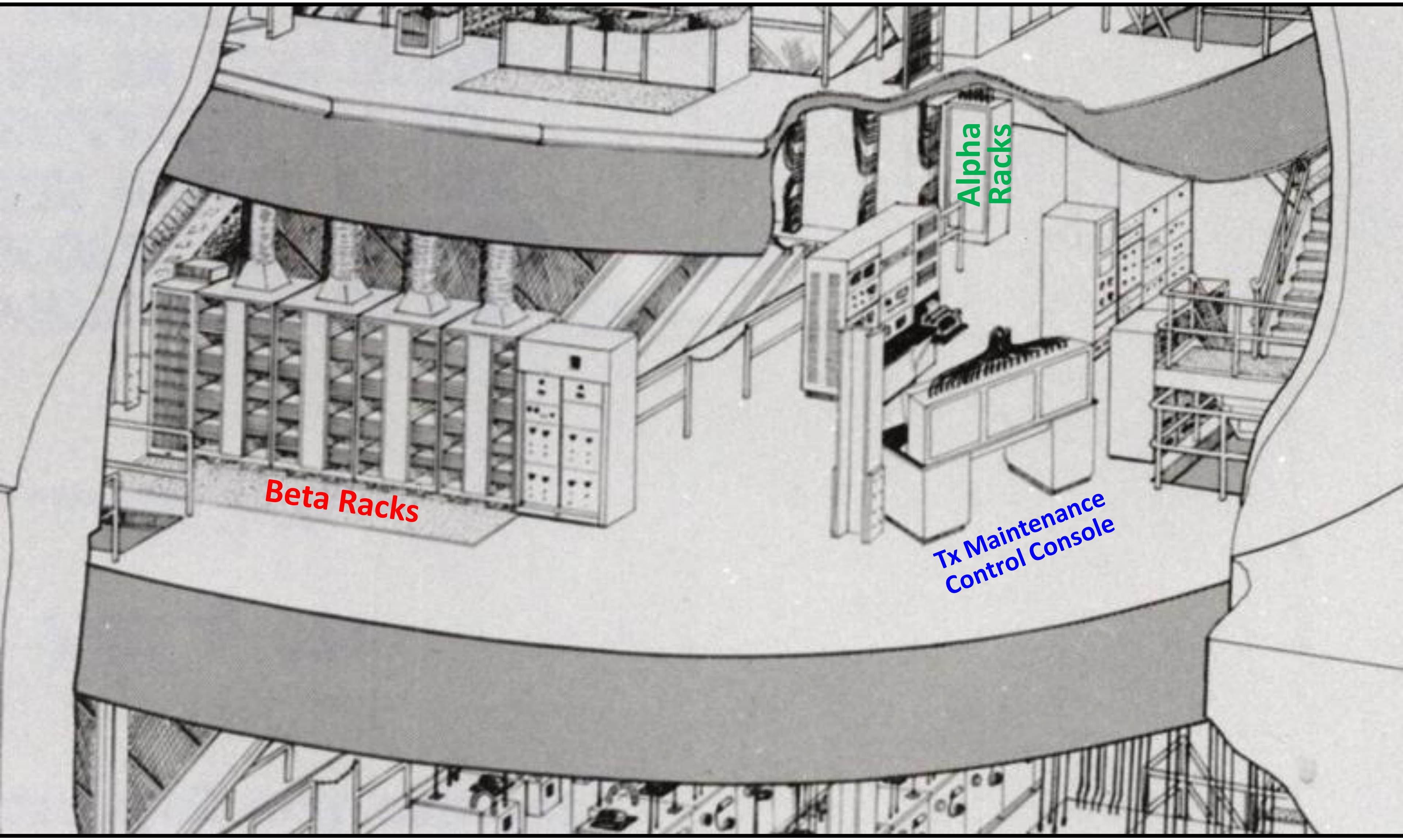
MAR-I Tx Dome Cutaway – Main Floor



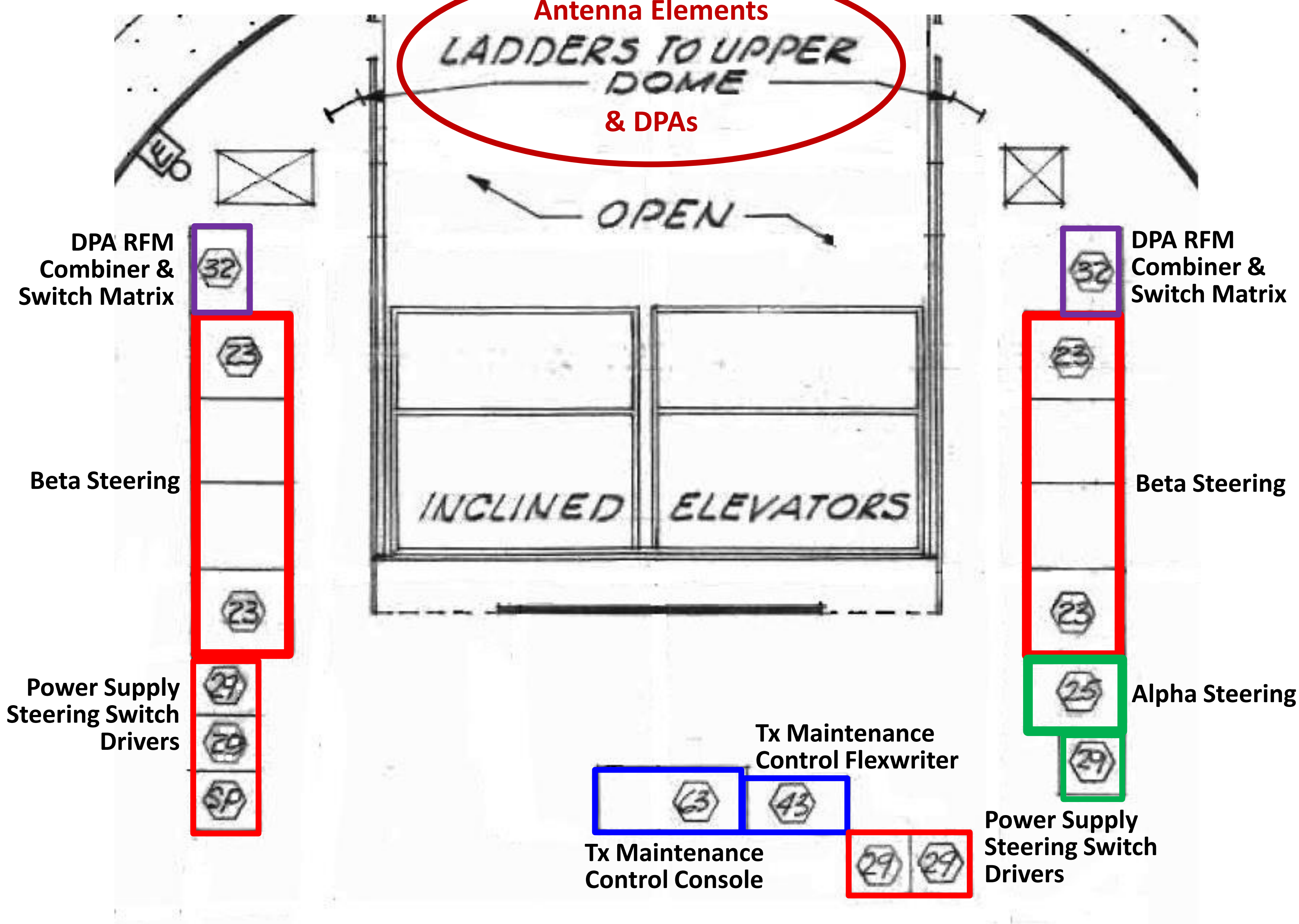
MAR-I Transmitter Racks – Main Floor Plan



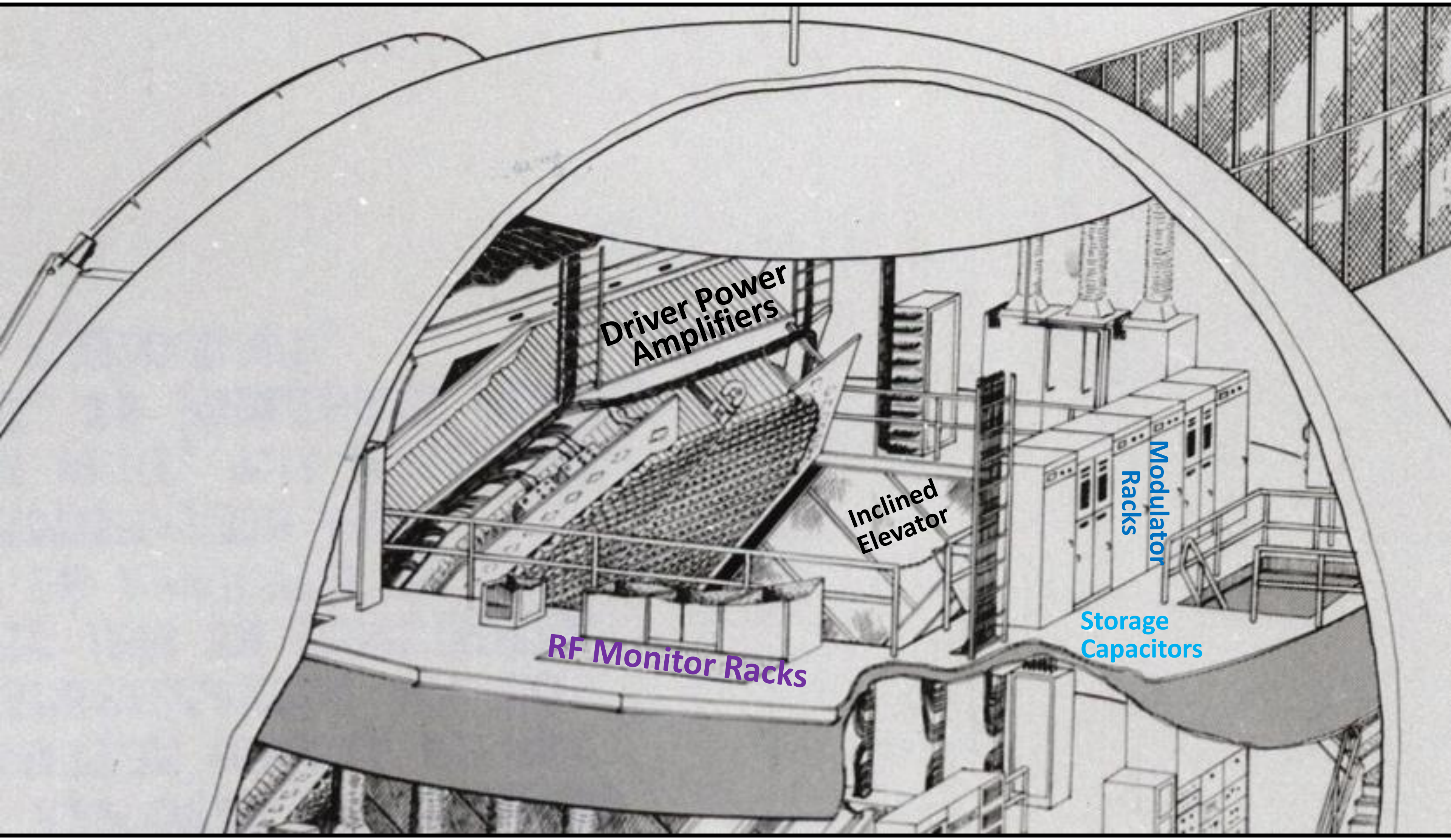
MAR-I Tx Dome Cutaway – Lower Level



MAR-I Transmitter Racks – Lower Level



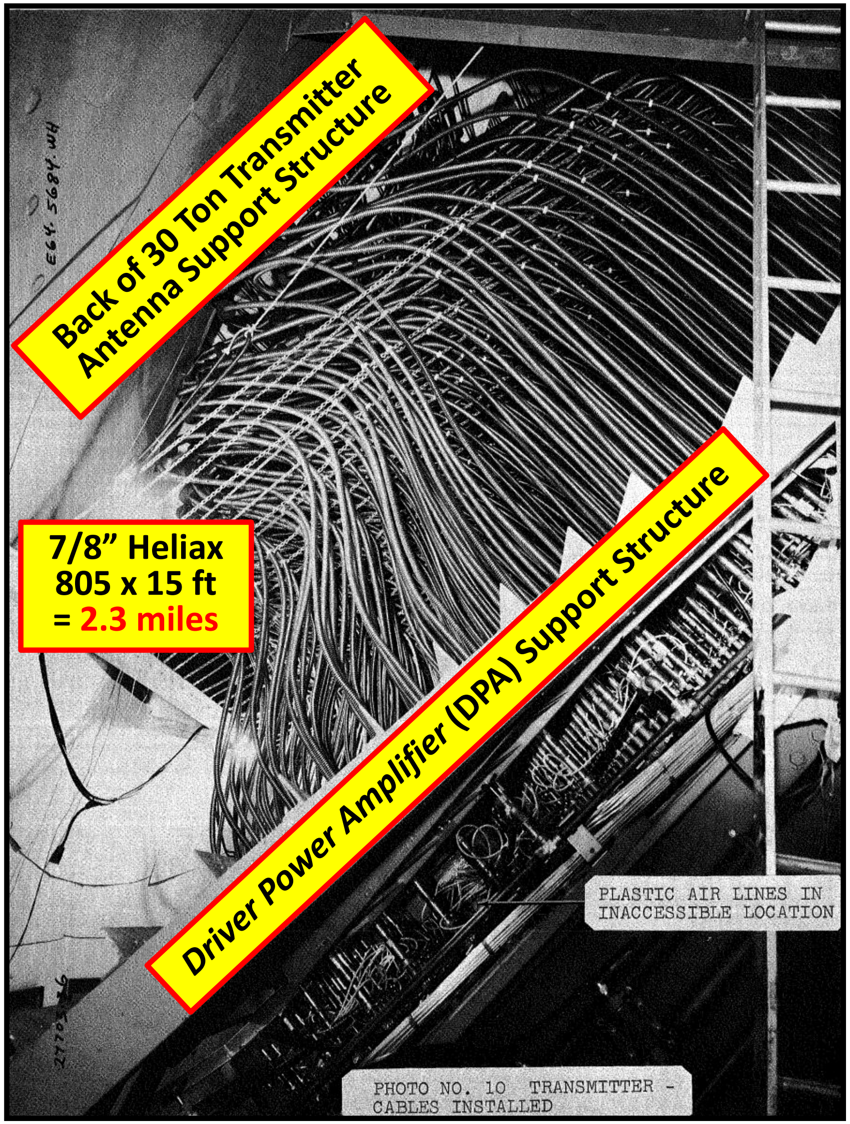
MAR-I Tx Dome Cutaway – Upper Level



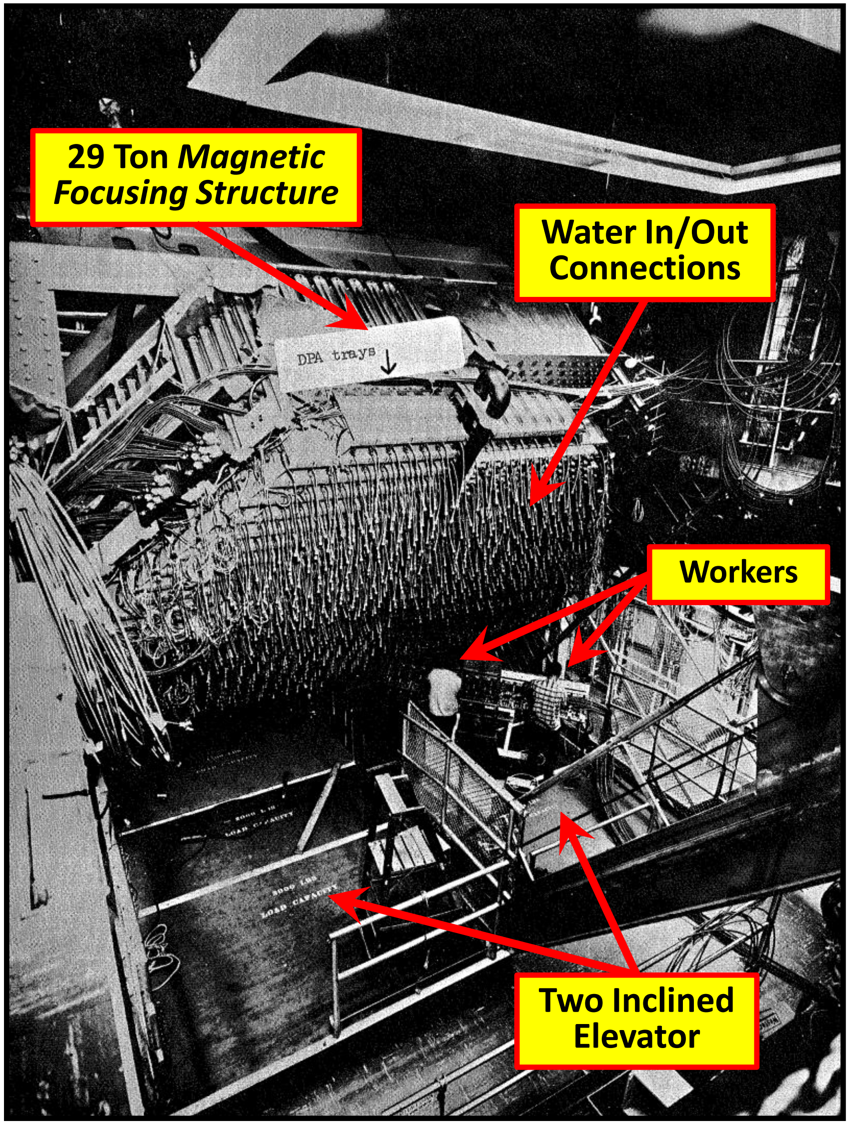
MAR-I *Transmitter Array* Signal Path & Interface Cabling

Inside the MAR-I Transmitter Dome

Side view of the 805 cables between the Antenna Elements and the *Driver Power Amps.*



Back view of the 805 *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's *Magnetic Focusing Structure*

The 805 DPA units were inserted into the Tx Array's *Magnetic Field Structure.*

It was essentially an 8-sided magnet which weighed about 29 tons.

It contained 1460 Alnico-5 permanent magnets which provided a completely balanced magnetic field for all the *Traveling Wave Tube* (TWT) electron beams.

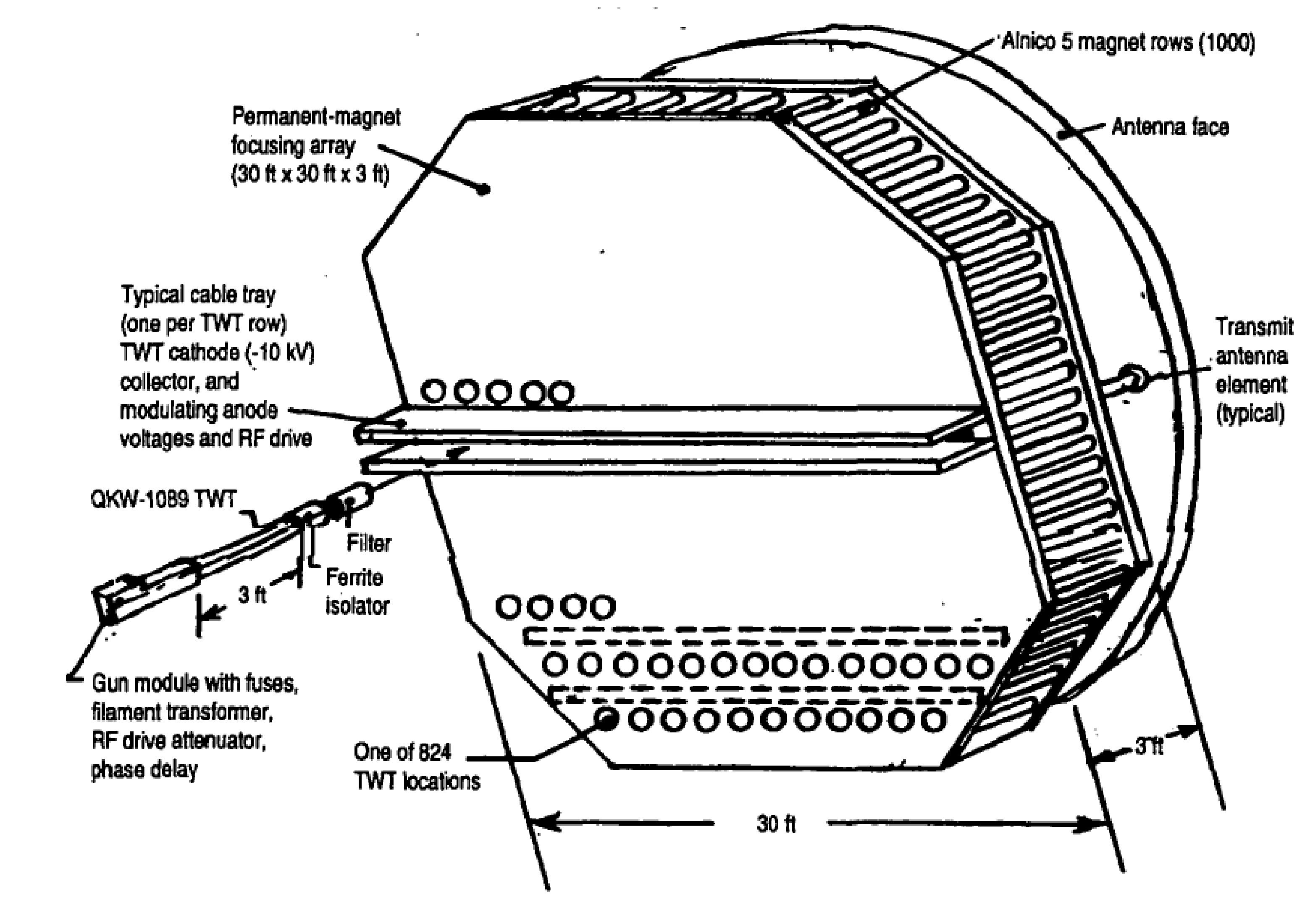
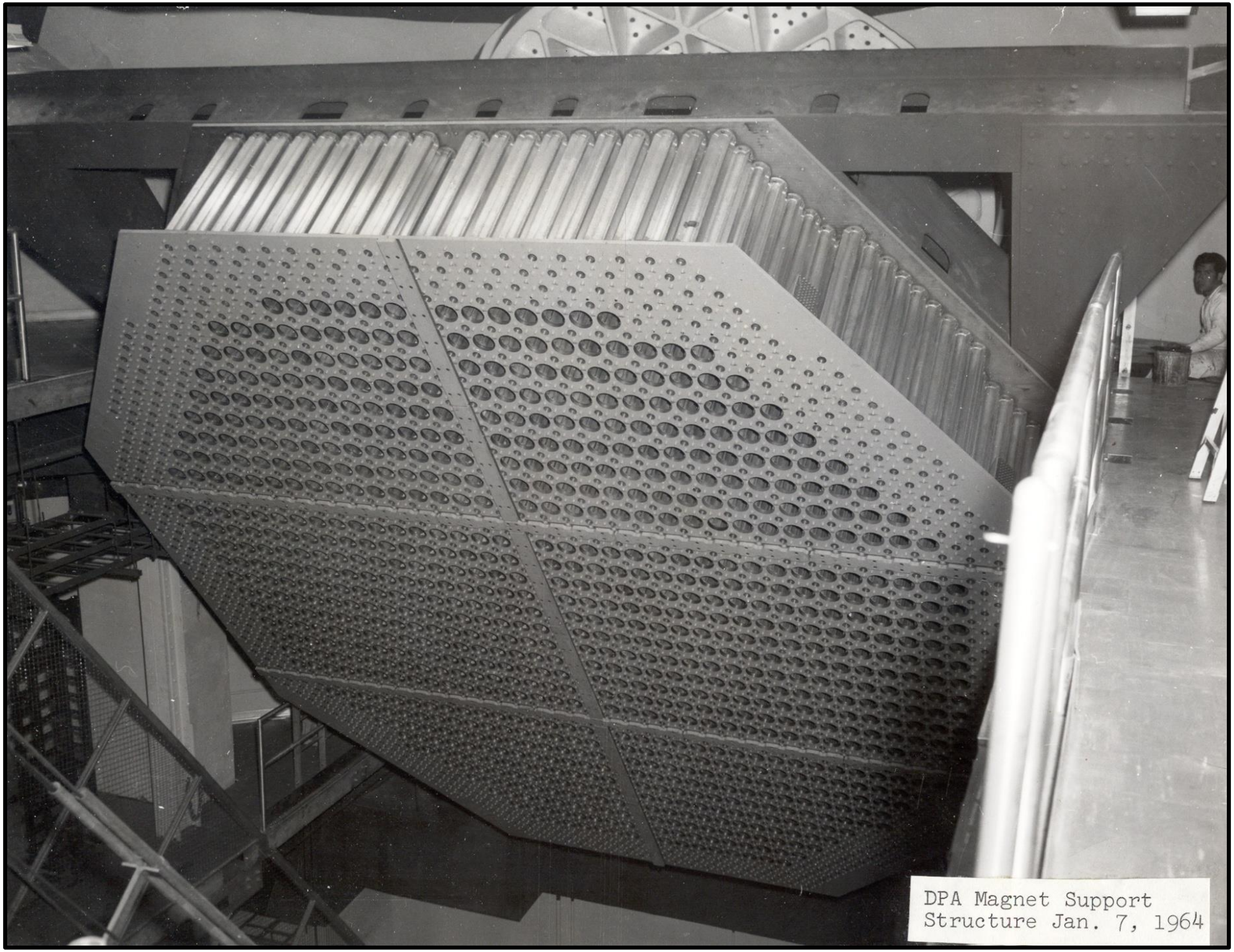


Figure 11-17. Simplified representation of the MAR-1 transmitter-array face.

