# THE ATS-F SATELLITE EXPERIMENT WITH CABLE TV DISTRIBUTION

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The ATS-F (applications technology satellite F) experiment in the Rocky Mountains is a joint experiment for which NASA is supplying satellite channel capacity to the Department of Health, Education and Welfare and associated local groups in the Rocky Mountain Federation of States.

This is part of NASA's general policy of making available satellite capacity we have to interested users: to provide them with experience in satellite communications operations and to give them an opportunity to experiment generally with the kinds of things that this technology helps to do well.

The burden of proposing sensible experiments, of developing and supporting the ground system and of operating the experiment rests with the user.

The ATS-F experiment is a departure in one new way. ATS-F is still in development. It will be launched in the early spring of 1974 and we were approached by HEW and the Corporation for Public Broadcasting together to ask if we would provide them with capacity to conduct a series of community broadcast experiments in public service, in education, in health teleconferencing and an assortment of other things.

Although we didn't have plans at the time for broadcasting in the appropriate bands, we agreed to the experiment and have since incorporated this capability into the satellite for the user's benefit.

I want to emphasize at the outset, to dispel what's a prevalent misconception, that NASA is not in any broadcasting or operational business and that this experiment is not a direct-to-home broadcast experiment.

Figure 1 is a series of notes to the frequency rules and regulations governing the various kinds of services. The broadcast satellite service is a general class in which the kind of experiment that we are going to work with HEW and CPB would fall when the experimental results are extrapolated to someone's operational system.

There is provision here for "individual reception." This is reception by simple domestic installations, and for community reception, which is the reception of broadcast signals by community receivers for local redistribution or for community viewing, as in a town meeting. This is the kind of reception the ATS-F experiments will provide.

The second important item (Figure 2) is that the band in which these experiments will be run is the 2500-to-2690 megahertz band, which is allocated exclusively to instructional and educational broadcasting. It is not available for commercial satellite communications and it's not available for generalized commercial broadcasting. This band is restricted primarily to public service uses such as education and instruction and, in a manner of speaking, health services where they relate to education and instruction.

Figure 2 shows all of the bands that are allocated in some way to broadcast services. The 11.7-to-12.5 gigahertz band is allocated to generalized broadcast services but must be shared coequally with the commercial satellite services of the Intelsat/Comsat kind, which don't necessarily envision broadcasting to anybody but do embrace telephony, telegraphy and communications of record.

Figure 3 is a photograph of a full-scale model of ATS-F. It is large. From tip to tip of the solar panels is 52 feet. The diameter of the deployed antenna is 30 feet, and the antenna is not extended until after the satellite is launched free of the booster and deployed in orbit. It's wound around a hub in a very tightly coiled spring arrangement and uncoils and erects in space.

From edge to edge of the equipment module at the bottom of the truss we measure 64 inches. The satellite weighs approximately a ton and a half and the power at the end of its two-year life is to be approximately 500 DC watts, available at the output terminals of the solar array. That converts to some smaller number, perhaps 80 watts at the 860-megahertz frequency and, for our purposes, 15 watts for each of two channels in the instructional TV broadcast band at 2500-to-2690 megahertz.

Figure 4 is a cartoon of the kind of experiment we expect to do with HEW and CPB. The satellite itself is placed in an equatorial orbit at an altitude of 22,300 miles. At that magic altitude it rotates once a day with the earth and so appears to be stationary over the equatorial trace on which it is parked. Therefore, you can get 24-hour coverage of any particular area toward which the satellite is pointed.

The satellite is visible over a very large surface region. We can see it from our control station at Rosman, North Carolina. The Rosman station is the standard operating site for control and all experiment operations of ATS-F.

The satellite itself is accessed through an uplink in the commercial communications band at 6 gigahertz. We can transmit anything compatible with the satellite receiver up that link; the receiver has approximately 500 megahertz bandwidth.

ATS-F can transmit down at a number of frequencies, some of which are in the 2500-to-2690 band, and those frequencies will be used to illuminate areas in the Rocky Mountain region and/or in Alaska, depending on how HEW allocates the time for its user experiments and how the various uses are disposed over the available time and power in the satellite.

We do not expect to provide signals for both rebroadcasting from local stations which will be equipped with ground receivers and distribution from cable head ends which may be equipped with ground receivers. We would also expect to provide, in rural towns, villages, regions where there aren't any available coverages either from cable or from broadcast stations, signals for direct village distribution from the local ground receiver that is supplied there.

HEW intends to procure and deploy approximately 500 of these small ground receivers.

We expect also to provide some back-links so that experiments can be done in interactive services. One-way service experiments are not very useful for determining attractive applications in education and health care information delivery, where future demands point to interaction and broad band. So we have to have voice back link capability, in which the access back to the satellite will be provided on a different but related frequency, in the same general frequency region, through the small ground stations.

Figure 5 shows the pairs of footprints that can be made available from the satellite in the Rocky Mountain region. We have two beams, each of which will provide a full TV channel with as many as four simultaneous audio links. The satellite antenna pattern is configured to produce one north-south pair only. The position of the pair on the ground can be changed by pointing the satellite where coverage is desired.

The area covered is approximately 360 miles east-west by 450 miles north-south in the lower beam and about 500 miles north-south in the upper beam. The elongation is due to the angular squint: the satellite is not looking down the nadir perpendicular to the surface, but is squinting upward from the equatorial plane to illuminate the Rocky Mountain region at an angle to the surface.

Figure 5 also shows the locations of some of the rebroadcast stations. These are Public Broadcast Service stations. Notice that in some areas (in Wyoming, for example, and in Montana) there aren't any Public Broadcast Stations at all. There may be some cable systems there that are interested in cooperating with the experiment.

To work with the satellite, we have developed an experimental model of a small ground station. Figure 6 is a photograph of the station that was developed at Stanford University under NASA sponsorship. It operates in the general S band region from about 2200-to-2700 megahertz. The antenna is made of flat stock, force-bent to a frame. It's very inexpensive. Two technicians can assemble it within two hours when it is delivered in boxes with the sections stacked.

The diameter of the antenna is 10 feet tip to tip. In the photograph the seams of one of the sectors are visible. The sectors are cut so that when bent to the frame they form a parabolic antenna. Above the reflector, behind its feed, is the entire electronics: a parametric amplifier or a tunnel diode front end, modulation converter and output cable. The cable may be connected wherever it will have to go, either to the cable system headend for redistribution or to conventional receivers to feed into the turret or on a particular standard TV channel.

