# SPACE ELECTRONICS INSPECTION STOP 5

Good morning. My name is Sanford Jones. My associate Dave Wright and I will show you some of the contributions to advanced space electronics and in particular, the application to communications being made by the LeRC. I will begin with a survey of the techniques presently being used in Communication systems. Up until the 1960's, information transmission across oceans was limited to underwater cable and was used primarily for telephone. On land, line-of-sight microwave towers were used to transmit television and telephone traffic was handled through a vast network of land lines. Until recently there was no television transmission across the oceans because of the infeasibility of constructing microwave towers on water over the long distances involved.

With the introduction of communications spacecraft, we have made a great change in communications. In 1964 the Olympics came from Japan and last year from Germany. Last year we saw the President visit Peking. Last year Brazil had six overseas telephone channels - this year 160. Early this year there were four channels to Peking - none last year. Now you can direct dial London and rates to Europe and Japan have recently been cut in half. Demand is growing at the rate of 100% per year and is being stimulated by the need for communication and trade. The world has now become much smaller because of communication spacecraft. Lewis is working in several technology areas that in the future will permit us to economically provide remote educational and health services, to transmit economic, law enforcement, and postal data, and to warn the populace of natural disasters such as hurricane or tornado.

All present communications spacecraft are what we call the repeater type and they are placed in synchronous orbit. A synchronous orbit is one that remains over a point on the Earth. To demonstrate this idea, we have a model of a TV communications system here on stage. On your right you see a TV camera. Here we have a transmitter and an antenna beaming a microwave signal to the spacecraft overhead which is approximately half scale.

The spacecraft accepts the signal through its receiving antenna denoted by the blue dot. The signal is amplified and retransmitted to the ground receiving station where the signal is converted and displayed. This is an operational system and I can interrupt it with my hand.

All spacecraft have been limited to transmitting power of only a few watts. This requires very sensitive ground receivers. Here we have a plot of ground station costs versus effective spacecraft power. As we can see, even present day S/C as represented by Intelsat IV require receivers far too costly for small users such as small medical clinics, schools, small city police stations, businesses, etc. However, there are two spacecraft which are to be launched in the near future which permit relatively inexpensive ground terminals. These are the Applications Technology Satellite F and the Communications Technology Satellite. The ATS-F is a NASA-sponsored satellite and the CTS is a joint venture between the United States and Canada and is managed for NASA by the Lewis Research Center. Both satellites will be used to conduct communications experiments. The initial experiments on ATS-F will be conducted with ground receivers in the United States. Later the satellite will be moved to a position over India where television programs will be broadcast directly to community receivers located in each village. The CTS experiments will be conducted in the remote northern regions of Canada and Alaska and remote areas of the United States.

Here we have a picture of the ATS-F satellite. The satellite uses a 20-watt transmitter and a 30-foot diameter antenna, and it will provide a signal strength adequate for low cost ground stations to an area about the size of Ohio. Here we have a picture of the CTS satellite. This uses a 200-watt transmitter and a 2-1/2 foot diameter antenna that will provide about the same signal strength as the ATS-F satellite but over an area about 1/3 the size of the United States. In these high power spacecraft efficiency of the various spacecraft systems becomes very important. The Lewis Research Center has been conducting several technology programs that contribute to the efficiency and utility of these communication spacecraft. We will describe five of them: our work in high efficiency amplifier tube technology - high voltage phenomena - contoured beam antenna - solar array technology - and thrusters for station keeping.

Here is a diagram of the high efficiency amplifier tube to be used on CTS. Power is provided from a solar array. A powerful electron beam is formed which emerges into an interaction region. This power is then used to amplify the input signal for retransmission back to Earth. It is what we do to the electron beam as it emerges from this interaction region that is new and more efficient. In previously used amplifier schemes, there was only a single collecting element so that as the electrons emerged from this interaction region at different velocities, large amounts of heat were generated on the collector surface. We have studied this electron beam and found that it resembles water droplets emerging from a fountain. If it were possible to catch the water droplets at a time or instant when they stop, there would be no splashing. Analogously, if it were possible to catch the electrons when <u>they</u> stop, there would be very little heat generated and the efficiency would be increased. To accomplish this, we have designed a set of carefully spaced and shaped collectors.

Here we have a model of a multistage collector. The size of the hole in the center and the shape of the plates are determined from rather sophisticated computer calculations.

To demonstrate the effect of using a multistage collector, we show here the efficiencies of a single collector system and that of a multicollector system. In previously used schemes, only 20% of the input power was converted to useful RF output signal and the remainder was dissipated as heat. With the multistage collector system, we now obtain $2\frac{1}{2}$ times as much output power. Now with each S/C we can provide $2\frac{1}{2}$ times the communication capability. This can be used to drastically lower ground station costs; or to provide more channels and also lower the cost to use a channel.

Over here we have a model of the amplifier tube that will be used on the CTS spacecraft. In this part, we have the electron gun - here is the interaction region and within this can-like enclosure is the multistage collector. Now the fact that we have enclosed this collector suggests another area of research being conducted by the Center. Ideally, it would be better not to have the collector enclosed so that dissipated heat could be radiated directly into space. Because space is a very good vacuum and therefore a good insulator, this should work; however, upon closer examination, we find that space is filled with many positively and negatively charged particles which we call a plasma. The spacecraft must operate while being immersed in the plasma and it is possible that exposed collector plates that operate at very high voltages might be short circuited. We have a diagram that illustrates the situation. Here we see a spacecraft with high voltage elements which must operate while being immersed in the plasma. Here we have a solar array wired to directly produce the high voltage needed by the tube, and here the high voltage amplifier tube and its set of multistage collectors. The possible short circuiting paths caused by the plasma are depicted by the large arrows.