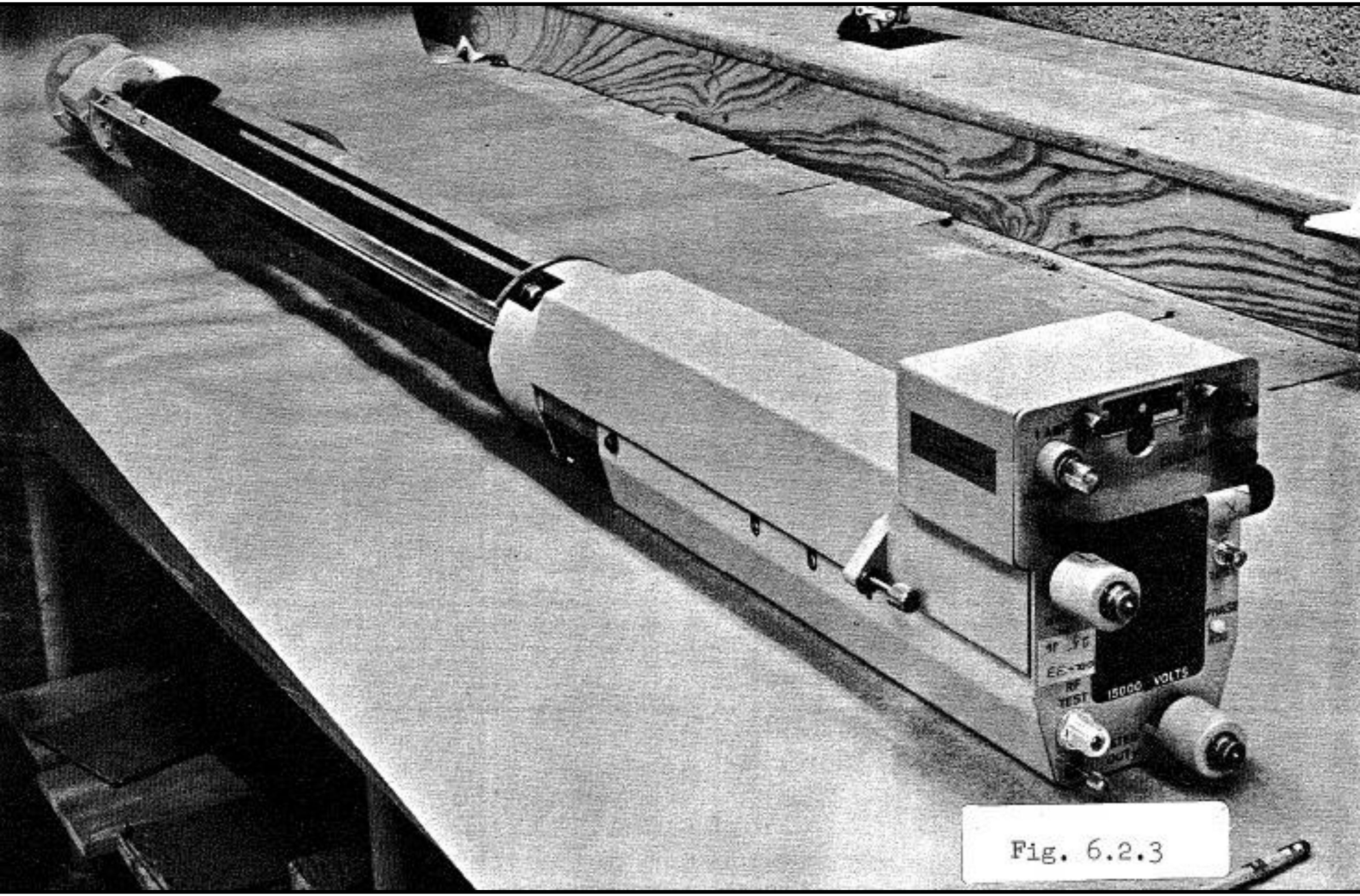
High-Power Microwave-Tube Transmitters, W. North, Las Alamos National Library Report, LA-12687-MS, Jan 1994

Transmitter - Blank *Magnetic Support Structure*



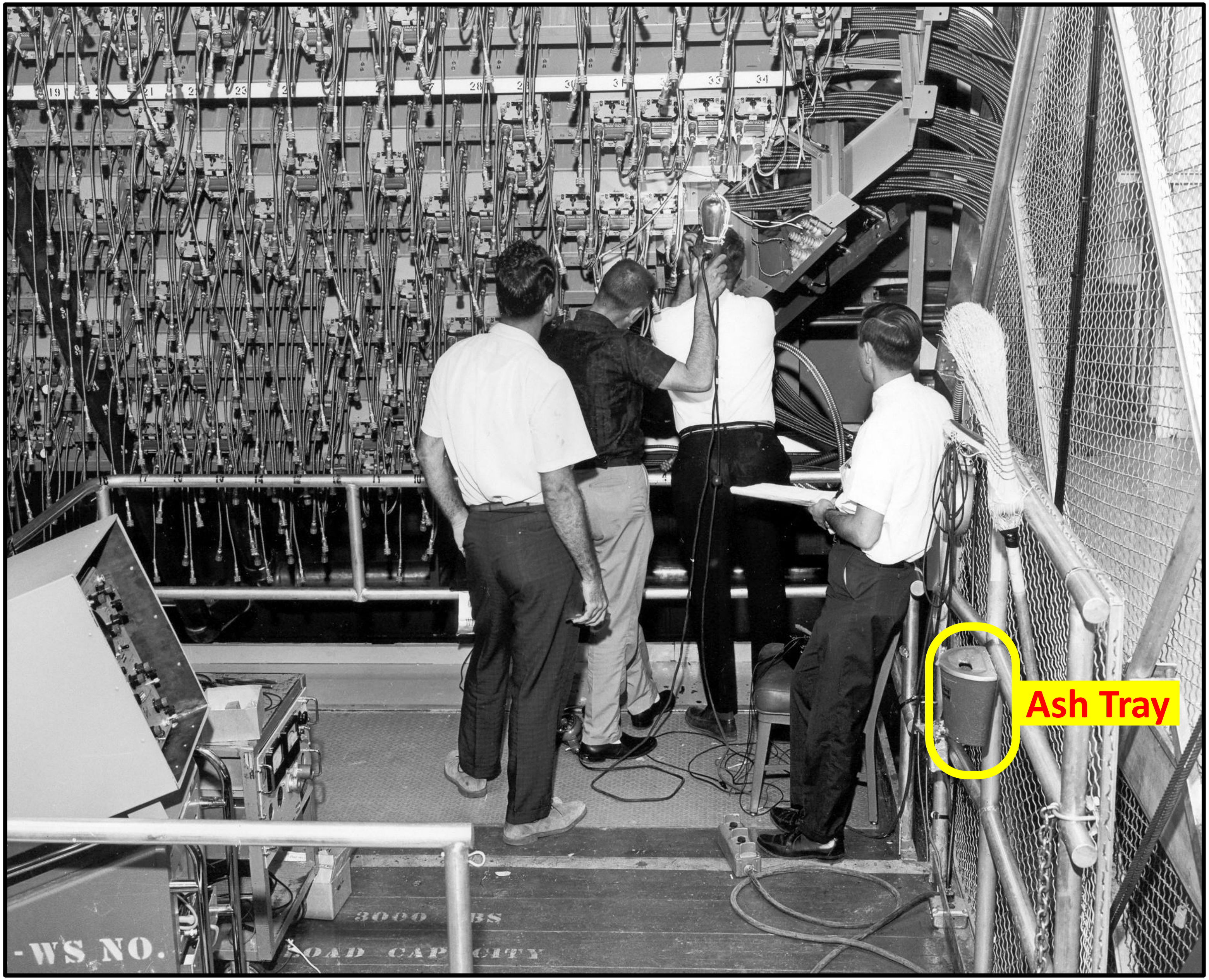
WSMR Archive ID # 03.013.001-267

Transmitter - *Driver Power Amplifier – 1 of 805*



WSMR Archive ID # 10-010-005_MAR I Critique_1964-06-15_Fig-6-2-3

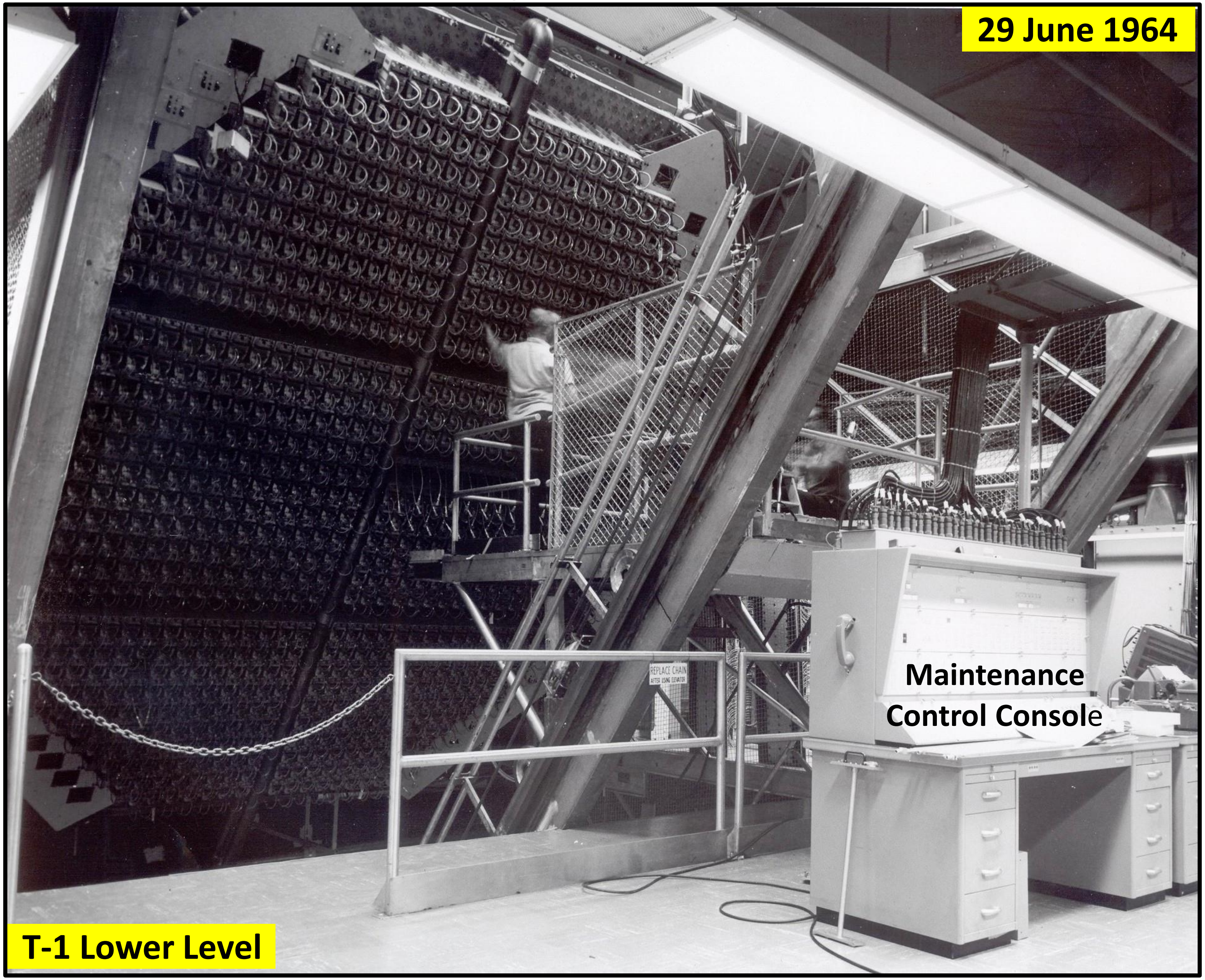
Transmitter - Workers installing *DPA Modules*



A sign of the times

WSMR Archive ID # 97.180.204-10

Transmitter - Fully Cabled (more or less)



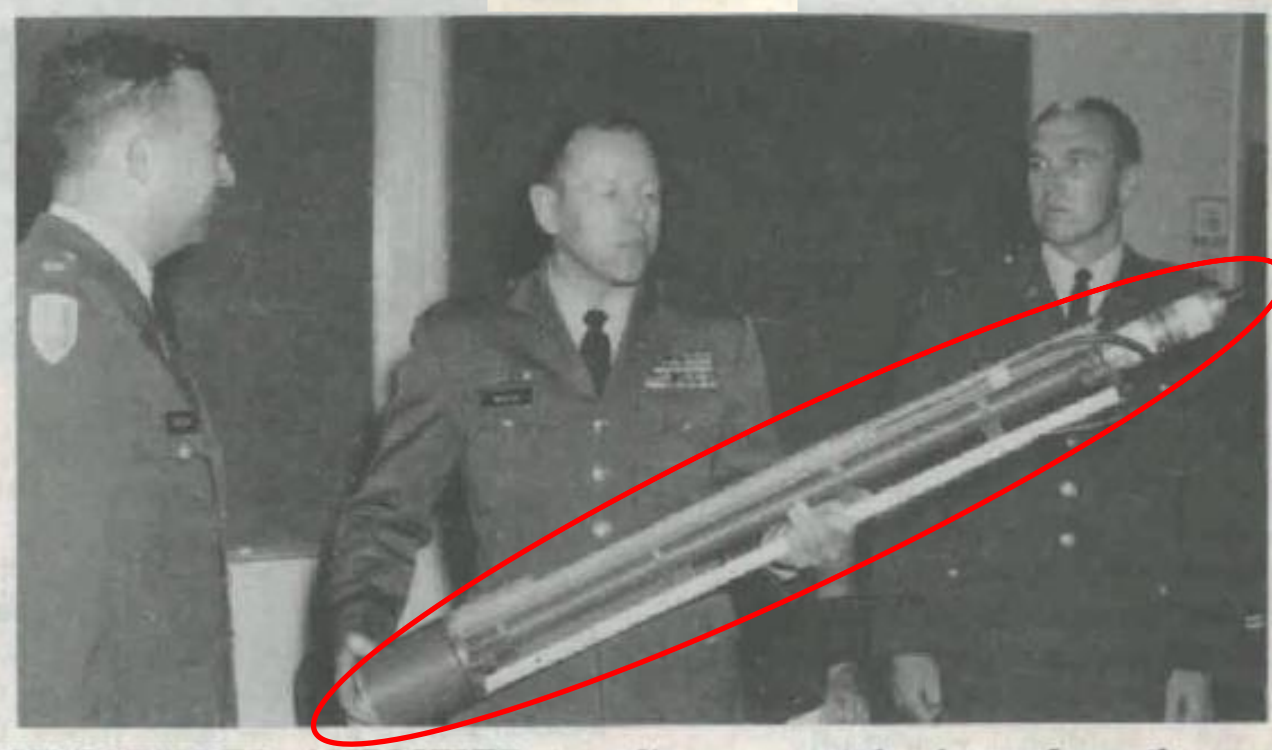
WSMR Archive ID # 12.007.779-5

The Chief of the MAR-I and his "*Symbol of Authority*" ~ A TWT

RESEARCH AND DEVELOPMENT **ARMY**

MONTHLY NEWSMAGAZINE OF THE OFFICE OF THE CHIEF, RESEARCH AND DEVELOPMENT

FEBRUARY 1969

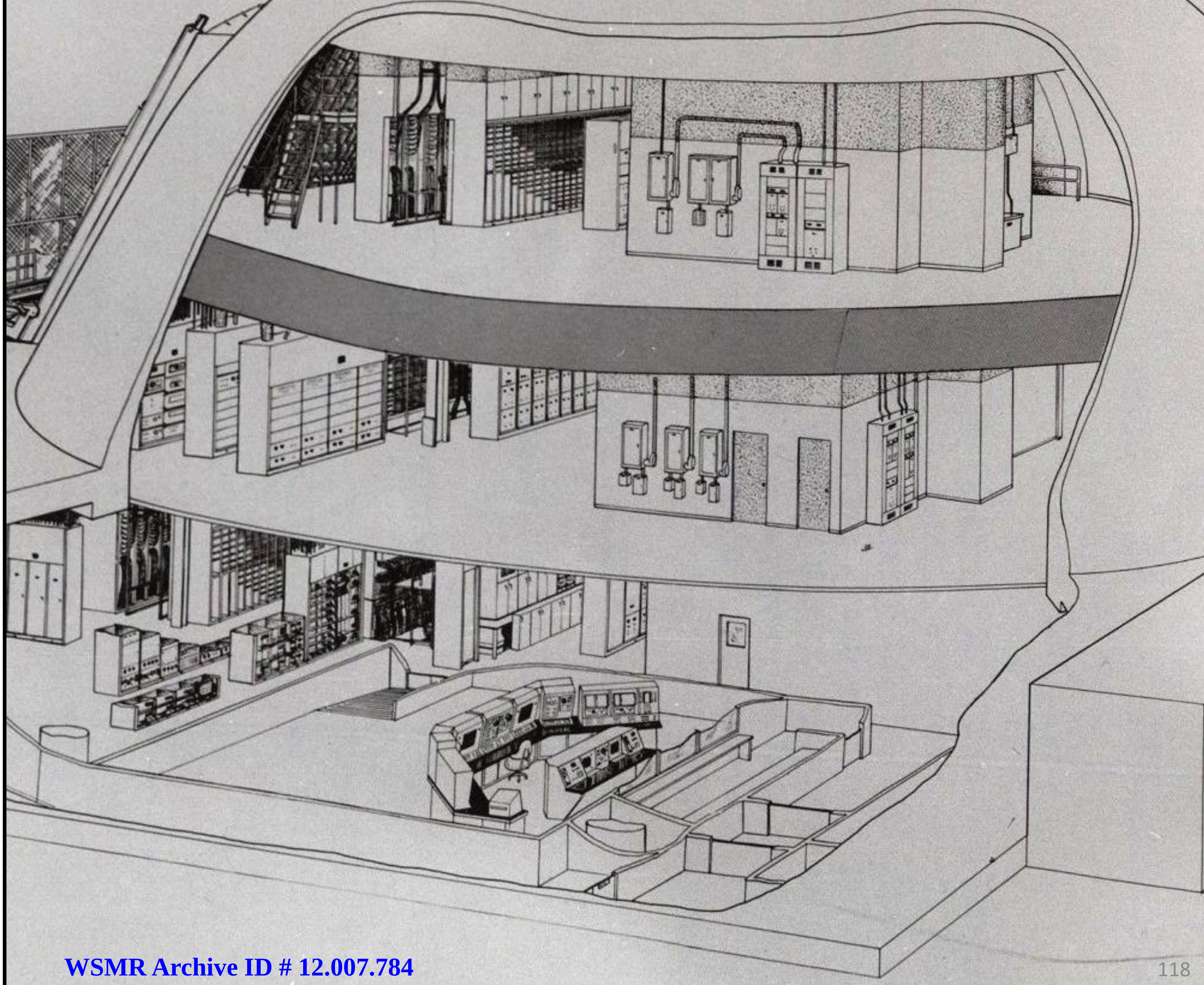


HIGH-POWERED AMPLIFIER traveling wave tube is used as the symbol of authority of the chief of the Multi-Array Radar (MAR-I) Test Branch in a change-of-command ceremony at White Sands Missile Range N. Mex. Col Frank J. Wasson Jr. (center), commander, Sentinel System Evaluation Agency, officiated as Maj Jerry L. Kintigh (left) was succeeded by Maj Terry M. Carlton as head of MAR-I. The tube is one of 805 such instruments used in MAR-I transmitters. Maj Kintigh was reassigned to Kwajalein Island.

Army Research and Development Newsmagazine, Vol. 10, No. 2, Feb 1969, p.11
http://asc.army.mil/docs/pubs/alt/archives/1969/Feb_1969.PDF