We use FM with approximately 25 megahertz total bandwidth for the signal. Four audio channels are provided, each in its own subcarrier. The four audio subcarriers each deviate the video carrier by about 490 kilohertz of peak audio deviation to its particular subcarrier. The four subcarriers are multiplexed with the video so that the whole signal package, video plus four audio channels, takes up 25 megahertz. These characteristics are for reception only. The NASA development has not addressed the problem of interactive talk-back capability. We have done this development to demonstrate what could be done and to show that it can be used with signals of appropriate small flux density. We have made and will continue to make the technology available to interested parties; it is in the public domain.

This technology is currently being used by HEW-CPB to go out on procurement for their 500 ground stations to their own design, which includes interactive talk-back capability for up to 50 voice channels.

Figure 7 shows some results of cost-size tradeoff studies to determine whether we really were in the right ballpark with the station sizing that we chose. We did this both at 860 megahertz, which is the frequency of a like experiment we have agreed to conduct with the Government of India in the second year of satellite life, and at 2500 megahertz.

In the figure we polt the gain-to-noise ratio of the receiver as a function of the antenna size and then determine, as best we could, what the ground station costs would be for some moderate quantity as a function of that ratio. In both cases, the cost minima occur about at the 3-meter size.

The situation is a little bit more flexible as the frequency goes lower, but 2500-2690 megahertz is the frequency band of interest in the United States, so we feel we are close enough to the bottom with our engineering model development to have substantially chosen the low-cost development about where it could be most attractive.

We have obtained preliminary estimates of what these stations would cost in quantity. The estimates are supplied by people who are in the production business, such as GE, Hoffman Electronics, others who make this kind of equipment in their normal business operations. In quantities of up to a thousand, the ground station of Figure 6 would run in the neighborhood of $500 emplaced. That's not a lot of money. It compares with the approximately $100,000 to $250,000 that one would have to pay for a 30-foot ground station to work television distribution with current commercial satellite designs of the domestic satellite variety that have been proposed. (Some cable operations could afford the more expensive approach but they would be operating still in the commercial satellite communication bands, not in the educational bands, so that is not relevant to our experiment.)

Figure 8 is a photograph of the NASA-developed engineering model of antenna electronics, showing the exterior or antenna unit and the indoor unit that is fed by the modulation converter on the antenna in both rear and front views.

Figure 9 shows the characteristics of the complete, experimental receiving system that we chose to do at 2.6 gigahertz, FM, 25-megahertz bandwidth, no tuning. It is a fixed, single-channel receiver.

The noise figure in the model we developed was 7 db. The 7 db can be achieved with a 39-cent transistor in the front end. A two-dollar transistor can be used to reduce the noise figure to 5 db. If one goes to more elaborate things such as an HP-21, the noise figure can be brought down to about 2 or 3 db but the cost of that device is $21. One can see where volume manufacturers might have difficulty coming to terms with that kind of component cost in the development and manufacture of low-cost systems.

Working with the experimental transmission capability of ATS-F, this set of characteristics leads to an output picture quality of 47 db CCIR weighted. This quality picture can be rebroadcast, can be redistributed, and will still yield a good deal better result than one is accustomed to on the home set most of the time. That quality is better than TASO-1. The experiment technical quality was designed this way deliberately because we do notwant the HEW-CPB experiment to be signal-limited. This is not typical of what one might approach or want to provide in an operational system, because the objective of the ATS-F experiments with HEW and CPB is not to show that we can communicate by satellite -- I think the Comsat/Intelsat system demonstrates that quite handily -- but to provide a capacity on which experiments of use can be conducted without complaints about the signal quality.

That summarizes the HEW-CPB experiments. They will be working with some 500 assorted towns, villages, cable headends and broadcasters. They will be experimenting in one-way and two-way education delivery, the kinds of programming that are effective, the methods of use or delivery that are effective, and how to mix CAI with more or less standard programming in audio/video.

The health people will be experimenting with off-campus professional education connecting the four medical schools in the region with advanced students at remote health stations for actual video instruction and,,in some cases, with two-way video remote diagnosis and prescription.

Figure 10 shows an artist's picture of the Communications Technology Satellite we are developing in concert with the Canadian government. This satellite is the first development inhthe 11-to-13 gigahertz band, where there is a larger application for broadcasting than in the instructional band at 2-1/2 gigahertz. The satellite will have the capability of providing one or two video channels sequentially across the country of Canada or, alternatively, across the entire United States, in a beam covering about 1/3 of the country at a time. We intend to launch it about the middle of 1975. Time for user experiments will be shared equally between the United States and Canada.

This satellite is intended not only to develop the technology, but to provide capacity for uses. Figure 11 lists the kinds of things we would like to demonstrate in making the satellite capacity available to interested users who wish to propose experiments.

The importance of this new development is that the band is available for both broadcasting and commercial satellite communication. At the 12 gigahertz frequencies one could conceivably work with an antenna as small as 2 feet in diameter and, once again, the development objective is to provide an inexpensive, relatively foolproof receiver that will stand up in remote regions and deliver a good quality signal.

Finally, since neither the ATS-F experiments nor the proposed experiments on the Communications Technology Satellite provide simultaneous, multiple-beam capability, it will become important to investigate the flexibility and the technology associated with the simultaneous coverage this capability could provide to different, geographically separate regions.

Figure 12 shows an artist's concept of one approach to multiple-beam capability that we are studying for possible launch by about 1977 or '78. The intent is to have as many as six beams which could be used simultaneously to cover the continental regions of the country, Alaska, and Hawaii; and to make available within each of those beams a number of channels. So this is, in a sense, the technology of the middle future in satellite communications. High power for multiple channels within a beam, multiple beams with footprints that are contoured to represent more closely the time zones, for example, or other geographical regions they wouldiilluminate and, again, for flexibility in experiments.

# BROADCASTING SATELLITE SERVICE

THIS IS A NEW SERVICE WHICH IS NOW DEFINED AS SHOWN BELOW:

MOD 84AP — Broadcasting Satellite Service

A radiocommunication service in which signals transmitted or retransmitted by space stations are intended for direct reception [(1)] by the general public.

ADD 84APA — Individual reception (In the Broadcasting Satellite Service)

The reception of emissions from a Broadcasting Satellite space station by simple domestic installations and in particular those possessing small antennae.