In order to obtain information, we conducted ground-based experiments in vacuum chambers similar to the one you see behind you. However, we encountered two difficulties. We could not adequately reproduce the space plasma and we had difficulty with the proximity of the vacuum chamber walls affecting the conduction of the plasma path. In order to obtain the data needed on the resistance of a spacecraft immersed in a plasma, we have designed a spacecraft which will be launched early next year. We call this spacecraft SPHINX, which is an acronym for space plasma high voltage interaction experiment. We have a model of the spacecraft here on stage. The spacecraft consists of solar arrays to produce power, communication antenna, attitude control thrusters and the experiments. The multi-electrode experiment is directly analogous to the multistage collector. We will also conduct an experiment on the efficiency of a high voltage array. This spacecraft will be launched early next January on a Titan-Centaur launch vehicle. The experiments will be conducted over a period of one year. The orbit is a long ellipse which will provide a wide range of plasma concentration. And now I would like to introduce to you Dave Wright who will continue our discussion on Lewis Research Center endeavors in space electronics.

Good morning. The next technology area that I will discuss is contoured beam antennas. Conventional parabolic reflector antennas such as those used on the ATS-F and CTS and as shown on the spacecraft overhead produce circular or elliptical patterns. These antennas are ideally suited for point-to-point communications. However, when we try to cover an irregular area such as Alaska, these antennas waste power. In this chart, we show the problem. Here we have the earth and a satellite in synchronous orbit using a circular beam antenna to provide the coverage pattern. As you can see, the radiation pattern which is shown by this dotted line just manages to encompass the entire state of Alaska on all the corners; however, in order to do this, a substantial amount of power is wasted and radiated into such areas as the Pacific ocean and over the horizon, not even intercepting the earth. For this case, of all the power radiated from the spacecraft only 17% actually falls upon the land surface of Alaska. The second problem with these circular beam antennas is that they create a possible problem of interference. In the example here, the wasted power fell harmlessly into the Pacific ocean or over the horizon. However, if our example would have been say Appalachia instead of Alaska, this wasted power would have appeared as unwanted power in the entire eastern United States. It could have interfered with existing terrestrial communications and other satellite communications.

In order to overcome these problems of circular beam antennas, we are investigating what we call contour beam antennas. Here you can see the same area, Alaska, being covered by five smaller radiation patterns. These patterns are provided by a contoured beam antenna which is shown by this model. It uses five feed horns arranged on a single reflector to produce the radiation pattern. Each one of these feed horns produces one of the five radiation patterns. The composite of these individual patterns produces the coverage defined by this contour.

As you can see, we have reduced substantially the amount of power that is radiated into the Pacific ocean and also the amount of power that is radiated over the horizon. This system is about 33% efficient, in other words of all the power radiated from the spacecraft approximately 33% of it falls on Alaska as usable power as compared with 17% for a circular beam. This approximately doubles the communication capability and ultimately results in lower costs for telephone and television time.

The next technology area that I will discuss is solar array technology. The ATS and the CTS spacecraft which we have described use solar cells to derive their electrical energy from sunlight. As you remember, the present trend in communication systems is toward higher power as Sanford has pointed out - the CTS spacecraft will radiate 200 watts, while the ATS spacecraft only radiated 20 watts. You can see from our pictures the substantial increase in the size of the solar arrays in CTS as compared with the ATS spacecraft. Since the size of the solar arrays are increasing drastically with time, it is important that we increase the efficiency and reduce the cost of solar arrays.

The diagram shows a cutaway of a typical solar cell - the semiconductor layers - the electrical contacts - and the various coatings and radiation protection. The present efficiency is 11%. The maximum theoretical efficiency of a solar cell is approximately 22%. Our goal is to raise the efficiency to 18%. In order to do this, we are investigating better anti-reflective coatings which will allow more sunlight to enter the cell and cause less to be reflected. We are also providing better electrical contact to the cells to reduce electrical losses. If we can achieve our efficiency goal of 18%, we can provide 50% greater communication capability aboard each spacecraft which translates into more channels and lower cost per hour to rent a channel.

We plan to reduce the cost of assembling solar arrays by simplifying the method of providing for protection from radiation damage. At present, each one of these glass covers has to be individually cemented in place and this is very time consuming and raises the cost of the arrays appreciably. We are studying a process that uses a large plastic sheet to encapsulate many cells into one module such as the one you see here. This process of taking a large plastic sheet and sandwiching it together with the cells and a plastic substrate is a process much like you would make a plastic identification card or credit card. As you can see, the model is quite flexible and lends itself to an unfolding array such as we have shown on this model on stage. With this technique, we can reduce the cost of large arrays by about 25%. On a 5000 pound spacecraft for example which might require a 10 kW solar array the savings would be $\frac{1}{2}$ million dollars which could provide 100 extra ground stations.

The last technology area that I will discuss is station keeping technology. All of the spacecraft which we have described will be placed in synchronous orbit. This means that they appear stationary over the earth. However, there are forces from the sun, the moon and out of roundness of the earth which cause these spacecraft to drift about from the desired position. Therefore, it is necessary to include thrusters, such as you see on each end of the spacecraft as denoted by the red dots/ to keep the spacecraft over the desired point. At the present time, all spacecraft use chemical thrusters for this station keeping maneuver. In order to derive their thrust, these chemical thrusters actually expel gas particles under pressure. This is a very inefficient process because the particles are emitted at a fairly low velocity. In the future, we foresee the possible use of ion thrusters for this station keeping maneuver and one such thruster is shown here on stage. This ion thruster creates its thrust by expelling charged particles or ions from this grid area using an electric field. Because this electric field accelerates these particles to a much higher velocity, the ion thruster makes much more efficient use of its propellant. I might point out that the ion thruster produces only about 1/60 of an ounce of thrust; however, even used intermittently this is sufficient for station keeping small to medium size spacecraft.