MAR-I Receiver Dome

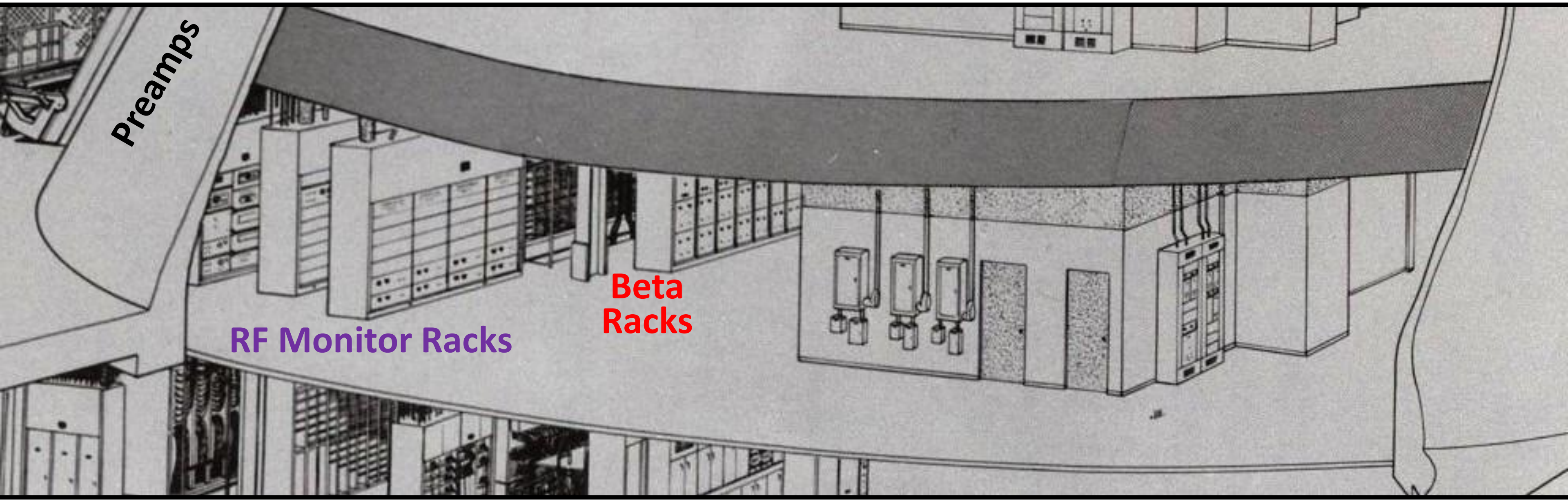
MAR-I Receiver Cutaway Drawing



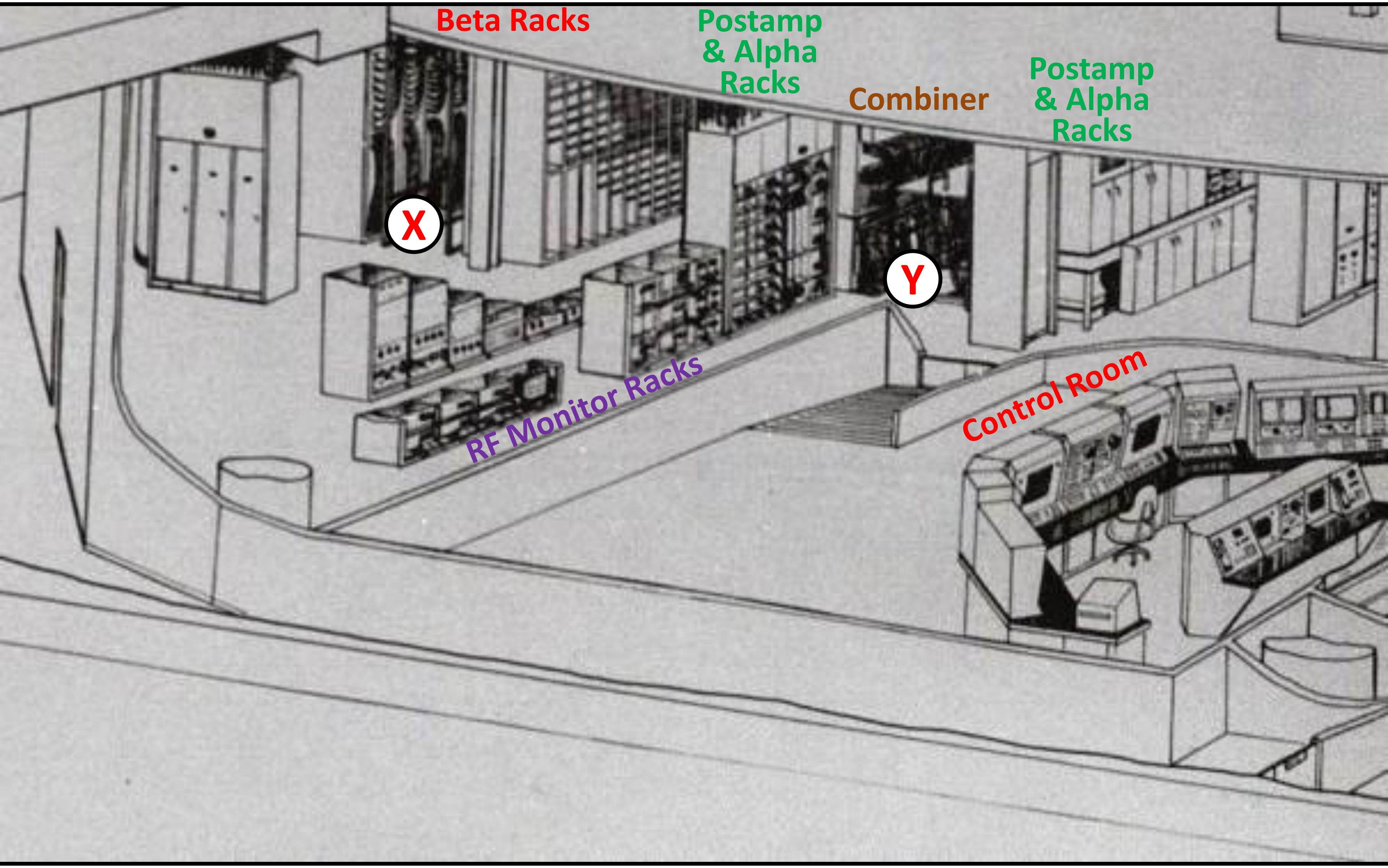
WSMR Archive ID # 12.007.784

MAR-I Rx Dome Cutaway – Upper Level

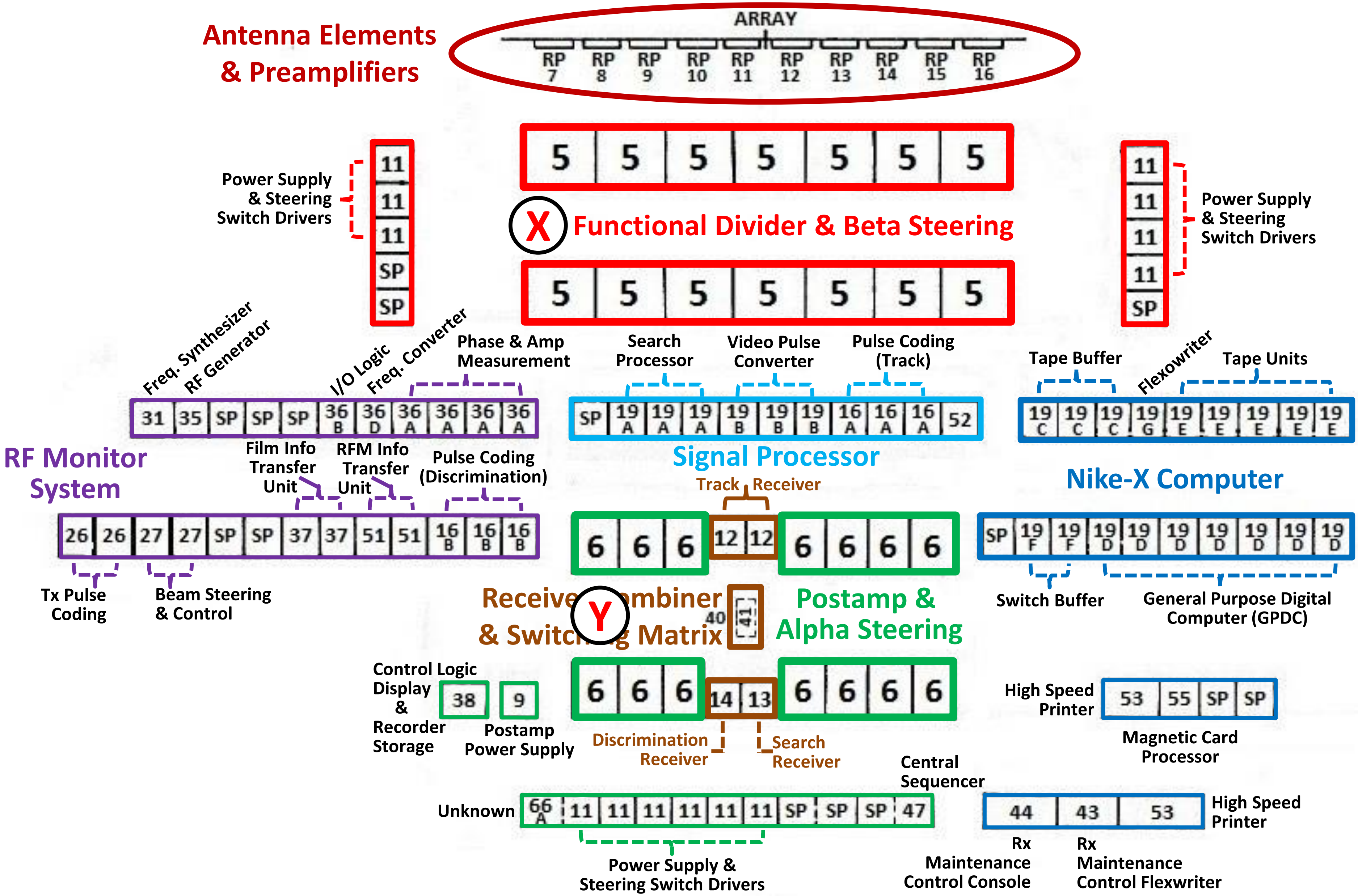
MAR-I Rx Dome Cutaway – Lower Level



MAR-I Rx Dome Cutaway – Main Floor



MAR-I Receiver Racks – Main Floor



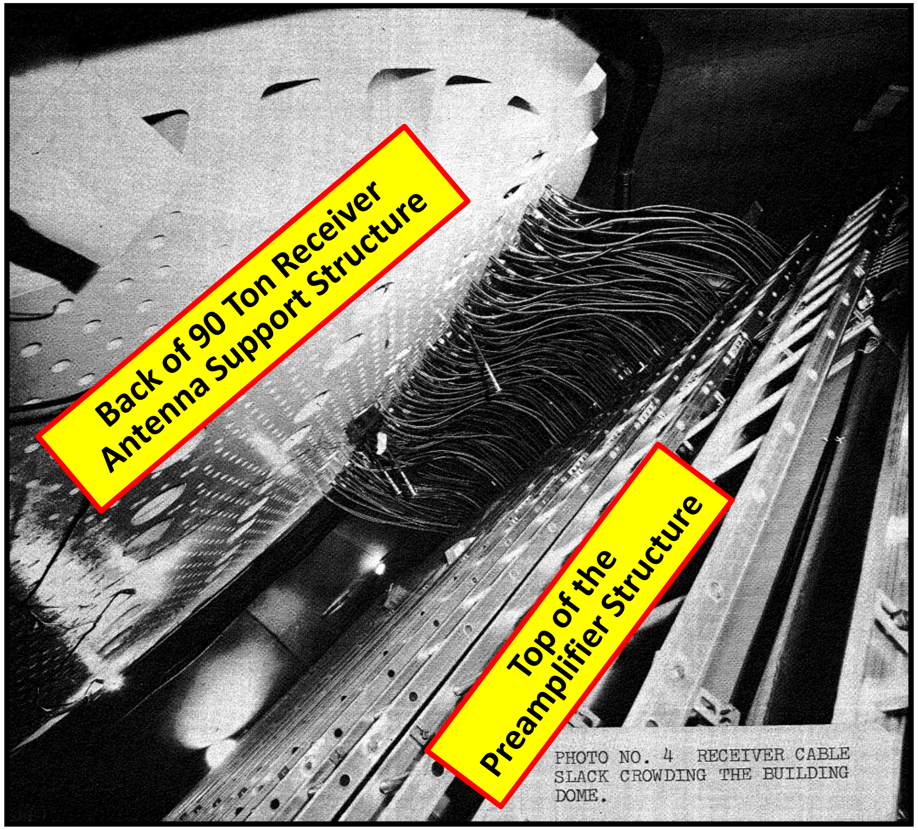
MAR-I *Receiver Array*
Signal Path & Interface Cabling

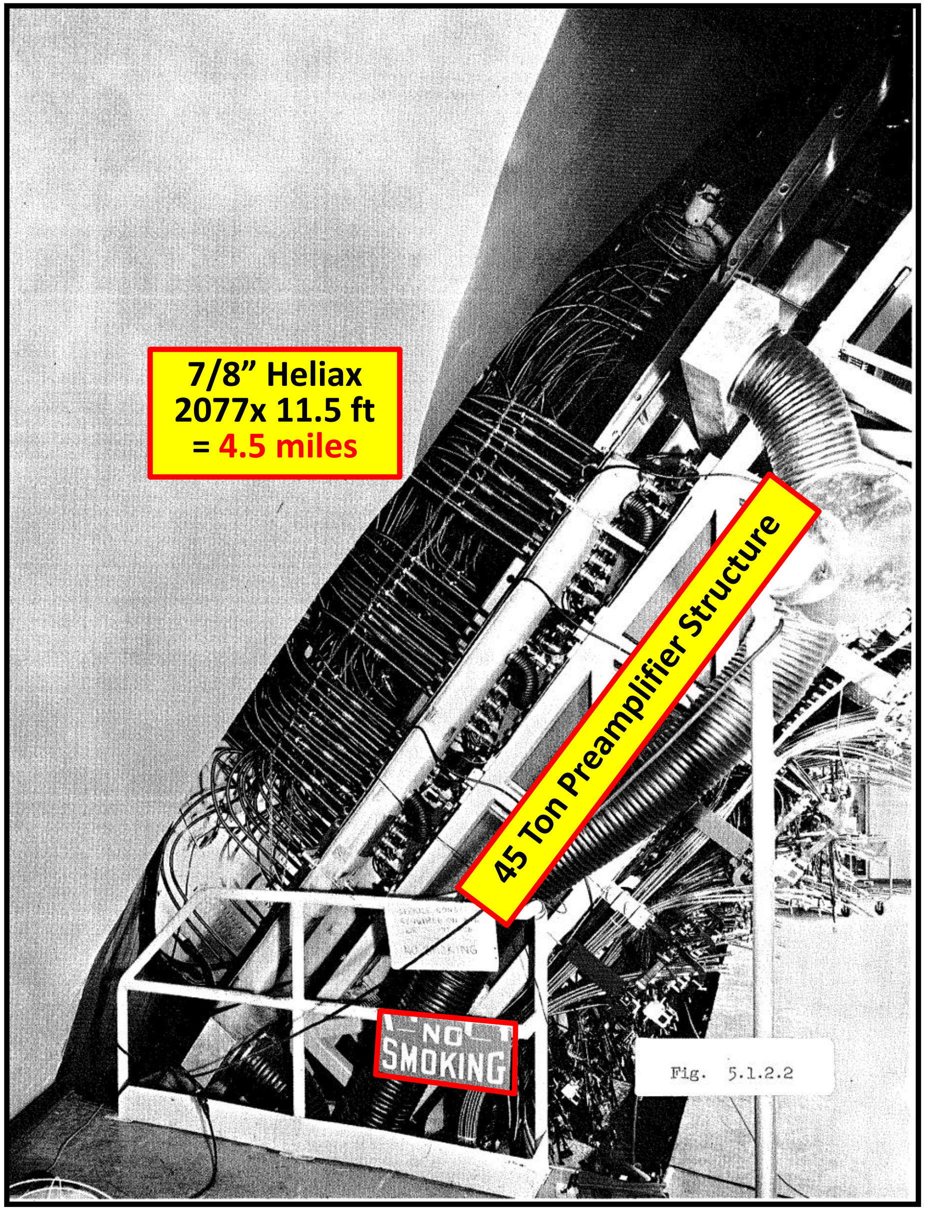
Inside the MAR-I Receiver Dome

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

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**

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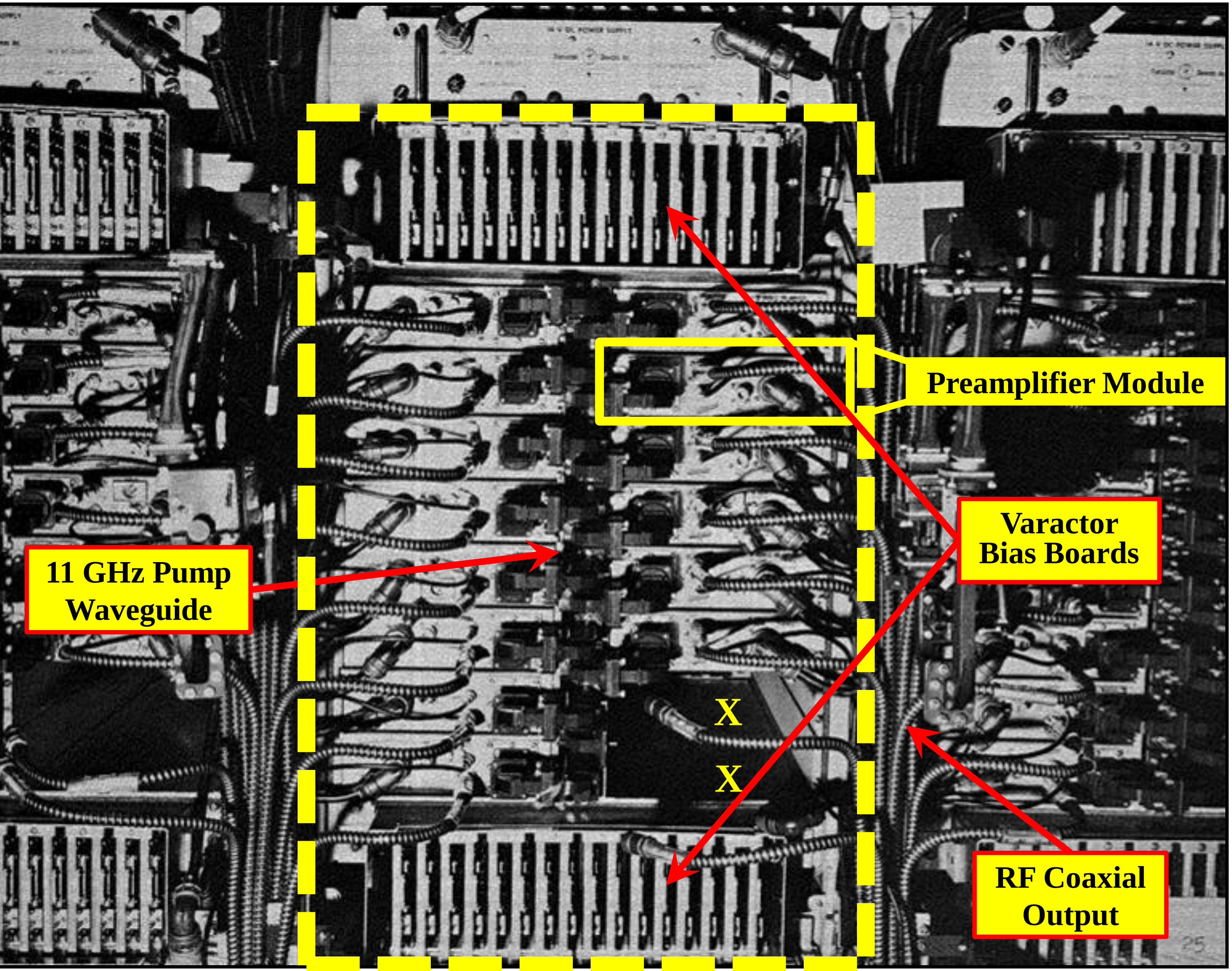
Receiver -

Backside of the *Preamplifier Structure* seen from the Upper Dome Level in June 1964

Image from the collection at the USASMDC/ARSTRAT Historical Office, Redstone Arsenal

View of the back of some of the 2077 MAR-I Preamps



WSMR Archive ID #10-010-005, Photo-D-25
MAR I Critique (Preliminary), BTL Report, W.G. Graves II & W.E. Kelley, 15 June 1964

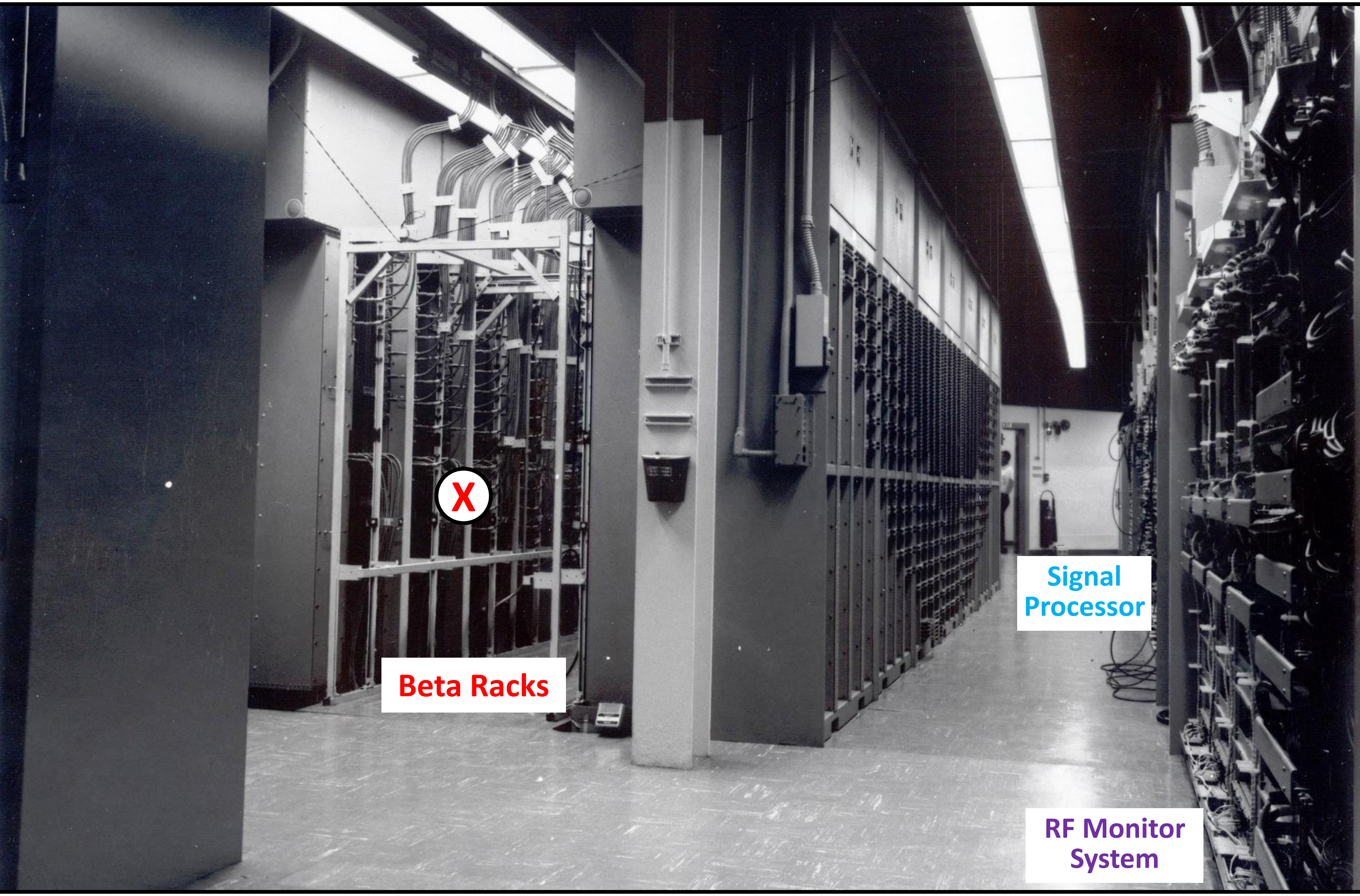
The signal received by each of the *Antenna Elements* first passed through a Western Electric *Preamplifier* unit.

Note the WR-90 waveguide used for feeding the 11 GHz *Paramp Pump* to each unit, as well as the 3/8" Output *Heliax Cables* and the *Varactor Bias Circuit Boards.*

Each *Preamp Rack* contained 16 *Preamplifier* units.

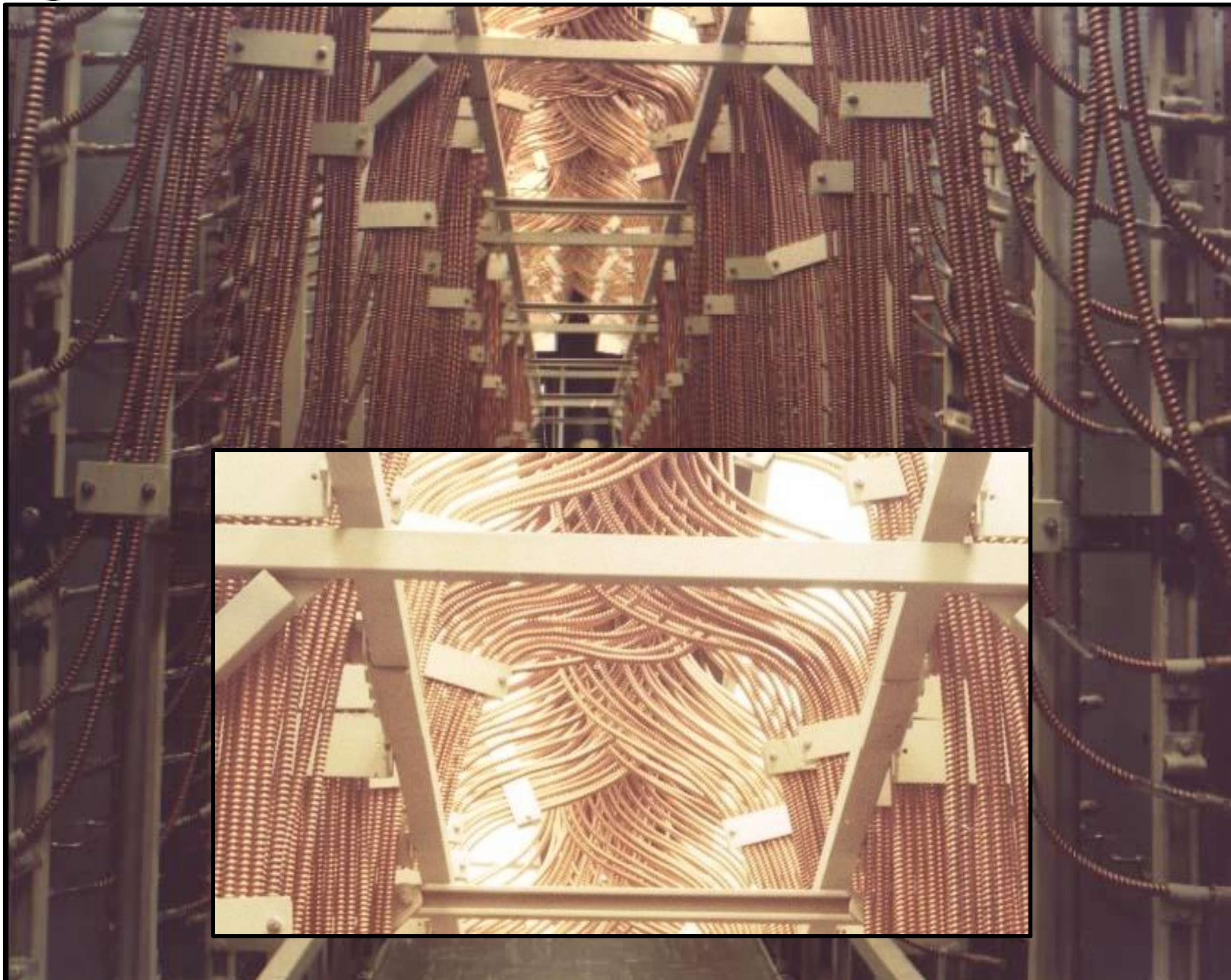
It required 131 of these racks to accommodate the radar's 2077 *Antenna Elements*.

Main Floor, Beta Racks - 29 June 1964



WSMR Archive ID # 12.007.779-3

X Main Floor "*Beta*" (Elev) Delay-Racks



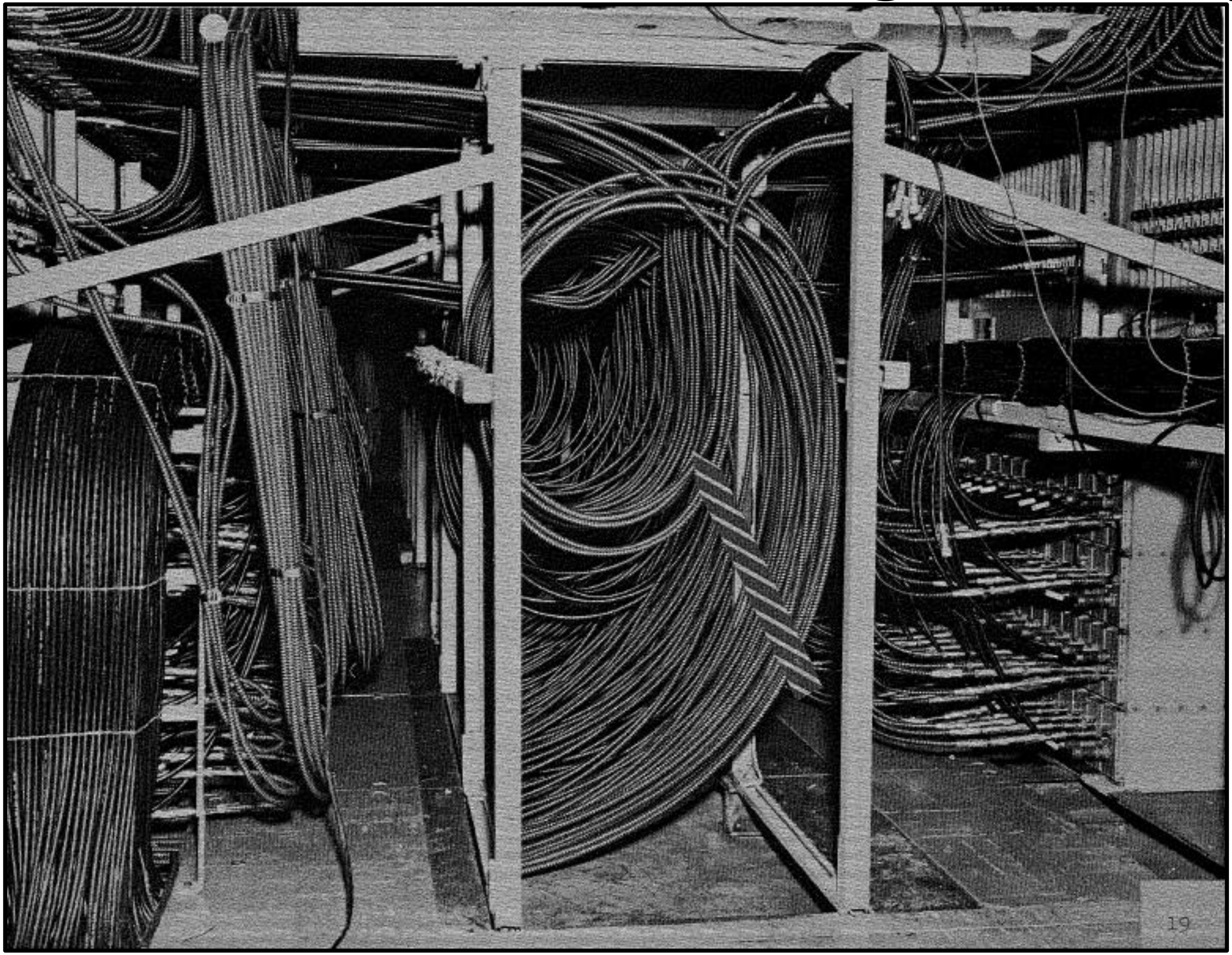
The *Beta Racks* was where the time delays *were* inserted to steer the beam in *Elevation*.

Length of factory pre-cut 3/8" Heliax microwave cables 12 Miles.