ADD 84 APB — Community reception (In the Broadcasting Satellite Service)

The reception of emissions from a Broadcasting Satellite space station by receiving equipment, which in some cases may be complex and have antennae larger than those used for individual reception, and intended for use:

- By a group of the general public at one location, or
- Through a distribution system covering a limited area.

ADD 84AP. 1 — [1]In the Broadcasting Satellite Service, the term "Direct Reception" shall encompass both individual reception and community reception.

NASA HQ EC72-15902 (1)
5-4-72



Figure 1

# BROADCASTING SATELLITE SERVICE

## Summary

THIS NEW SERVICE WAS DEFINED AND AUTHORIZED IN THE FOLLOWING FREQUENCY BANDS:

| | |
|---|---|
| 620 - 790 MHz | Footnote status with PFD * limits and qualifying footnotes |
| 845 - 935 MHz | Final protocol reservation permitting experimentation in India with PFD limits and qualifying footnotes |
| 2500 - 2690 MHz | Primary shared allocation, with PFD limits and qualifying footnotes |
| 11.7 - 12.2 GHz | Primary shared allocation, with qualifying footnotes limiting service to domestic systems in Region 2 |
| 12.2 - 12.5 GHz | Primary shared allocation, in Region 1 only with qualifying footnotes |
| 22.5 - $23^{0}$ GHz | Primary shared allocation, in Region 3 only, with PFD limits |
| 41 - 43 GHz | Exclusive allocation, world wide |
| 84 - 86 GHz | Exclusive allocation, world wide |

* Power Flux Density

NASA HQ EC72-15901 (1)
5-4-72



Figure 2

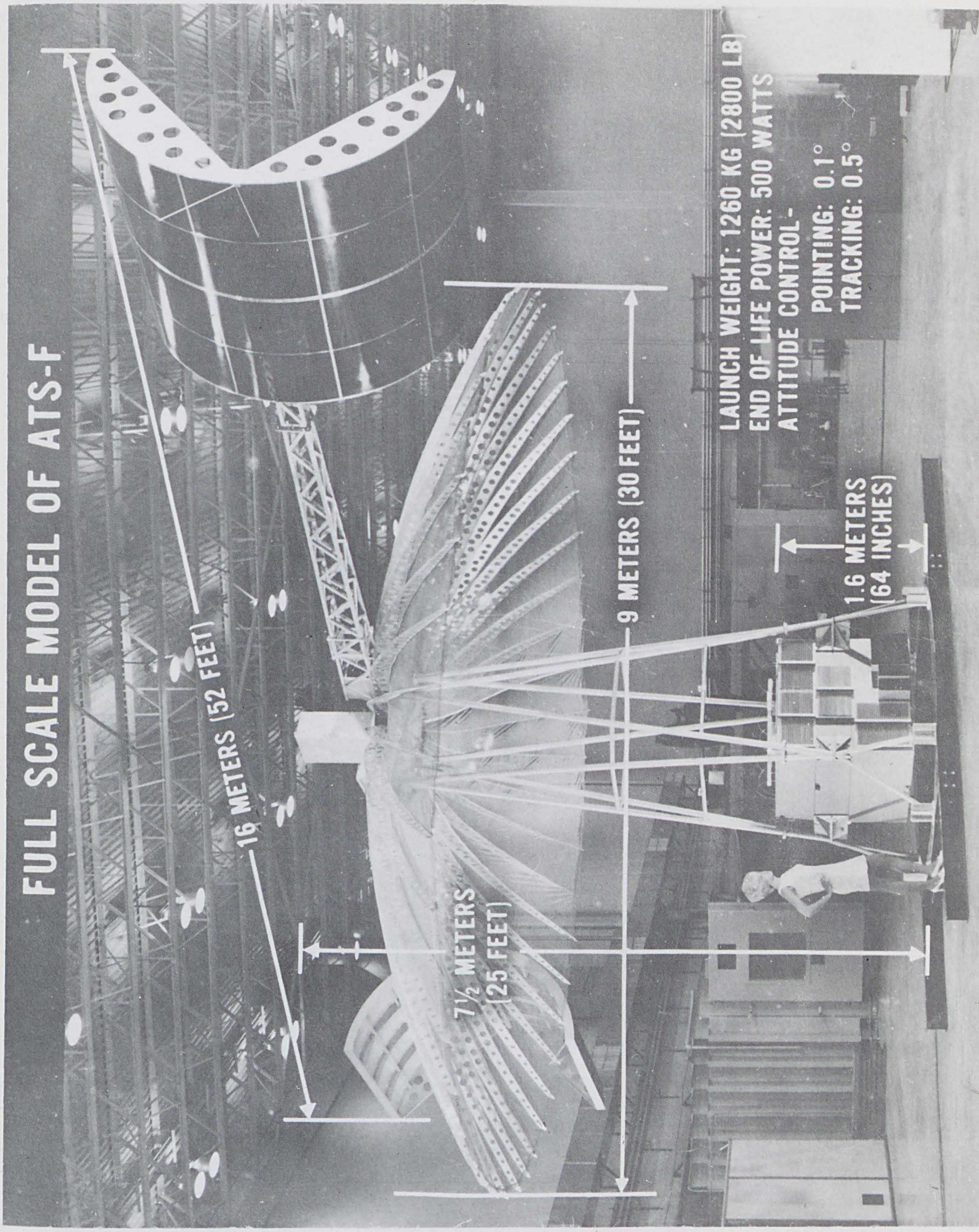
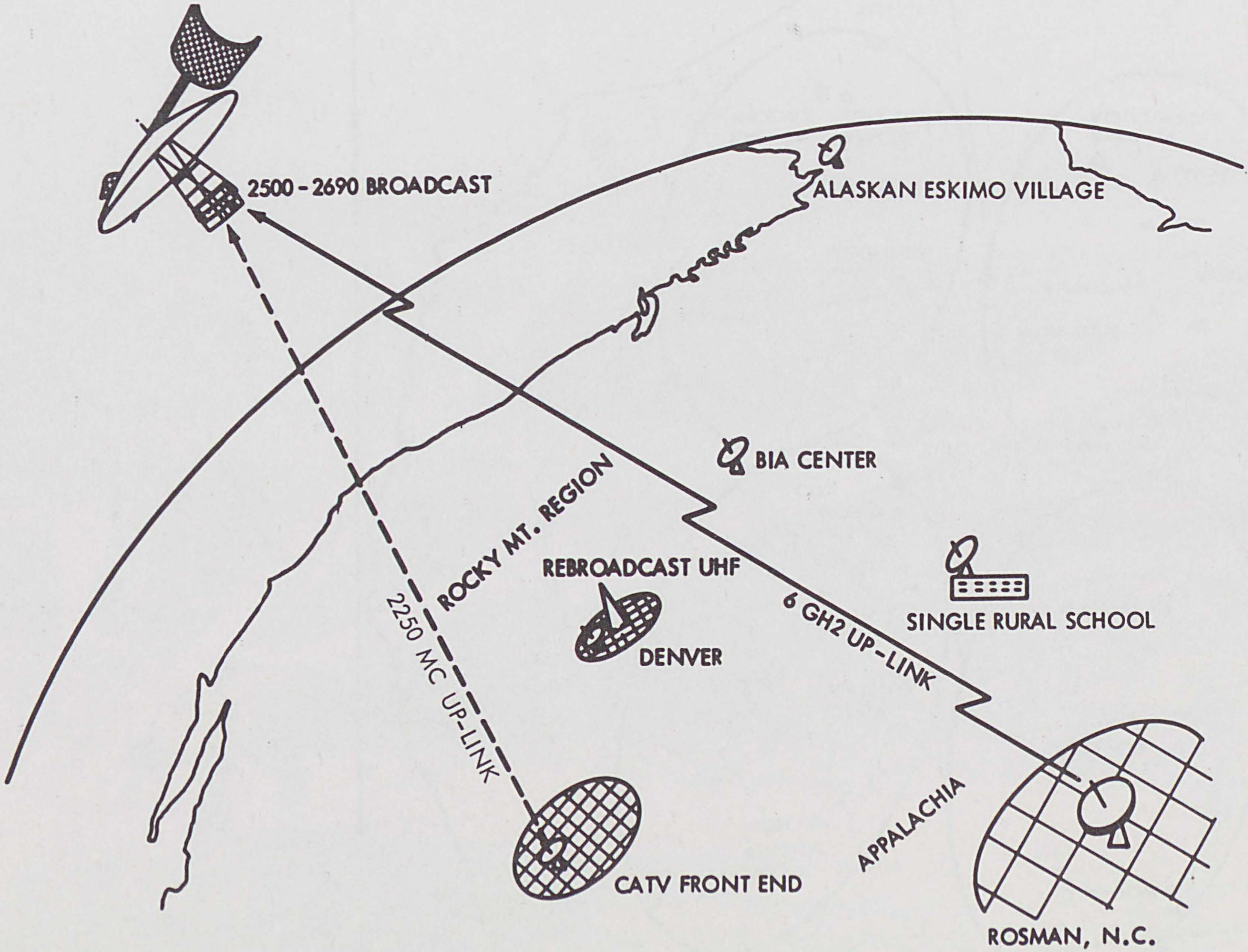