On this chart, we have a comparison between the/ station keeping efficiency of the chemical thruster and the ion thruster. As you can see on this vertical axis, we plot the weight of the thruster system and its propellant as a percent of spacecraft weight and on the horizontal axis we plot the years in synchronous orbit. The empty weight of the two systems is indicated by the zero years in orbit point and you can see that the empty weight of the chemical thruster and the ion thruster are approximately equal. The increase in each curve then indicates the amount of propellant that must be initially provided to do the station keeping job for the years indicated. For a ten-year mission, the ion thruster and propellant comprises only about 8% of the total/ initial spacecraft weight. On the other hand, the chemical thruster and propellant comprises approximately 25% of the/ initial spacecraft weight. At the present time, missions are tending toward these longer times because this reduces the cost per year of the spacecraft. The savings we can obtain with an ion thruster, as shown, could increase the communications capability by 50% which again translates into more channels or lower cost per minute or hour for rent of these channels. Besides this small ion thruster which I have talked about, we are also studying larger ion thrusters such as you see in the pictures and displays on the left. These ion thrusters can produce approximately ½ ounce of thrust and are sufficient to station keep a large satellite or can be used for interplanetary propulsion.

In summary, we have described the five following areas of technology - high efficiency, high power microwave amplifiers, high voltage space technology, contoured beam antennas, more efficient solar arrays and we have shown the advantages of ion thrusters for long life station keeping. The application of these five areas of technology will result in increased communications coverage in the form of lower cost ground stations, more channels or lower cost coverage to remote areas such as Alaska. Specifically, we foresee low cost communications systems having the following direct benefits for mankind. Benefits will appear in the areas of medicine and health, education, law enforcement, postal distribution and disaster warning. Thank you.

STOP 5 EVERETT HURST 4110

CS 67779 (SPACE/EARTH COMMUNICATIONS)

CS 67780 PAST-PRESENT AND FUTURE

CS 67781 3) GROUND STATION COST AS A FUNCTION OF SPACECRAFT POWER

CS 67782 4) TECHNOLOGY AREAS

CS 67783 HIGH EFFICIENCY AMPLIFIER

CS 67784 TUBE EFFICIENCY

CS 67785 ) CURRENT LEAKAGE PATHS SURROUNDING A SPACECRAFT

CS 67786 CIRCULAR BEAM OVER ALASKA

CS 67787 ) CONTOUR BEAM OVER ALASKA

CS 67788 ) SOLAR CELL IMPROVEMENTS

CS 67789 ) THRUSTER SYSTEM WEIGHT COMPARISON

CS 67790 SPACE ELECTRONICS RESEARCH AND TECHNOLOGY

STOP 6

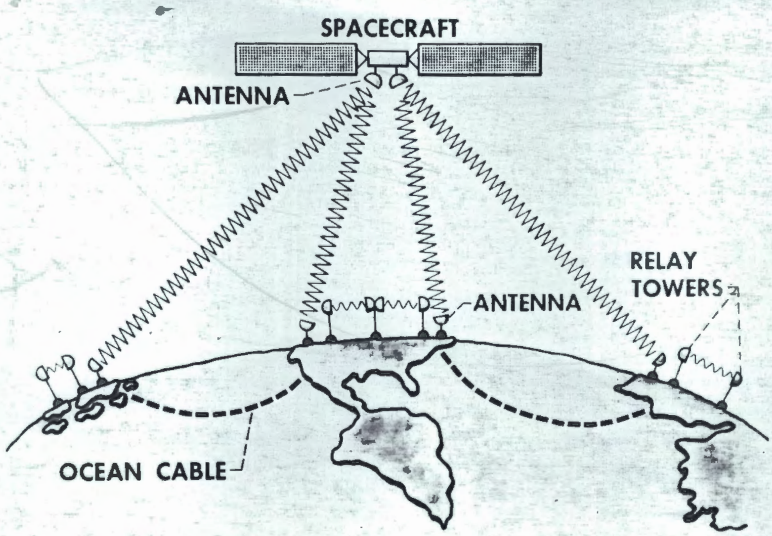



CHART 1 (CS-67779)

| PAST | PRESENT | FUTURE |
| --- | --- | --- |
| • OLYMPICS<br>– JAPAN 1964<br>– MEXICO 1968<br>– GERMANY 1972<br><br>• PRESIDENTIAL VISIT TO PEKING | • BRAZIL – 160 OVERSEAS TELEPHONE CHANNELS (LAST YEAR –6)<br>• CHINA – 4 OVERSEAS TELEPHONE CHANNELS (LAST YEAR –0)<br>• DIRECT DIAL LONDON<br>• RATES CUT 25% TO EUROPE & JAPAN<br>• 16,000 TELEPHONE CHANNELS ACROSS ATLANTIC (24 COLOR TV)<br>• 8000 TELEPHONE CHANNELS ACROSS PACIFIC (12 COLOR TV)<br>• 2 MORE SPACECRAFT RECENTLY LAUNCHED – INCREASE CAPACITY 50% | • 100% INCREASE PER YEAR<br>• TRADE<br>• MEDICAL<br>• EDUCATIONAL<br>• LAW ENFORCEMENT<br>• POSTAL<br>• DISASTER WARNING<br>• GOALS<br>– IMPROVE CAPABILITY<br>– LOWER COSTS<br>↓<br>TECHNOLOGY |

