HARPER

1973 LEWIS INSPECTION

STOP NO. 4

BIG BOOST FROM ROCKETS

9-13-73

(1st Speaker)

You have just seen the last few seconds of a typical launch operation conducted by the Lewis Research Center. During the last 10 years we have conducted 55 such operations. Today we are going to show you how rocket technology has benefited mankind using the technology associated with the Centaur vehicle.

~~(Slides of LeRC Mission Summary -- Off)~~

(Show Slide #1 - Satellite Cloud Cover Picture)

The missions we have launched include the Nimbus weather satellites. These are now an operating system that is routinely producing 24-hour coverage of not only the weather but the entire Earth's climatic cycles. The information from these satellites is available to any nation on earth. It has saved thousands of lives and billions of dollars of property.

(Show Slide #3 - Communication Satellite - TV Setup)

The communication satellites, such as Intelsat, have made world wide television possible. Yet they have cut the investment cost per year for an intercontinental telephone link from $25,000 to about $1000. Domestic telephone calls have grown from 18 billion per year to 200 billion per year in the last decade. With the advent of television and data communications, our present ground system has been pushed to its virtual limits of expansion. The communication satellite offers this country a means by which we can meet the communication demands of tomorrow.

(Show Slide #5 - Nebula Photograph)

Earth's ~~obscuring~~ atmosphere has limited the effectiveness of astronomical observatories since Galileo's time. The Orbiting Astronomical Observatory has transferred the observation equipment to space, outside the Earth's envelope. It is now providing the clear view needed to investigate and better understand the celestial mechanisms which affect our lives on this planet.

Much has already been accomplished in understanding our Solar system. (Show Slide #7 - Surveyor on Moon). The success of the Apollo manned lunar landing program was due in large part to the earlier information obtained about the lunar surface from the unmanned impact probes, soft landers and orbiting spacecraft we have launched. Here is an Apollo Crewman visiting a Surveyor soft-lander we launched in 1967.

(Show Slide #9 - "Grand Canyon" of Mars)

The Mariner spacecraft have successfully mapped Mars. They have provided a wealth of data that has completely revised the previous concepts of our neighboring planet. We will get a similar close look at the planet Jupiter at the end of this year and again next year using the Pioneer 10 and 11 spacecraft which are now well on their way in their two year journey.

(Slide #9 - Off) (Slide Open Panel to Expose Models)

None of these remarkable accomplishments would have been possible without (point to each model; first the booster, then the upper stage), the Thor/Agena, Atlas/Agena, and Atlas/Centaur launch vehicles. A new and more powerful launch vehicle will soon be added to the Lewis family. (Point to Titan/Centaur model). This vehicle called the Titan/Centaur, will make its maiden flight early in 1974.

(Show Slide #11 - Launch Schedule). As you can see from this launch schedule, our launch vehicle program will continue to be a busy one in the coming years.

Of the ~~20~~ 27 ~~more Atlas/~~Centaur launches now planned, eleven ~~are being~~ WILL BE launched for commercial organizations: Intelsat for COMSAT Corporation (Point to Intelsat missions on slide) and Domestic Satellites for AT&T. The government is being reimbursed for these missions. ~~The balance~~ FIVE are ~~communication satellite missions.~~ (Point to FLTSATCOM missions on slide) for the Department of Defense, ~~earth orbital missions (point to HEAO on slide), and planetary missions (point to Venus/Mercury and Pioneer/Venus on slide)~~ AND THE REST ARE for NASA. ~~The Titan/Centaur missions include the Viking Mars Orbiter and Lander missions, the Helios Solar Probe missions, and the Jupiter/Saturn planetary missions.~~

(Slide #11 - Off)

From our flight history and our schedule of future launches you can see that Centaur has been and will continue to be a work horse in the unmanned space program. So let us take a little closer look at this remarkable engineering accomplishment. (Refer to Full Size Centaur Model Suspended Above Stage).

(Pause and take a few steps)

A little over a decade ago, Centaur began the first evolutionary step from rocketry using conventional low energy fuels to the high-energy vehicles fueled with liquid hydrogen. In Centaur we faced numerous new problems, many of them demanding solutions which were then beyond the current state of the art.

For example, almost nothing was known about storage and transfer of liquid propellants in a weightless state. The unique Zero Gravity Facility in which you are now located provided much of the needed experimental data. Up to ten seconds of weightlessness can be achieved under the <u>dome</u> to your right, which covers an evacuated shaft almost 500 feet deep. Suspended above is an actual Centaur upper stage with a mock-up of a Surveyor spacecraft. It is 10 feet in diameter, 30 feet long and weighs about 35,000 pounds fully tanked. Liquid hydrogen and liquid oxygen are the primary propellants. (Turn on engine lights). Two RL-10 engines provide a total thrust of 30,000 pounds. (Turn engine lights off). The propellant tanks are made of stainless steel thinner than a dime. The tanks are so thin that they must be pressurized, like a football, at all time to prevent collapse. (Turn on insulation lights). The hydrogen tank ~~sidewall and forward bulkhead are~~ IS insulated with multiple layers of aluminum coated Mylar to prevent PROPELLANT boiloff from ~~aerodynamic~~ heating ~~during ascent through the atmosphere and from solar radiation during long coast periods~~ in flight. (Turn off insulation lights).

(Turn on Electronic Box Lights)

The Centaur is controlled by an avionics system consisting of 15 electronic packages. They steer the vehicle without instructions from the ground, keep the vehicle from tumbling, control the flow of propellants to the engines, start and stop the engines, and sequence other events. (Turn Off Electronic Box Lights).

Advances in many different technologies had to be made before Centaur and the other vehicles in the NASA family could become a reality.

(Take a few steps)

It is very significant, but not widely understood, that the technical and financial support provided by NASA to develop specific new technology needed by the space program acts as a "technology driver." This support accelerates a technology ~~directly and indirectly~~ to reach new levels much sooner. As this advanced space technology becomes available it is being used in many diverse applications on earth.

Today we will tell you about a few of these applications and show you how they offer new solutions to some of the world's most pressing problems.

(2nd Speaker)

One application is electronics. The need for complex electronic control systems on launch vehicles, (Turn on Electronic Box Lights), and the large effort put forth in the space program to meet this need has helped create an entire new industry that is still expanding today - the semi-conductor industry. Semi-conductors - the world of solid state diodes, transistors, and integrated circuits. These names, unknown less than 25 years ago, can be found today in mail order catalogs. Of course, the space program did not invent semi-conductor technology but it has nurtured it to become the industry it is today. (Slide Open Panel to Expose Electronic Items).

The basic building block of electronics is a device to amplify electrical signals. Up to the late 1940's this basic device was the vacuum tube. (Hold up vacuum tube). (Show Slide #2). Because a typical launch vehicle would need hundreds of these tubes, something had to be done because they were too big, used too much electrical power and weren't reliable enough. (Slide #2 - Off).

In 1948 a new amplifying device was invented by the Bell Laboratories that was immediately recognized as a giant step forward in getting around the shortcomings inherent in the vacuum tube. This revolutionary innovation was the transistor. (Show Slide #4 - Transistor). (Holds up a transistor). Exploding growth in transistor and semi-conductor technology quickly followed to meet launch vehicle requirements and many other uses. Today the transistor has attained a prominent place in the world's economy. And for good reason. (Slide #6 - Vacuum Tube and Transistor). It certainly is smaller, operates on less power, and is very reliable. (Slide #6 - Off).

Let me show you an example of how transistors and semi-conductors have conserved electrical power using items that are familiar to you. Do you remember the vacuum tube portable radio (place hand on vacuum tube radio) with its big, heavy and expensive battery (hold up battery in left hand). Here is a transistor radio with the battery necessary for its operation. (Pick up and replace transistor radio and then hold battery in right hand.) This battery size comparison is indicative of the reduced electrical power required by transistorized electronic systems. (Put batteries back on shelf).

The transistorized hearing aid shows the miniaturization made possible by semi-conductors. Compare the size of this current model hearing aid (takes off hearing aid he was wearing and place in pocket) with this earlier vacuum tube type (holds up tube type hearing aid). (Put hearing aid on shelf).

From the transistor, the advancing technology has progressed to the integrated circuit and the so-called "large scale integrated circuit". Large-scale integrated circuit technology can crowd the equivalent of over 50,000 transistors into an area of one square inch.

Here are five large-scale integrated circuits called chips (hold up card with five LSI's affixed) in this plastic box. (Show Slide # 8 - Size Comparison, Transistor, Integrated Circuit Chip).

If you can't see them it is probably because the largest chip is approximately 5/32 of an inch by 7/32. (Show Slide #10 - Magnified Chip). On the screen is an enlarged photograph of one chip to give you an idea of its amazing electronic circuitry. Note the pin head on the right side to give you a size comparison. These chips are the main portion of this electronic calculator (remove calculator from pocket). This device will not only add, subtract and multiply like this mechanical calculator (Slide #12) (Point to mechanical calculator) but it also does far more complex operations like trigonometric and logarithmic functions plus other operations. (Slide #12 - Off). A comparable calculator using only transistors would require about 25,000 transistors instead of the five large-scale integrated circuits. This versatility and compactness is built into today's computers and electronic equipment.

In the medical field, the remote heart monitor is a good example of an improvement made possible by space age electronics. Today, medical facilities all over the country are using these monitors to observe heart patients who are free to move about instead of being wired to a monitor. (Hold up heart monitor sensor and then stick to shirt). This sensor is like the one that is taped to our "patient" out in the audience (Patient moves from under spot to stage and shakes hand of talker). Here on this screen (point) you see the patient's heartbeat as he moves freely about the room. Note that a change in the patient's heartbeat is easily seen.

These are only a few examples in the still expanding field of semi-conductors and their applications. Semi-conductors conserve electrical power, drastically reduce the size and weight and greatly improve the reliability of electronic devices. ~~Important as these attributes have been to the space program, this importance is almost insignificant when compared to the advantages semi-conductors have brought into our daily lives here on Earth~~. The semi-conductor industry will continue to benefit mankind in future years.

Let's look now at THE PROPELLANT ~~another~~ technology area, embodied in Centaur.

