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NASA TECHNICAL MEMORANDUM

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TRENDS IN NASA COMMUNICATION SATELLITES

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ABSTRACT

Satellite telecommunications can help to satisfy several national needs such as education, health care, cultural opportunities, and data transfer. There are current experiments being conducted with NASA spacecraft ATS 1, 3, and 5 in an attempt to satisfy these national needs. Future experiments are planned for the ATS F/G and CTS spacecrafts. The next generation of communications satellites must provide multiple region coverage, multichannel capability, high quality TV pictures, and must allow low cost ground receivers to be used. The proposed NASA spacecrafts, ATS H/I, will satisfy these requirements. Other countries of the world can benefit from ATS H/I technology.

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SUMMARY

Telecommunications has the potential for providing significant assistance in the drive to satisfy a variety of national needs in the USA in the 1980's. These needs include education, health care, cultural opportunities and the efficient transmission of data over large distances. These future telecommunications systems will include both satellite and terrestrial segments and will have the capability of direct broadcast, networking and interactive communication. Before the requirements of such operational telecommunications systems can be firmly established, a period of experimentation with various modes of programming and information transfer is necessary. Currently, such experimentation is being done using the ATS 1, 3, and 5 spacecrafts. In 1974 and 1975 the ATS F/G and CTS spacecrafts will be launched and will be used to continue communications experiments.

The next generation of communications satellites must meet the following requirements: (1) multiple region coverage, (2) communications between regions, (3) multichannel capability, (4) high quality TV pictures, and (5) must allow the use of low cost ground terminals. A high power satellite (amplifier power of 1 kW or more) with an advanced antenna is needed to meet the requirements. The proposed NASA communications satellite ATS H/I meets the requirements. Not only can ATS H/I satisfy the communications needs of the United States, but it can also be used by one or more countries in other parts of the world to satisfy their communications needs.

INTRODUCTION

This paper discusses some of the national needs of the United States and indicates how communications satellites can help solve some of these needs. High power satellites that allow a significant expansion in communications capabilities as well as lower costs are a good way to satisfy the national needs. NASA's proposed communications satellites ATS H/I has been designed to meet these needs.

Satellite telecommunications has received considerable attention and is certainly not new. However, the application of satellite telecommunications capability in an effort to provide for national needs other than those associated with the business activity of a country is new.

Many of the major problems facing the USA and certainly many nations throughout the world stem from the inadequacy of education, health care services and cultural opportunities due to uneven population distribution. As a national goal, therefore, the USA is striving to provide adequate educational and health care opportunities for all. But, to provide adequate services for all the population regardless of where the people reside can place an enormous and perhaps impossible burden on available resources. It is imperative that innovations in service delivery be utilized in order to accomplish the goals within the limits of the resources available.

Recent studies have indicated (refs. 1 to 3) that telecommunications, in general, and satellite communications, in particular, can be instrumental in the mitigation of the problems indicated. In addition, these same studies have also indicated that satellite communication systems can also provide economic benefits in the transmission of large amounts of data such as would be required by an electronic mail handling system.

Although massive terrestrial telecommunications networks exist throughout the USA, the demands continue to exceed the capability. In addition, there are large geographical areas, such as Alaska, where telecommunications capabilities are primitive by national standards. The growth of these regions, both culturally and economically, will be limited until adequate communication systems are provided. Communication satellites offer particularly attractive means for providing a timely and cost effective solution to the communications need. It would appear that the same conclusions could be drawn on an international scale for many underdeveloped nations.

There are many commercial satellite system options available to communications users throughout the world. The international INTELSAT system is perhaps the best known. However, many countries are seriously considering domestic satellites to serve the specific needs of their country. Seven separate proposals have been made by private industry to provide domestic satellite service in the USA. Canada will be launching a domestic communications satellite this fall. NASA has provided much of the technology upon which these systems were based. Most of this effort has been documented elsewhere and this paper will not address itself to this type of service. The paper will discuss NASA's trends in advanced experimental communications satellites and indicate how their capabilities will be dictated by the needs to be fulfilled.

NATIONAL NEEDS

Some of the more important national needs of the USA are:

- Education
- Health Care
- Cultural Opportunities/Public Broadcasting
- Data Transfer
  - Electronic Mail Handling
  - Remote Printing of Newspapers
- Technology Transfer

This list is certainly not unique. Inadequate educational and health care opportunities do exist in the USA as a result of the significant segment of the population that reside in rural communities and remote areas. This is, of course, particularly true in the regions of Alaska and to some measure in the Rocky Mountain states and Appalachian mountain region. The islands of Hawaii present a unique problem of communication. Cultural opportunities are also inadequate in these regions.

Our modern society seems bent on the generation of paper and data in all forms along with a desire to send this proliferation of work over long distances so that data transfer requires a major investment in labor and resources. The use of electronic mail handling and similarly the remote printing of newspapers may offer significant cost savings.

An area of concern in this world where new technology is being developed at an ever increasing rate is the gap between the time when new technology is available and when it is effectively applied. In the USA over 95 percent of the new technology is generated at the federal levels of government with the remainder at state and local levels. However, solutions to most of the problems discussed here are the responsibility of state and local governments and hence the urgent need to transfer the advancement in technology to those who need it most. A similar situation exists between the highly developed nations and the developing nations.