CHART 2 (CS-67780)

## GROUND STATION COST AS A FUNCTION OF SPACECRAFT POWER

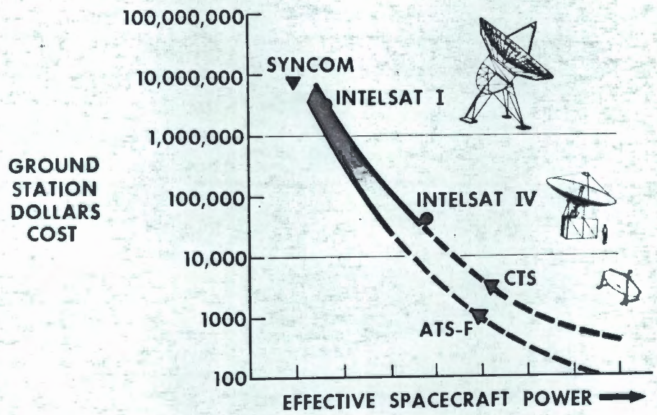



CHART 3 (CS-67781)

## TECHNOLOGY AREAS

- EFFICIENT HIGH POWER MICROWAVE AMPLIFIERS
- HIGH VOLTAGE SPACE TECHNOLOGY
- CONTOURED BEAM ANTENNA
- IMPROVED LOW COST SOLAR ARRAY
- LONG LIFE STATION KEEPING

CHART 4 (CS-67782)

## HIGH EFFICIENCY AMPLIFIER

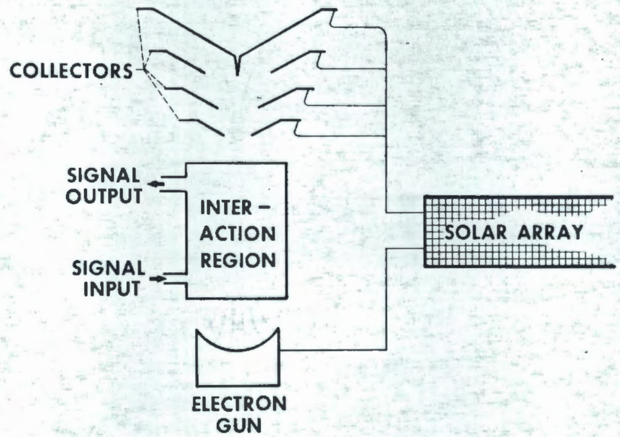
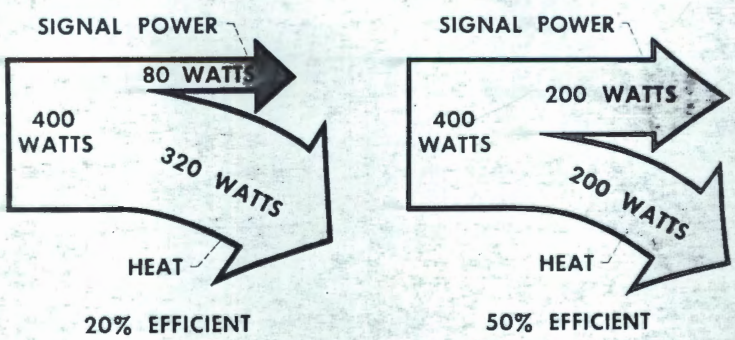



CHART 5 (CS-67783)

## TUBE EFFICIENCY

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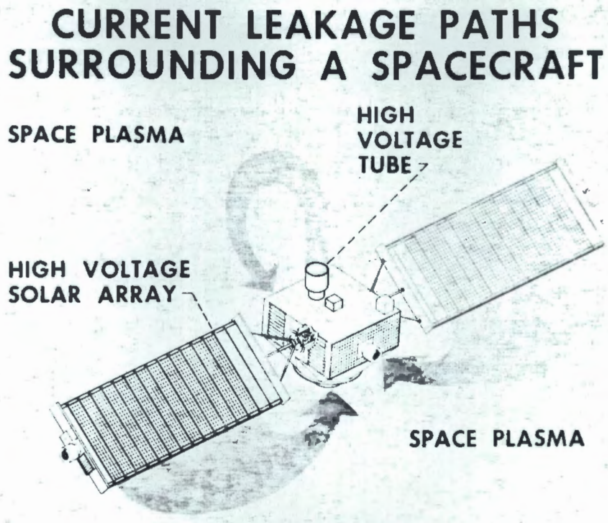
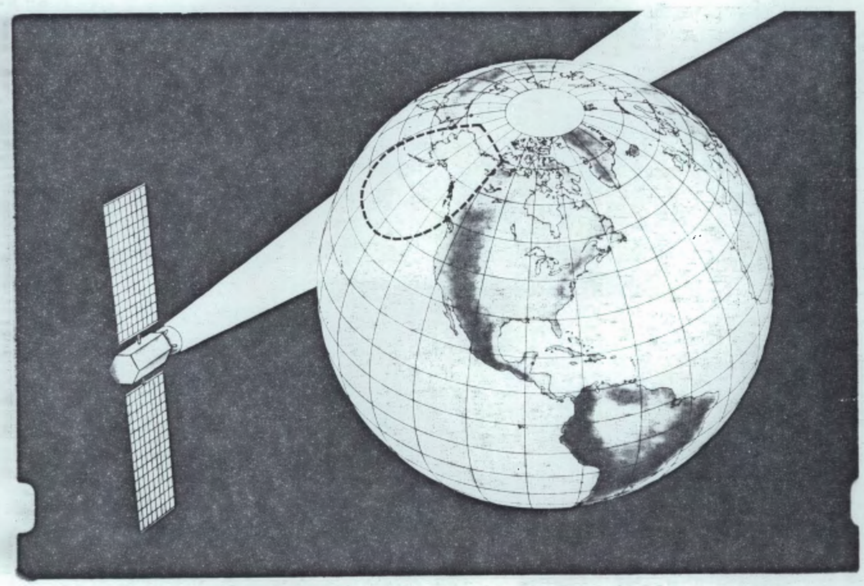