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

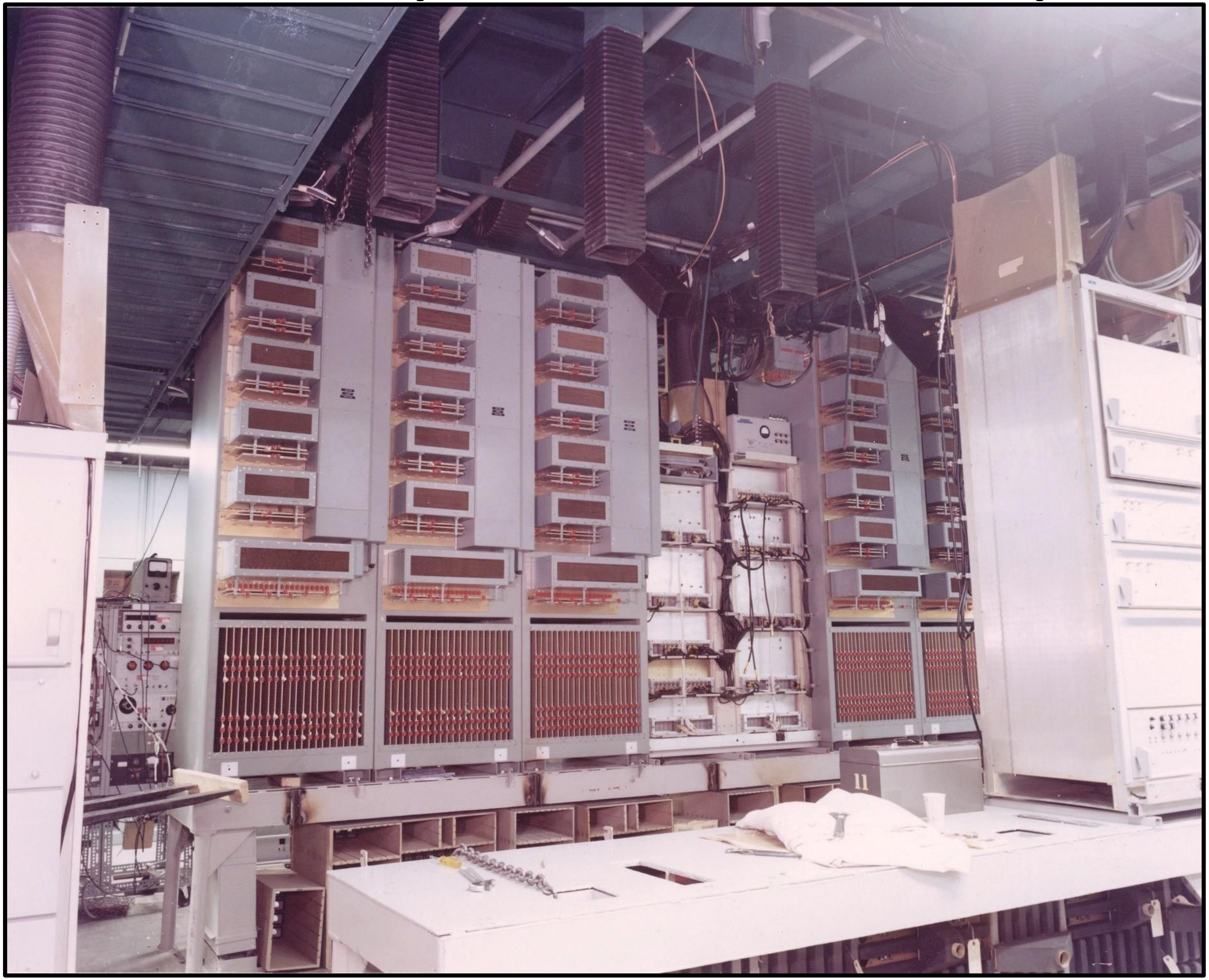
Photo courtesy of Doyle Piland

Main Floor, Cables Feeding Post-amps



WSMR Archive ID # 10-010-005_MAR I Critique_1964-06-15_Photo-D-19

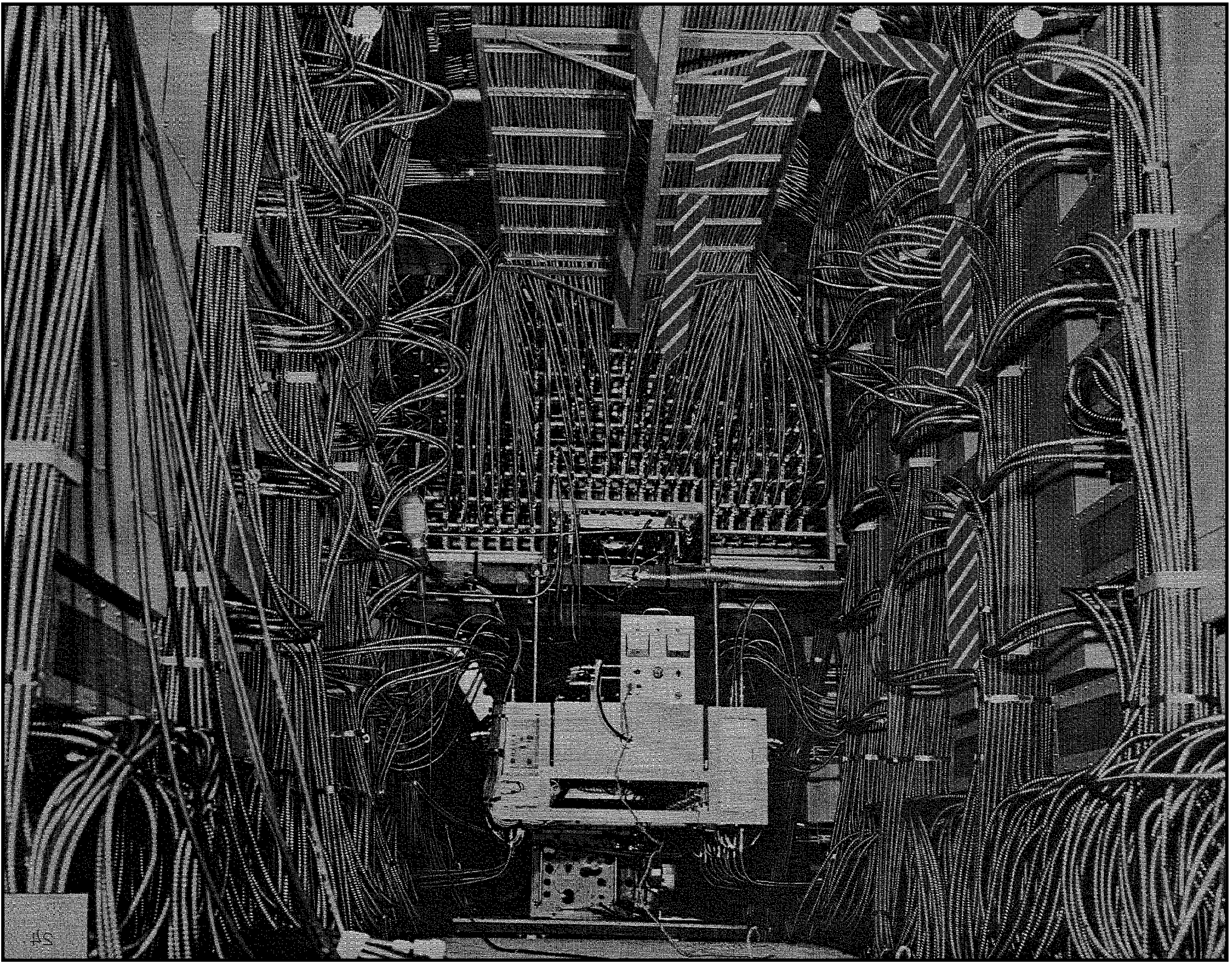
Main Floor, Alpha Racks – 28 Apr 1964



WSMR Archive ID # 97.180.197-2

MAR-I Beam-Former

Miles & Miles of 3/8" Heliax cables feeding the
Alpha Search, Track & Discriminate 16:1 & 12:1 Combiners



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

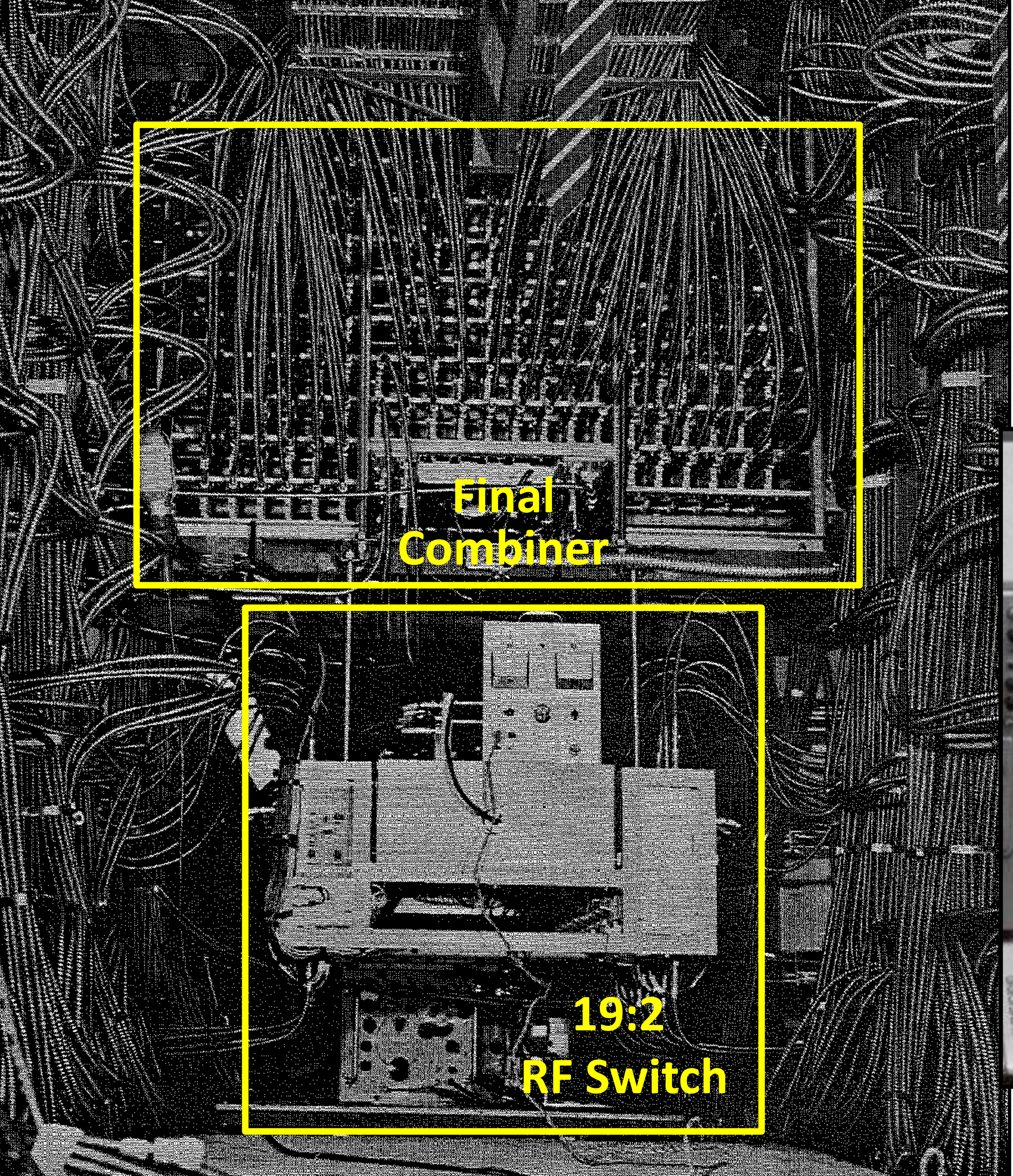
The *Alpha Chamber* was where the signals from the summed columns in the *Receiver Array* were combined.

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**

MAR-I Beam-Former

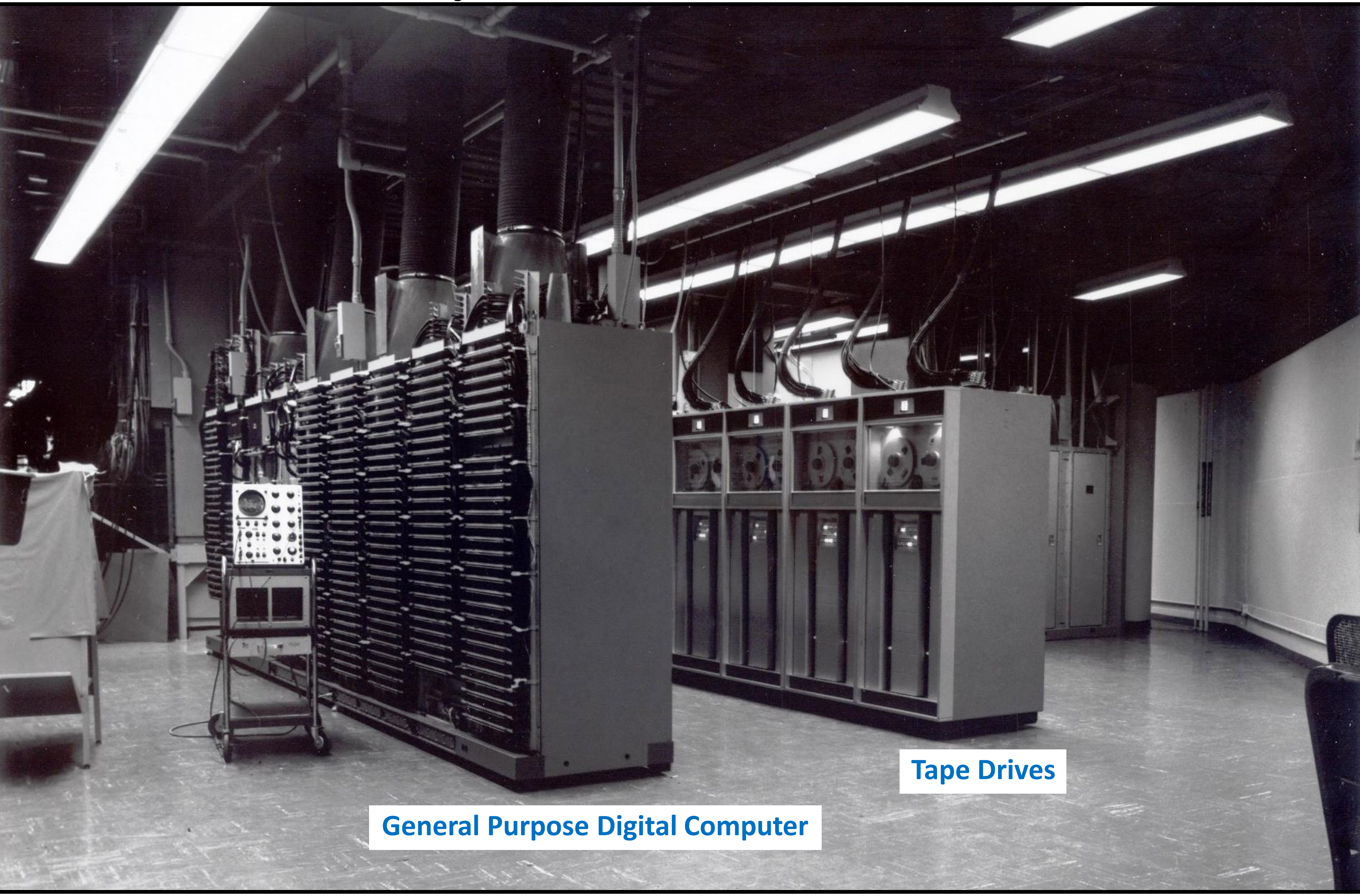
There is a 19:2 RF switch on the bottom for selecting 2 of the 19 Discrimination Beam outputs



MAR I Critique (Preliminary), BTL Report, W.G. Graves II & W.E. Kelley, 15 June 1964
WSMR Archive ID # 97.180.204-17

MAR-I Interior Equipment

GPDC & Tape Drives - 29 June 1964

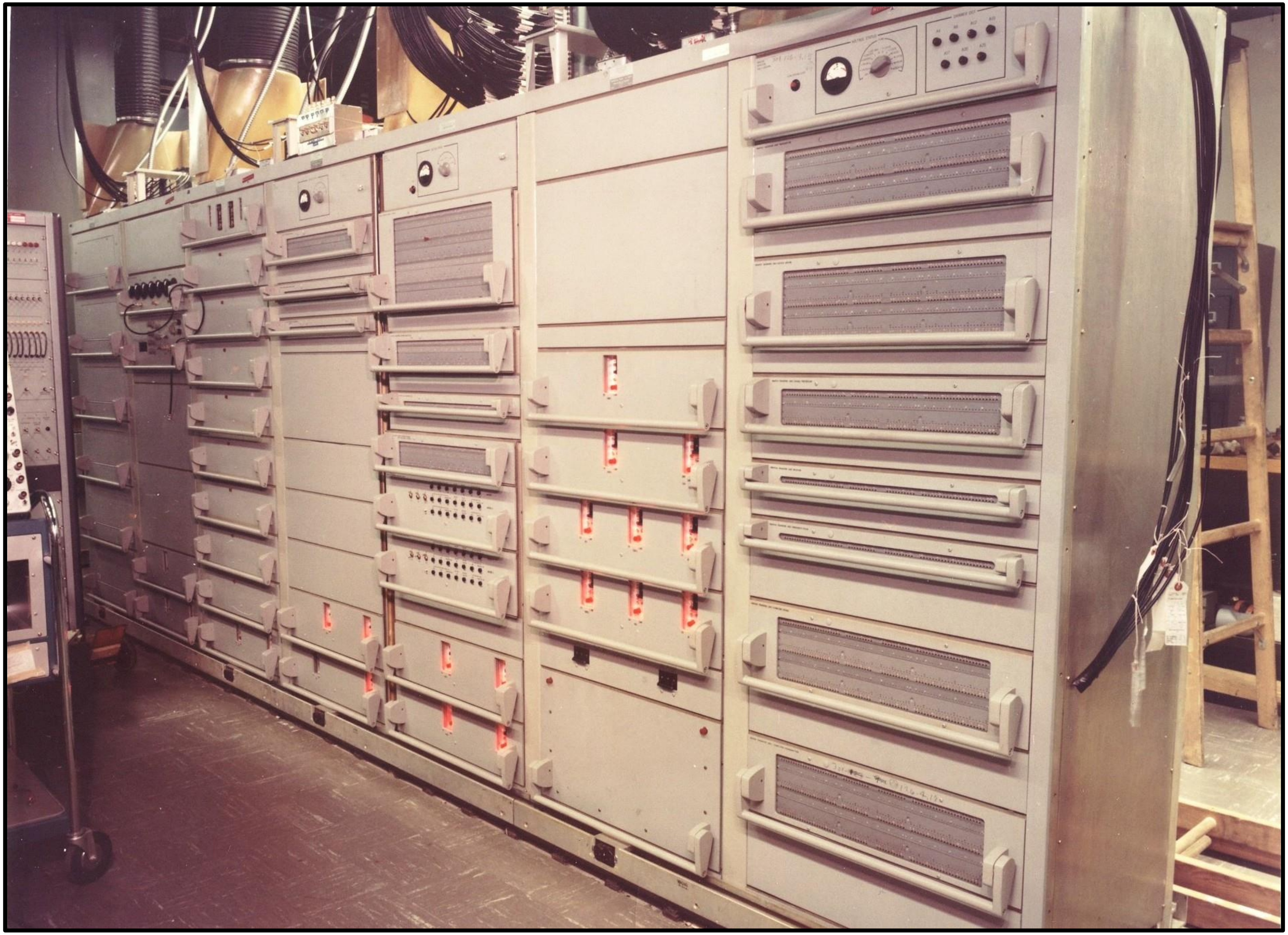


WSMR Archive ID # 12.007.779-2

Signal Processor & Tape Drives

WSMR Archive ID # 97.180.204-14

Fault Location Monitor (FLAM) on Main Floor - 28 Apr 1964



WSMR Archive ID # 97.180.197-9

Pre-Amp Test Room, Rx Dome, Back of Lower Level – 28 Apr 1964

WSMR Archive ID # 97.180.197-3

MAR-I Timeline
&
Summary

Comprehensive MAR-I Timeline (as compiled by R. Hayward, 2 March 2016)

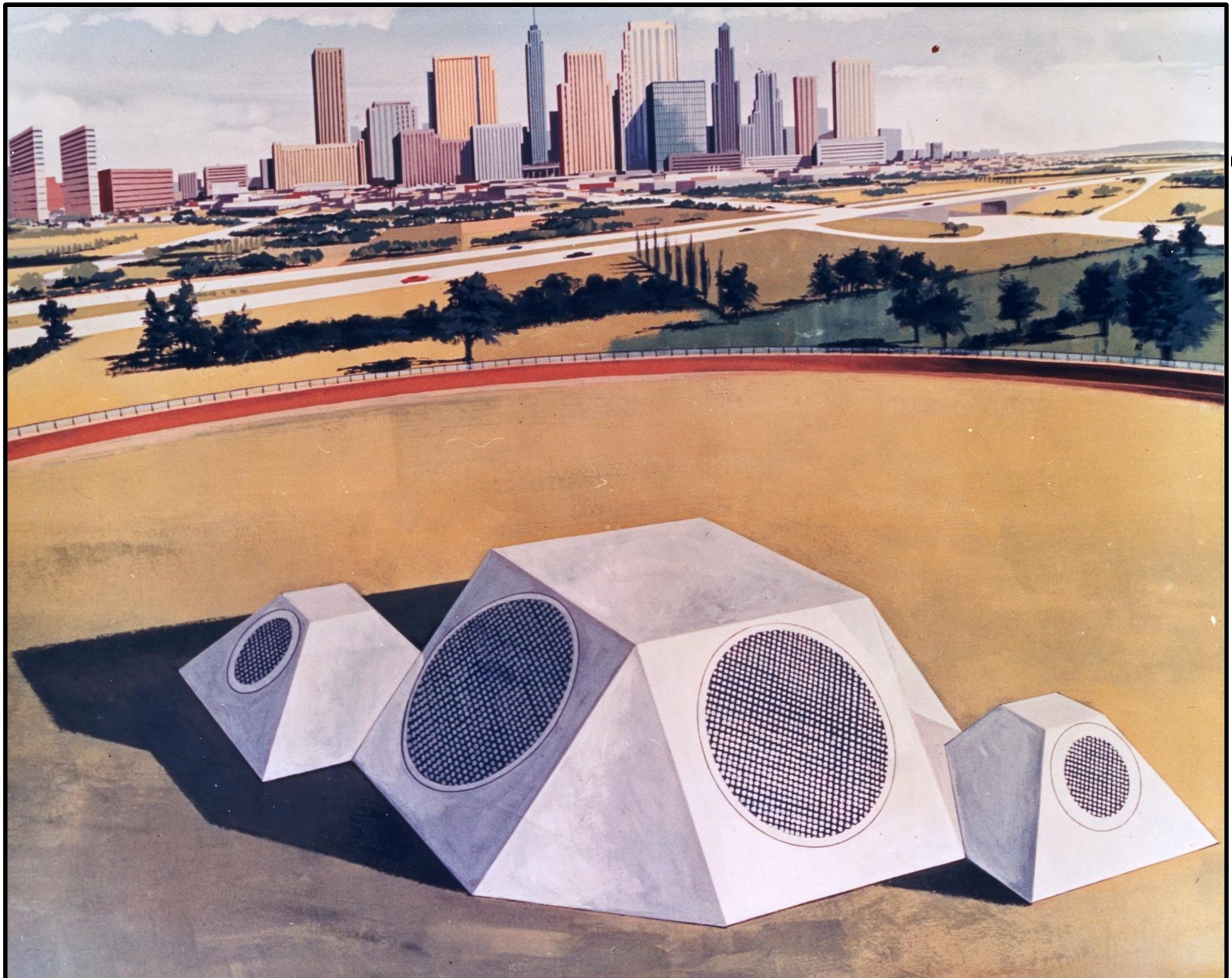
1960	Engineering studies and conceptual designs for a multifunction array system developed at BTL.
June 1961	WECo authorized to proceed with the design of a prototype phased-array radar. BTL was responsible for supervising the design. Sylvania was selected as the subcontractor for the detailed design & 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.
Sept 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 System Evaluation Agency* (SENSEA) 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. (Report not yet verified.)
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 Systems 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.

What was Learned from the MAR-I…

- **The MAR-I was not planned as a true prototype of the Nike-X's MAR system.**
- **It was essentially a laboratory R&D test bed to:**
  1) **Study the feasibility of large phased-array radars.**
  2) **Study the viability of a multifunction radar.**
  3) **Assist in the design of the tactical prototype radar, the MAR-II, on Kwajalein.**
- **Demonstrated the feasibility of using a phased-array radar for a multiplicity of simultaneous functions.**
  - **Extensive antenna pattern measurements of single beam & multiple-beam clusters closely matched the calculated patterns.**
  - **Stability and repeatability of these antenna patterns over extended time periods.**
- **One of the important lessons learned was the need to thoroughly test all the hardware elements that are duplicated in large numbers in an array radar.**
  - **Design faults resulting in poor reliability were uncovered in the Traveling Wave Tubes.**
  - **Designers of later array radars (e.g., MSR & PAR) were required to run exhaustive laboratory tests on elements that were to be duplicated thousands of times.**
- **Demonstrated the broad frequency-bandwidth capability of phased-arrays using time-delay steering in both the transmit & receive modes.**
- **Demonstrated the ability of microsecond time switching and the use of multiple frequencies for simultaneous radar functions.**
- **Demonstrated the use of a centralized digital computer to control all radar functions, and execute large-scale, real-time data processing.**
- **The next stage of the Nike-X program moved on from White Sands to Kwajalein, with the construction of an operational MAR prototype, known as the MAR-II.**

The MAR-II / CAMAR on Kwajalein

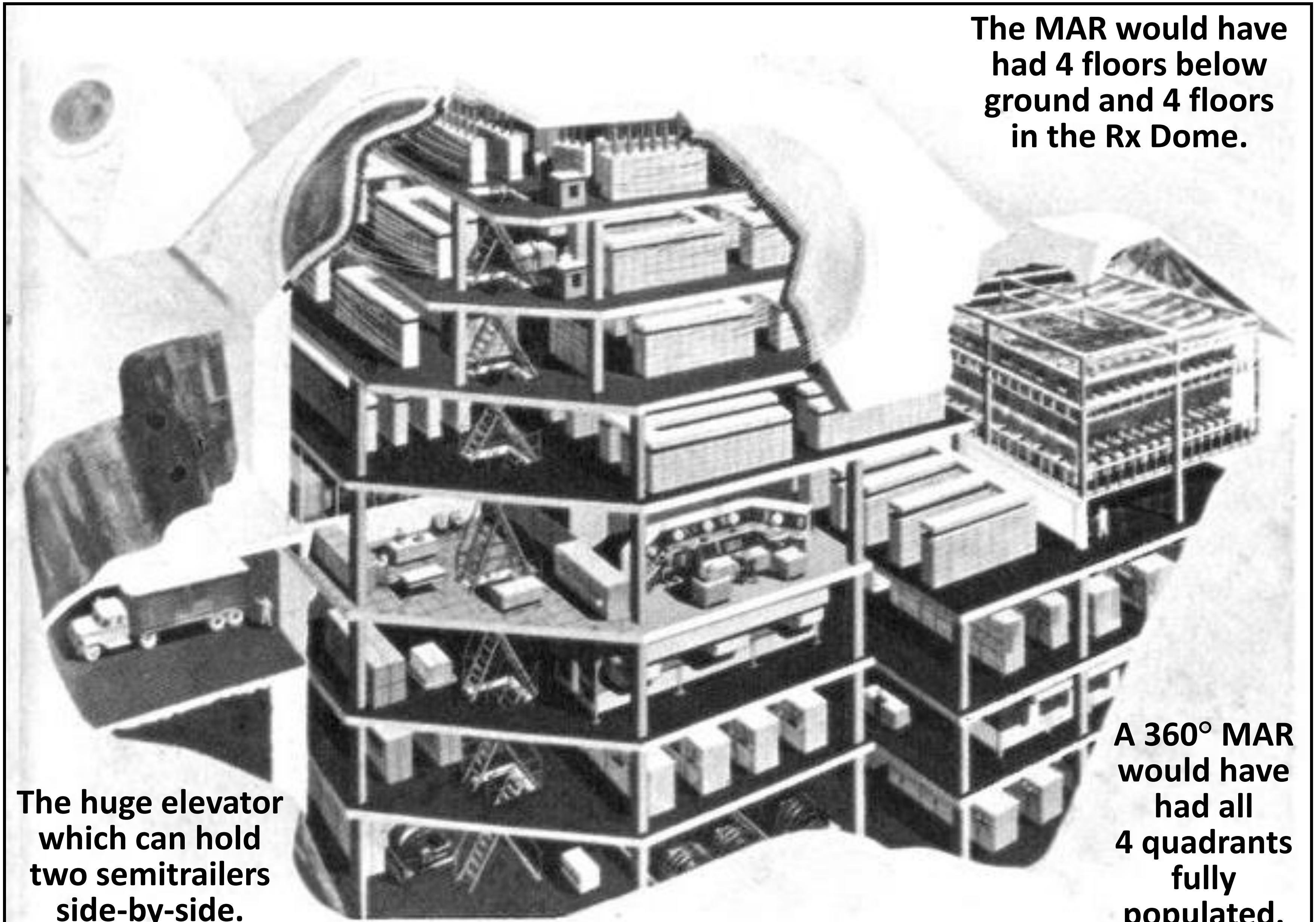
Multifunction Array Radar - MAR



Gone were the domes of the MAR-I, being replaced by a large 8-sided structure for the receiver arrays, with smaller truncated pyramids for the transmitter arrays.