(Turn Off Electronic Box Lights)

(3rd Speaker)

The missions being flown by NASA require vast amounts of energy from the launch vehicle stages. Hydrogen, when used as a fuel, provides the maximum energy per pound of propellant. In order to make use of the high energy hydrogen-oxygen propellants and still achieve maximum vehicle efficiency, the 15 tons of propellants used by Centaur (point to propellant tanks) must be stored in as small a volume as possible. By liquefying the hydrogen and oxygen before loading, we shrink their bulk to about one thousandth of the equivalent gaseous volume. In the liquefied or cryogenic state the temperature of the hydrogen is ~~below~~ ABOUT 400 DEGREES BELOW ZERO ~~-400^{o}F~~ and the temperature of oxygen is close to 300 DEGREES BELOW ZERO, ~~-300^{o}F~~. (Roll out cart).

To store and handle these super cold propellants we had to learn how to cope with a number of problems. For example, many commonly used materials become very brittle at very low temperatures.

This carbon steel tube (holds up room temperature sample. Place in device) is made of the same material as many parts of your car. It bends quite easily without breaking at room temperature. (Release dropweight. Remove bent sample. Reset dropweight). When this same material is chilled to 320 DEGREES BELOW ZERO ~~-320^{o}F~~ in liquid nitrogen (withdraws similar sample from LN_2 dewar. Place in device) it becomes so brittle that it is no longer usable. (Release dropweight). That's fine if you want to ~~chill~~ SHATTER junked cars. ~~so that they can be shattered into easily handled scrap~~. And that process is being used today. (Remove sample fragments. Resets dropweight).

However, for Centaur metal alloys had to be found for the propellant tanks and plumbing containing these super cold liquids. (Remove stainless steel sample from LN_2. Place in device). This tube is made of one such alloy, a stainless steel. Although its temperature is also ~~$-320^{\circ}F$~~ 320 DEGREES BELOW ZERO it retains the needed flexibility and strength. (Release drop weight). In fact it is 37 percent stronger at the low temperature.

We had to use high performance insulations (turn on insulation lights) to prevent these cryogenic liquids from boiling off in the tanks during storage. These insulations (holds up sample) consist of highly reflective metallized plastic films separated by low conductivity spacers. In cryogenic applications these blankets must be used in a vacuum. On earth, the blanket is placed in an evacuated space formed by the inner tank wall and an outer vacuum jacket. In space, the absence of any atmosphere provides the ideal vacuum.

Not only can this insulation be used to keep cold things cold, but it can also be used to afford protection to humans from becoming too hot. (Rotate turntable with fire suit). An application of this is the firefighter's suit. This suit is made of rayon on which a very thin coating of aluminum is deposited. To illustrate the effectiveness of the aluminum coating in reflecting heat, we are going to place a specimen of the material next to this radiant heater. On one spot we have removed the aluminum. Without this protection, the uncoated fabric chars and burns through almost immediately. (Perform demonstration).

The principle of reflective insulation can also be used to protect humans from severe cold. For example, this commercially marketed blanket (unfold and shake open blanket) is used by hikers, campers, and mountain climbers (Show slide #13 - Police carrying victim). A variation of this blanket is also routinely carried by rescue squads of policemen and firemen in order to protect accident victims from loss of body heat. (Slide #13 - off) (Turn off insulation lights).

Because the space program required tonnage quantities of cryogenic propellants, an impetus was provided in the early fifties to the cryogenic industry which was sufficiently developed so that it could expand to meet the increased need. Today large scale manufacturing, storage, and shipping of cryogens provides benefits to all of us years sooner than would have occurred otherwise. Liquefaction plants (slide #15 - Liquefaction plant) such as this one are routinely manufacturing liquid hydrogen, liquid nitrogen, and liquid oxygen. (slide #17 - Storage tank and RR Dewar), large storage tanks contain the fluids either at the manufacturing plant while awaiting shipment, or at the users plant. For transportation, large railroad tank cars also shown here AND (SLIDE #19 DEWAR TRAILER) HIGHWAY TRAILERS ~~were developed~~. ~~These tank cars~~ are routinely used to make shipments to the users' sites. ~~(Slide #19 - Dewar Trailer)~~.

~~For shipments to users not served by rail~~, ~~over-the-road trailers are now commonplace.~~ For large quantity users, such as the steel mills (slide #21 - On site liquefaction plant) air reduction plants built on or adjacent to the customer's site provide delivery of high purity, low cost liquid oxygen.

(Slide #23 - LN_2 food freezing). Cryogens are being used to freeze food more rapidly so as to better preserve flavor and texture and to prolong storage life. (Slide #25 - LN_2Ref RR car). Some refrigerator trucks and railroad cars now use cryogens to keep food at temperatures far below that previously possible with mechanical refrigeration. And they do it without the risk of mechanical breakdown and the attendant spoilage of cargo while being shipped. (Slide #25 - off).

During the last few minutes, I have given you a glimpse of how cryogenic technology developed for space propulsion has served to stimulate new and beneficial products and processes that are helping to improve our living standards.

~~In view of a threatened energy crisis~~, The technology embodied in the Centaur can play an even greater role in the future. LET US LOOK AT HOW ~~This is the subject to be~~ THIS TECHNOLOGY CAN HELP US MEET OUR EVER INCREASING DEMANDS FOR ENERGY. ~~covered by the next speaker~~.

(4th Speaker)

One hundred years ago, that great science fiction writer, Jules Verne, predicted the use of hydrogen as a major fuel. In his book, (holds up book), the Mysterious Island, Captain Cyrus Harding, an engineer, is asked, (reads from book) "What will men burn when coal and other fuels are exhausted?" "Water" he says. "Yes my friend, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light." (closes and puts aside book).

Today, a growing number of scientists and engineers believe that this vision of a hydrogen economy is approaching reality. Many concepts for such an economy have been proposed. One proposal, by Dr. Derek Gregory and his associates at the Institute of Gas Technology, is presented here in schematic form. (Slide #14 - Hydrogen Economy - Schematic).

On great floating platforms in the ocean, some miles offshore, a series of large nuclear power plants would be built. The power thus produced would be used on the spot to decompose sea water into its main gaseous elements, hydrogen and oxygen. Both gases would flow onshore continuously into a network of underground pipelines. At underground distribution points, the streams of hydrogen and oxygen from the sea would be piped to electric power generating plants as well as a wide variety of industrial processes and transportation systems.

Unlike electricity which cannot be stored, but must be used as it is generated, some of the hydrogen can be stored as a gas in underground cavities or as a ~~highly compressed~~ cryogenic liquid in large insulated tanks, to meet fluctuating power demands.

Twenty years ago the Lewis Research Center began the pioneering research on hydrogen oxygen rocket engines. Much of the experience we and others have gained since then and the technology developed for space propulsion is directly applicable to uses of hydrogen on earth. Let me give you an example. The two RL-10 engines (points to engines on Centaur) that power the Centaur stage burn hydrogen-oxygen propellants cleanly and efficiently. They produce tremendous power in a small package because of the high energy available from the combustion of hydrogen fuel and because they operate at high pressure, over 400 pounds per square inch.

Hydrogen and oxygen, the ultimate in clean burning propellants, unite to form pure steam which of course is just water vapor. There are no oxides of nitrogen, no acids, and no smoke. The exhaust from these rocket engines is entirely steam plus some excess hydrogen. They can be thought of as very efficient steam generators.

Here is a model of a hydrogen-oxygen rocket LIKE THE CENTAUR ENGINES (holds up model) with two pumps to force the hydrogen fuel and oxygen into the combustion chamber. Now, if we borrow the pumps and combusion chamber from this rocket engine, we can devise an efficient electric power plant. (Removes and sets aside nozzle). Let us remove the nozzle that is used to produce thrust and substitute instead a steam turbine and electric generator. (Attaches combustion chamber to turbine inlet pipe).

In this power plant we use the (point) pumps and combustor from the rocket engine, but we adjust the flow of hydrogen and oxygen so that there is no left over hydrogen or oxygen, only pure steam.

The steam passes directly from the (point) combustor to the (point) steam turbine.

The spent steam coming out of the turbine goes to a (point) condenser where most of it is condensed to liquid water. ~~A small portion is exhausted.~~ STET [~~The water (point) is recycled back to the combustor to produce more steam and to lower the steam temperature from about 6000^{o} to 1500^{o}F.~~]

The turbine provides the mechanical power to drive (point) the electric generator. (Turn on lights behind city skyline background).

In addition to cleanliness, the hydrogen-oxygen power system has other advantages over today's conventional electric power generating plants. For one thing, it is much smaller (Slide #16 - Power plant size comparison) because it uses rocket-type high pressure combustion, rather than low pressure air-fed boilers that are as big as a seven-story building. ~~(Slide #18 - Photo of conventional boiler).~~ Another advantage is that it does not consume any of our precious fossile fuels, like coal, oil, or natural gas.

The application of rocket technology to electric power generation is not something far in the future. (Slide #20 - Drawing of Rocketdyne peaking plant). A light hydrocarbon-oxygen power plant built by the Rocketdyne Division of Rockwell International is being installed right now ~~(Slide #22 - Aerial view of Joliet power plant)~~ by the Commonwealth Edison Company in Joilet, Illinois, WHERE IT IS REPLACING A COAL FED BOILER 500 TIMES ITS SIZE. ~~to replace an air-fed boiler.~~ It will soon be producing enough electric power to serve about 10,000 homes. Although the ultimate system, using hydrogen-oxygen, must await a cheaper and more plentiful supply of hydrogen fuel, the necessary technology is ready and waiting. (Slide ~~#22~~ #20 - Off).

In summary, the technology and engineering development embodied in every component of our launch vehicles (points to launch vehicle models) has opened the door to space and, thereby, a whole new dimension to the future of man. Here on earth, this same wealth of new technology in avionics (points to areas on full-scale model), cryogenics, fabrication techniques, insulation, and propulsion is being applied in many ways throughout our economy to provide new goods and services, create new industries, and offer a better life for all of us.

(Points to sign - "BIG BOOST FROM ROCKETS") ~~Maybe this says it all.~~ WE BELIEVE OUR SIGN SAYS IT WELL.