CHART 7 CS-67785



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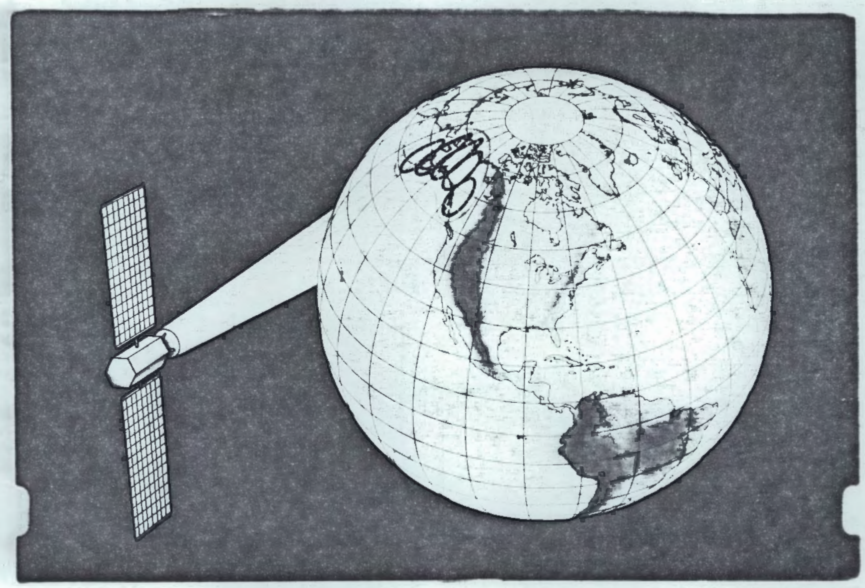