CURRENT ROLE OF SATELLITE TELECOMMUNICATIONS

In general, a satellite system consists of a ground transmitter where a message originates, a satellite which acts as a repeater and amplifier of the signal, and a ground receiver. There are several modes in which the communications user can make use of the satellite. He can receive the signal directly from the satellite as shown in figure 1. This could provide educational television to remote communities, schools, and homes.

Where there is an existing terrestrial system, such as in urban areas, the transmissions can be received at a particular location and redistributed through the existing network to the user (fig. 2). An example of this kind of networking is cable television.

A third type of communications service is shown in figure 3 where two-way transmission capability between users is provided, for example. This kind of service could be used for remote medical diagnosis.

TELECOMMUNICATION EXPERIMENTS

NASA has three experimental communications satellites in synchronous orbit at this time. They are called Applications Technology Satellites or ATS. ATS-1 is positioned over the Pacific Ocean. ATS-3 and ATS-5 are in orbit over the Atlantic Ocean. A picture of the ATS-3 satellite, which is typical of 1 and 5 also, is shown in figure 4. It is a relatively small satellite weighing 750 pounds and has an earth coverage antenna system on board.

Several satellite communication experiments are being conducted using these satellites, some of which are listed in table I. In Alaska medical instruction and emergency medical services are being provided using two-way voice communications via ATS-1. Experiments in voice broadcast for education and public broadcasting are also being conducted. In Hawaii two-way voice communications are used to link Hawaiian universities also via ATS-1. This experiment has been extended to include other universities in the Pacific area. Other experiments for the National Bureau of Standards, Federal Aviation Administration and the Federal Maritime Commission are being conducted using ATS-3 and ATS-5.

The next satellite in the NASA Applications Technology Satellite series will be launched in 1974. A picture of this satellite, ATS F, is shown in figure 5. This is a much bigger satellite weighing about 2500 pounds and dominated by a very large antenna. This satellite will allow television transmission along with voice to be used in the conduct of experiments. The earth coverage capability in the USA of this satellite is shown in figure 6. In addition to experiments conducted in the USA, this satellite will also be used in the India telecommunications program. The coverage capability for India is shown in figure 7. Virtually all of India will be served during the 1-year program.

Another advanced Communications Technology Satellite called CTS (shown in fig. 8) is currently being developed in a joint Canadian/USA program. This satellite will provide additional experimental communications capability starting in 1975. The earth coverage capability of this satellite is shown in figure 9.

The type of communications experiments planned for these new satellites is shown in table II. For ATS F an educational television experiment will be conducted in the Rocky Mountain region. Direct satellite broadcasting will be used to provide educational television programming to 300 to 500 remote receive terminals. This will permit the evaluation of ETV as an educational aid for rural communities.

After the Rocky Mountain experiment, the satellite will be moved from 94° W longitude to 35° E longitude so that the India instructional television experiment can be conducted. This experiment will provide instructional television to 5000 villages throughout India. About 3000 direct receive units will be used along with 2000 conventional TV sets. The important element of this test is the use of low cost direct receive terminals which allows widespread coverage at a manageable cost.

The Canadian/USA satellite will extend the experimentation in Canada and the USA in both education and health care. Again, the goal is to evaluate the use of satellites in conjunction with low cost receive terminals for use in remote regions.

It should be noted that the experiments are limited in scope and coverage. In the future, more extensive telecommunications capability is required for experimentation. NASA and the users are currently in the planning stages for these follow-on experiments.

FUTURE NEEDS

The kinds of characteristics that are envisioned for future satellites to meet user needs are as follows:

(a) Multiple Region Coverage - The ability of the satellite to illuminate specific areas of the earth very precisely with simultaneous broadcast capability to selected specific areas.

(b) Communications Between Regions - There is a need for transmission of TV and data both to a particular region as well as interconnects between regions.

(c) Large Numbers of Ground Terminals - A very important requirement, particularly in the remote areas of the country, is the provision of large numbers of low-cost ground terminals capable of receiving direct broadcasting from the satellite. This is necessary for an economically viable system.

(d) Multichannel Capability - Future needs will likely expand such that diverse programming will be required. For example, educational and instructional programming as well as health services will require many information channels.

(e) High Quality TV Pictures - There will be a need for a high quality reliable signal.

The kinds of coverage patterns contemplated are shown in figure 10. These footprints are concentrated for the most part in the mountainous areas of the continental USA plus Alaska and Hawaii. The satellite can be moved to cover other areas if required. Simultaneous transmission to all four areas with two to three television channels is planned.

To a large extent the success of these future telecommunications satellites will depend on the ability of people to receive the signal. This will require large numbers of low cost ground terminals. The kind of ground terminal that is envisioned is shown in figure 11. It consists of a 7' antenna connected to a small box which processes the signal such that it can be received on a conventional TV set. The cost of this receiver in quantities of 1000 is estimated to be \$3000- \$4000.