STOP 4 BOB KOHL 8122

1) CS-66829

2) RADIO TUBE

3) COMMUNICATIONS SATELLITES

4) TRANSISTOR

5) NEBULAS

6) TUBE AND TRANSISTOR

7) CS-67030

8) TRANSISTOR AND CHIP

9) CS-64957

10) ENLARGED CHIP AND HEAD OF PIN

*11) LAUNCH SCHEDULE

12) CALCULATOR (MECHANICAL)

13) CS-43028 "SPACE" RESCUE BLANKET

*14) HYDROGEN ECONOMY

15) OIL OR STEEL MFG.

*16) POWER PLANT SIZE COMPARISON

17) PLUM BROOK DEWARS

18) TRAILER DEWAR

19) CUTAWAY DRW.

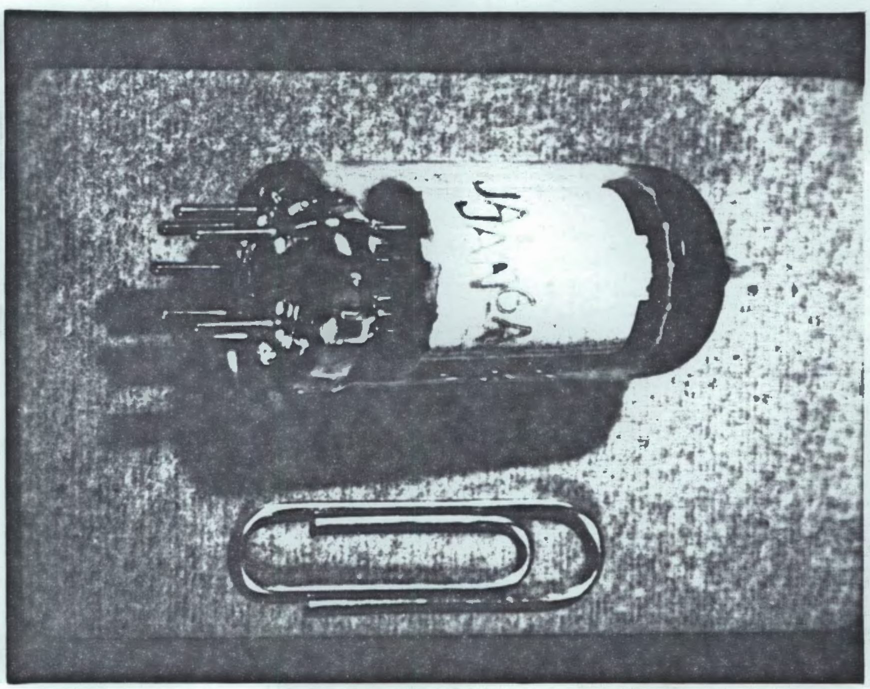
20) OXYGEN MFG.

21) MANUFACTURING

22) REFRIGERATOR TRUCK (PATH-MARK)

1-1

SLIDE 1 CS-66829



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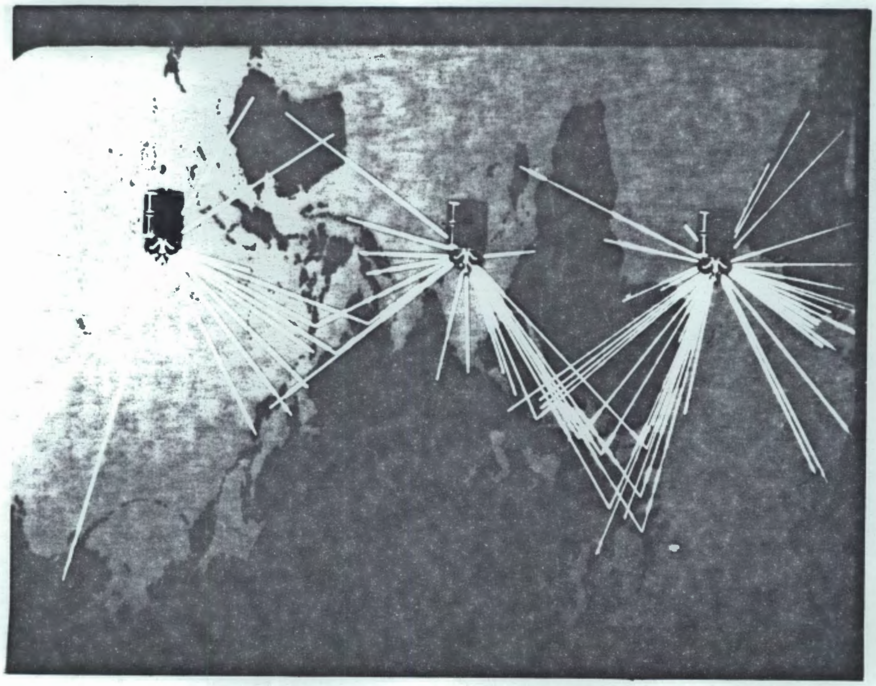
SLIDE 2



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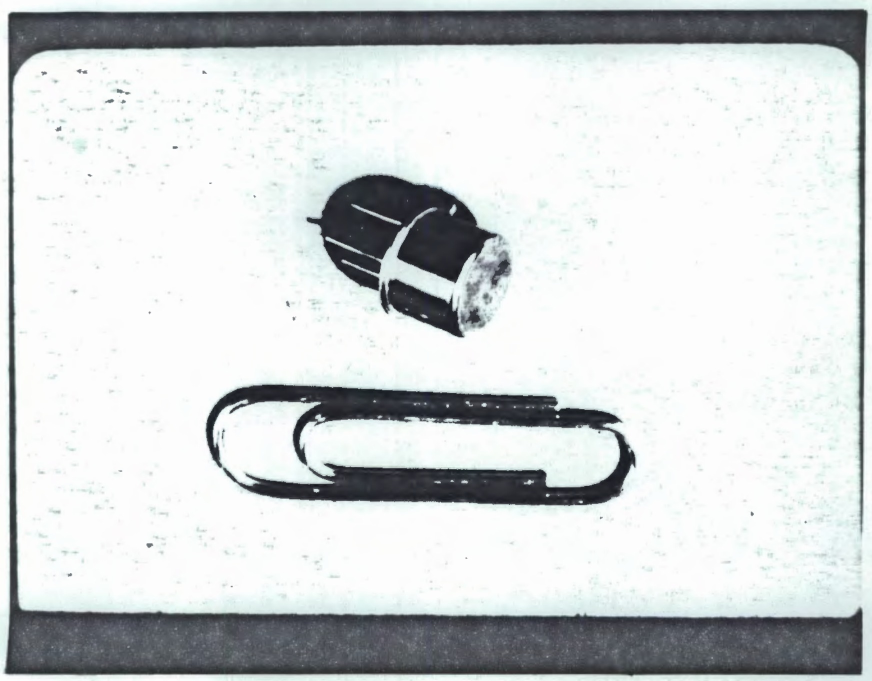

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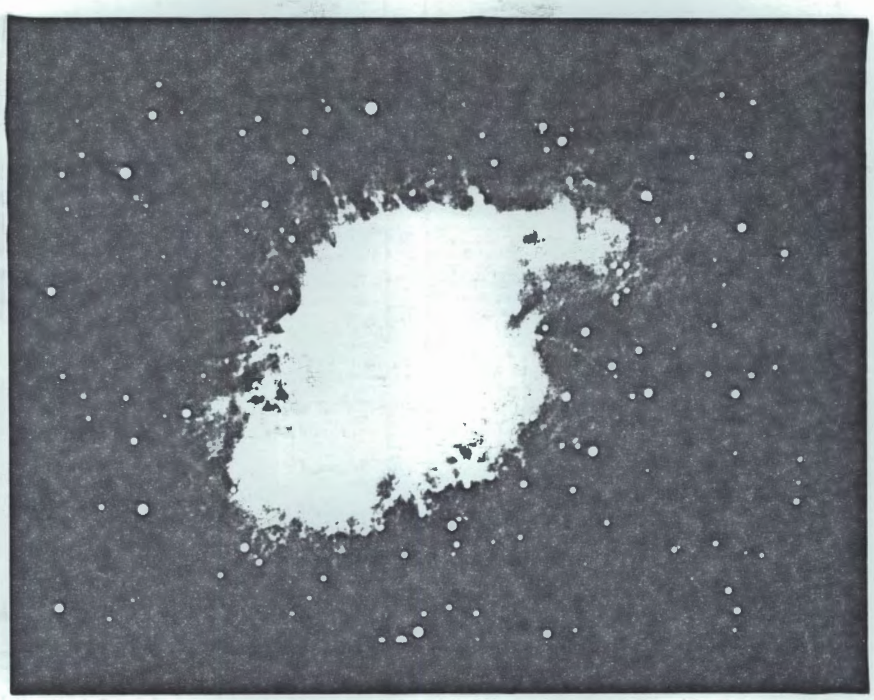

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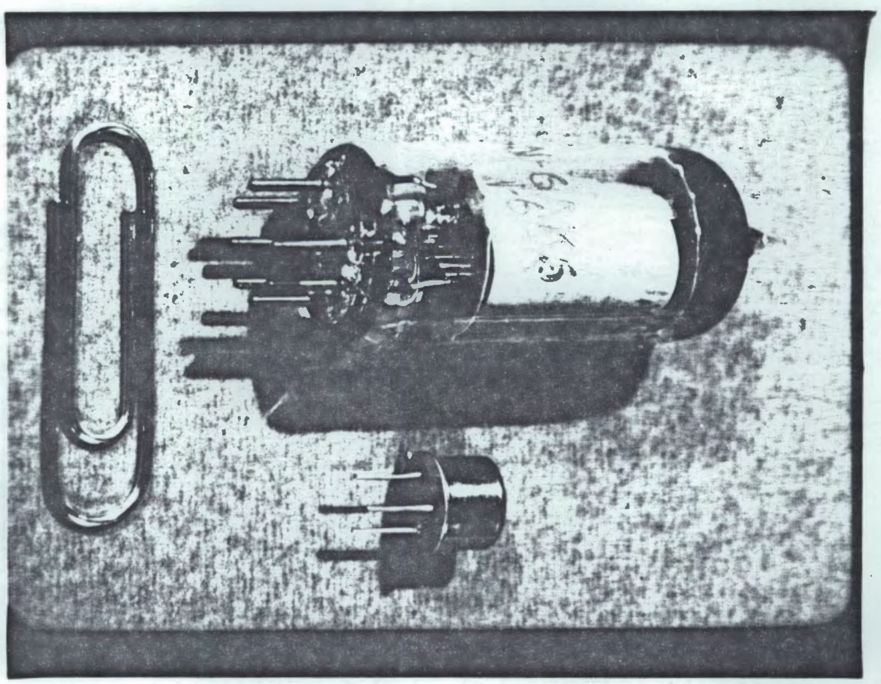