CHART 9 CS-67787

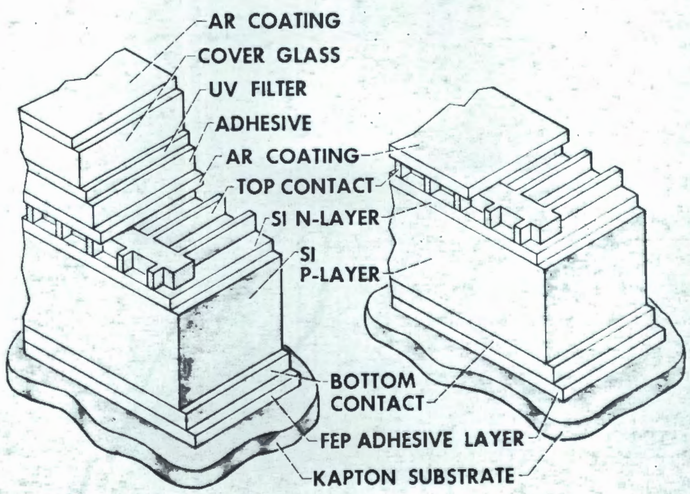



CHART 10 CS-67788

## THRUSTER SYSTEM WEIGHT COMPARISON

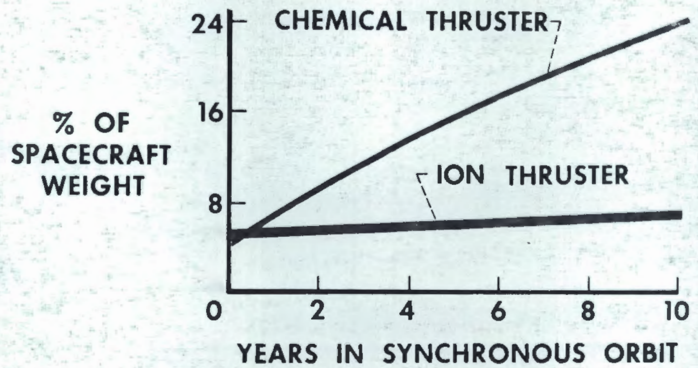