The requirement for low cost ground receivers has a major impact on the satellite power level as shown in figure 12. The trends in satellites have been in the direction of higher and higher power. The first geostationary satellite, SYNCOM, was associated with very large antennas and ground receiver costs of over a million dollars because the satellite power was low. The direction has been, therefore, toward higher power satellites to minimize ground receiver costs. The present commercial satellites are associated with ground receiver costs of 10's of thousands of dollars. In contrast, for the planned and future satellites ground receiver costs will be a few thousand dollars. The trend in future satellites, therefore, is toward higher powers.

The amount of information to be communicated is increasing steadity. At the same time, the present radio frequencies are being used up. For these reasons, higher frequencies will be utilized in the future communications systems.

A spacecraft that will meet the requirements outlined above is the ATS H/I. It is shown in figure 13. It also has the capabilities of:

(1) Generating large electrical power.

(2) Remaining stationary over a single point on the earth.

(3) The ability to be moved from one position to another to cover various segments of the earth.

(4) The spacecraft is approximately 100 feet long - antenna diameter 8 feet.

INTERNATIONAL APPLICATIONS

There are also international applications for these advanced satellites. Typical possibilities for coverage of South America are shown in figure 14. Precise area coverage of any country can be provided as shown with separate programming on a noninterference basis. With proper positioning of the satellite, any continent can be covered. Another example is Africa (fig. 15).

CONCLUSIONS

Important national needs, such as education, health care, cultural opportunities, and data transfer can be significantly satisfied by telecommunications. And communications satellites are a cost-effective method of providing the needed telecommunications. There are several modes in which the communications user can make use of the satellite: direct broadcast, redistribution, and interactive.

The ATS 1, 3, and 5 spacecrafts are currently being used for education and health care and other experiments. In the near future, the ATS F and CTS spacecrafts will be available to continue and expand experiments of this kind. For example, ATS F will be used to broadcast instructional television to 5000 remote Indian villages.

The next generation of communications satellites must provide multiple region coverage, multichannel capability, high quality TV pictures, and must allow low cost ground receivers to be used. A high power satellite (amplifier power of 1 kW or more) with an advanced antenna is needed to meet the requirements. The proposed ATS H/I satellites meet these requirements. The technology developed for ATS H/I can also be utilized by other countries of the earth to satisfy their communications needs.

REFERENCES

1. Morgan, R. P.; and Singh, J. P.: Program on Application of Communications Satellites to Educational Development. Washington Univ. (NASA CR-124724), Nov. 16, 1971.

2. Dysinger, J. H.; Foster, D. E.; and Haviland, R. P.: An Investigation of Network Television Distribution Satellite Systems. Vol. 1 - Summary Report. Prepared for Public Broadcasting Service by General Electric Co., Space Div., Space Systems Organization, Feb. 1971.

3. Dei Rossi, J. A.; Heiser, R. S.; and King, N. S.: A Cost Analysis of Minimum Distance TV Networking for Broadcasting Medical Information. Rep. RM-6204-NLM, The Rand Corp., Feb. 1970.

ALASKA

MEDICAL INSTRUCTION & EMERGENCY COMMUNICATIONS
2-WAY VOICE BY SATELLITE
ATS-1

EDUCATION & NATIONAL PUBLIC RADIO
DIRECT BROADCAST OF VOICE
ATS-1

HAWAII

EDUCATION - COMMUNICATIONS BETWEEN UNIVERSITIES
2-WAY VOICE BY SATELLITE
PEACESAT - EXPANSION TO INCLUDE PACIFIC UNIVERSITIES
ATS-1

NATIONAL BUREAU OF STANDARDS

RELAY OF PRECISION TIMING TO U.S.A.
DIRECT BROADCAST BY SATELLITE
ATS-3

FEDERAL AVIATION AGENCY

POSITION LOCATION OF AIRCRAFT VIA SATELLITE
ATS-5

FEDERAL MARITIME COMMISSION

POSITION LOCATION & DATA TRANSFER FOR SHIPS
ATS-5

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Table I. - Ongoing Telecommunications Experiments.

Table I

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ROCKY MOUNTAIN STATES

EDUCATIONAL TELEVISION
SATELLITE BROADCAST TO 300-500 REMOTE TERMINALS
ATS-F SATELLITE (MID-1974 LAUNCH)

INDIA

INSTRUCTIONAL TELEVISION (FAMILY PLANNING, FARMING, ETC)
SATELLITE DISTRIBUTION TO 5000 VILLAGES
ATS-F SATELLITE

CANADA

EDUCATION & HEALTH CARE BY TELEVISION
SATELLITE TRANSMIT & RECEIVE TO REMOTE TERMINALS
CTS SATELLITE (MID-1975 LAUNCH)

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Table II. - Future telecommunications experiments.