Image from the collection at the USASMDC/ARSTRAT Historical Office, Redstone Arsenal

Cutaway Drawing of the Proposed MAR



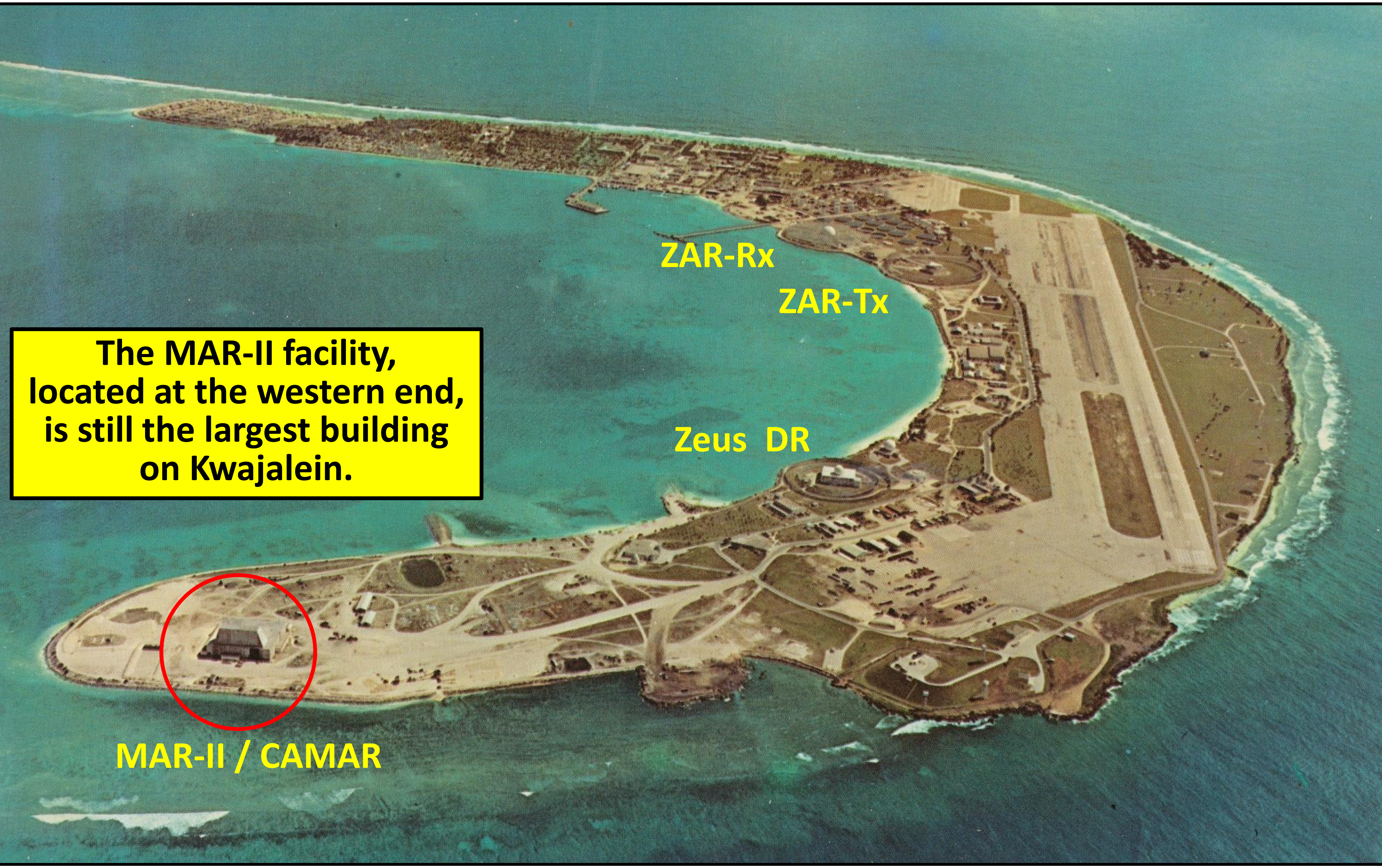
The MAR would have had 4 floors below ground and 4 floors in the Rx Dome.

The huge elevator which can hold two semitrailers side-by-side.

A 360° MAR would have had all 4 quadrants fully populated.

***Bids Due Soon on New Nike-X Radar*, Missiles and Rockets, May 30, 1966, p 14-15**

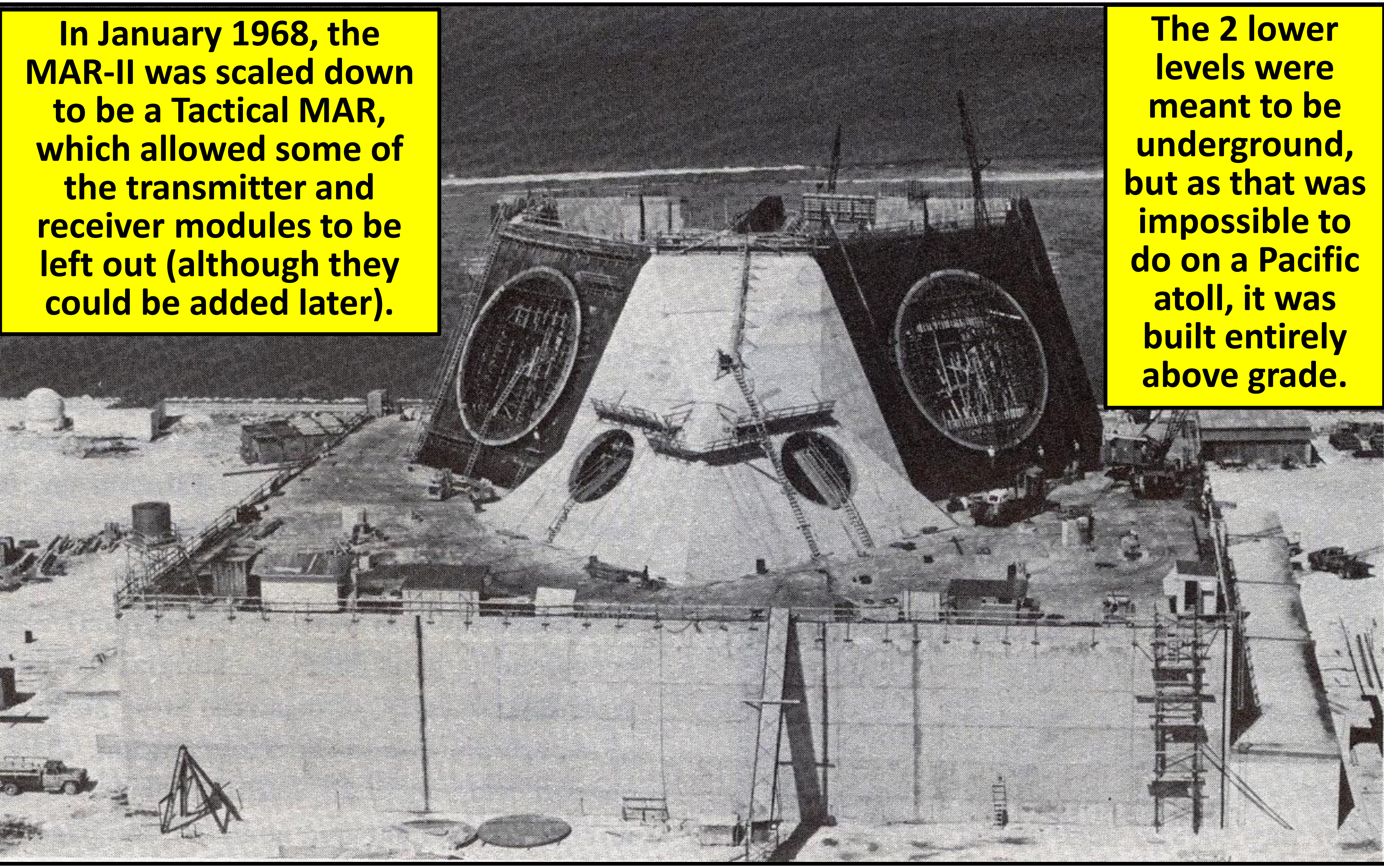
The MAR Prototype, MAR-II, was built on Kwajalein, along side the Nike-Zeus Radars from the early 1960s



http://mcnerney.us/kwaj/index.php?_year=1974&_month=December

MAR-II Construction, Aug 1969

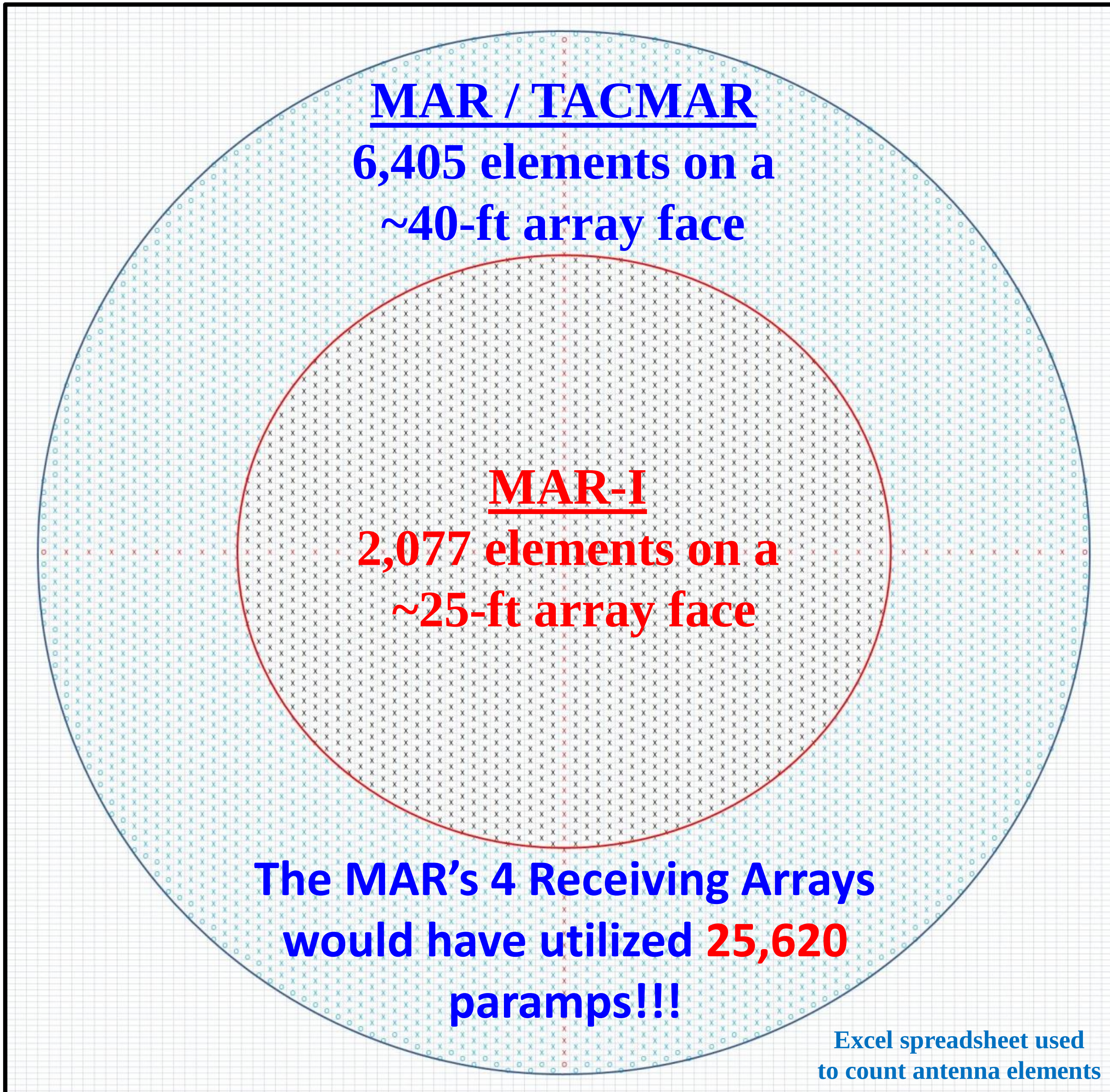
In January 1968, the MAR-II was scaled down to be a Tactical MAR, which allowed some of the transmitter and receiver modules to be left out (although they could be added later).



The 2 lower levels were meant to be underground, but as that was impossible to do on a Pacific atoll, it was built entirely above grade.

ABM Research and Development at Bell Laboratories - Kwajalein Field Station, 1975, p81, WSMR Archive # 03-013-010

The MAR vs. the MAR-I Receiver Array



The Fate of the MAR-II and Nike-X

GoogleEarth

Because of its complexity & high-power requirements, the costs of the MAR-II system escalated to the point that the deployment of the TACMAR prototype continued to be delayed.

In May 1968, the MAR-II was changed to provide data on discrimination techniques. Since the Tx & Rx would use the same phased-array face, it was called the *Common Aperture Multifunction Array Radar* (CAMAR).
In August 1969, now called *Guardian,* it was cancelled due to funding cutbacks.

A *Nike-X* ballistic missile shield to protect America's 50 largest cities would need 3 TACMARs & 8 MARs, costing $3.2B ($25.1 B today, at $3.2 B per site)
It would also require 95 MSRs, costing $7.9 B ($62.0 B in 2019).
Adding the cost of the ABMs & their nukes, the total cost could have been as high $33 B ($258 B in 2019).

With the Vietnam War underway, there was reluctance to deploy *Nike-X*.
It would be replaced by *Safeguard* which would protect ICBM sites in the Midwest.

The Safeguard ABM Radar System

~ ~ ~ ~ ~

PAR = "*Perimeter Acquisition Radar*"

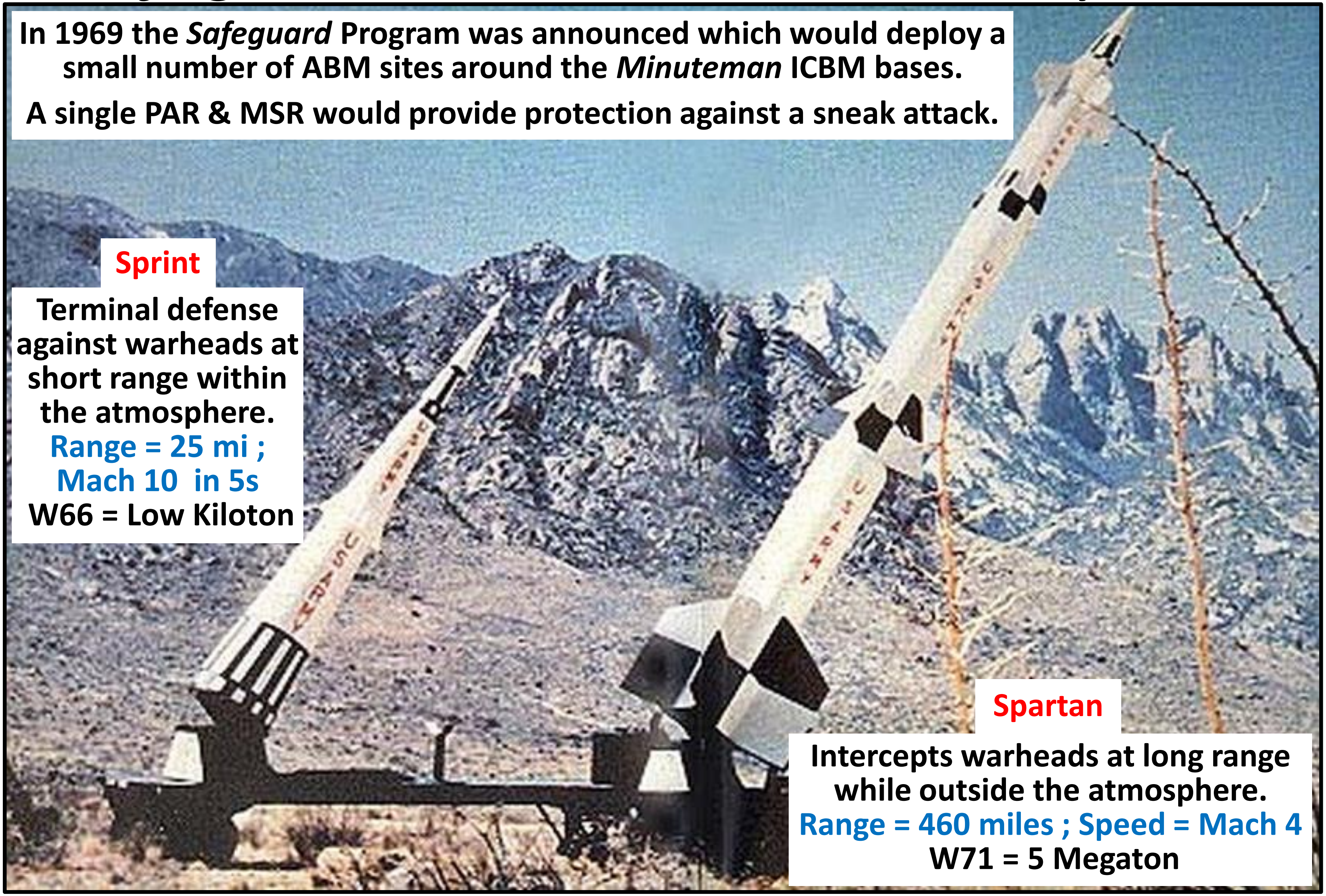
&

MSR = "*Missile Site Radar*"

Safeguard Anti-Ballistic Missile System

In 1969 the *Safeguard* Program was announced which would deploy a small number of ABM sites around the *Minuteman* ICBM bases.

A single PAR & MSR would provide protection against a sneak attack.



Sprint

Terminal defense against warheads at short range within the atmosphere.
Range = 25 mi ;
Mach 10 in 5s
W66 = Low Kiloton

Spartan

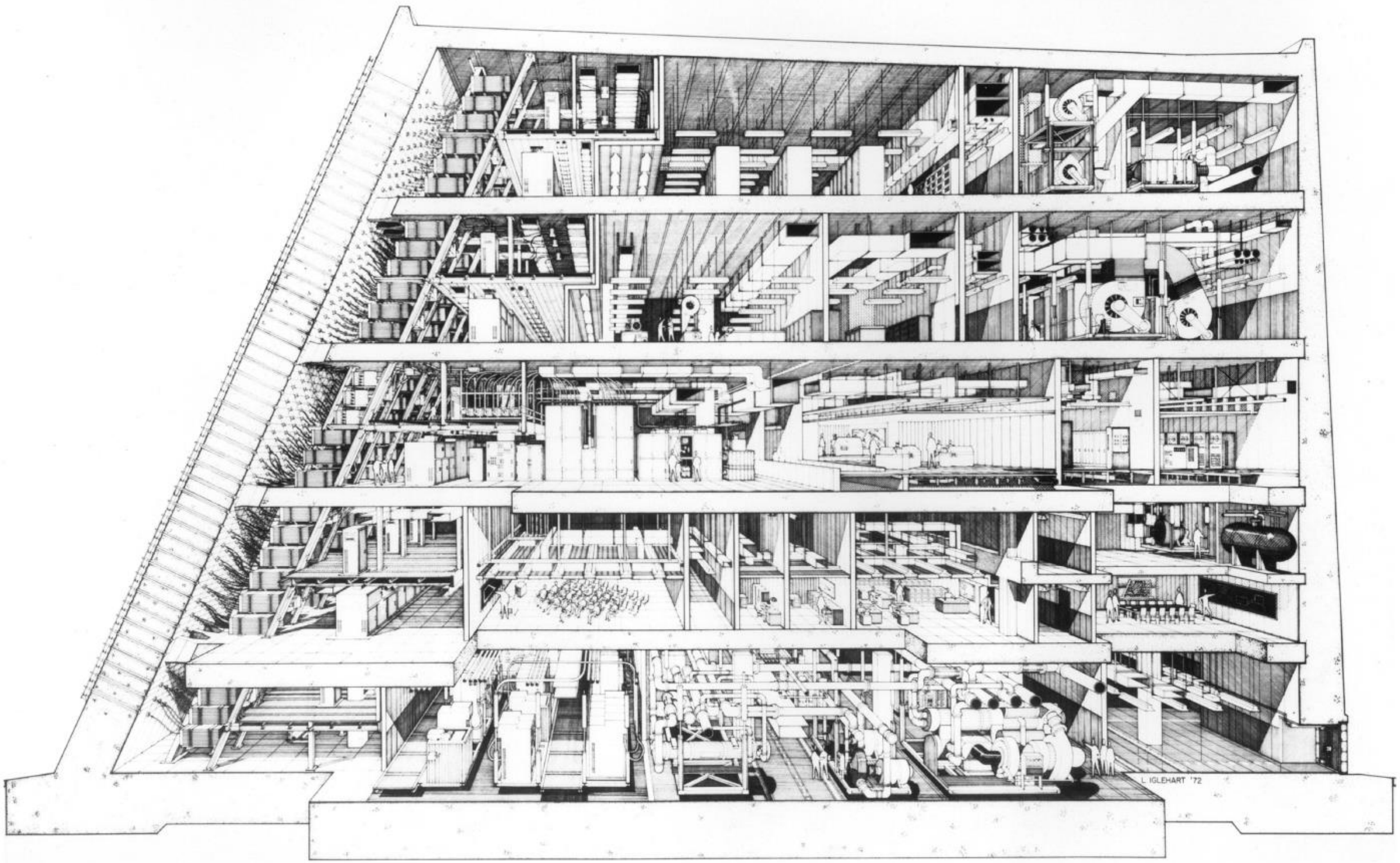
Intercepts warheads at long range while outside the atmosphere.
Range = 460 miles ; Speed = Mach 4
W71 = 5 Megaton

http://sggpnews.org.vn/international/thirty-new-countries-could-acquire-nuclear-weapon-iaea-chief-2547.html#&gid=1&pid=1

Safeguard *Perimeter Acquisition Radar* (PAR) located near Concrete, ND

The world's most powerful radar – can track a basketball at a range of 2,000 miles in space.
Construction Start = April 1970 ; Complete = Aug 1972 ; Operational = Sept 1974
Array Diameter = 120 ft ; Frequency = 420-450 MHz ; Number of elements = 6,144
Height = 128 ft (2nd highest building in ND when built) ; Complex encompassed 250 acres
The Stanley R. Mickelsen Safeguard Complex Photo CD Version 1 (9 Nov 2009), Picture #3002

Cutaway Diagram of the PAR

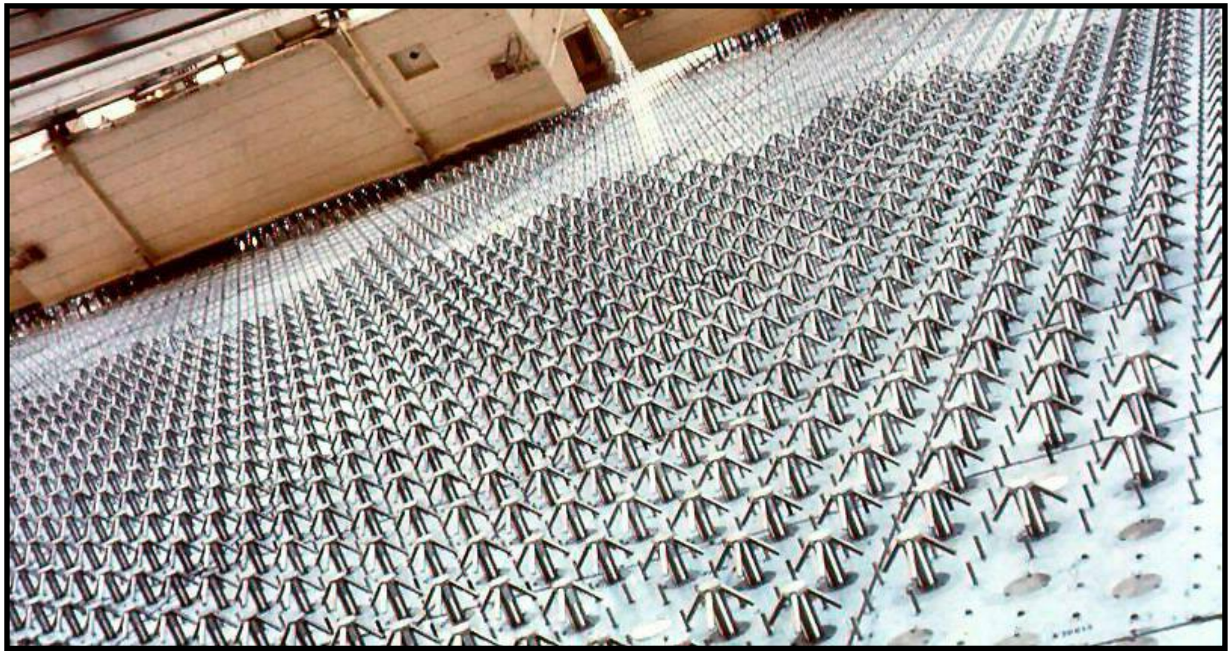


The reinforced walls were 4 to 7 feet thick.