CHART 11 CS-67789

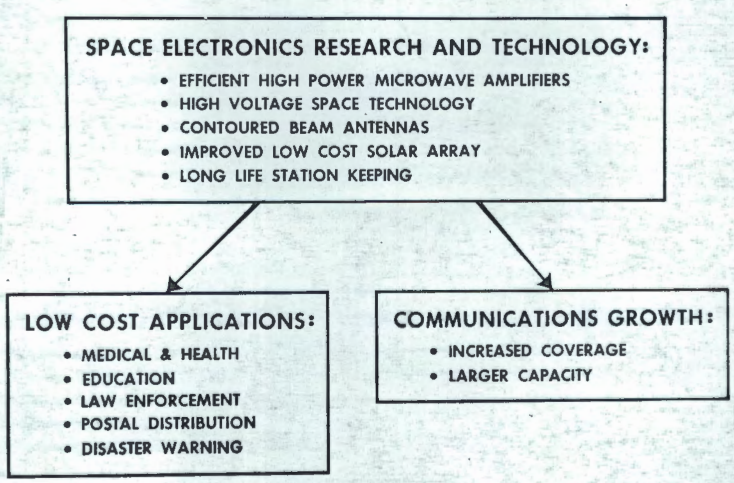
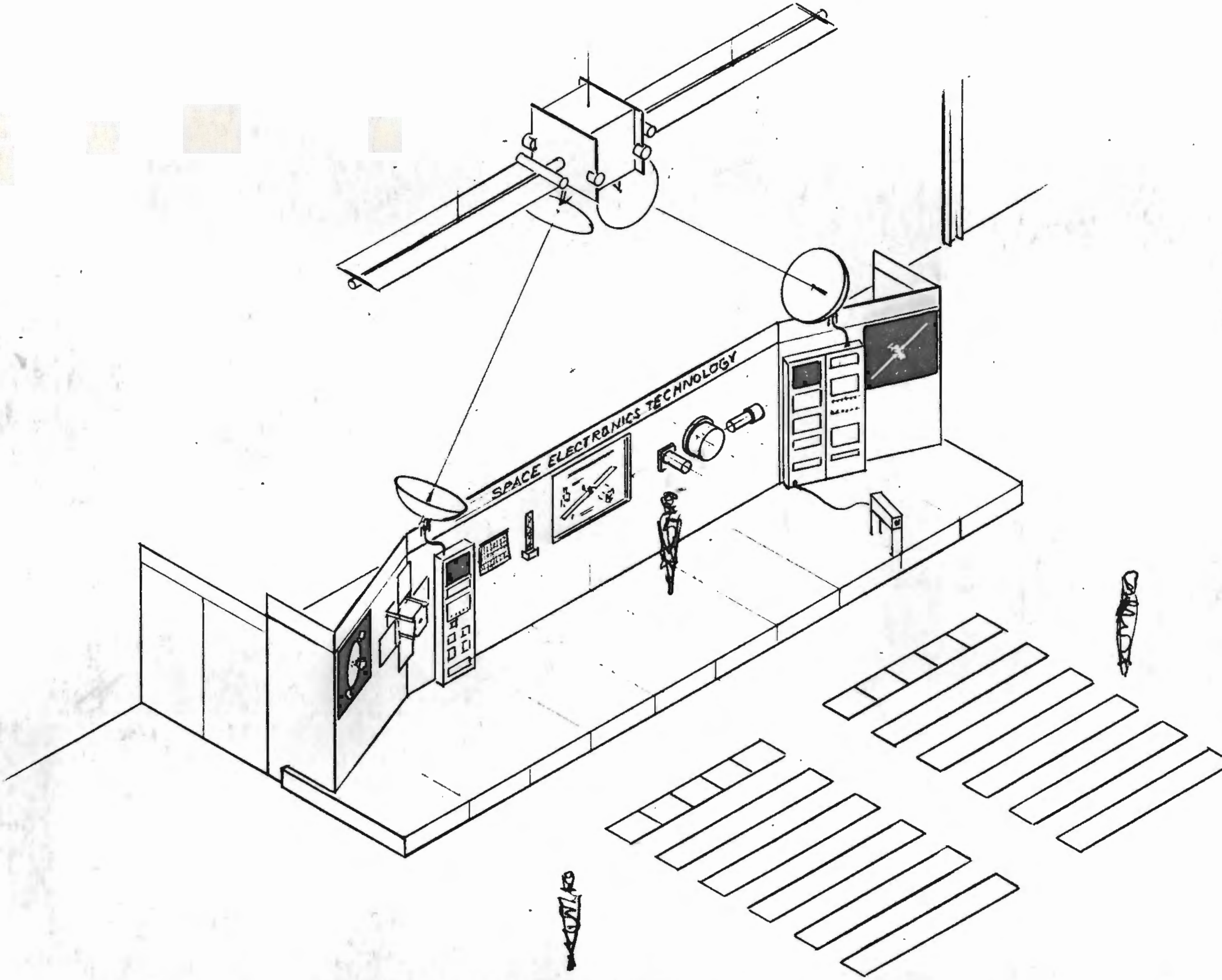
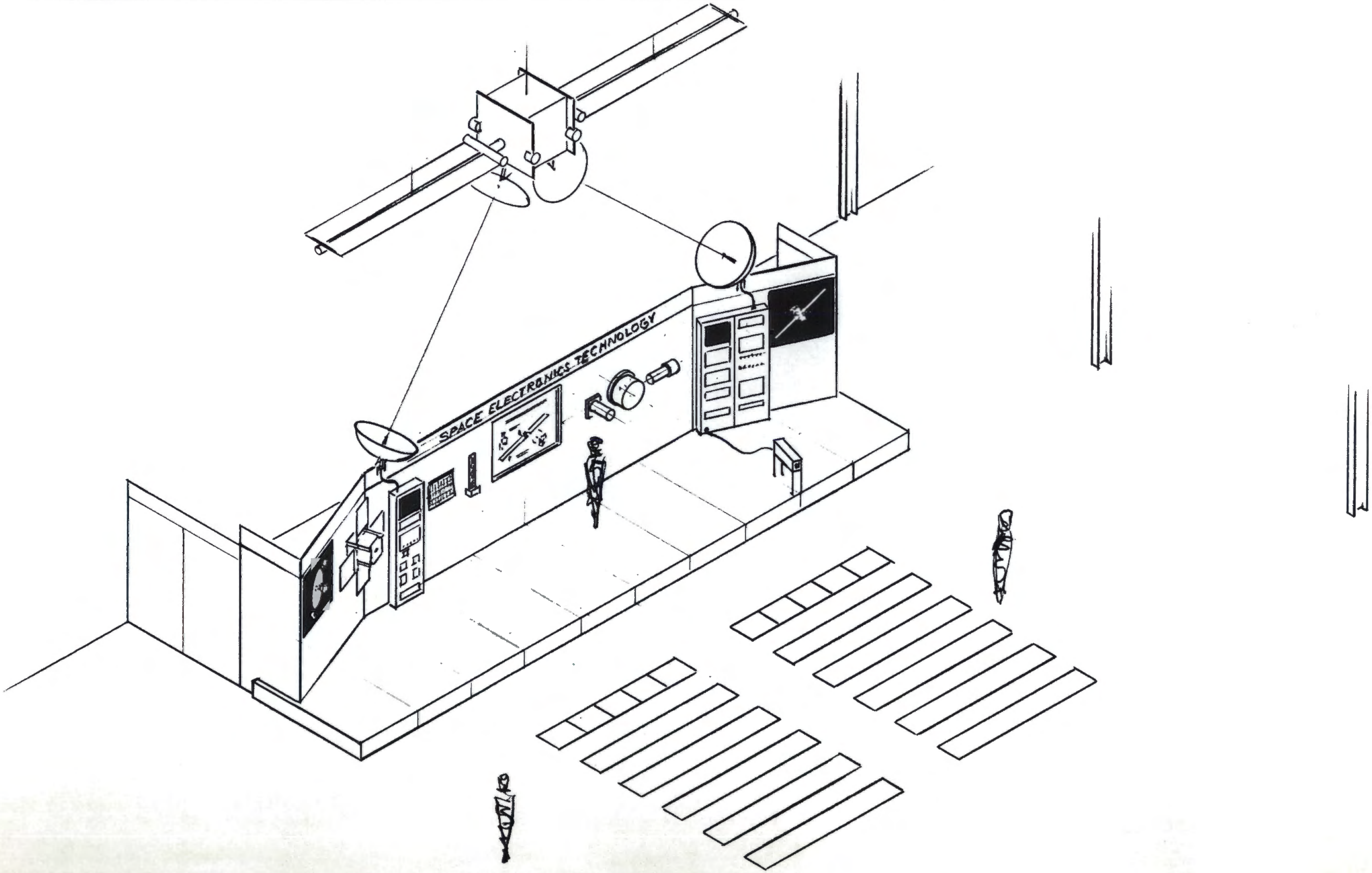