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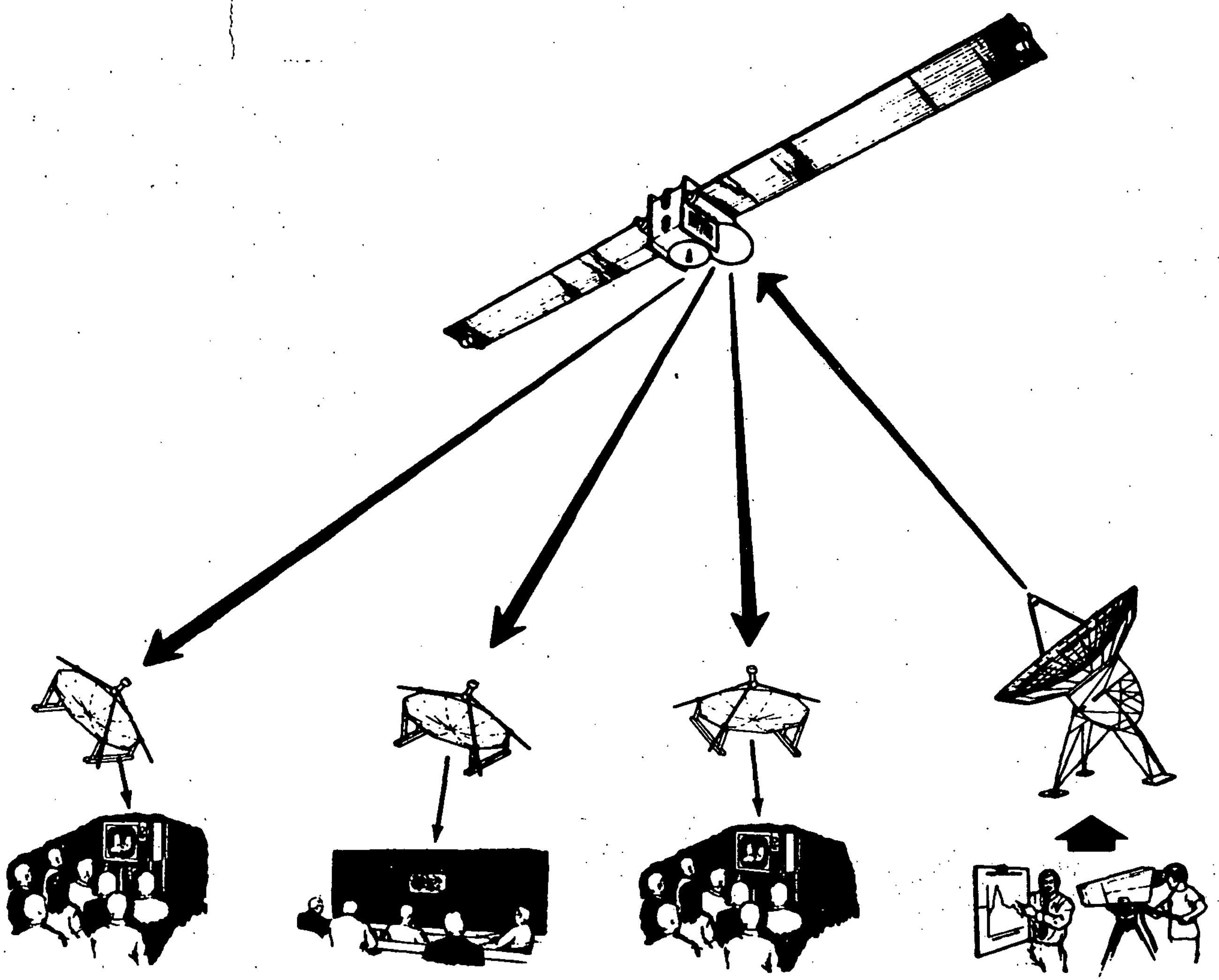

Figure 1. - Broadcast mode.

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Figure 1.