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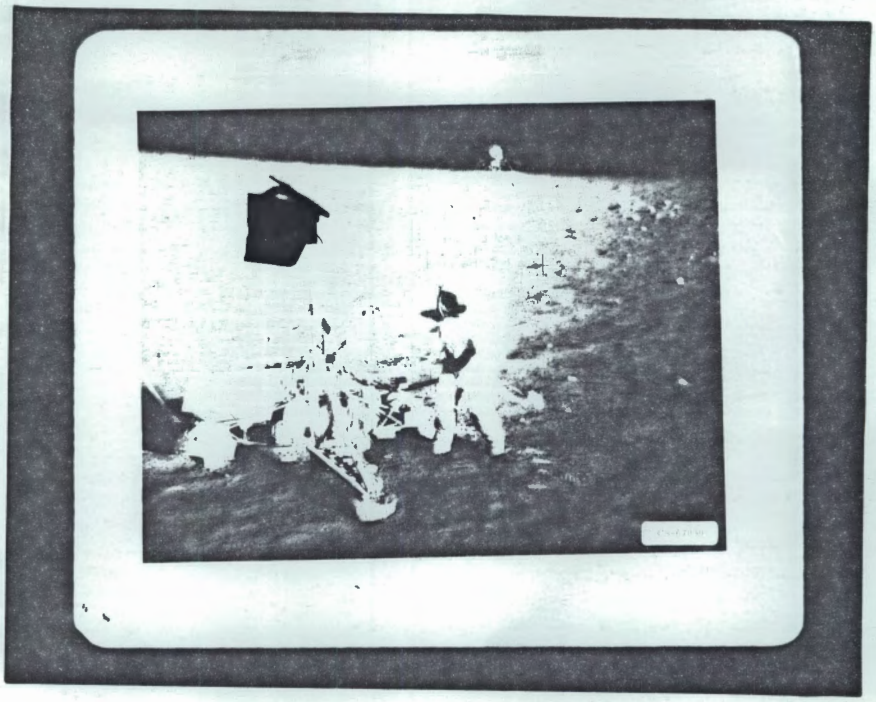

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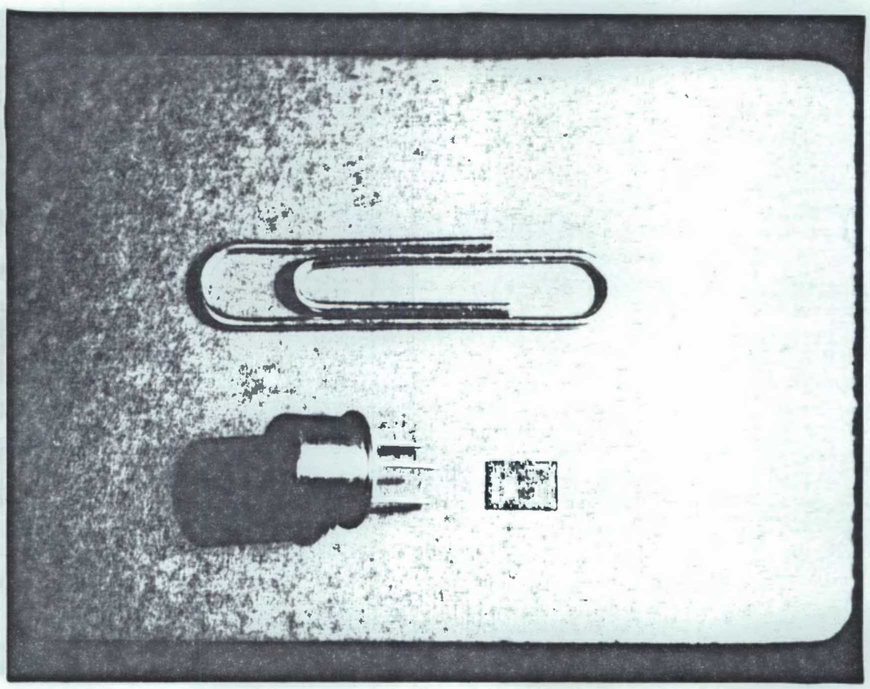
SLIDE 7 CS-67030



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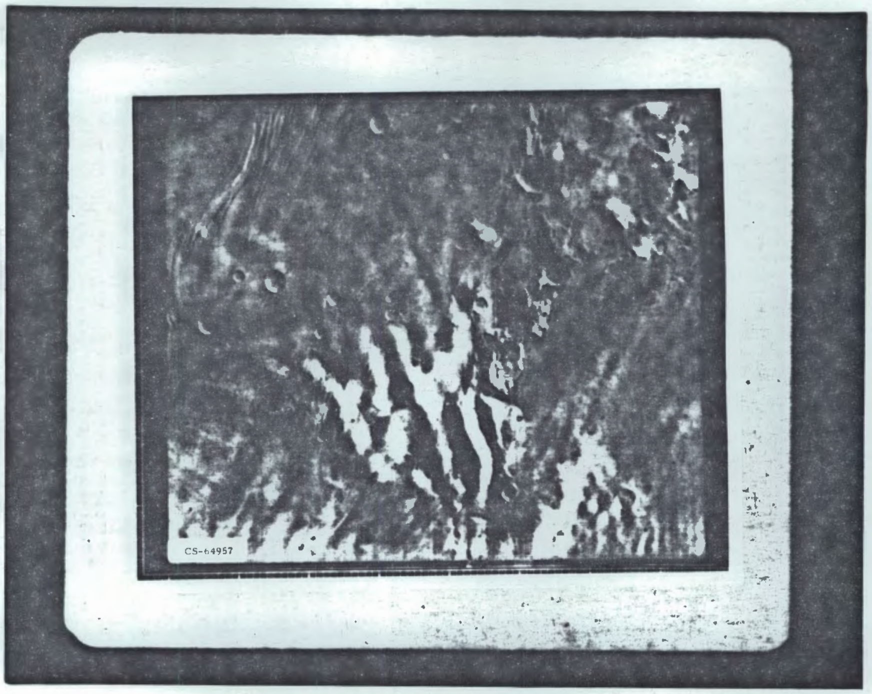
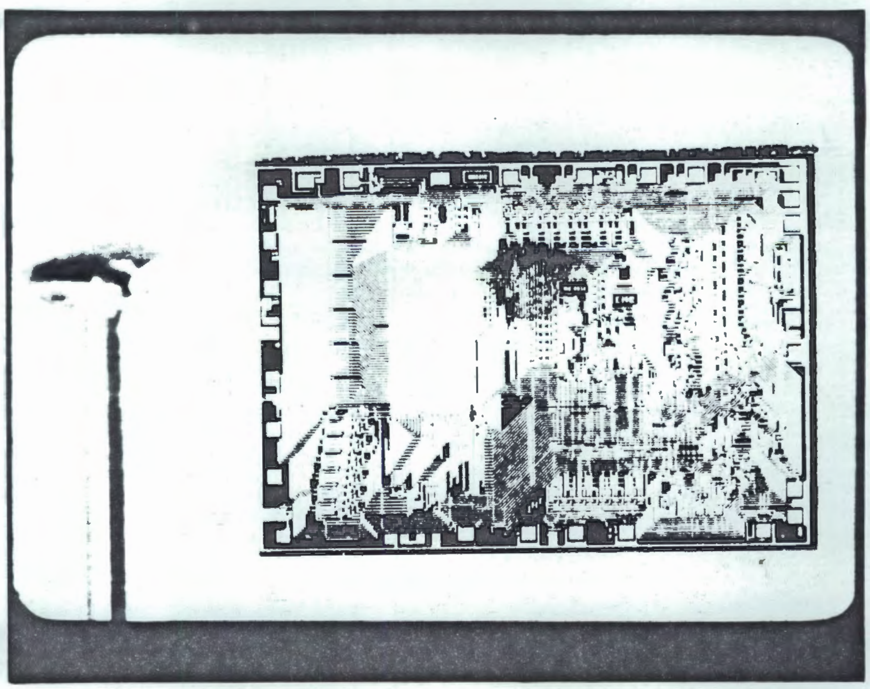
SLIDE 8



SLIDE 9 CS-64957



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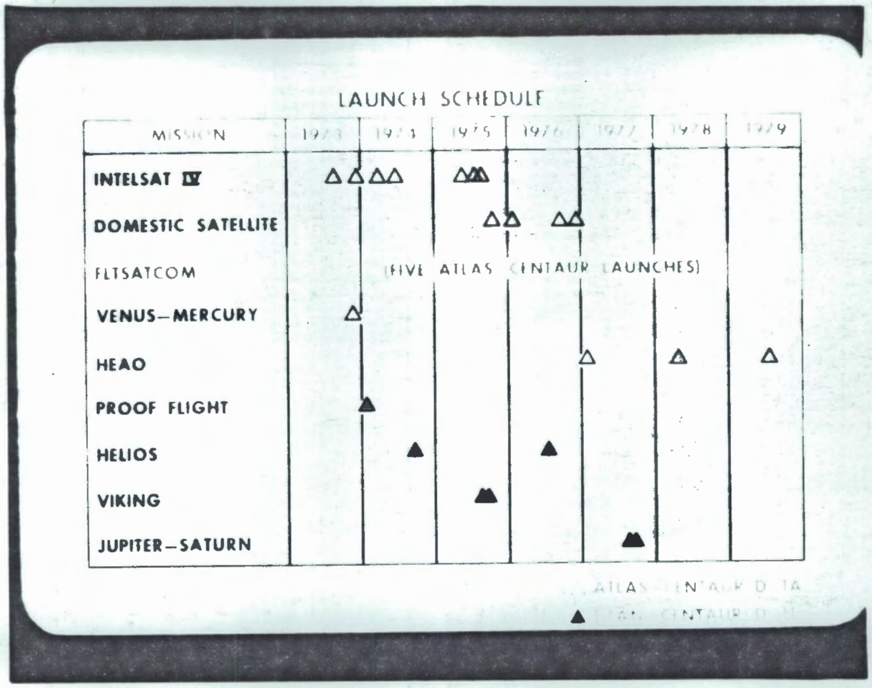
SLIDE 10