Figure 3

NASA EC72-4156 (2)
2-5-72

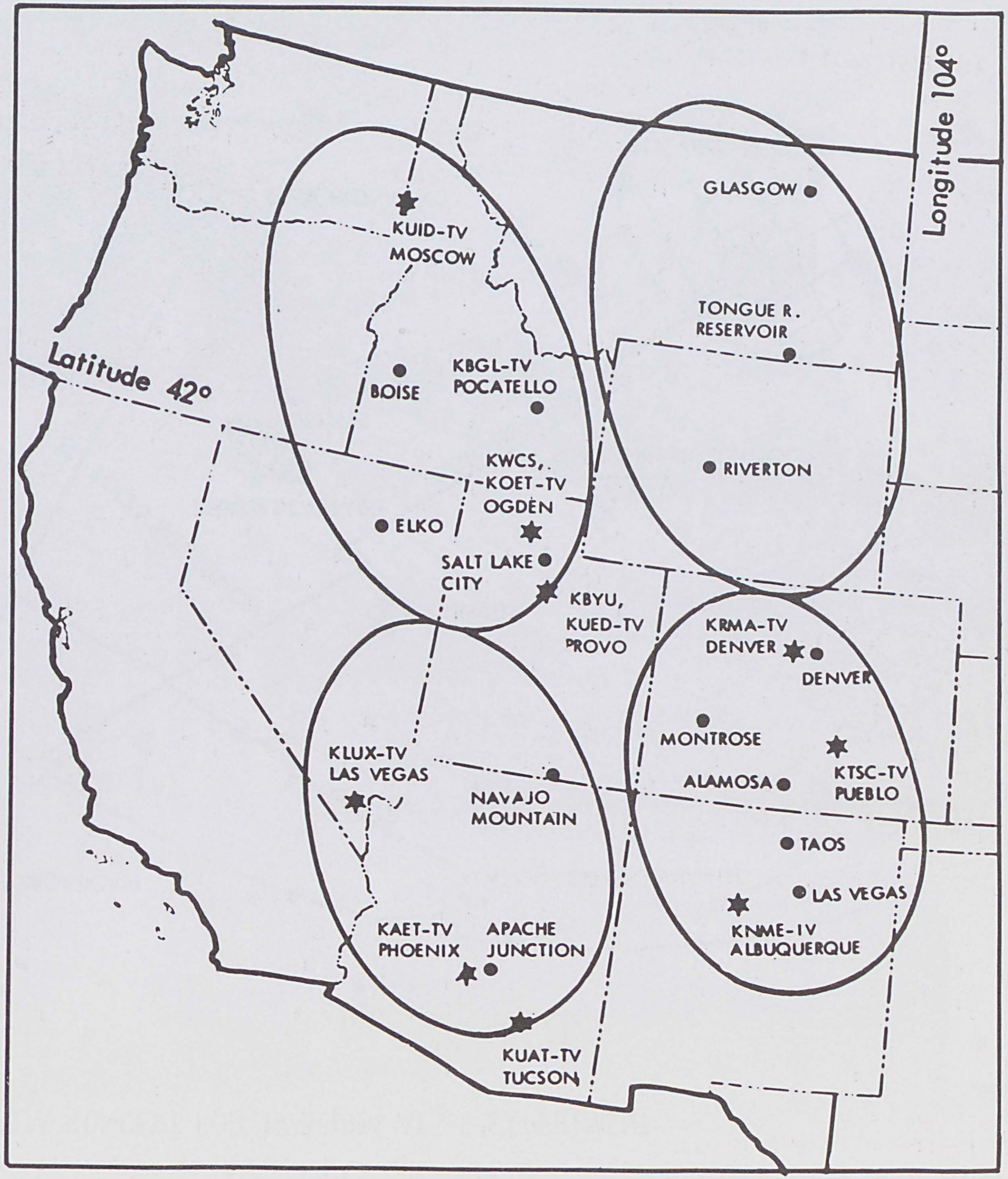
## SYSTEM CONCEPT FOR 1973-1974 ATS-F EXPERIMENT




NASA HQ EC72-15923 (1)
Rev. 6-8-72



Figure 4




NASA HQ EC72-15922 (1)
5-22-72



Figure 5

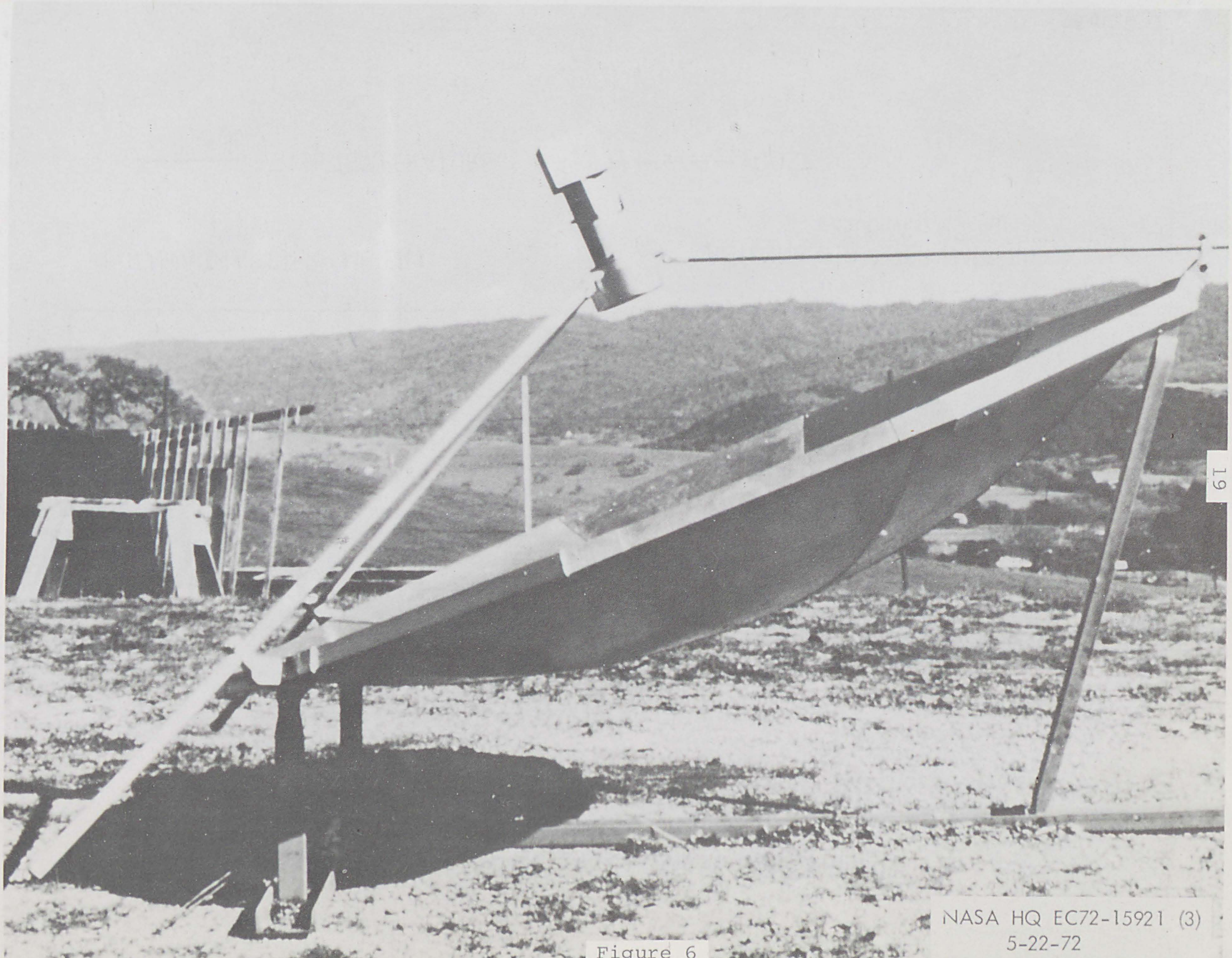



Figure 6

GROUND STATION COSTS, SYSTEM NOISE TEMPERATURE