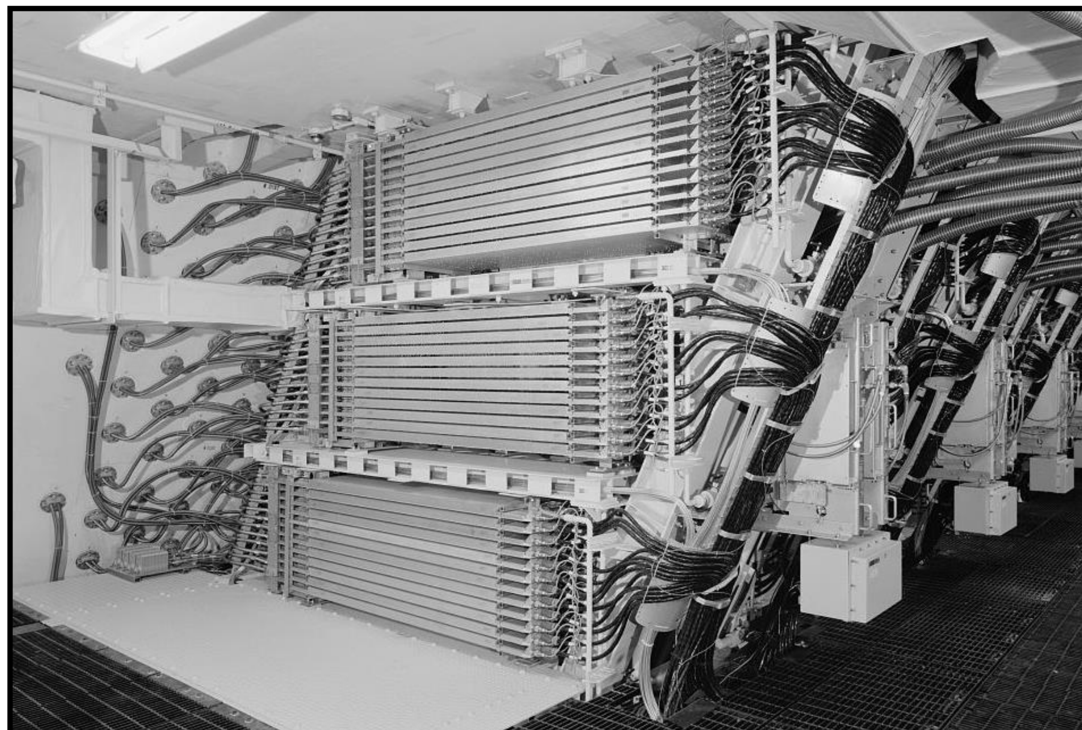
The structure required 17 million pounds of steel reinforcing rods and 58,000 cubic yards of concrete.

The USACE claimed *"The PAR design may be the most solidly constructed building in the world, the Egyptian pyramids not withstanding.*

***The Stanley R. Mickelsen Safeguard Complex Photo CD Version 1* (9 Nov 2009), Picture #3014**
***A History of the Huntsville Division, U.S. Army Corps of Engineers 1967-1976*, J. Kitchens, 1978**



PAR Elements



Above – Some of the ~6,000 Crossed-Dipole Antenna Elements during installation

Right – Some of the ~6,000 Phase-Shifters behind the Array Face

The Stanley R. Mickelsen Safeguard Complex Photo CD Version 1 **(9 Nov 2009), Picture 1080b & 7482b**

Safeguard *Missile Site Radar* (MSR) located near Nekoma, ND

Construction start = Spring 1970 ; Power Up = Early 1973 ; Operational = April 1975
Diameter of each Array = 13 ft ; Frequency = 2,800 MHz; Range = 400 miles;
Height = 75 ft ; Number of elements = 4 Quadrants of 5,001 each = 20,004

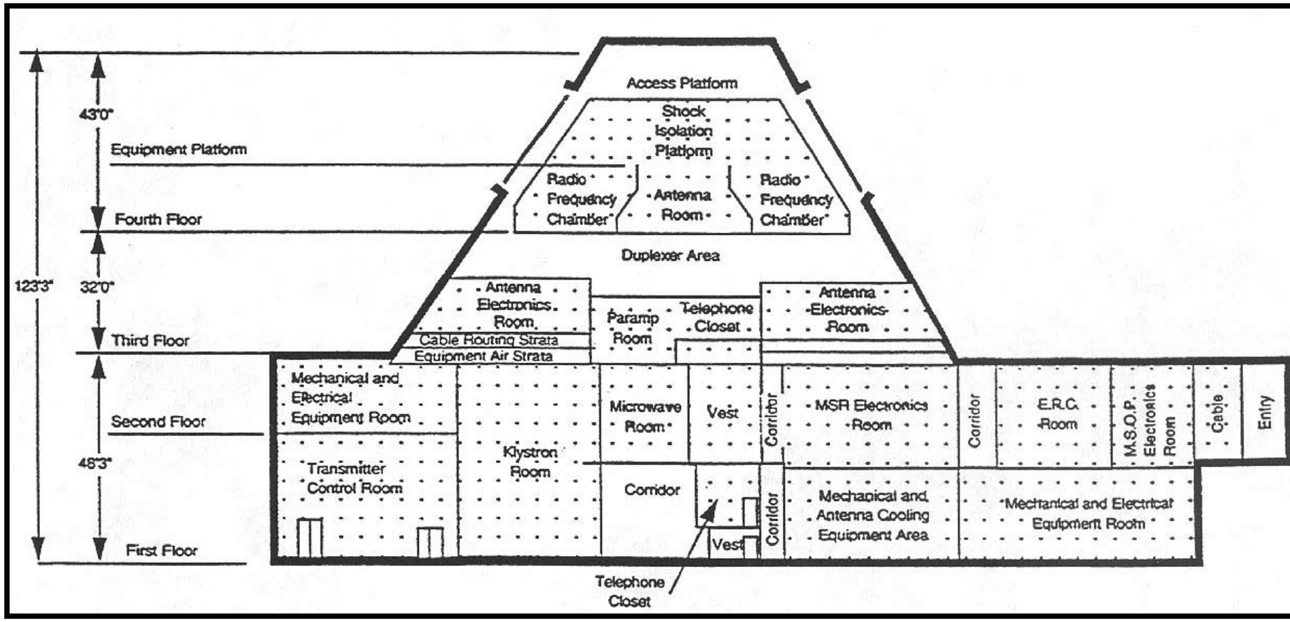
The MSR Complex covered 430 acres & contained a field of 16 short-range *Sprint* and 30 long range *Spartan* defensive missiles, both of which carried nuclear weapons to destroy incoming warheads.
The MSR also controlled 4 additional remote *Sprint* launch sites which provided a total of 100 ABMs.

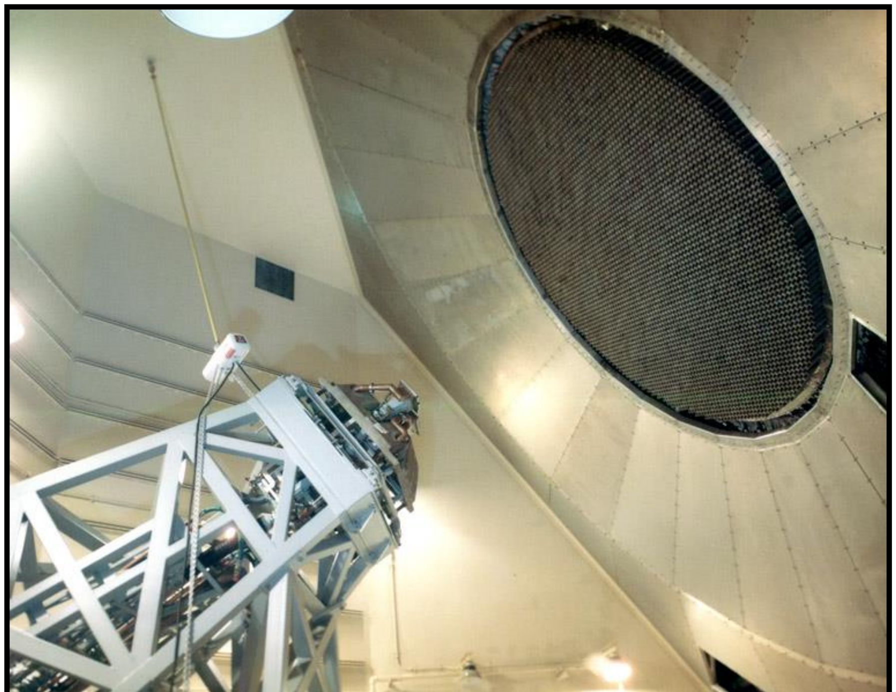
***The Stanley R. Mickelsen Safeguard Complex Photo CD Version 1* (9 Nov 2009) , Picture #1016**

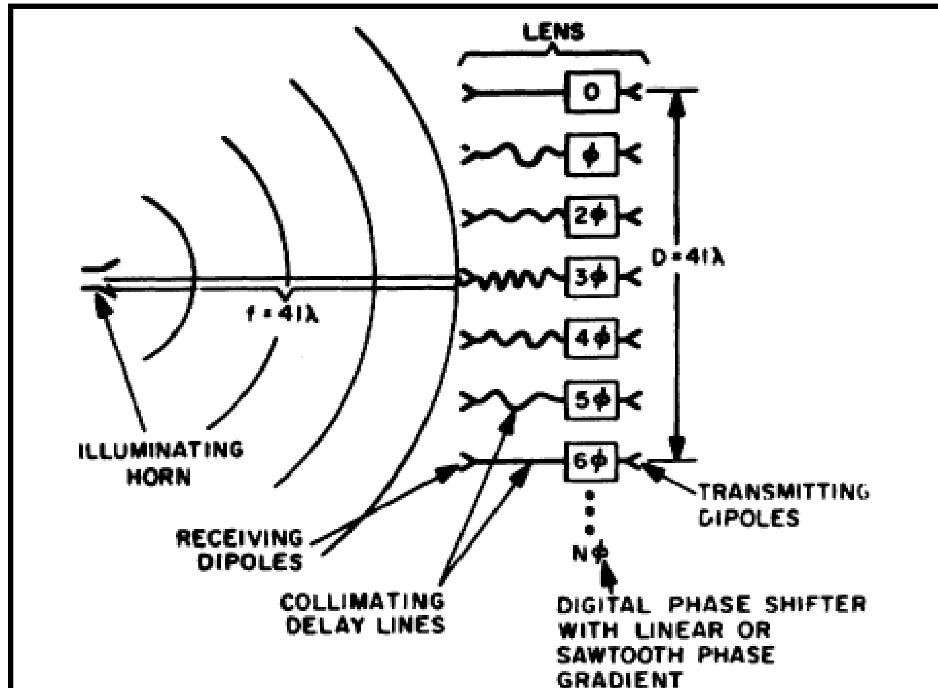
Cutaway of MSR & its Space-Fed Phased-Array

The Anechoic Chamber was the largest microwave oven in the world.

- Vestal Fulp, MSR Tx Eng.







The Stanley R. Mickelsen Safeguard Complex Photo CD Version 1 (9 Nov 2009) , Picture #0026 & 7510

HAPDAR-An Operational Phased Array Radar, Proceedings of the IEEE, P. Kahrilas, Nov 1968

The MSR & PAR Today

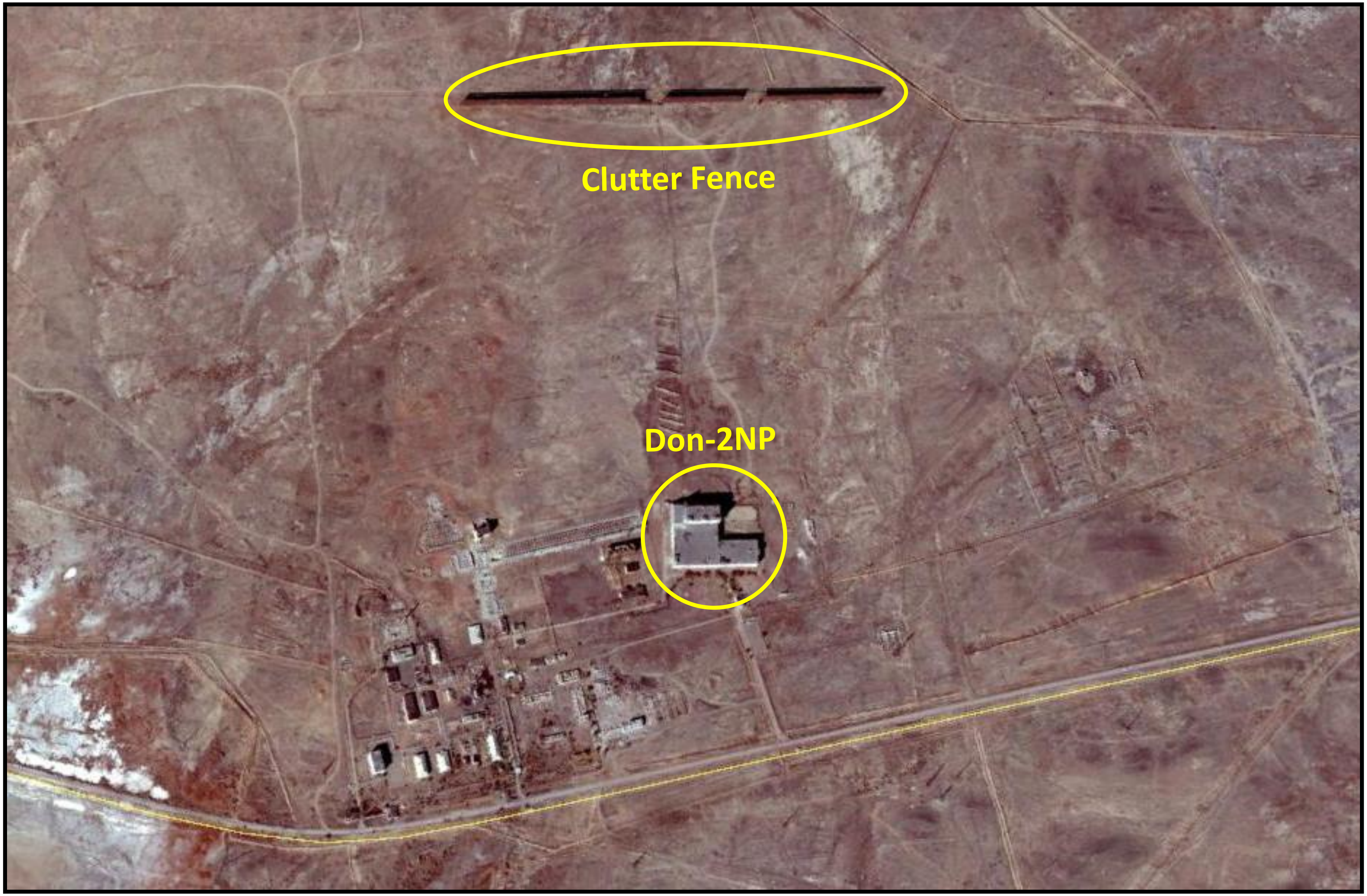
- The PAR & MSR trace their development directly back to the MAR.
- The *Safeguard* site at Grand Forks was declared fully operational on 1 Oct 1975.
- One day later, the *House of Representatives* voted to deactivate it.
- The decision was based on the argument that a single ABM site could be overwhelmed, and that its 100 interceptor missiles were not nearly enough to counter a determined Soviet attack.
- The MSR was shut down in February 1976. Its 100 *Spartan* & *Sprint* missiles were removed, the pyramid was sealed, and the site was placed in caretaker status.
- In 1977 the PAR became the *Perimeter Acquisition Radar Attack Characterization System* (PARCS) operated by the USAF. It now monitors and tracks potential missile launches against North America and also tracks over half of all earth-orbiting objects as part of the *Space Surveillance Network.*
- In 2012, the MSR facility was bought by a Hutterite Colony for $530,000.
- The total cost of the *Safeguard* project was about $5 billion, or $35 billion today.

Photo courtesy of Bob Gamboa

Meanwhile - Back in the USSR
and the Soviet version of the MAR-I
~
The Don-2NP Prototype ABM Radar
(built & tested in the late 1970s)

Don-2NP Prototype Radar, Sary-Shagan, Site 8

Priozersk, Kazakhstan, 46° 0'13.47"N, 73°38'56.23"E



GoogleEarth - 15 Oct 2014

Don-2NP Radar Tx & Rx Array Faces

GoogleEarth Photo # 77466618

Don-2NP Radar from the Side

GoogleEarth Photo # 77466679

Rear of Don-2NP & Clutter Fence

GoogleEarth Photo # 110248741 & 77466662

The Soviet / Russian Version of the Nike-X MAR ~ Operational Don-2N “Pillbox” Radar

USSR/Russia *Don-2N* Operational ABM Radar

30 miles N. of Moscow, 56°10'23.81"N, 37°46'11.87"E

GoogleEarth Image

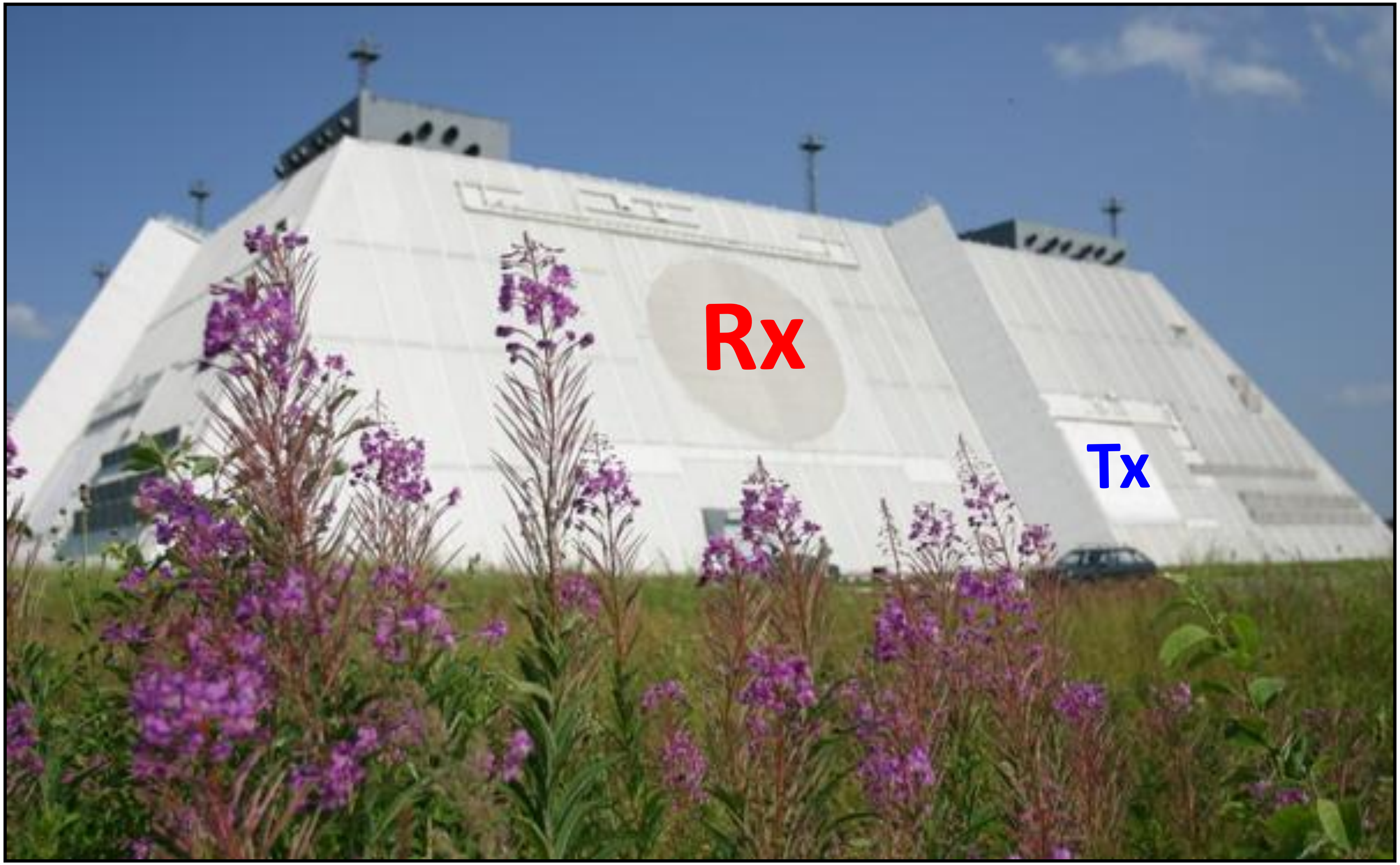
Russian Don-2N Multifunction Array Radar

(The *Don-2N* Radar - called "Pillbox" by NATO)

The Soviet-era radar was developed in the period from 1973-1989.
It can detect, track and discriminate ballistic targets, and guide interceptor missiles, just as the American MAR was to have done 20 years earlier.
It is still operational.

http://www.panoramio.com/photo/13572904

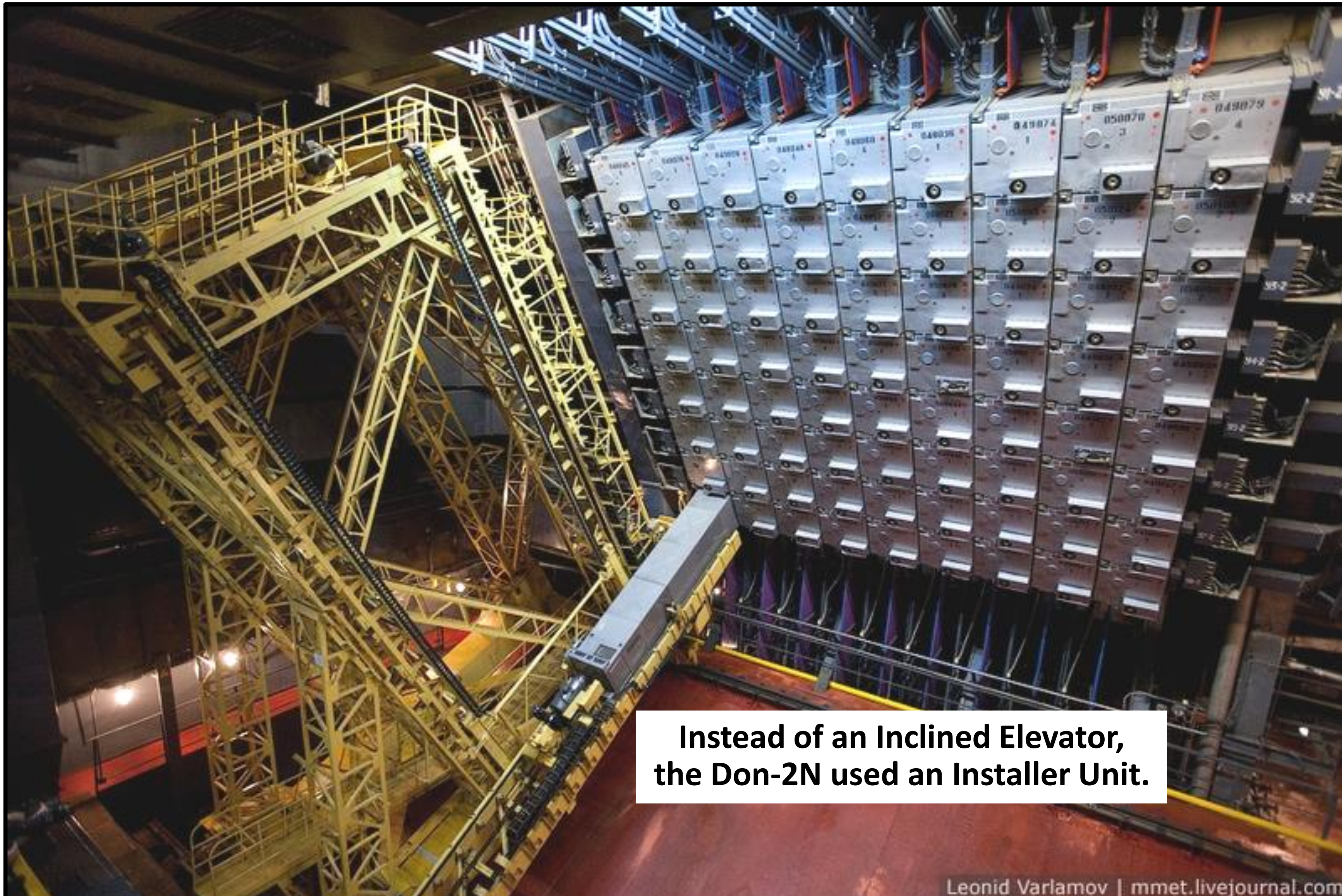
Don-2N Multifunction Array Radar



This space-fed radar uses a circular Receiver Array 16 m (52-ft) in diameter.
The rectangular Transmitter Array is 7x8 m (23 x 26 ft).
Construction started in 1978. Over 30,000 tons of metal, 50,000 tons of concrete.
The radar started functioning in 1989.

http://forum.keypublishing.co.uk/showthread.php?t=68936 & http://englishrussia.com/2011/12/29/military-legacy-of-the-ussr/2/

Don-2N Transmitter Array - Backside



Installer unit used for replacing the electronic cells on one of the four Transmitter antennas.

http://englishrussia.com/2011/12/29/military-legacy-of-the-ussr/
http://translate.google.com/translate?hl=en&sl=ru&tl=en&u=http%3A%2F%2Frussos.livejournal.com%2F899567.html&sandbox=1

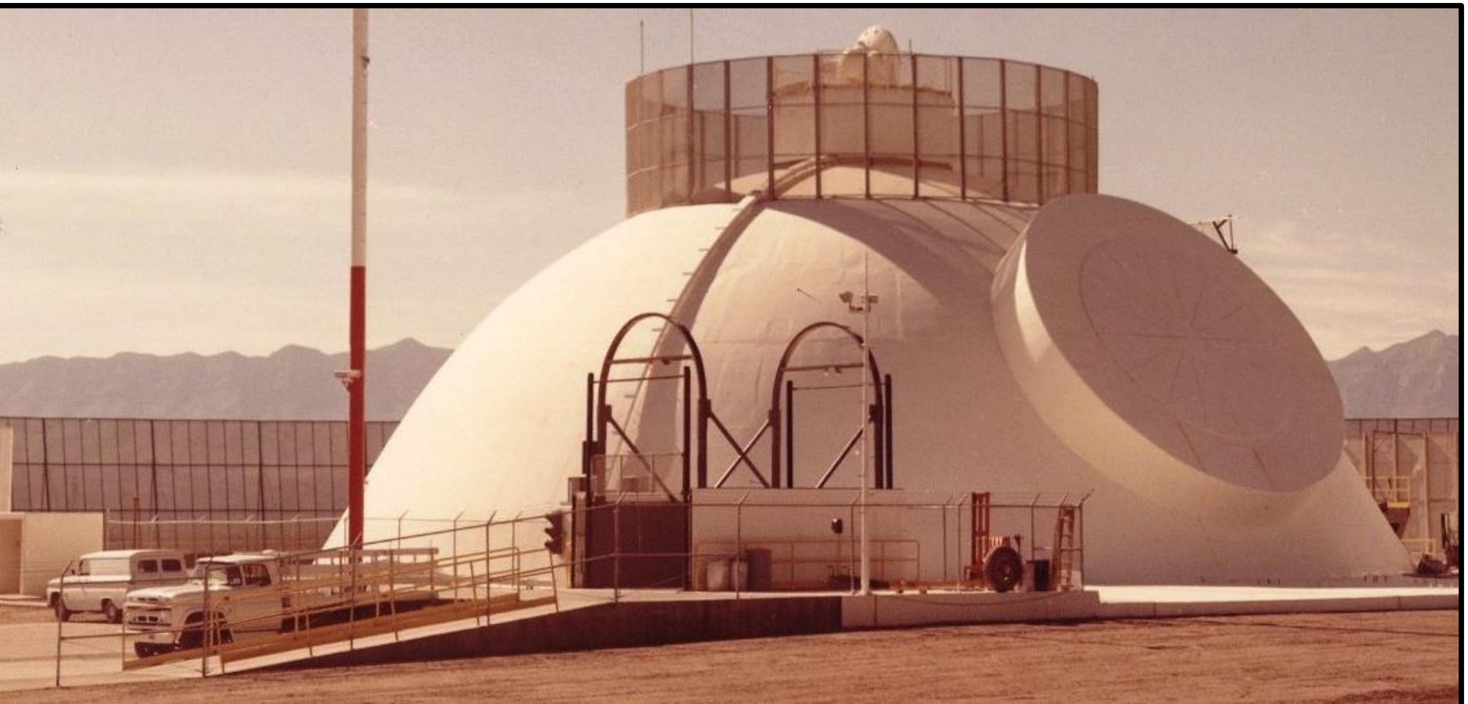
The Salvage of the MAR-I by New Mexico Tech (NMT) University located in Socorro, NM

Recollections from John Reiche, NMT's Instrument Manager, & Joe Martinic, an NMT student during the MAR-I salvaging

- NMT had a good reputation for acquiring copious amounts of military & government surplus material & equipment from installations in the Southwest, including a missile silo.
- The MAR-I site had been abandoned by Fall 1970 when the first NMT salvage crew arrived.
- John Reiche & his colleagues went down to investigate the site and were waiting at the gate for the military liaison to arrive and open it for them. They noticed that the combination lock on the gate was the same type that NMT used on one of their secure areas back in Socorro. So they tried the same number (2026) and it opened, much to the consternation of the guard when he finally arrived.
- All of the electronics in the various bays were removed, as well as the miles & miles of Heliax and copper cables. John described the demolition effort as a fun project.
- Joe recalled that the demolition teams only spent the weekends working at the MAR-I site.
- The weekend crew typically drove down in 3 carryall trucks with a total of 15-20, most of them 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.
- The MAR-I work was the single largest salvaging effort ever carried out by NMT.
- The salvaging work lasted about 6 months. It was a big effort - maybe 250 truck loads in all. There was literally at least a truck a day showing up with surplused stuff.
- We don't know the exactly the terms & conditions of NMT's contract with WSMR to salvage the MAR-I site. Did NMT pay WSMR, or did WSMR pay NMT, or was it "at no cost"?