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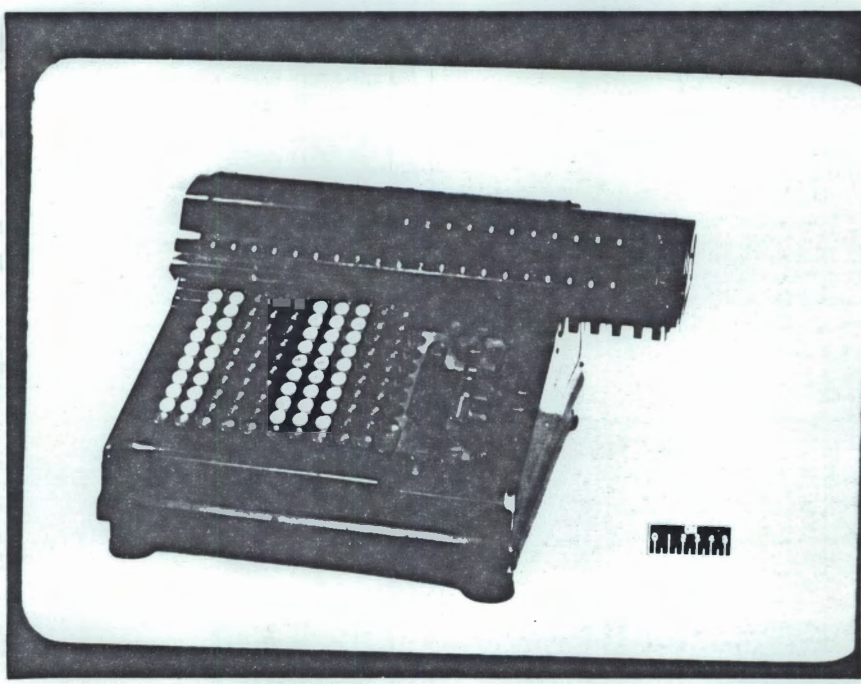
SLIDE 11



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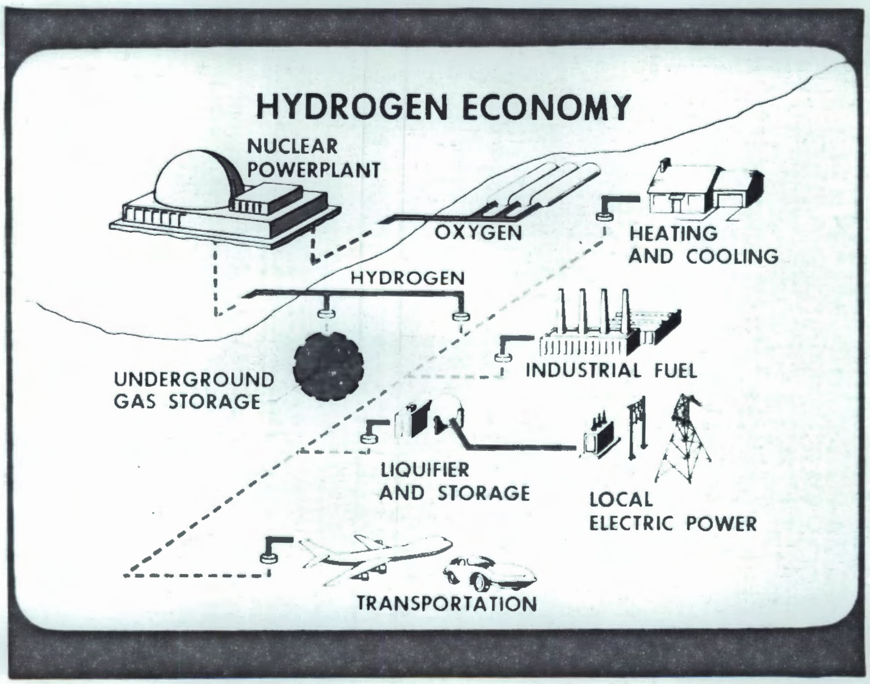
SLIDE 12

SLIDE 13 CS-43028



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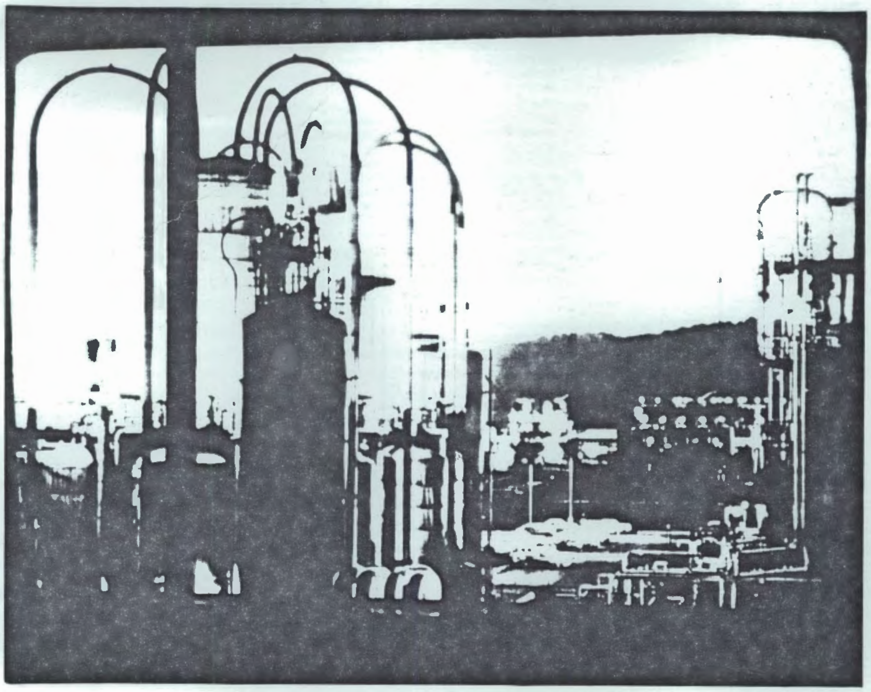

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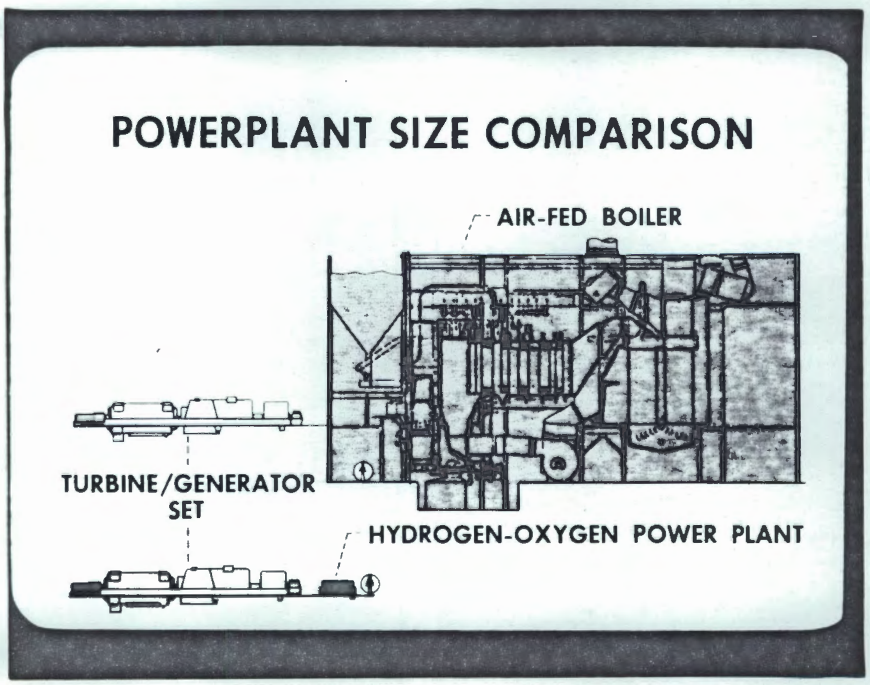
SLIDE 15



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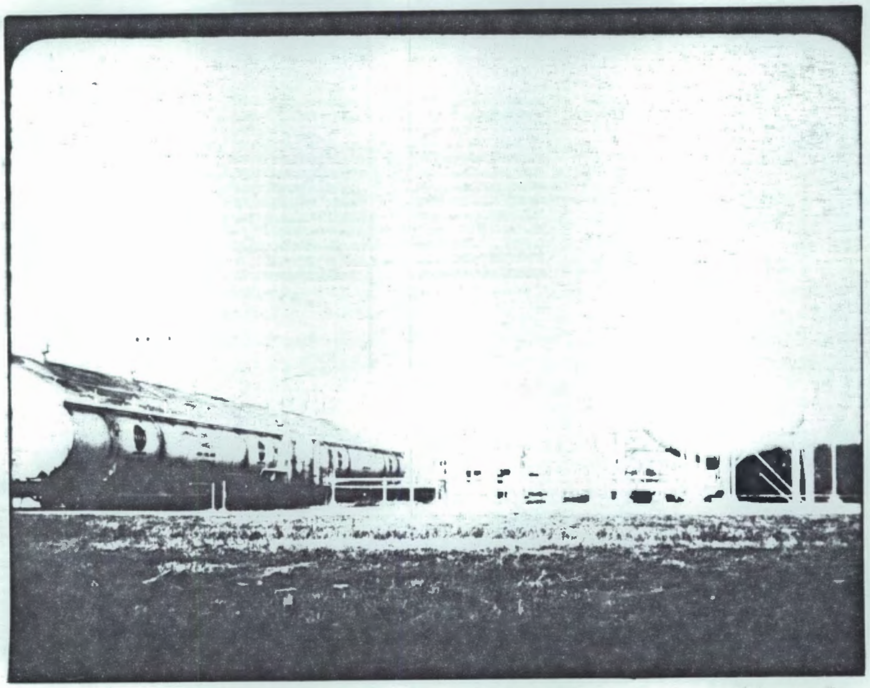
SLIDE 16