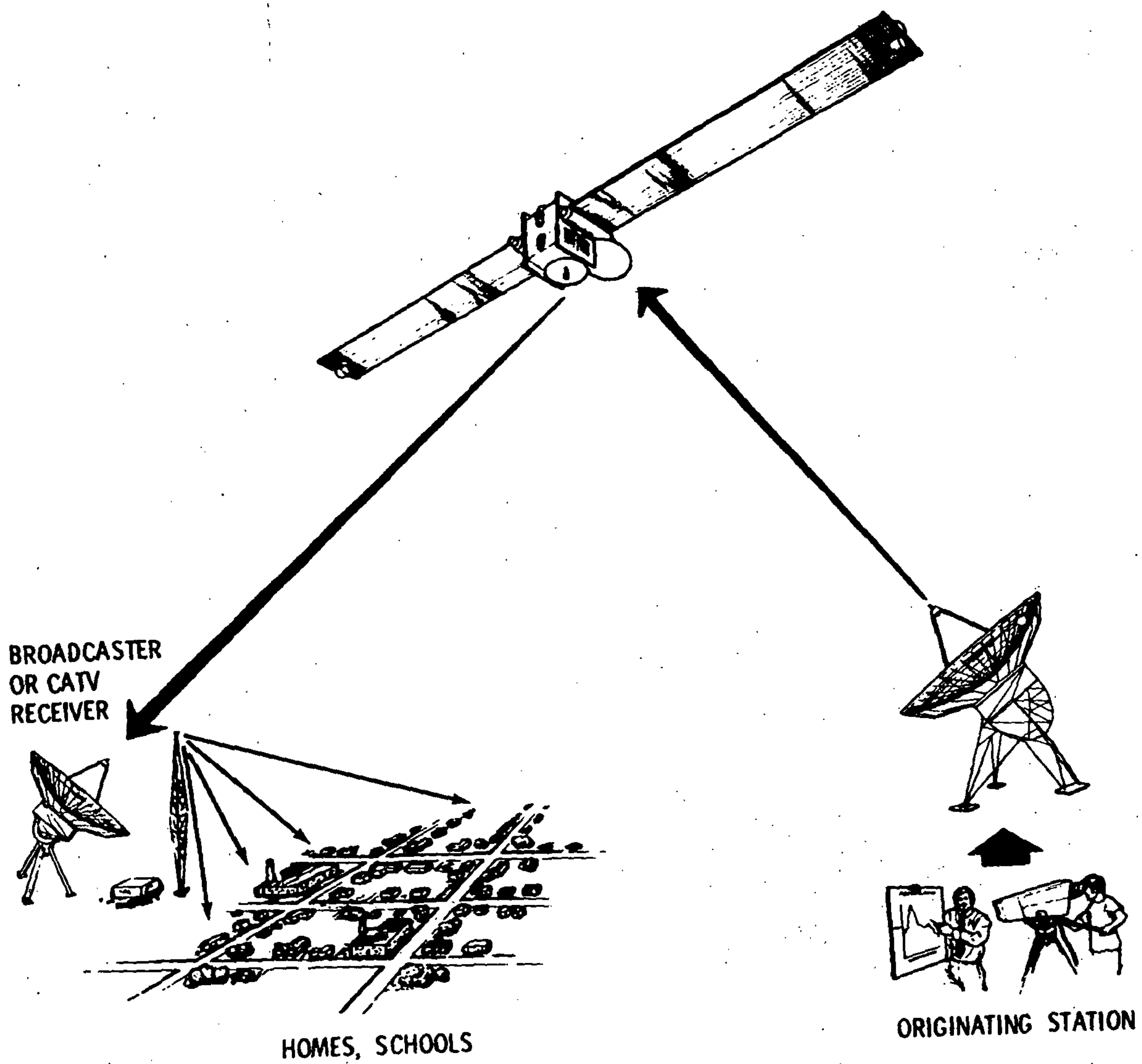

Figure 2. - Distribution mode.

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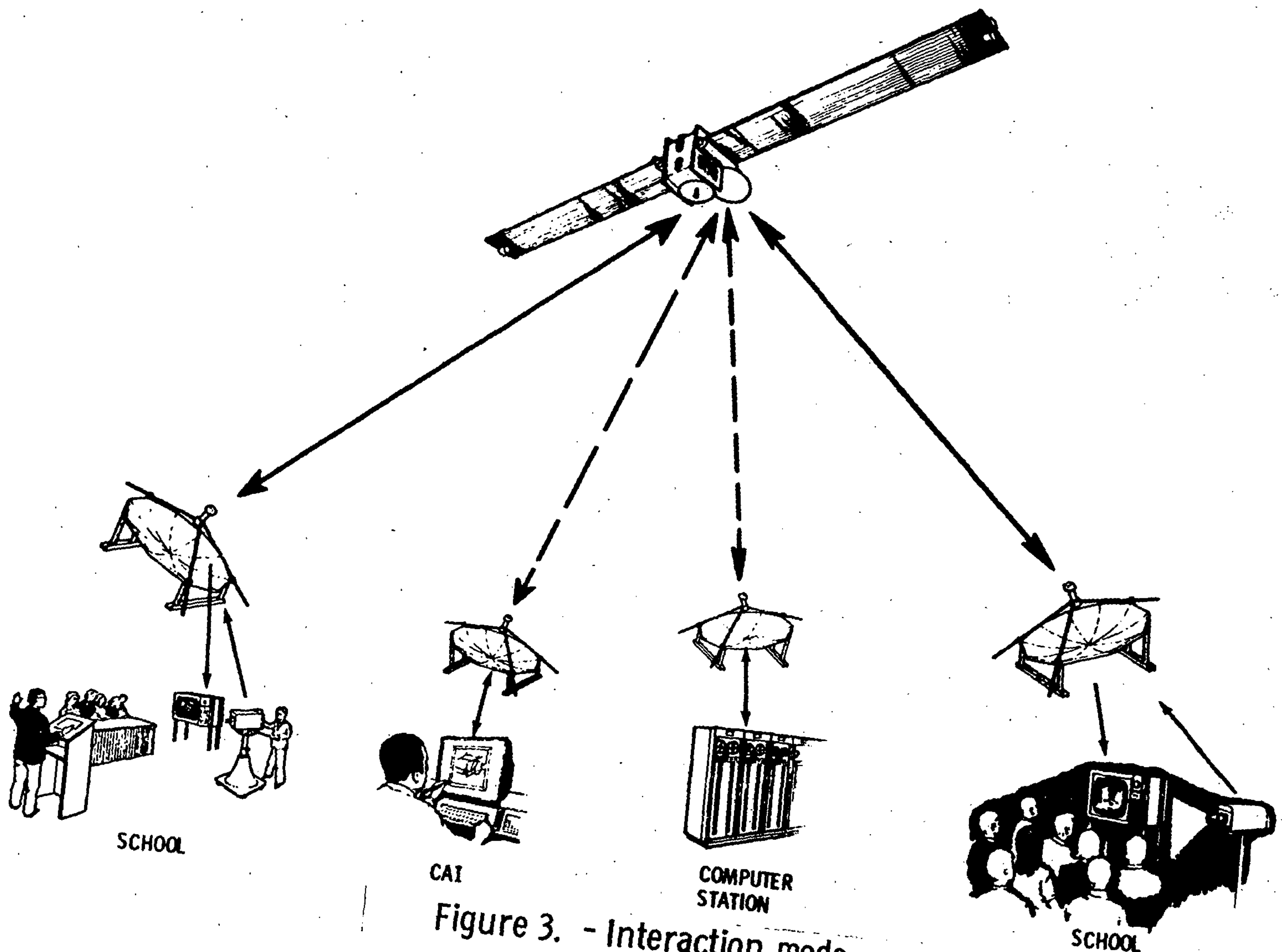