Steve Hunyady & the MAR-I

- **Steve Hunyady was a first year student at NMT when he assigned to go with the demolition team down to the MAR-I site in Dec 1970.**
- **He was working on one of the floors when he noticed that it had gotten awfully quiet.**
- **Being the “new guy” on his first trip, the others had forgotten about him when they headed home on Sunday evening. No one else was due to return for days.**
- **None of the telephones worked (even the one labeled "White House").**
- **All the exterior doors were locked from the outside, so he couldn’t get out. He found that the cargo elevator still worked, but if he used it, he wouldn’t be able to get back in.**
- **He managed to find an old truck outside and get it working. He drove to Organ, the nearest town, and called his roommate, who drove down to pick him up the next day.**
- **Steve would become an Instrumentation Engineer at the NMT’s Lagmuir Lab in 1988.**



WSMR Archive ID # 12.007.781

MAR-I & the Tech Bone Yard

Most of the salvaged MAR-I material was sold as scrap.

In 2010, Joe Martinic found a number of MAR-I bits & pieces still residing in the NMT *Bone Yard* after nearly 40 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 Preamp Modules (lower right).

What Happened to the MAR Site?

MAR-I in Caretaker Status – 7 Feb 1968

WSMR Archive ID # 97-180-199-1

Decommissioned MAR Site - 10 May 1974

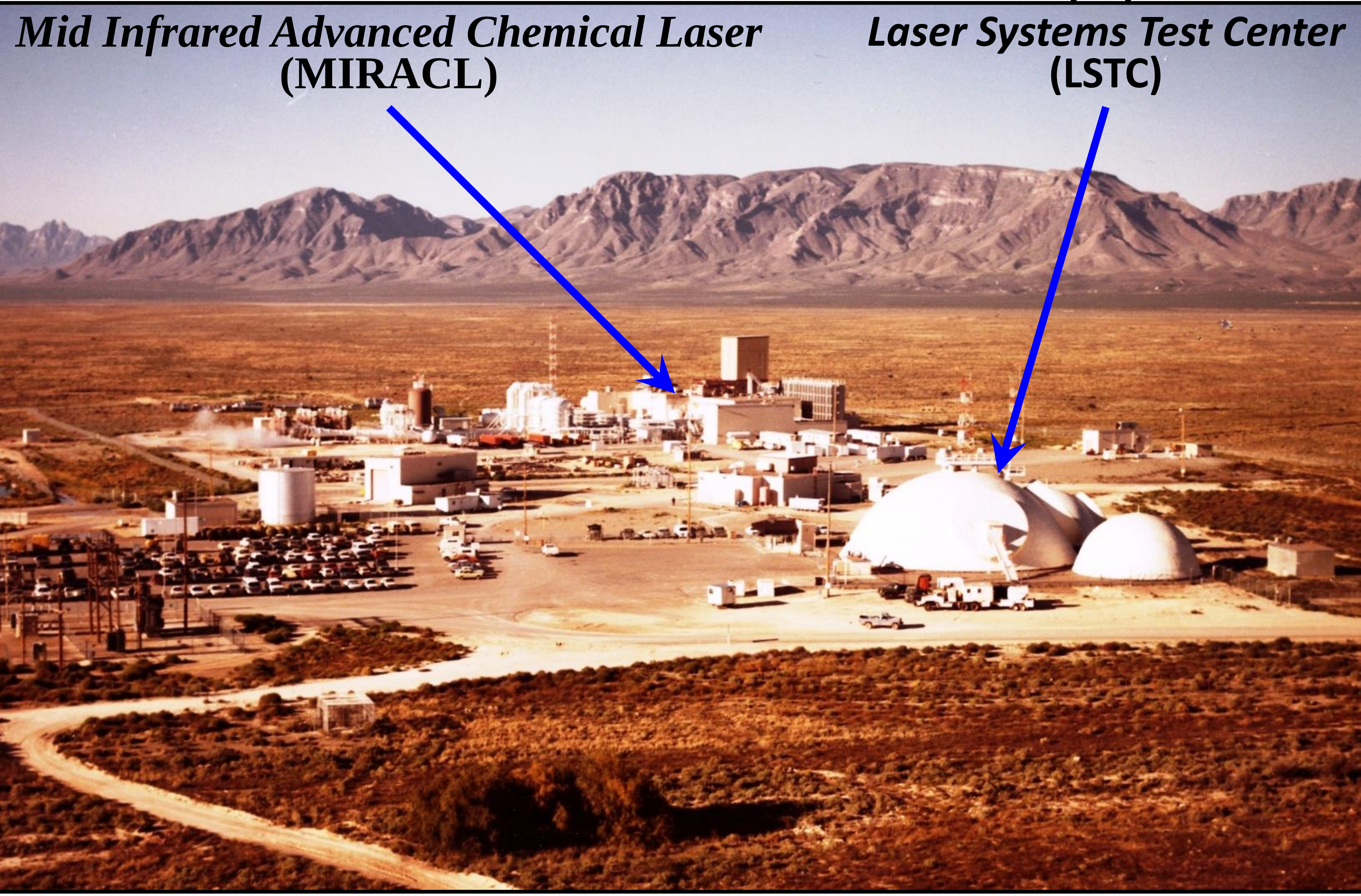
WSMR Archive ID # 00.026.038

The MAR-I Site becomes HELSTF

- **In 1974, Congress directed the DOD to create a "national" tri-service (Army, Navy and Air Force) *High Energy Laser Systems Test Facility* (HELSTF).**
- **It was established at the deactivated MAR-I site where the 90,000 sq. ft. concrete reinforced bunker lended itself well for safety, security & instrumentation.**
- **Construction took place between 1981 to 1984.**
- **HELSTF is the home of the *Mid Infrared Advanced Chemical Laser* (MIRACL), the U.S.'s most powerful laser.**
- **HELSTF became operational in Sept 1985 when MIRACL was used to destroy a Titan missile booster in a static test.**

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

HELSTF Site – Mid 1980s (?)

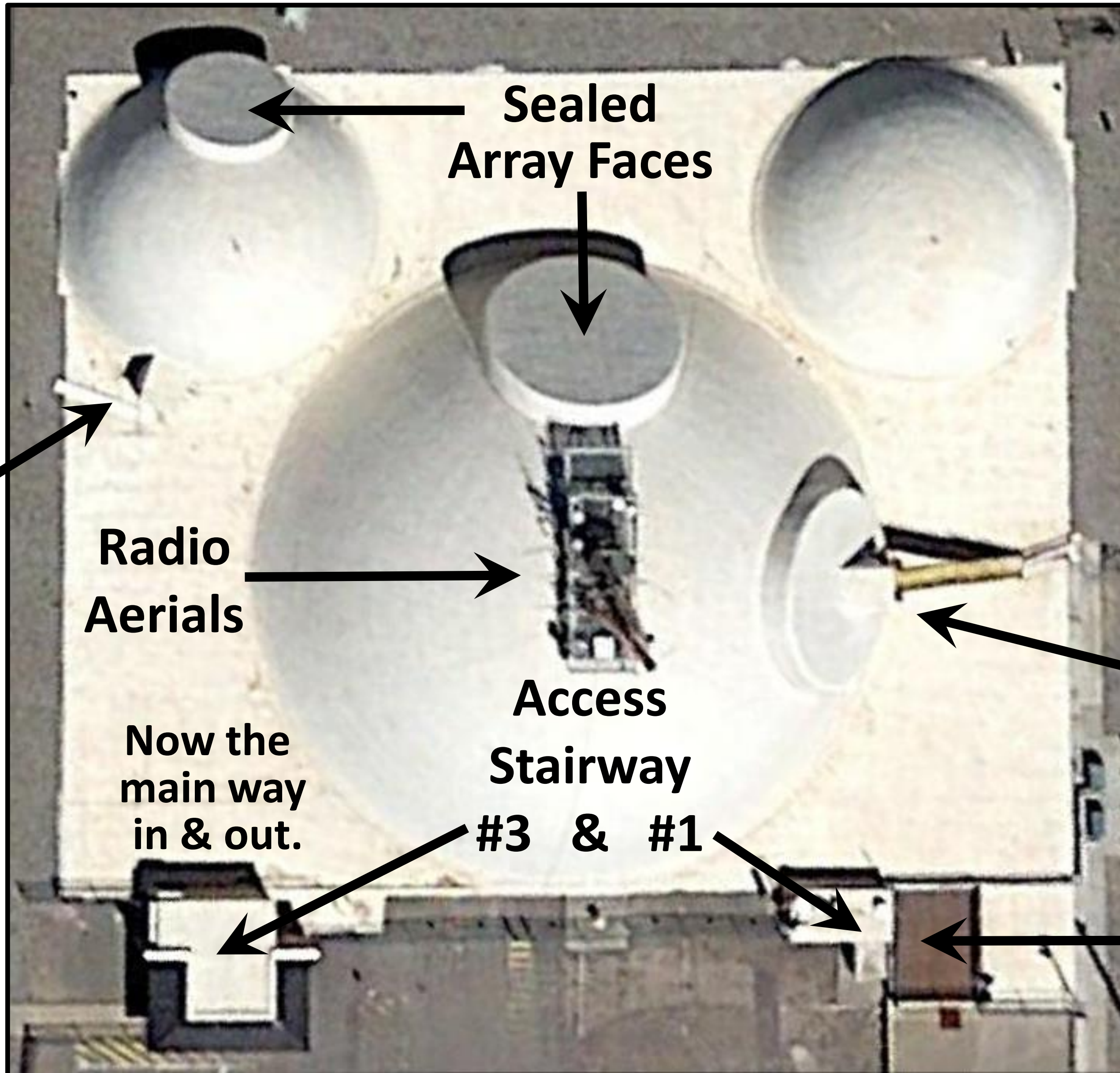


WSMR Archive ID # 97-181-039-2

The MAR-I / LSTC Building Today

To comply with modern OSHA workplace requirements, 2 new exits were added:

New Door into T-1 Dome (it took about 8 months to cut thru the 5-ft wall made of cement and rebar)



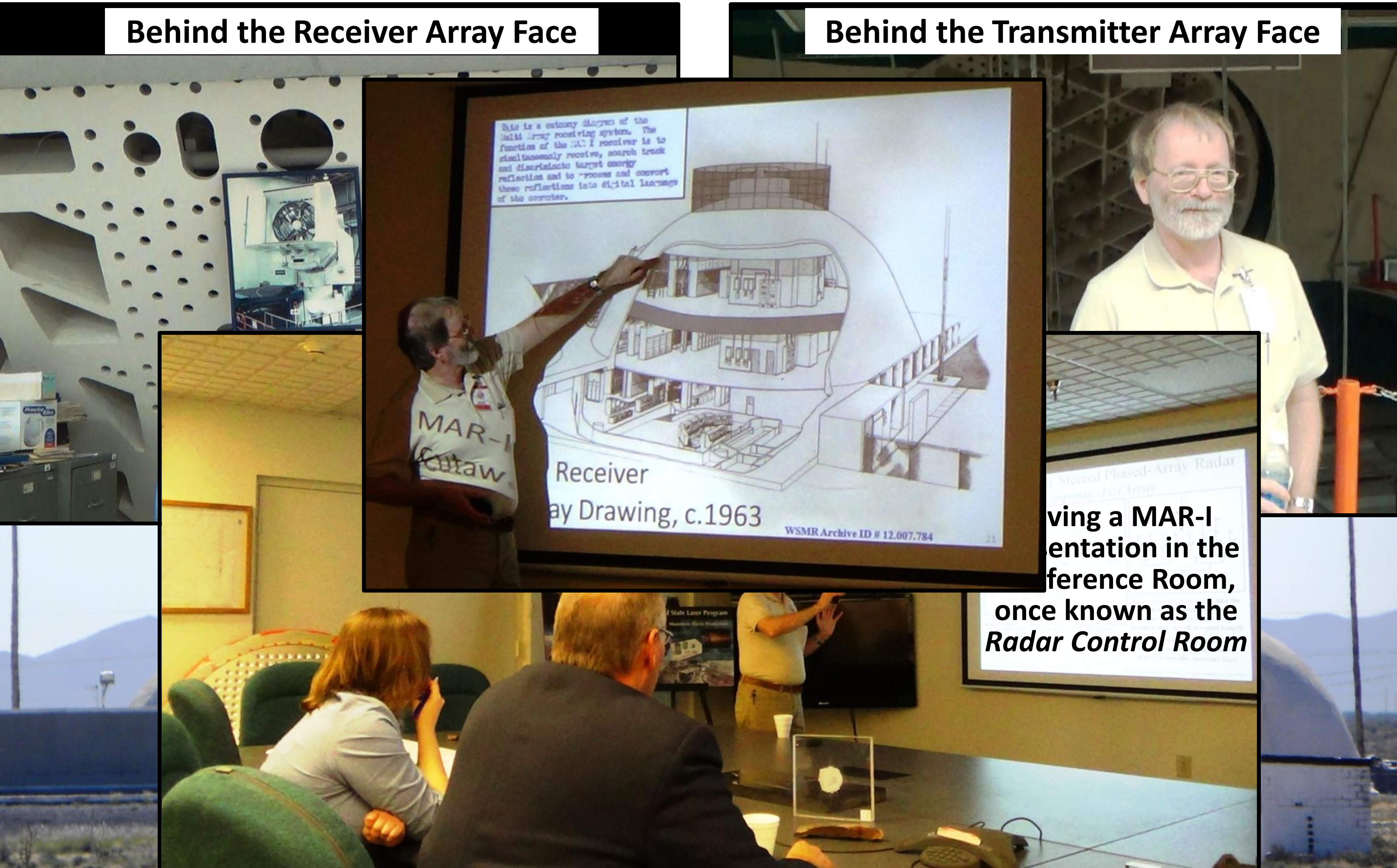
New Emergency Stairway into the Rx Dome through the unused R-2 Array Face

Cargo Elevator

GoogleEarth – 27 May 2016

A visit to MAR-I/HELSTF on 19 Oct 2016

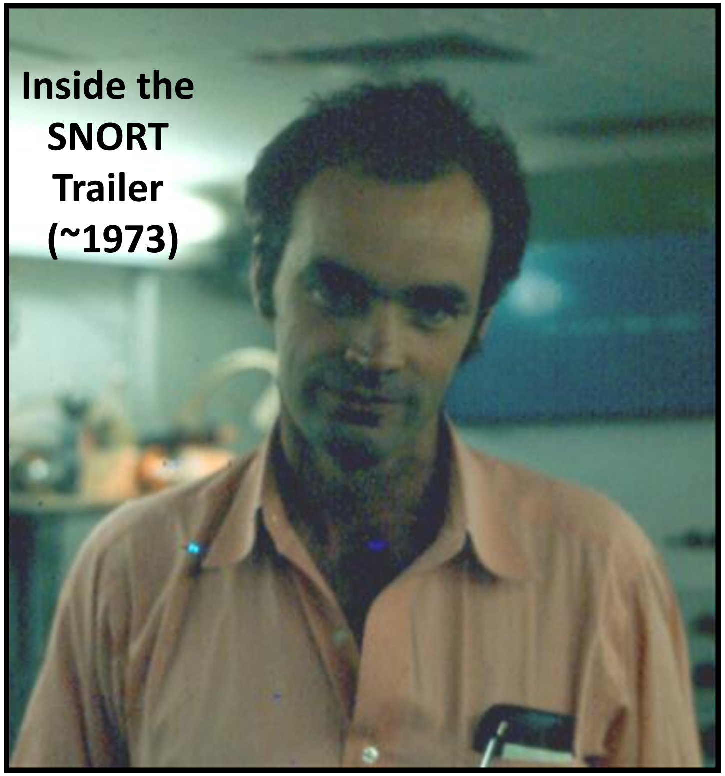
A chance to finally see the place I had been studying from afar



Photos Curtesy Bill Godby, WSMR Archaeologist/Cultural Resource Program

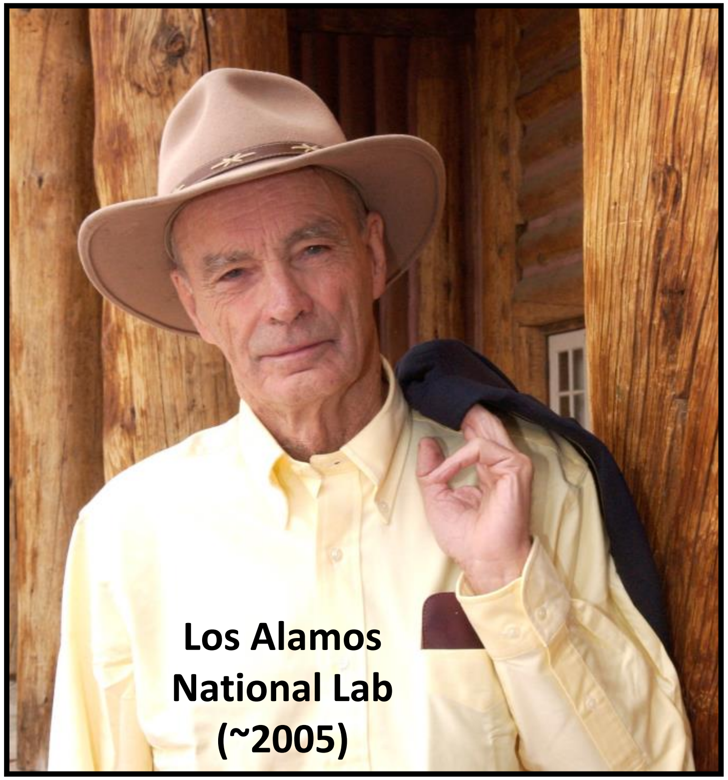
The "*Colgate Paramp*" & The MAR-I's Impact on Radio Astronomy ~ (the original reason why I got interested in the MAR-I)

Stirling A. Colgate
President of New Mexico Tech, 1965-1975



"Toothpaste scion by birth and thermonuclear physicist by choice"

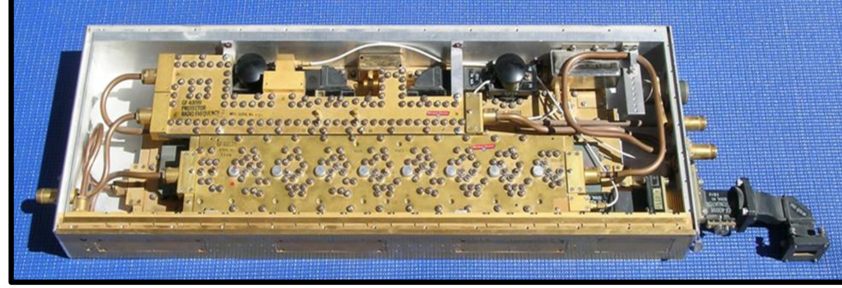
The 4 Percent Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality
by Richard Panek, 2011



- **He was considered to be one of the foremost diagnosticians of thermonuclear weapons.**
- **After WWII, he joined the *Livermore National Laboratory* and worked with Edward Teller on developing diagnostic measurement techniques for nuclear explosions.**
- **In 1954, he was placed in charge of making diagnostic measurements of the *Castle Bravo* test on Bikini of the first deliverable H-Bomb.**
- **While President of NMT, he conducted both astrophysics & atmospheric physics research.**
- **Stirling Colgate died on Dec 1st, 2013 in Las Alamos, NM, at the age of 88.**

Photo courtesy of Bruce Blevins **http://www.lanl.gov/news/albums/people/Stirling_Colgate.jpg**

Setting the Scene
Letter Jan 1972 printed in *Science* Magazine



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.

$1.2 Billion in 2019

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.

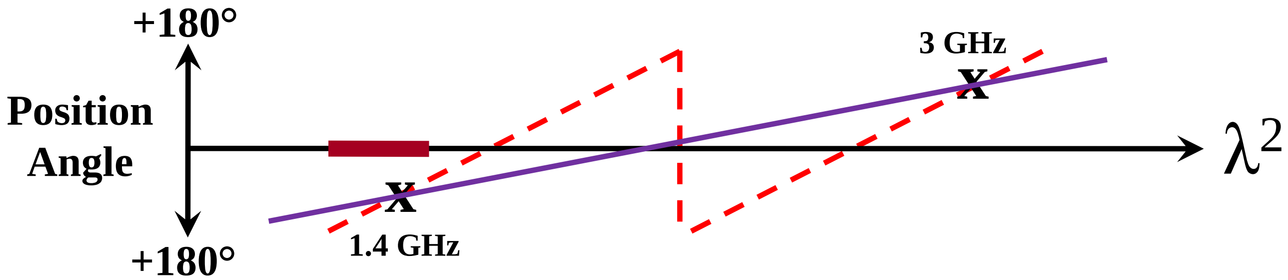
STIRLING A. COLGATE
New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

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

The Colgate Paramp & Green Bank

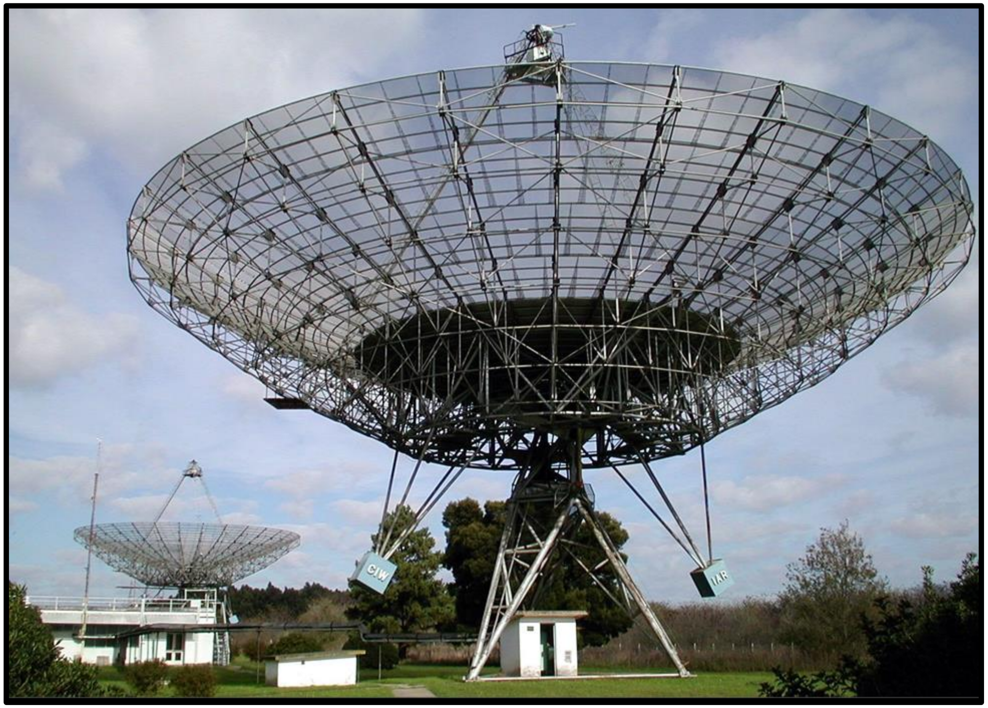
Its Most Significant Astronomical Result

- **NRAO obtained about 10 of the paramps from Stirling Colgate.**
- **These 2-stage room temperature paramps were no where near as sensitive as the cryogenically-cooled paramps which were then in use on the Green Bank 140-ft telescope.**
- **However, the noisier Colgate Paramp had a much wider bandwidth, over 200 MHz compared to a few 10's of MHz for the existing custom built NRAO receivers.**
- **In 1972 NRAO built a receiver using the *Colgate Paramp* 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.**
- **What was needed to eliminate any ambiguity were polarization observations done with a receiver that had much wider bandwidth than had ever been used before.**

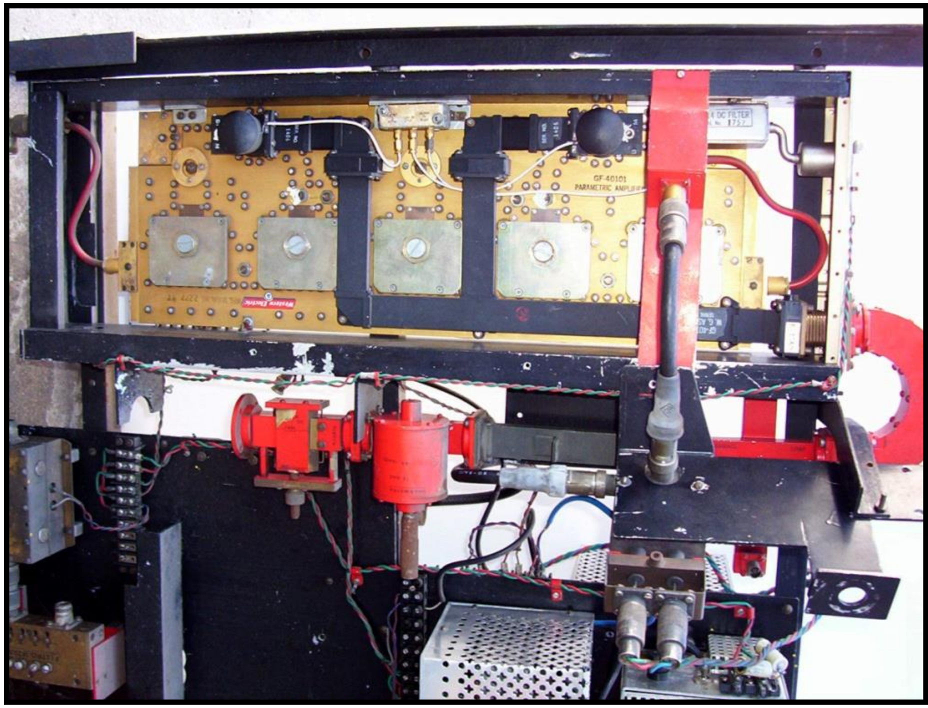


- **By analyzing the slope of the curve, it was possible to confirm that the previous polarization measurements did agree, thus removing all questions about ambiguities.**
- **While not an earth-shattering result, it was an important one, and at the time, could only have been done with a Colgate Paramp.**

The Colgate Paramp & Argentina



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


View of the IAR receiver showing the gold stripline paramp that had been removed from the MAR-I *Preamplifier* Module donated by Stirling Colgate.