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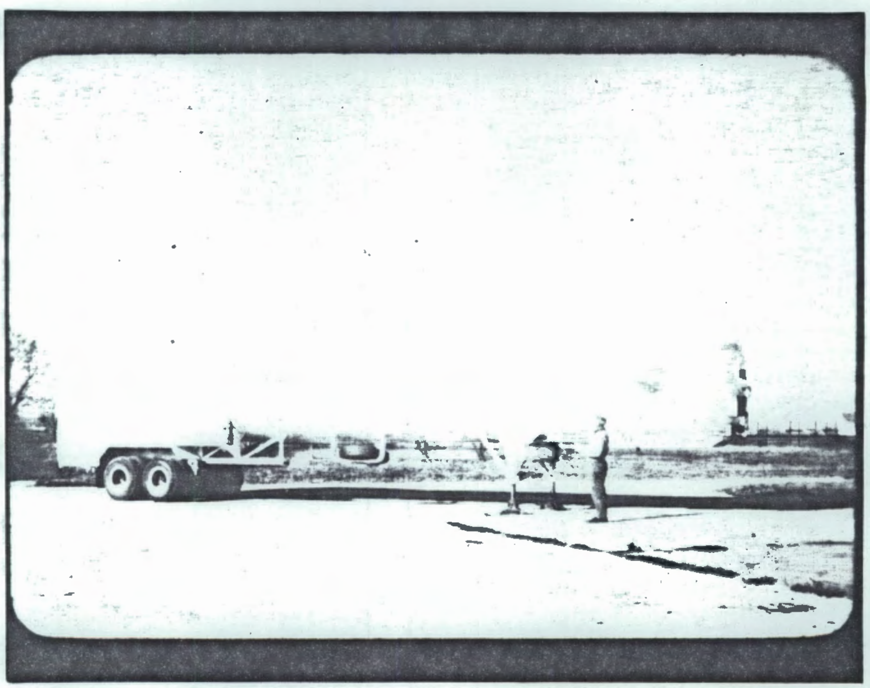

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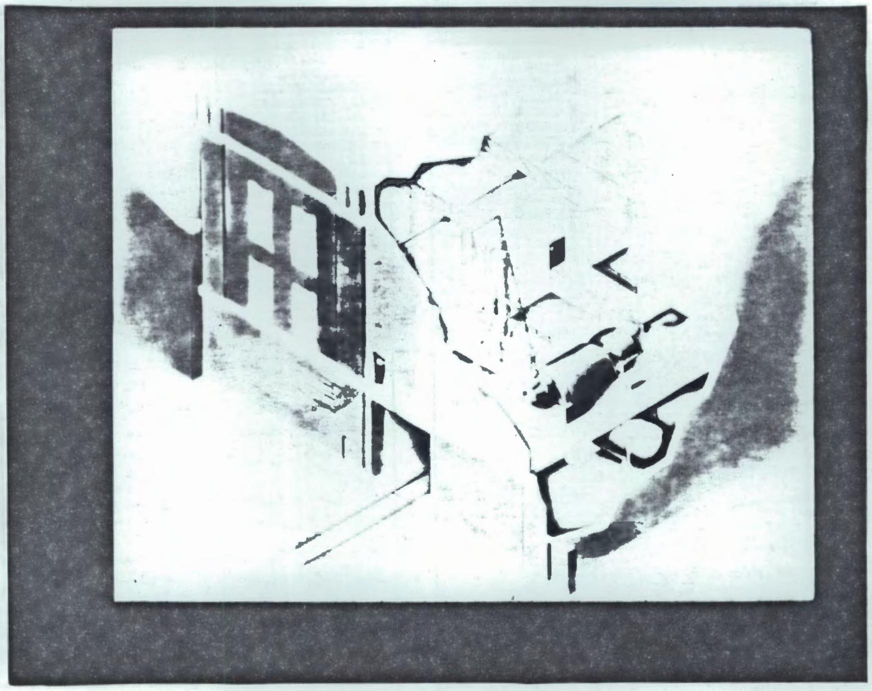

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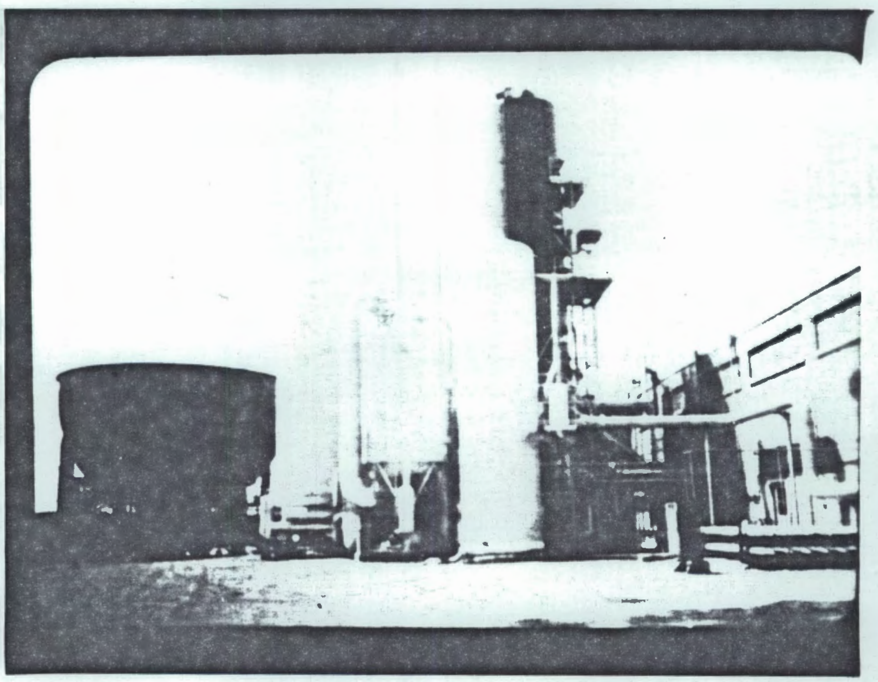
SLIDE 19



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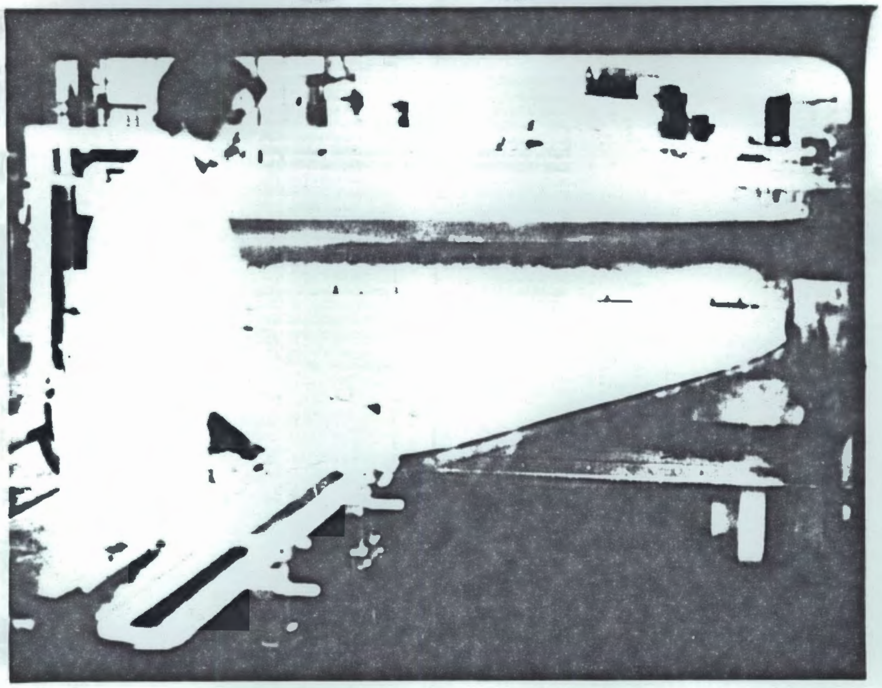
SLIDE 20



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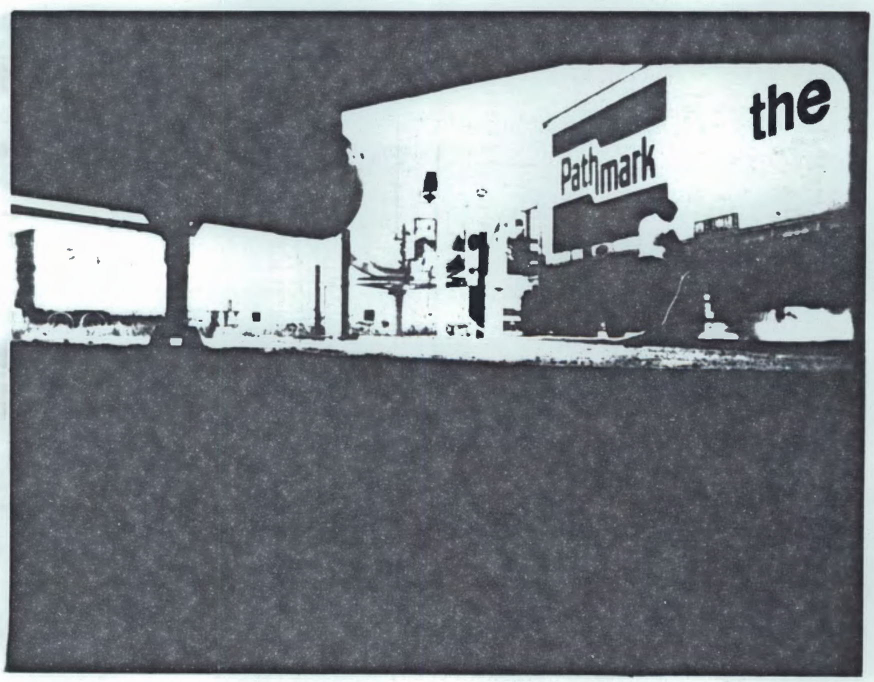
SLIDE 21