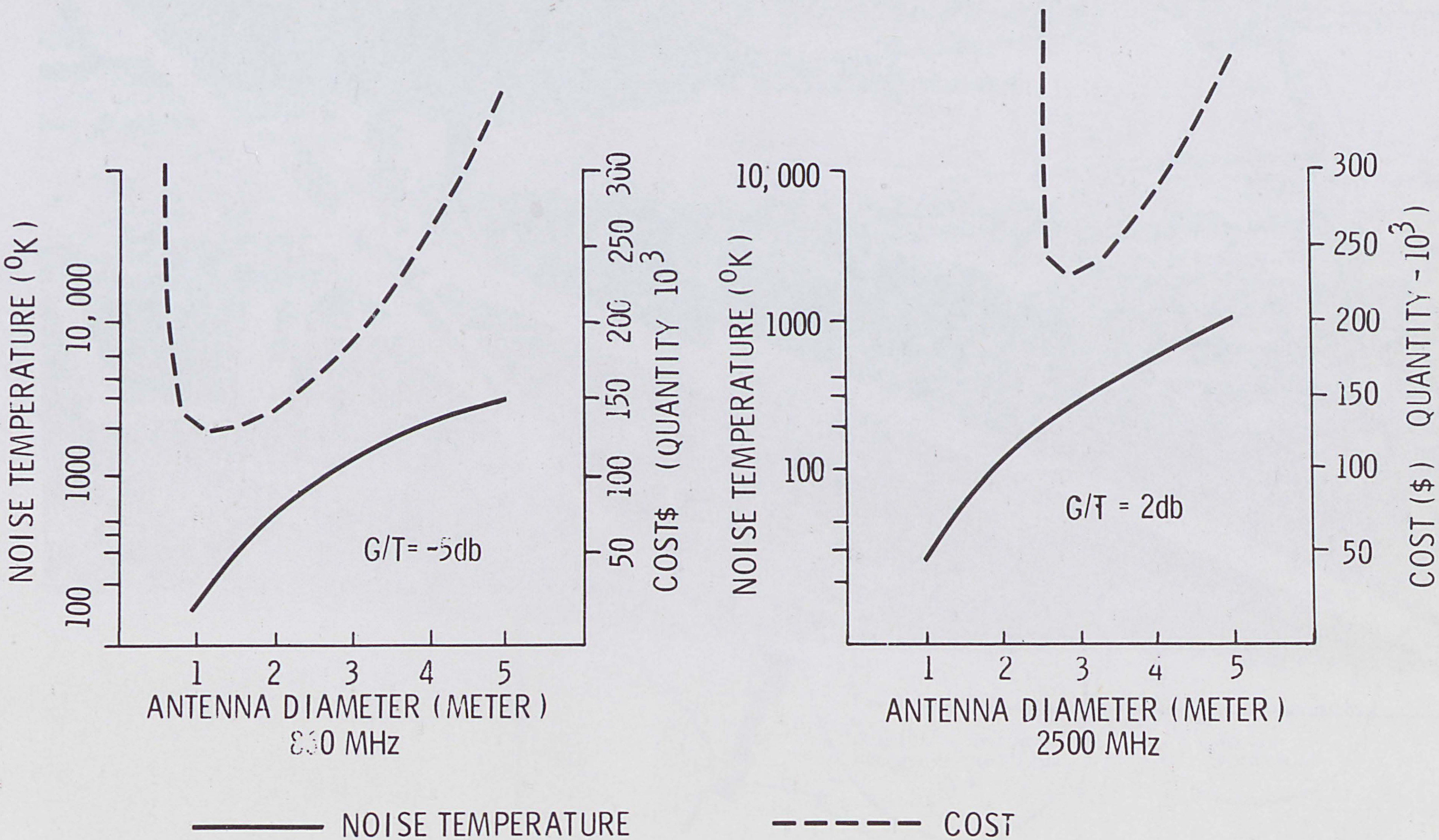





Figure 7

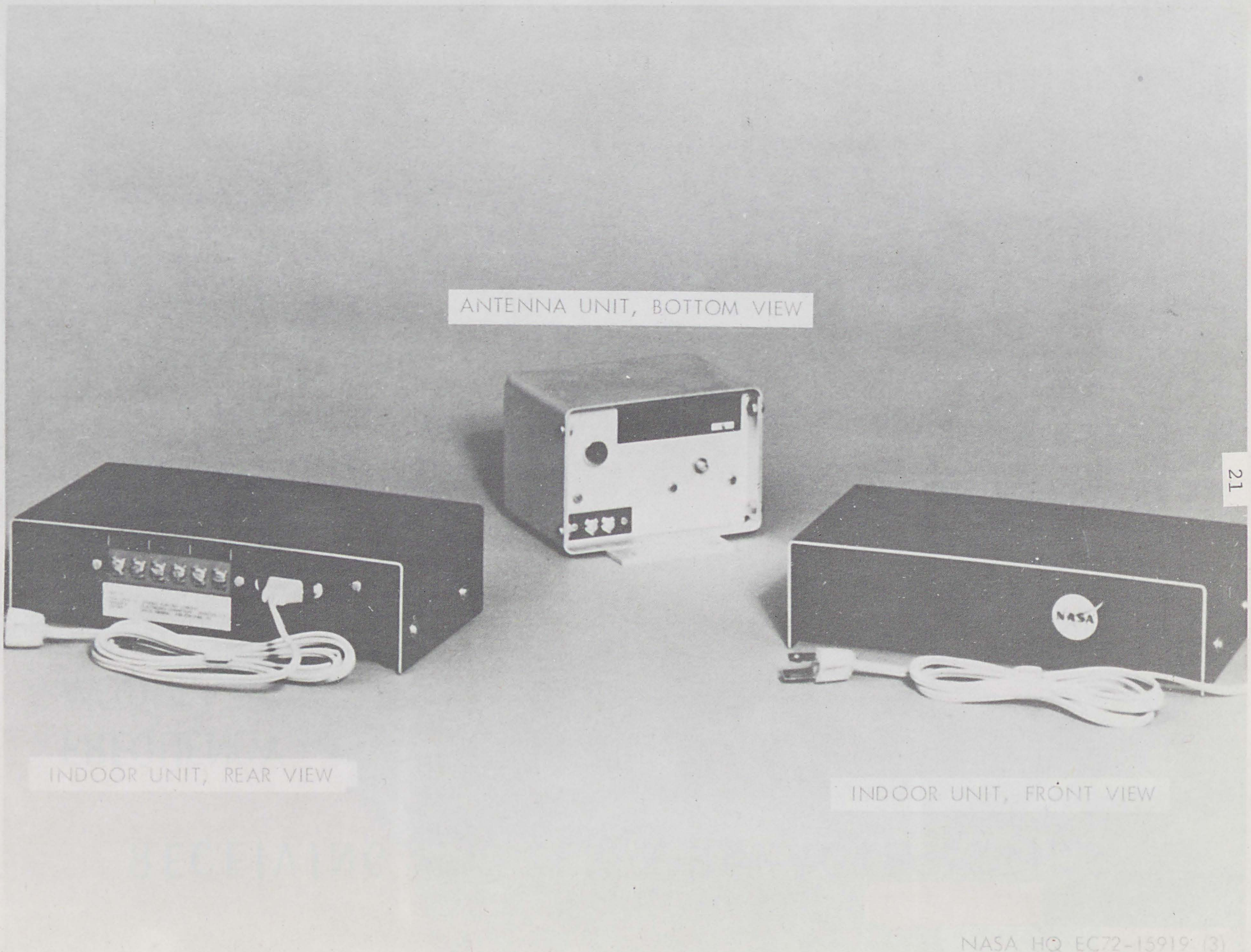

ANTENNA UNIT, BOTTOM VIEW
INDOOR UNIT, REAR VIEW
INDOOR UNIT, FRONT VIEW
NASA
NASA HQ EC72-15919 (3)
5-22-72

Figure 8

# RECEIVING SYSTEM CHARACTERISTICS

| | |
|---|---|
| FREQUENCY | 2.62 GHz |
| MODULATION TYPE | FM |
| SIGNAL BANDWIDTH | 25 MHz |
| RF TUNING | NONE |
| RECEIVER NOISE FIGURE | 7 dB |
| ANTENNA DIAM | 2.1 m (7 FT) |
| ANTENNA GAIN | 32 dB |
| ANTENNA EFFICIENCY | 55% |
| RECEIVING SYSTEM G/T | 0.4 dB |
| VIDEO S/N (CCIR WEIGHTED) | 47 dB (AT C/N = 15 dB) |
| RECEIVER OUTPUT | VHF/AM-VSB |