- **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* and the *National Science Foundation*, construction began on a 30-m antenna located 20 km from the city of La Plata.**
- **In 1972, a receiver utilizing a *Colgate Paramp* was installed on *Antenna-I*.**
  - **It had a T(sys) of 200°K.**
  - **It stayed in use until about 1980 when it was replaced with a new generation receiver that used a paramp from the Netherlands.**

http://www.iar.unlp.edu.ar/images/imagenes/a-034.jpgevins)
Photos courtesy of Gloria Dubner & Juan Carlos Olalde

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 & Australia

Kelvin Wellington was a radio astronomer-engineer employed by the *Netherlands Foundation for Radio Astronomy* (NFRA) from 1968 to 1974 who wrote this Trip Report after a visit to Australia.

There wasn't enough funds to upgrade the *Molongo Cross* from 408 to 1420 MHz so they never used the *Colgate Paramp.*

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*".

While the early 1960s era "*Colgate Paramps*" had respectable sensitivity, by the time radio observatories acquired them in the early 1970's, they were no longer quite so competitive.
Room temperature paramps had become available from commercial sources.
Many radio observatories designed their own cooled paramps which significantly improved sensitivity.
And by the late 1970's, transistor amplifiers were close to matching the noise performance of paramps and were much more stable and easier to use.

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 de Radioastronomia (IAR)	1	1	Disassembled to see how it worked	G. Dubner, J.Olalde, E.Filloy, T. Gergely
	1	1	Used on 30-meter Antenna I	
	2	2	Unknown	
Massachusetts Institute of Technology	6	10	Perhaps used in Microwave Thermography	P. Crane, P. Myers, J. Barrett
National Radio Astronomy Observatory (NRAO)	1	1	Polarization observation on Green Bank 140 ft	M. Ballister
	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…

…but what about the rest of the 2000+ units 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 nearly 2 ounces 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…**

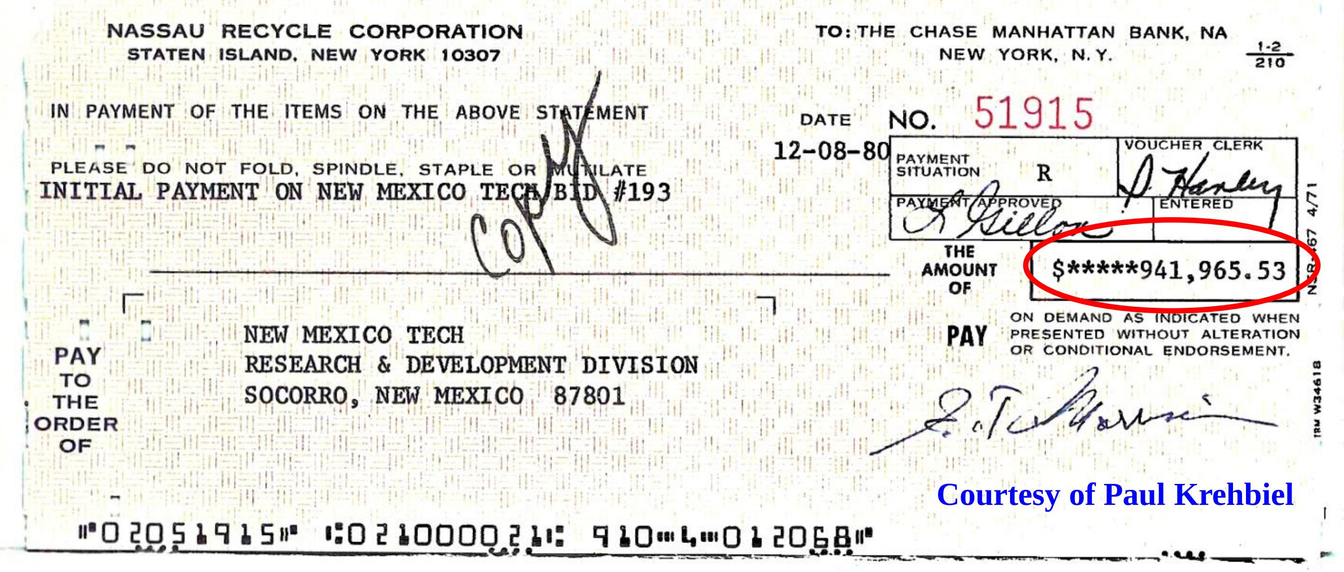
$941,966 → ~$2.5M today

- **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

Formerly the Bureau of Geology "Mineral Museum"

Photo by R. Hayward



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

DATE 12-08-80

NO. 51915

PLEASE DO NOT FOLD, SPINDLE, STAPLE OR MUTILATE

INITIAL PAYMENT ON NEW MEXICO TECH BID #193

PAYMENT SITUATION R

VOUCHER CLERK

PAYMENT APPROVED

ENTERED

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

PAY

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

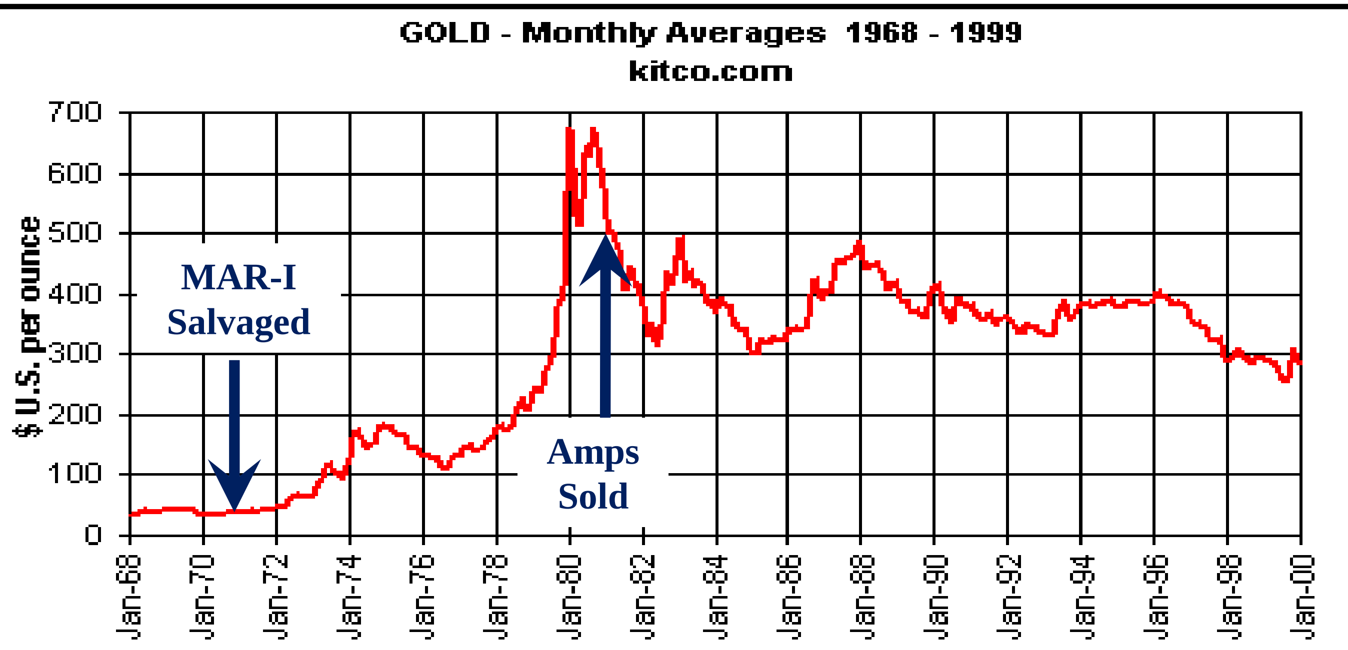
PAY TO THE ORDER OF

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

Courtesy of Paul Krehbiel

The "Gold Check"

Monthly gold prices from Jan 1968 to Jan 2000



Although the material from the MAR-I had been officially transferred from the US government to NMT, 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. All three reviews gave the university a clean bill of health.

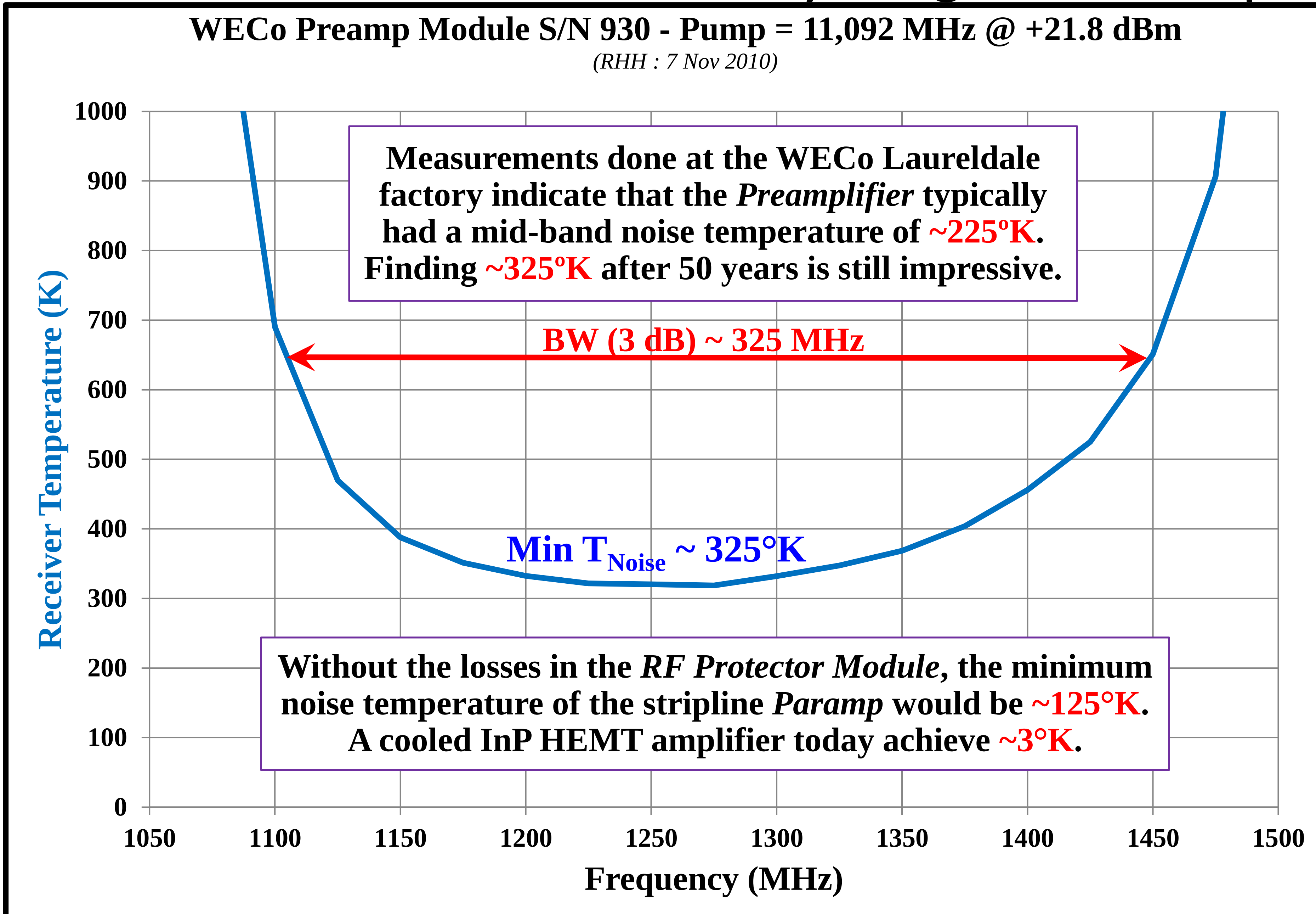
Being able to argue that NMT had attempted to help the scientific community by giving many of them away was a useful argument in the university's defense.

Finding a Colgate Paramp

- **After spending much of 2009 digging into the story of the *Colgate Paramp*, it was hoped we could find a surviving unit to look at, but with no success.**
  - **Upon hearing that John Reiche would be passing through Socorro, Paul Krehbiel (professor emeritus of physics at NMT) 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 the Archive at the Tech Library*". She had retired as the its Director in 2003.**
- **In lower left photo, Bob and Paul examine the Colgate Paramp in the *Skeen Library*.**
- **And so, I was 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

eBay Buyer Protection

Covers your purchase price plus original shipping.

Learn more

Seller information

dlinventory (4051 ★)

99.7% Positive feedback

Save this seller

See other items

Visit store: DL Online Inventory

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

The 3 Known Surviving Colgate Paramps

- Alas, the final disposition of the two *Colgate Paramps* found on Ebay is unknown.
- While visiting the *Dominion Radio Astronomy Observatory* (DRAO) in Penticton, BC, in 2015, it was found that the pair of paramps that Colgate had sent them 40 years earlier were still there.
- Finally, the last surviving *Colgate Paramp* in possession of NMT is on display at the *Skeen Library* on the Socorro university campus.

Conclusions

MAR-I Conclusions:

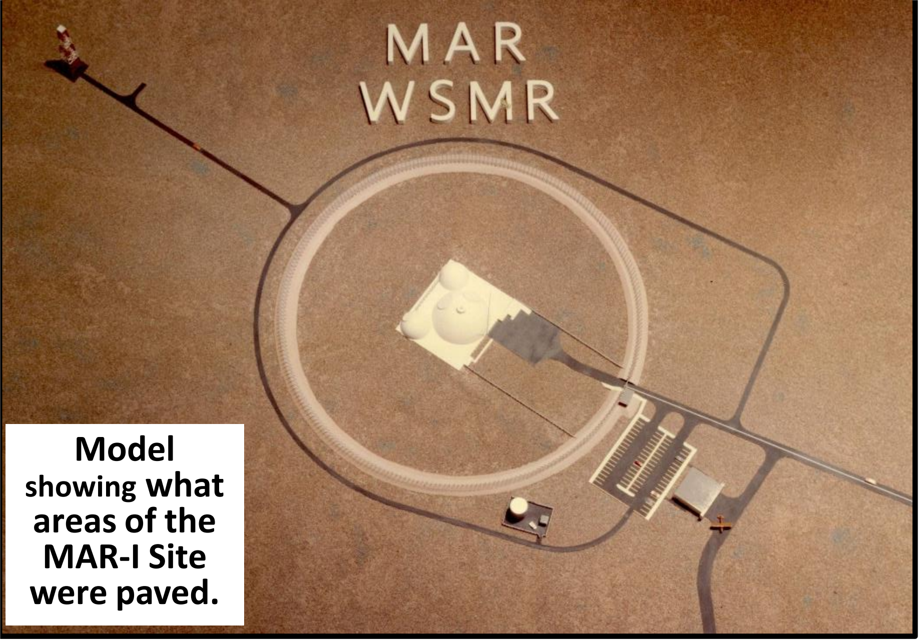
- **The MAR-I's visually striking triple white domes still sit in the desert sands on the *White Sands Missile Range*. The radar has largely become forgotten.**
- **During the height of the Cold War, the MAR-I would be seen as a unique facility that was a major departure from previous types of mechanically steered radars, and it would influence the design of many of the phased-array radars that came later.**
- **As a test bed system, its lifetime was short but it did successfully verify the satisfactory performance of a multifunction array radar in a real target environment.**
- **The MAR-I pioneered a number of new technologies and mass-produced microwave components, from TWTs, to paramps, to digital delay lines, to digital computers.**
- **The MAR site would be resurrected in the 1980s to play an important role in the creation of the *High Energy Laser Systems Test Facility* (HELSTF).**
- **Thanks to the efforts of Stirling Colgate, 280 of ihe MAR-I paramps would be donated by NMT to observatories & science organizations around the world, several of which were used to do interesting or unique radio astronomy projects:**
  - **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**
- **Unlike other old amplifiers that have been pushed aside by technological obsolescence, the MAR-I's paramps still had one last, if somewhat unusual, role to play…**
- **The gold in the surviving paramps was reclaimed in 1980, providing a $1M windfall.**
- **The contribution of the MAR-I to science & technology continues to live on 5 decades later in the *Gold Building* on the NMT 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.**

The  End

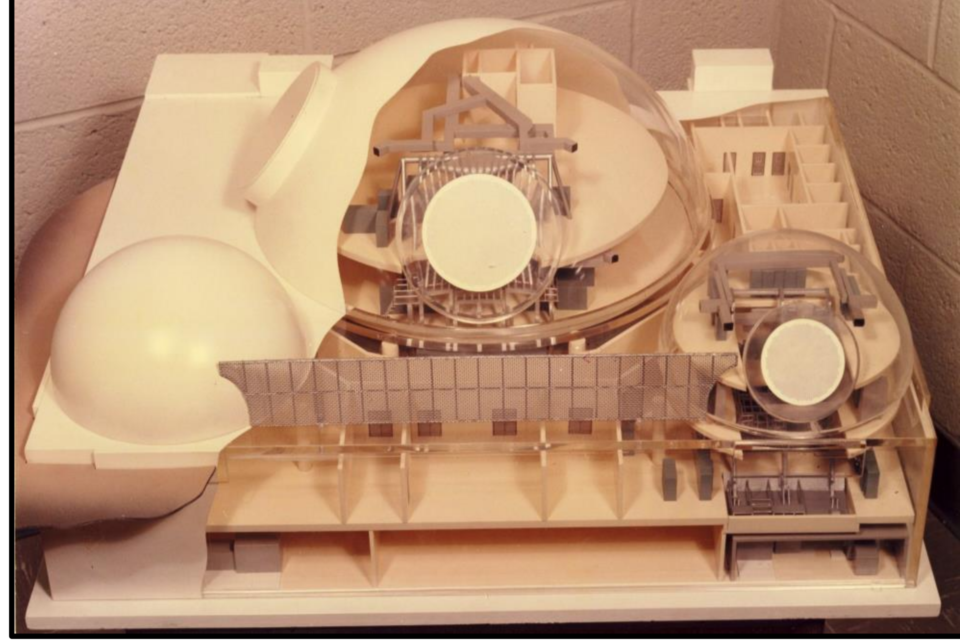
Any Questions ?

(from those who are still awake)

Extra Slides



Model showing what areas of the MAR-I Site were paved.



Unfortunately the end fate of this model is unknown.

- **<u>Acknowledements</u>:**
  - *WSMR Archive* : Doyle & Lutisha Piland, and Debbie Walters
  - *Bell Labs* : Norm Hillman. Charlie Johnson, and Joe Nevarez
  - *Western Electric* : Sam Freshour, Vestal Fulp, Bob Gamboa, and John Ondria
  - *New Mexico Tech* : Paul & Kay Krehbiel, John Reiche, and Bill Winn
  - *Former NMT Students* : Bruce Blevins, Bill Holmes, Steve Hunyady, Joe Martinic, Charley Moore, and Gary Schwede
  - *WSMR* : Bill Godby and Katherine Seikel
  - *HELSTF* : Steven Squires
  - *Redstone Arsenal* : Sharon Watkins-Lang
  - *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, Tim Robishaw, Ken Tapping, Adrian Webster, and Kelvin Wellington
  - *NRAO* : Miller Goss, who got me interested in the history of radio astronomy
  - And Stirling Colgate (NMT & LANL)

The Somewhat Secret History of the MAR-I

- **Only a few technical papers can be found in the published literature:**
  - **2 x BTL papers on Stripline Paramp & Circulator design (1964)**
  - **1 x Sylvania paper on Equipment Interconnection (1965)**
  - **Mentioned in 2 papers on Clutter Fences (1966 & 1968)**
- **Brief discussion in Bell Labs Histories:**
  - ***ABM R&D at Bell Laboratories – Project History* (1975)**
  - ***A History of Engineering & Science in the Bell System - National Service in War & Peace* (1978)**
  - ***A 20-Year History of Antiballistic Missile Systems*, 1976 film by WECo & BTL for the US Army**
- **Personal biographies from former Bell Labs employees:**
  - ***A Witness to a Century - A Memoir*, by Dietrich Alsberg (2002)**
  - ***An Electrifying Journey - The 1920's into Retirement*, William Mraz (2008)**
- **Official Archives:**
  - ***Redstone Arsenal*, AL (initial FOIA was fruitless, but a number of photos turned up later, including 3 of the "Display Boards" used for Tours given by the Nike-X Program Manager)**
  - **Nothing at the *Missile Defense Agency* in Washington, DC**
  - **Several files at the *AT&T Archive* exist but are still classified**
- **The *WSMR Museum Archive* is by far the best repository:**
  - **All donated by former workers at the MAR-I (or their spouses)**
  - **3-ring binder belonging to George Sharpe (BTL's second-in-command of the MAR-I project)with 284 MAR-I construction photos (1963-64)**
  - **Numerous B&W & Color pictures of the MAR-I**
  - **Vestal Fulp collection - 5 x BTL Reports (including *MAR-I Critique - Preliminary*)**
  - **Bob Gamboa collection - 2 x Tour Guide "crib notes" for the MAR-I**
  - **Norm Hillman collection - 15 BTL Technical Memos**
  - **Charlie Johnson collection - 49 BTL Technical Memos**
  - ***Zeus Multifunction Array Radar Facilities – Definite Drawings* (discovered at HELSTF in 2016)**

The Missing BTL Reports

Perhaps they are hiding with the Ark!!!

- **Have been seeking several "top level" reports on the MAR-I & MAR-II that would provide a more detailed overview of this Nike-X radar system.**
- **They are listed in the bibliography of the historical account about the "*ABM Research & Development at Bell Laboratories – Project History* (1975). . .**
- **1) *MAR-I Multifunction Array Radar at White Sands, Test Planning Handbook*, Vol 1 and 2**
  - **Bell Laboratories, October 1, 1964.**
  - **Defines the testing program outlined for the MAR-I at White Sands. In addition, gives a brief description of the MAR-I functional capabilities. Vol 2 offers a detailed description of the MAR-I system and its subsystems. The descriptions contain tables and figures of the MAR-I radar parameters.**
- **2) *MAR-I, An Atlas of the Multifunction Array Radar at White Sands***
  - **Bell Laboratories, October 1964.**
  - **Deals exclusively with MAR-I at White Sands. The level of detail in the document is greater than any of the others listed herein. Gives detailed coverage of both system design and operation. This volume contains a profuse collection of functional schematics and line diagrams of consoles.**
- **3) *MAR Design Manual***
  - **Bell Laboratories, June 1965.**
  - **Lists functional requirements and gives detailed functional schematics, equipment location drawings, etc. Document also gives a detailed description of each MAR subsystem.**
- **4) *NIKE-X Weapon System — Kwajalein System Description***
  - **Bell Laboratories, November 30, 1965.**
  - **Presents complete description of the Kwajalein System, including MAR-II. Detailed radar design parameters are given as well as functional drawings, etc. Siting considerations are also shown.**
- **5) *TACMAR Reconfiguration to CAMAR***
  - **Case 27703-1300, H. D. Hurlbut, Bell Laboratories MFF, June 17, 1968.**
  - **Briefly outlines the major design iterations of the MAR to TACMAR to CAMAR.**

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?**

There are a myriad of reasons why this 5-decades old radar should be of interest to us today. . . .

- **For those with a love for New Mexico History, the MAR-I was one of the most unique facilities ever built in the 'Land of Enchantment'.**
- **For those obsessed by Cold War History, it provides an unusual sidebar to one of the most frightening periods of the 20th Century.**
- **For those fascinated by Radar Technology, the MAR-I achieved an evolutionary leap in performance for an anti-ballistic missile radar.**
- **For those with an affinity for Civil Engineering & Architechure, its beautiful triple-domed structure was designed to survive a nuclear blast.**
- **For those involved with Microwave Technology, the MAR-I pioneered many early generation devices, including its 805 Traveling Wave Tubes and its 2077 stripline Parametric Amplifiers, as well as with thousands of Transistorized RF Post-Amplifiers, and over 10,000 Digital Delay Lines.**
- **For those excited by Electronic Harward, the facility utilized over 200 racks worth of 1960s era control & monitor circuitry.**
- **For those enticed by System Integration, its equipment interconnection system required over 30,000 cables with a wire list that ran 7,000 pages.**
- **For those interested in Lasers, the site would later become the control center for the United States' most powerful laser.**
- **The MAR-I was an extraordinarily innovative & complex radar for its time, and was incredibly expensive - as much as $1,2 Billion in today's dollars.**

MAR-I : Then vs. Now

1960s		Today
Travelling Wave Tubes	Transmitter	High-Power Transistors
Parametric Amplifiers	Receiver	Low-Noise Transistors
Analog Delay	Beamformer	Digital Delay & DSP
Transistors & SSI Mainframe	Computer	Networked, LSI Parallel Processors