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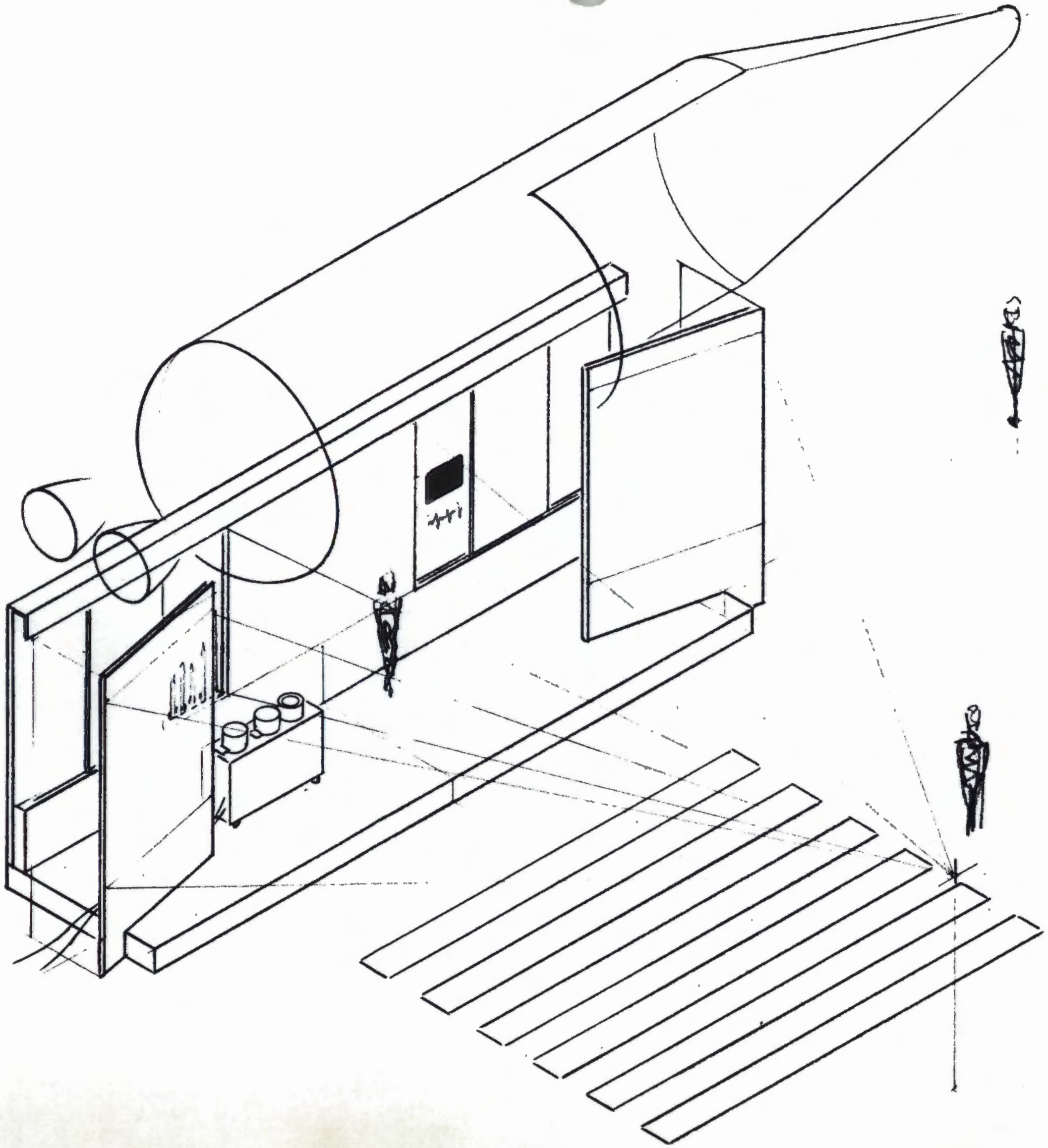
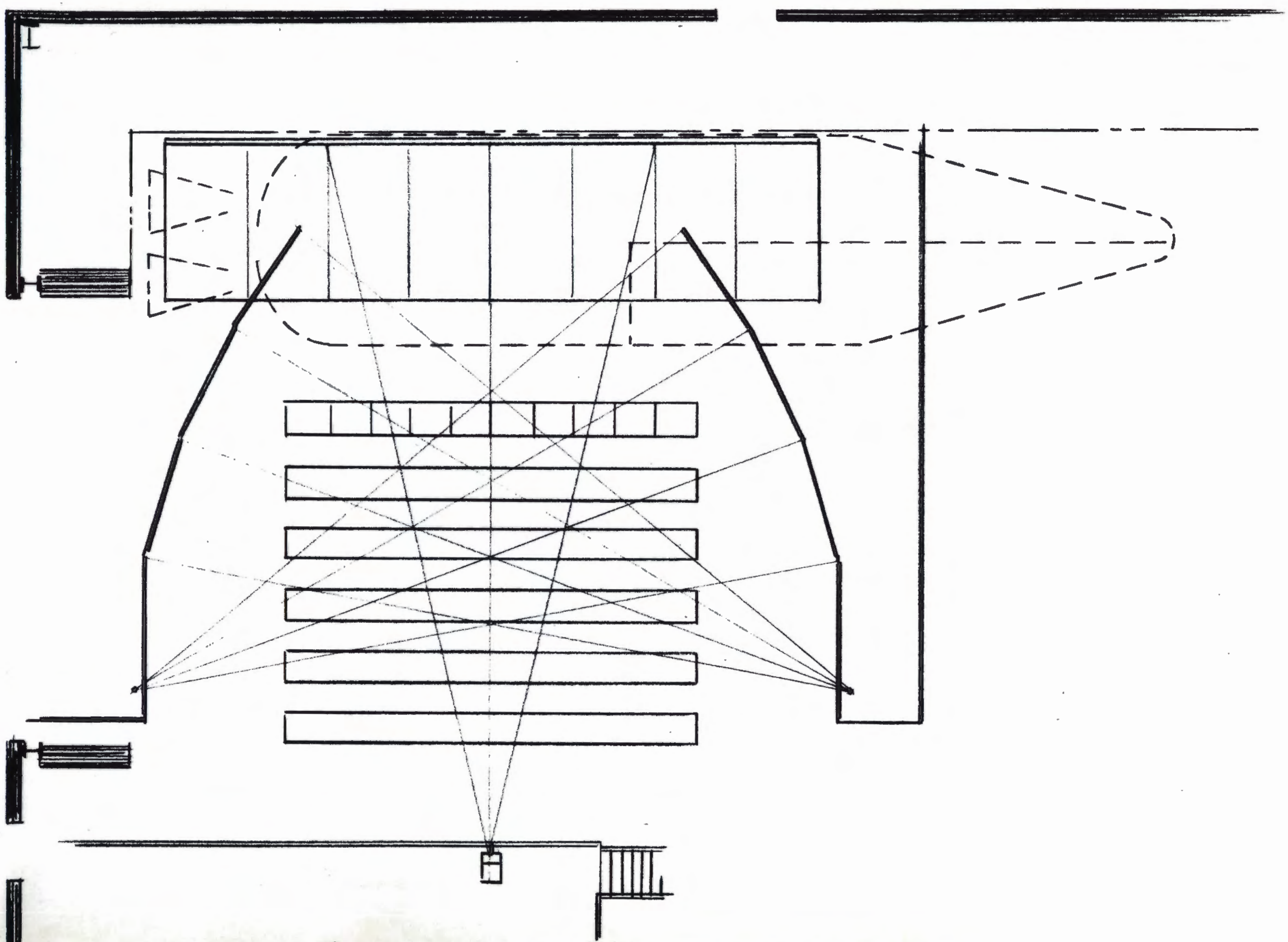
SLIDE 22