Figure 3. - Interaction mode.

Figure 3.

E-7144

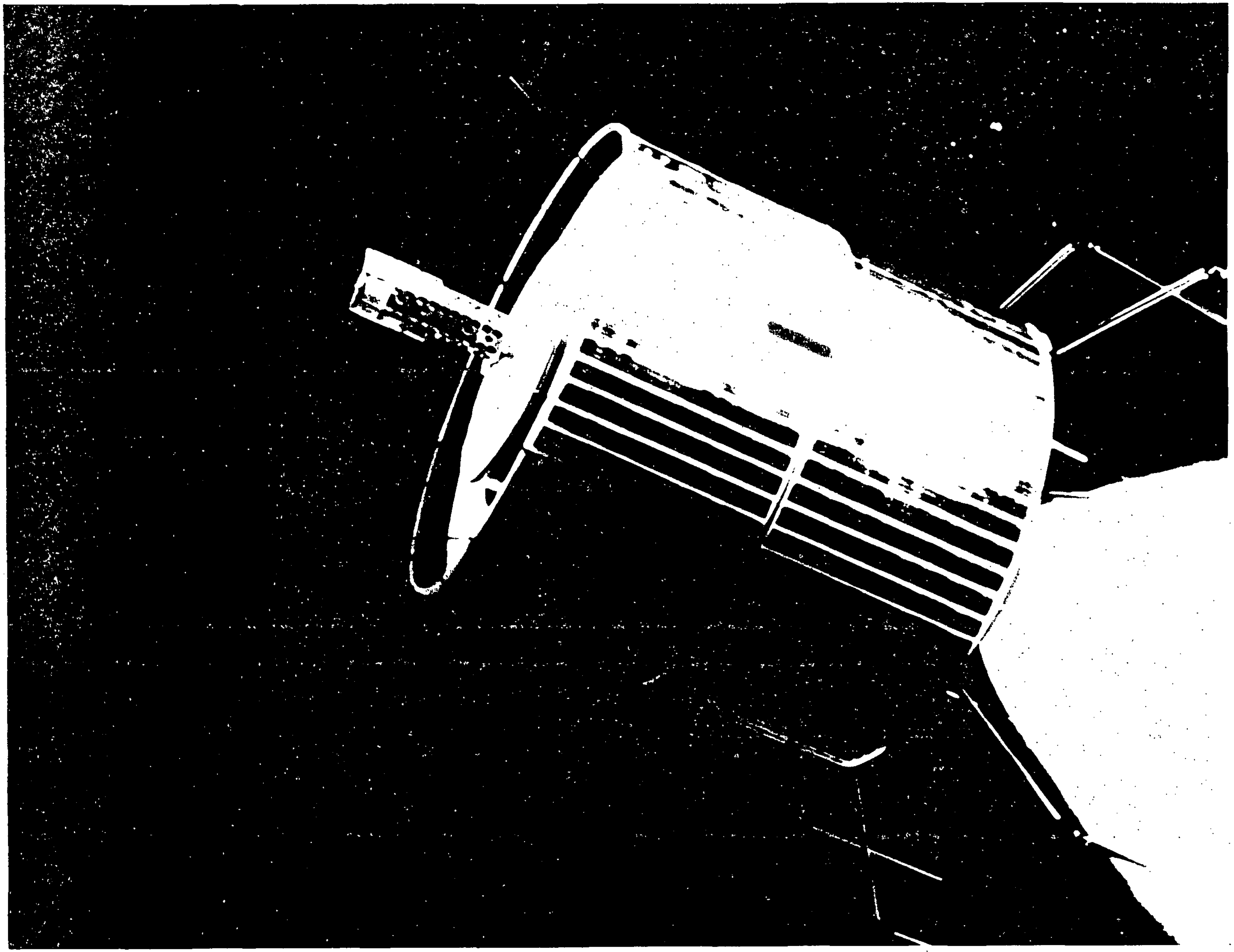

Figure 4. - Applications Technology Satellite - 3.