NASA HQ EC72-15925 (1)
5-22-72

Figure 9

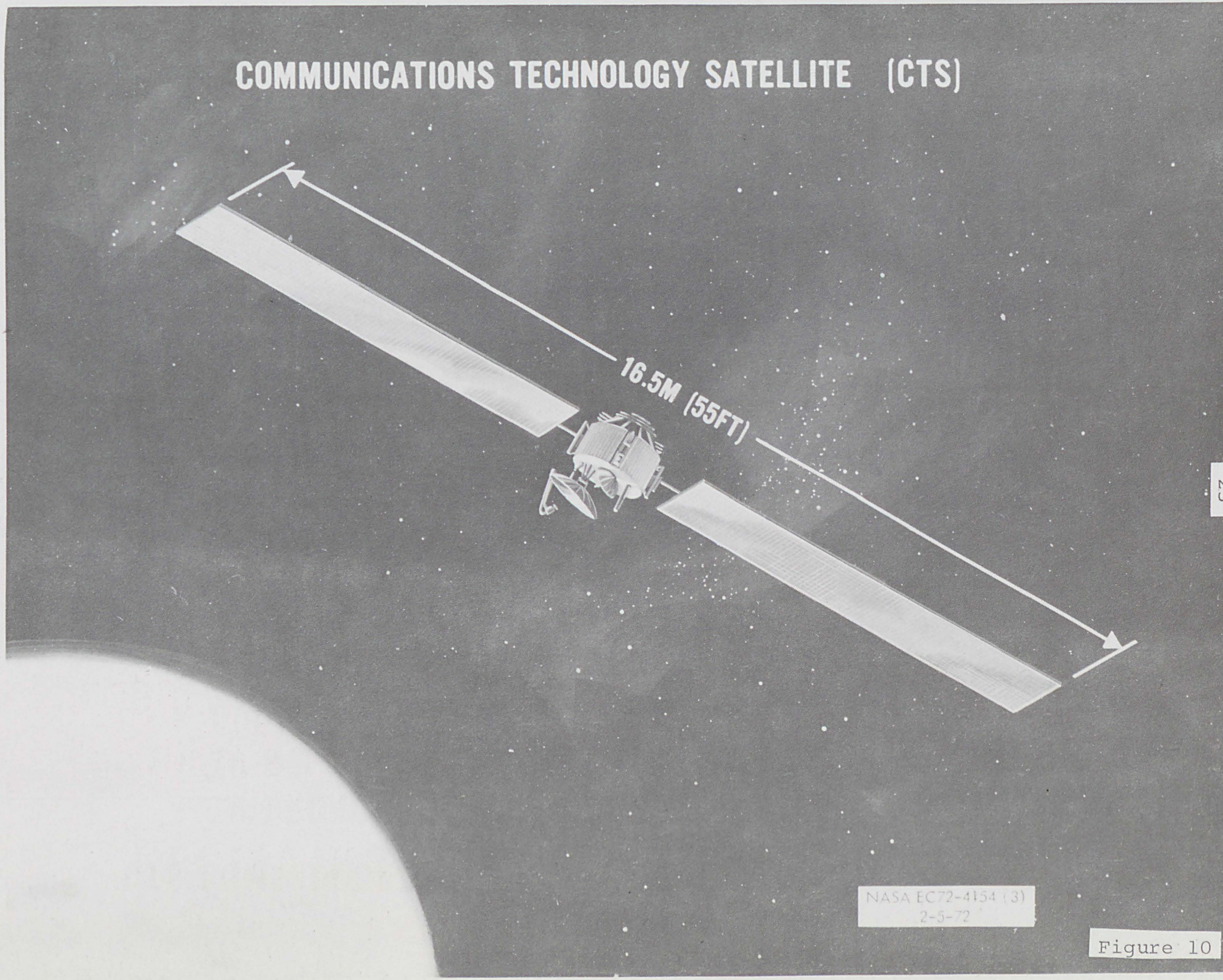

COMMUNICATIONS TECHNOLOGY SATELLITE (CTS)
16.5M (55FT)
NASA EC72-4154 (3)
2-5-72

Figure 10

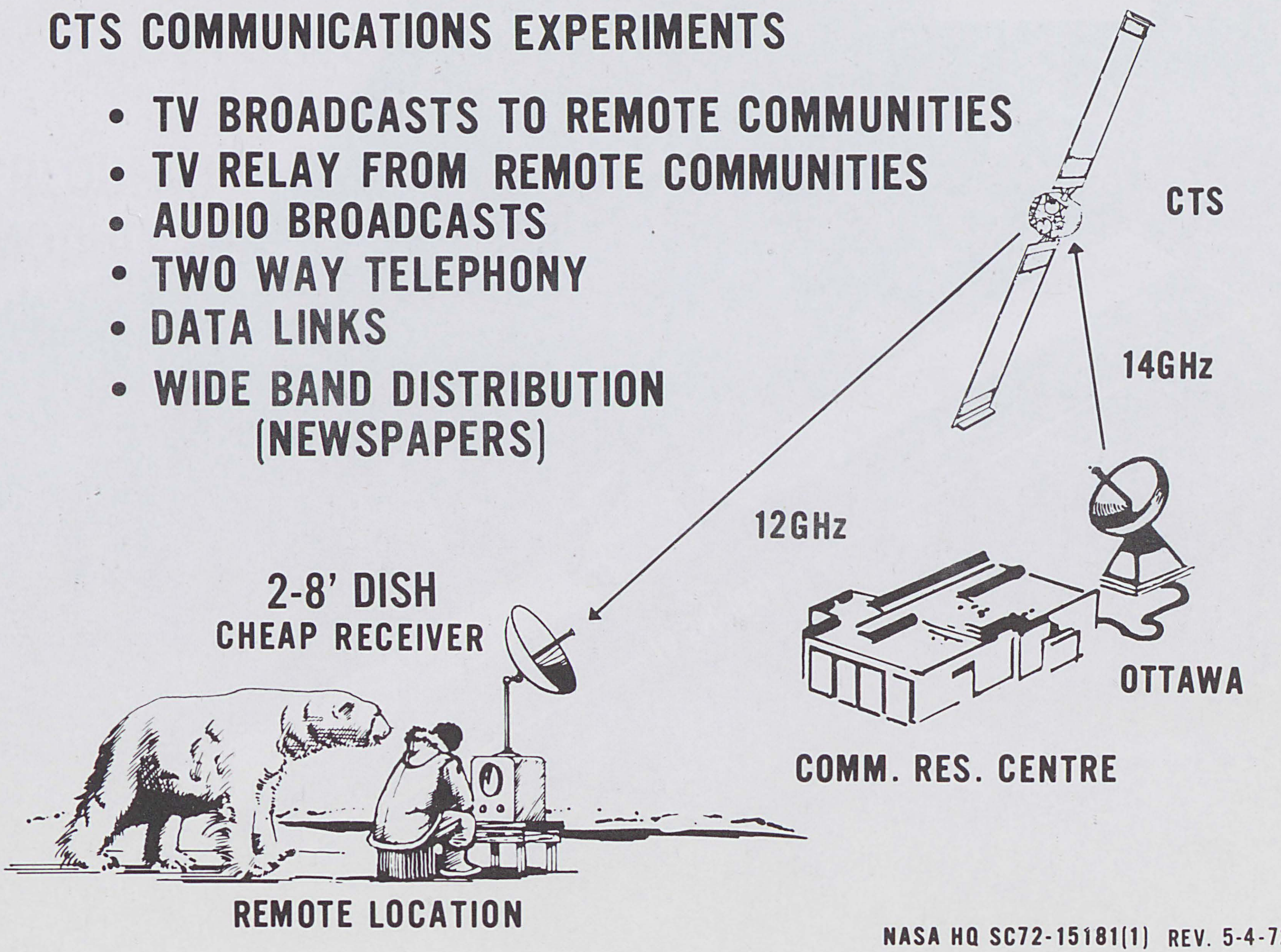
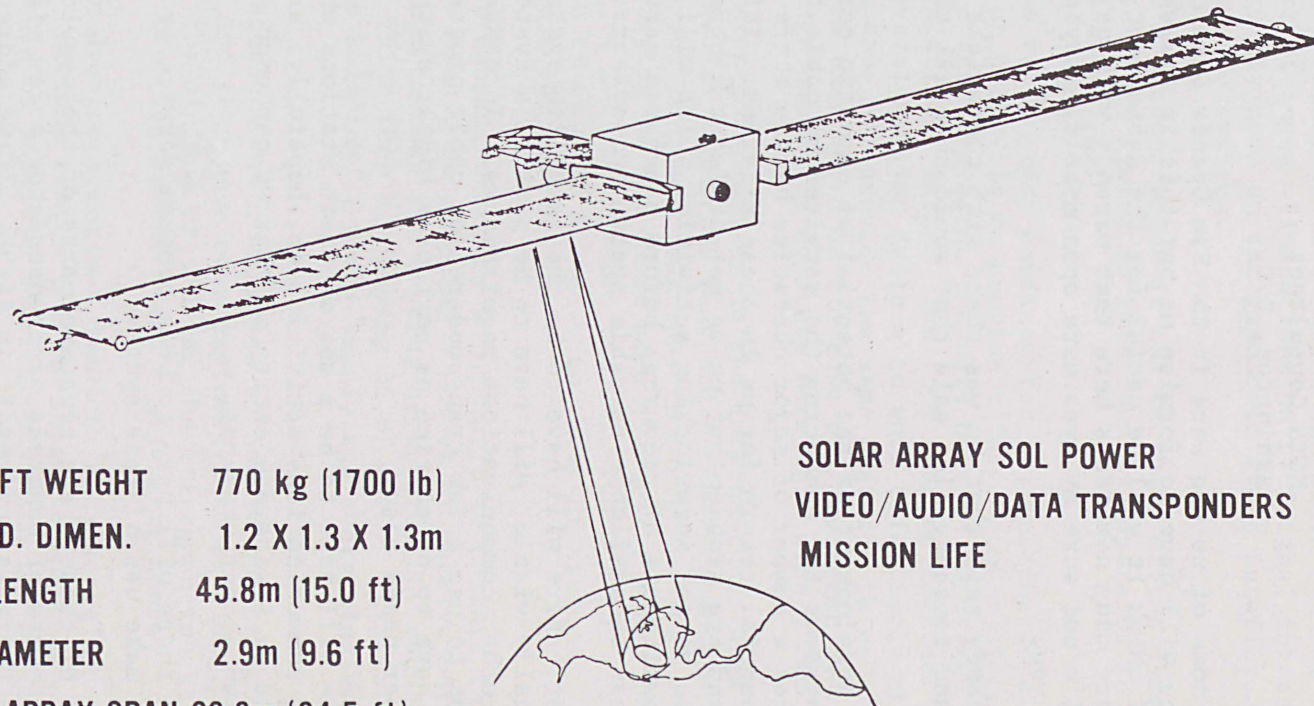

CTS COMMUNICATIONS EXPERIMENTS
• TV BROADCASTS TO REMOTE COMMUNITIES
• TV RELAY FROM REMOTE COMMUNITIES
• AUDIO BROADCASTS
• TWO WAY TELEPHONY
• DATA LINKS
• WIDE BAND DISTRIBUTION (NEWSPAPERS)
CTS
14GHz
12GHz
2-8' DISH
CHEAP RECEIVER
OTTAWA
COMM. RES. CENTRE
REMOTE LOCATION
NASA HQ SC72-15181(1) REV. 5-4-72

Figure 11

# ATS - ADVANCED MISSION SPACECRAFT II
## (Direct Ascent - SLV3D/Centaur D-1A/Burner II Launched)
## SUN ORIENTED



| | |
|---|---|
| SPACECRAFT WEIGHT | 770 kg (1700 lb) |
| EQUIP. MOD. DIMEN. | 1.2 X 1.3 X 1.3m |
| OVERALL LENGTH | 45.8m (15.0 ft) |
| FOLDED DIAMETER | 2.9m (9.6 ft) |
| EXTENDED ARRAY SPAN | 28.8m (94.5 ft) |

| | |
|---|---|
| SOLAR ARRAY SOL POWER | 5.5 kW |
| VIDEO/AUDIO/DATA TRANSPONDERS | 4 |
| MISSION LIFE | 2-5 YEARS |

NASA HQ EC72-15898 (1)
5-4-72

Figure 12