STOP #4 BIG BOOST FROM ROCKETS

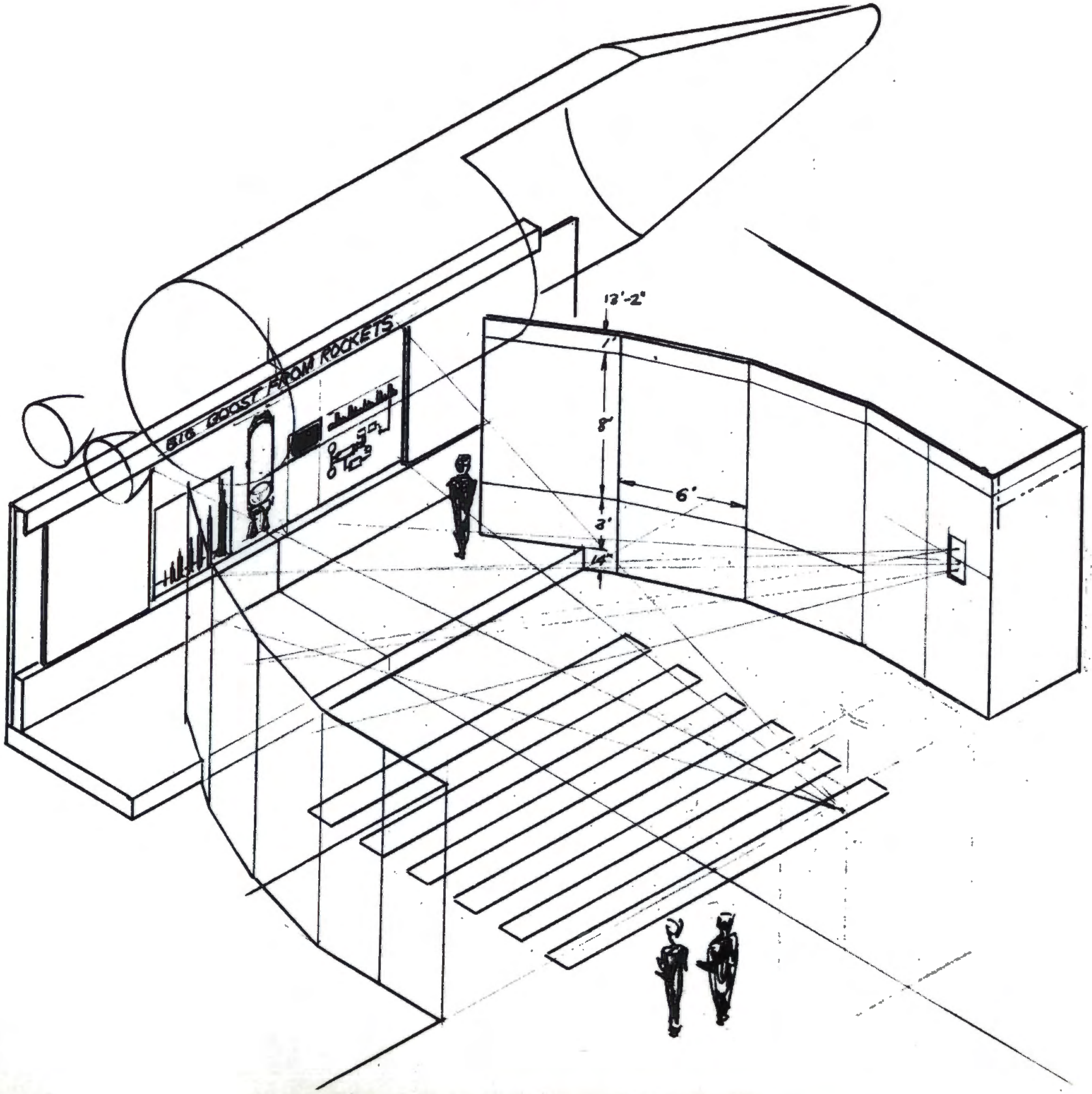
ZERO - G 1/8" = 1' R.S. ~~6-13-73~~

6-26-73



STOP # 4 BIG BOOST FROM ROCKETS

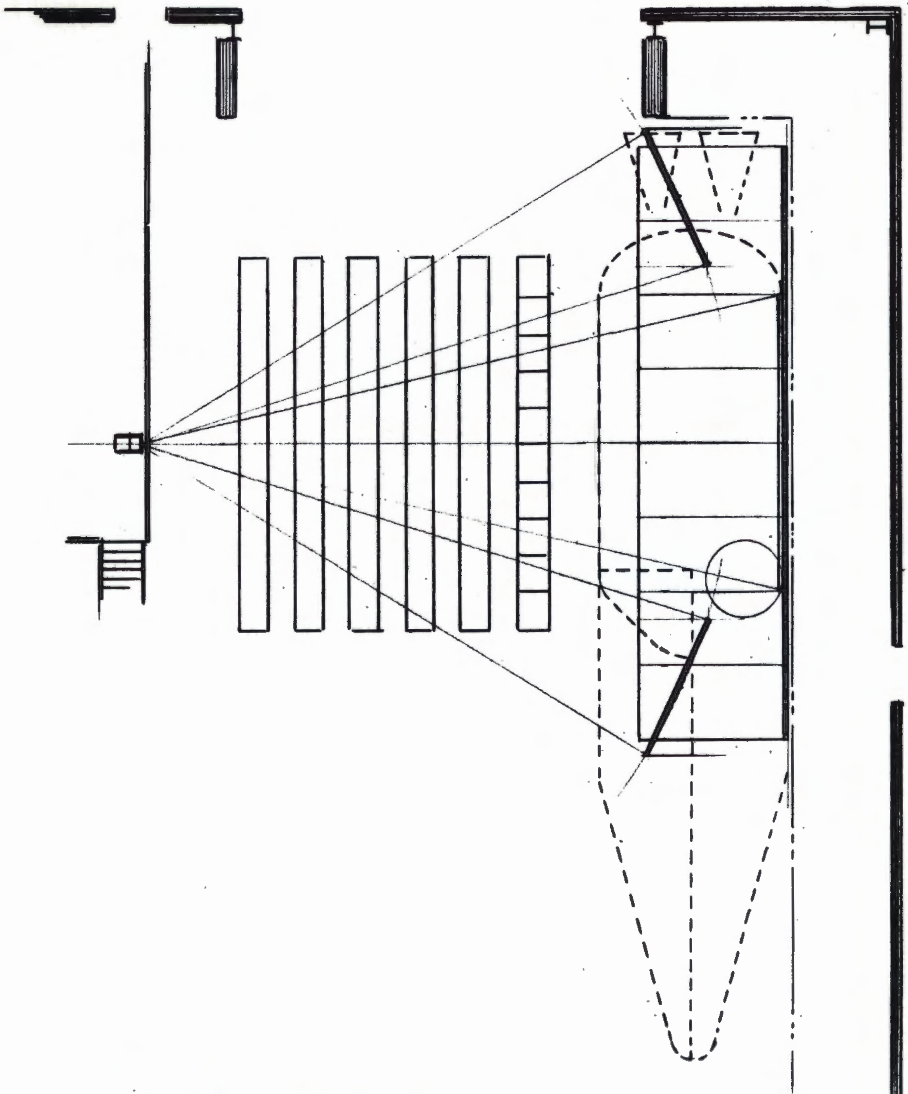
ZERO - G $\frac{1}{8}$" = 1' R.S. 6-26-73



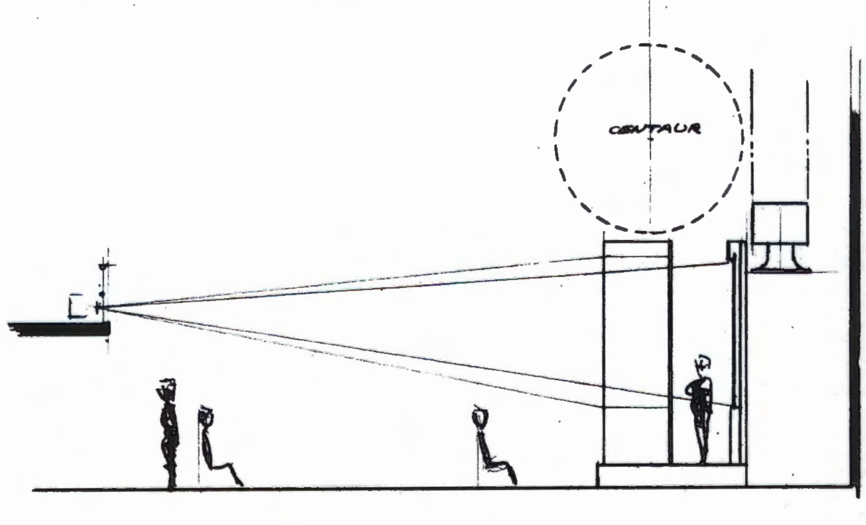
STOP # 4 BIG BOOST FROM ROCKETS

ZERO-G 1/8" = 1' R.S. ~~5-31-73~~

6-2-73



STOP #4
BIG BOOST FROM ROCKETS
ZERO G 1/8"=1' R.S. 6-13-73



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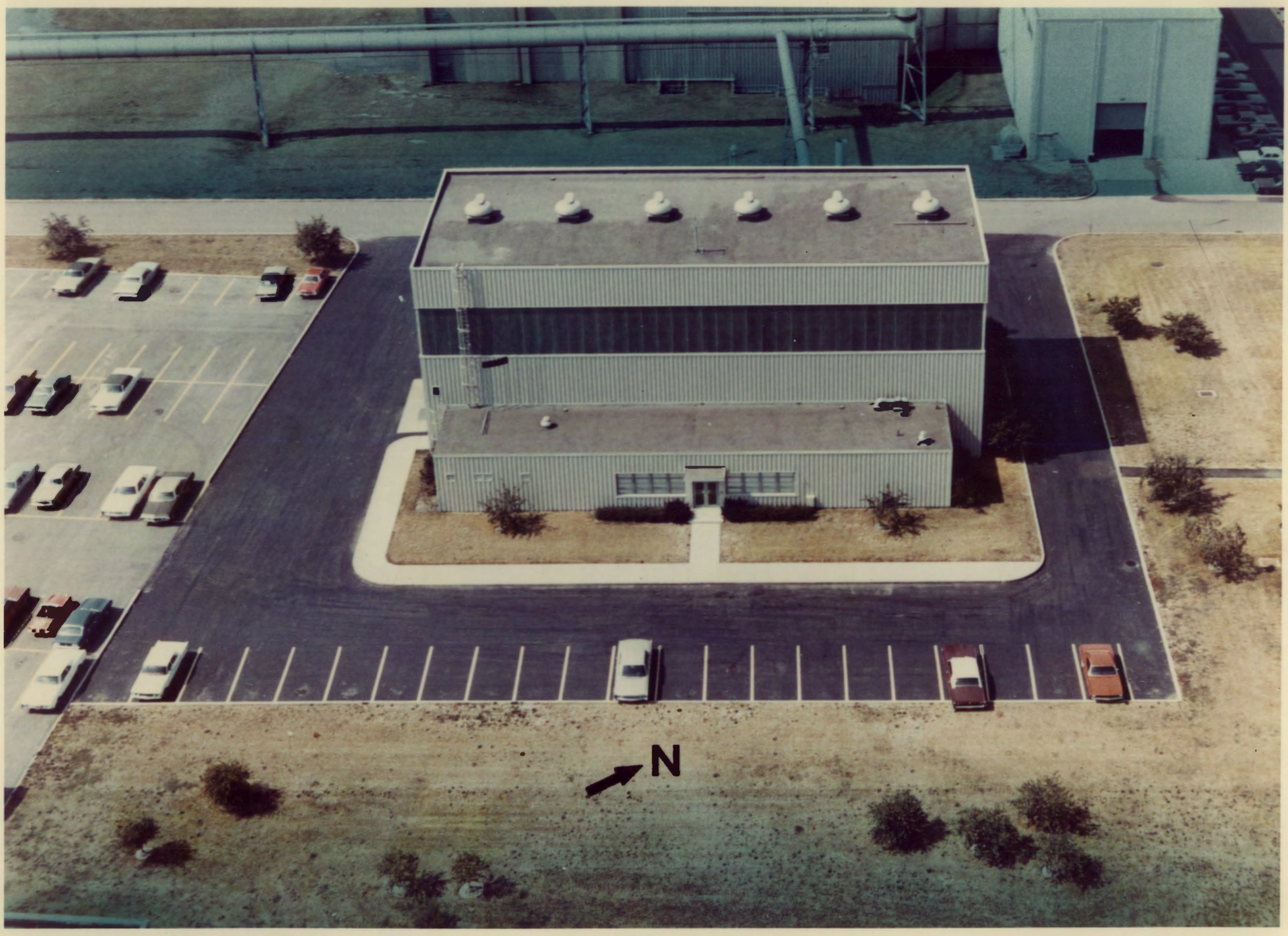
ZERO GRAVITY FACILITY



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