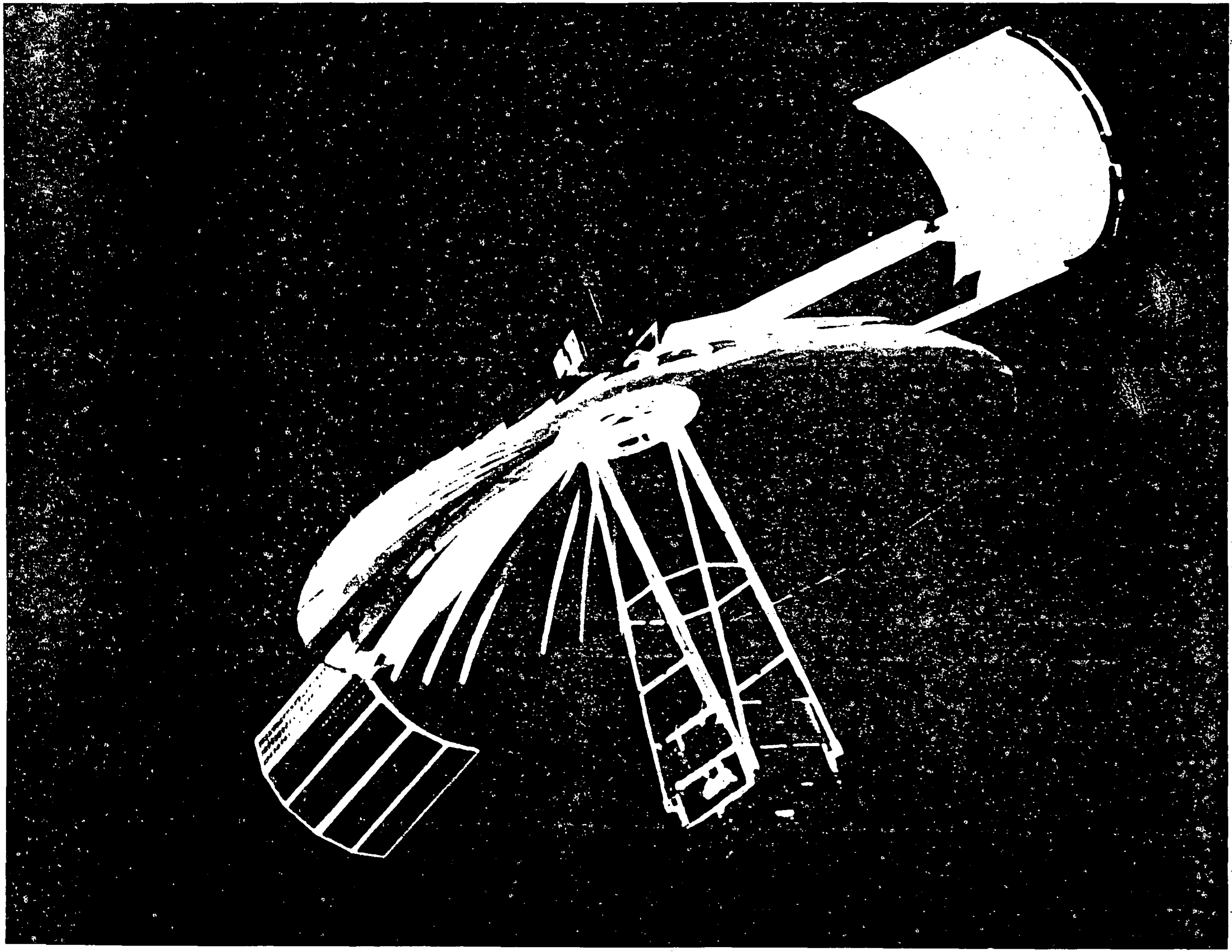

Figure 5. - Applications Technology Satellite -F.