CHART 12 CS-67790




STOP #5 SPACE ELECTRONICS TECHNOLOGY

EPL 1/8" = 1' R.S. 6-21-73

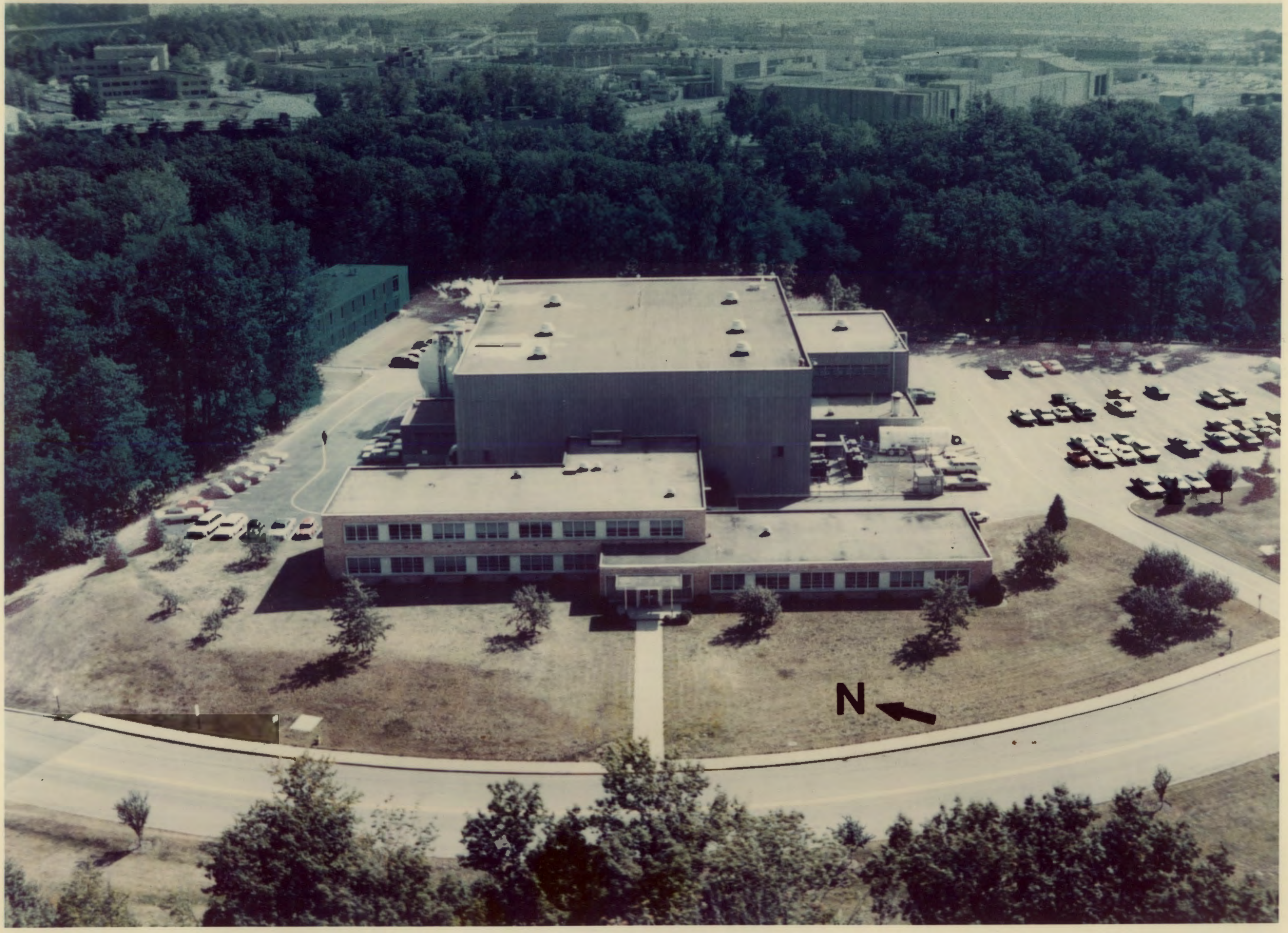



STOP #5 SPACE ELECTRONICS TECHNOLOGY

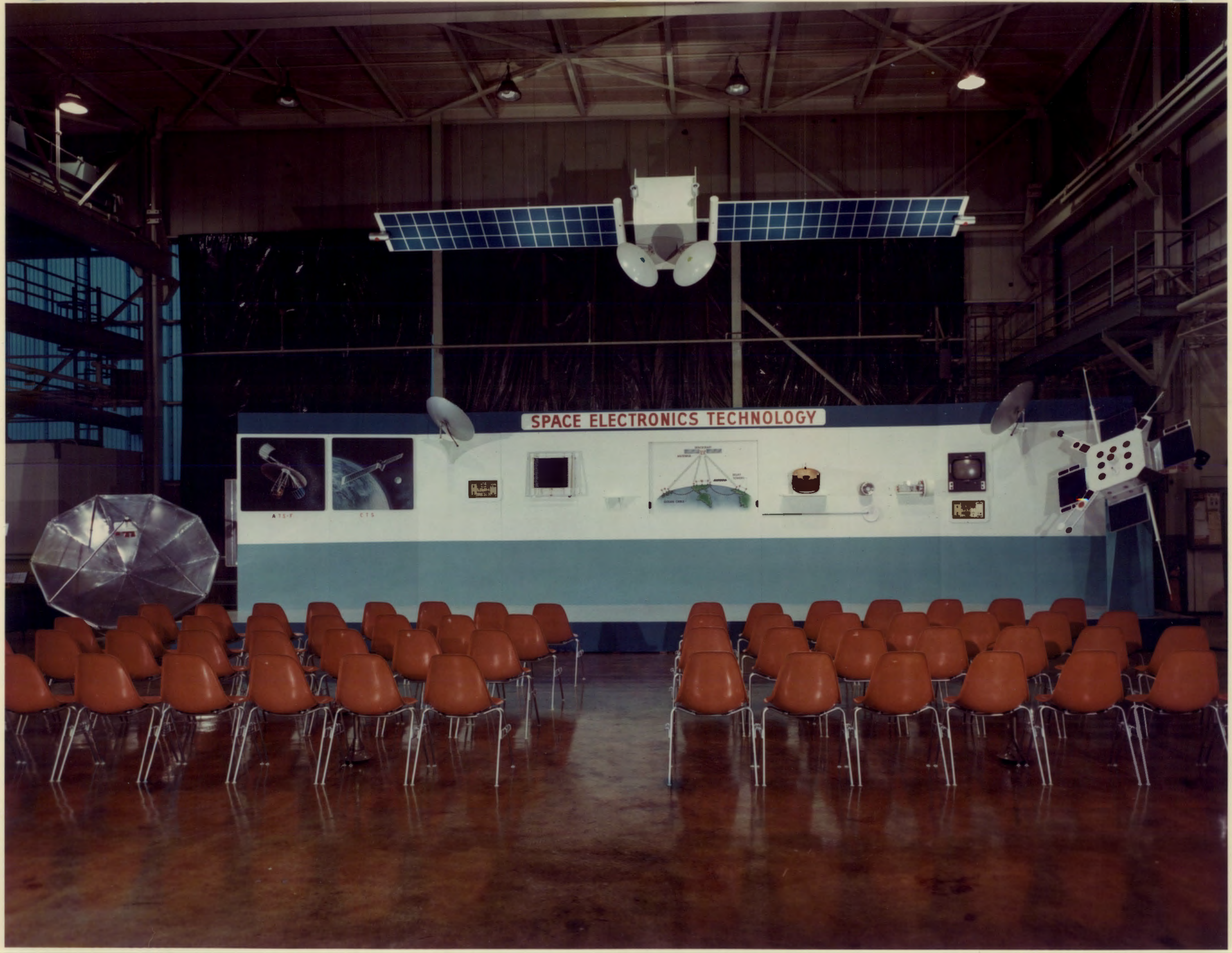
EPL $\frac{1}{8}$" = 1' R.S. 6-21-73

NASA
C-73-1522

# ELECTRIC PROPULSION LABORATORY



NASA
C-73-3382



**NASA**
C-73-3374


NASA EARTH RESOURCES SURVEY PROGRAMS
STRIP MINING
REMOTE SENSING ASSESSES
Strip mining extent and success of land reclamation efforts
State strip mining test site in Noble county
TRUE COLOR
False color infrared
Spectral signature of soil types
Airborne remote sensing identifies toxic soil types.
EXTENDED NAVIGATION SEASON
NIMBUS SPACECRAFT
WATER QUALITY
LAKE ERIE POLLUTION