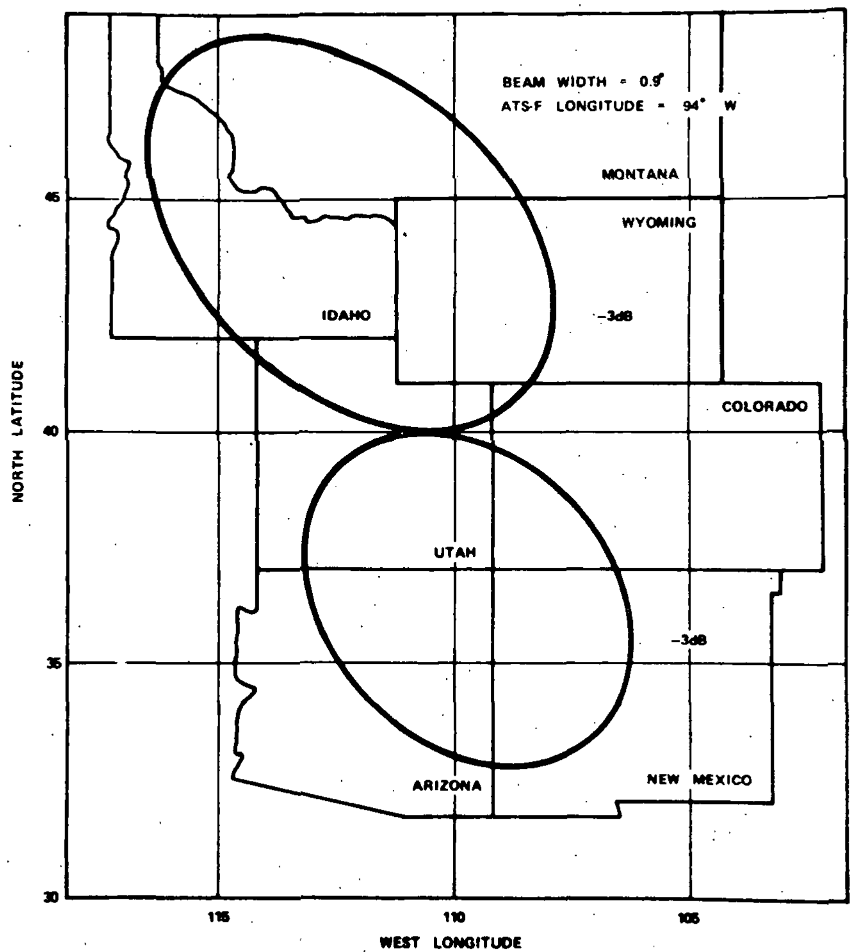

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Figure 6. - Antenna beam coverage of ATS F; Rocky Mountain States ETV.

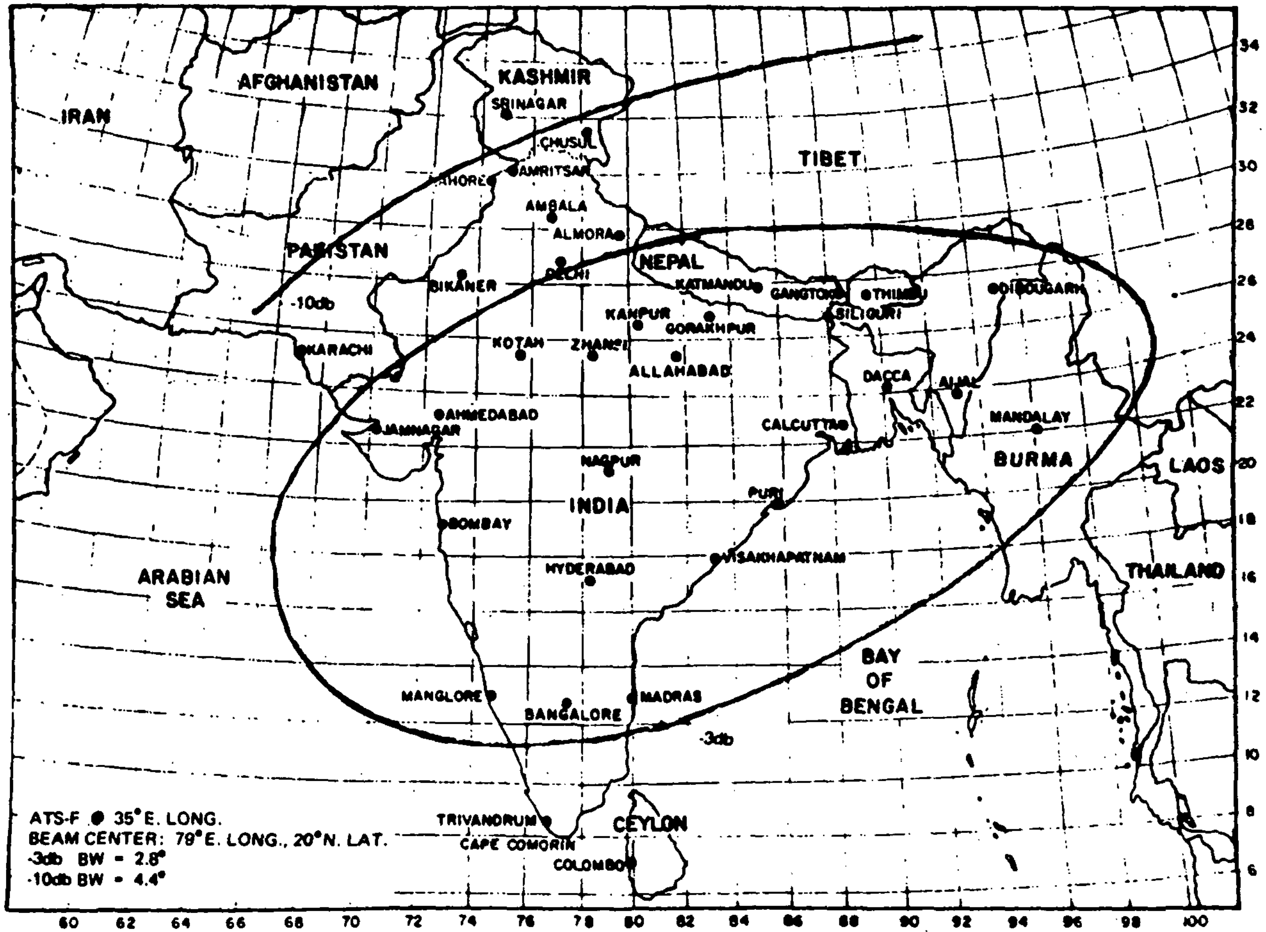

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Figure 7. - Antenna beam coverage of ATS F; India ITV.

E-7 44

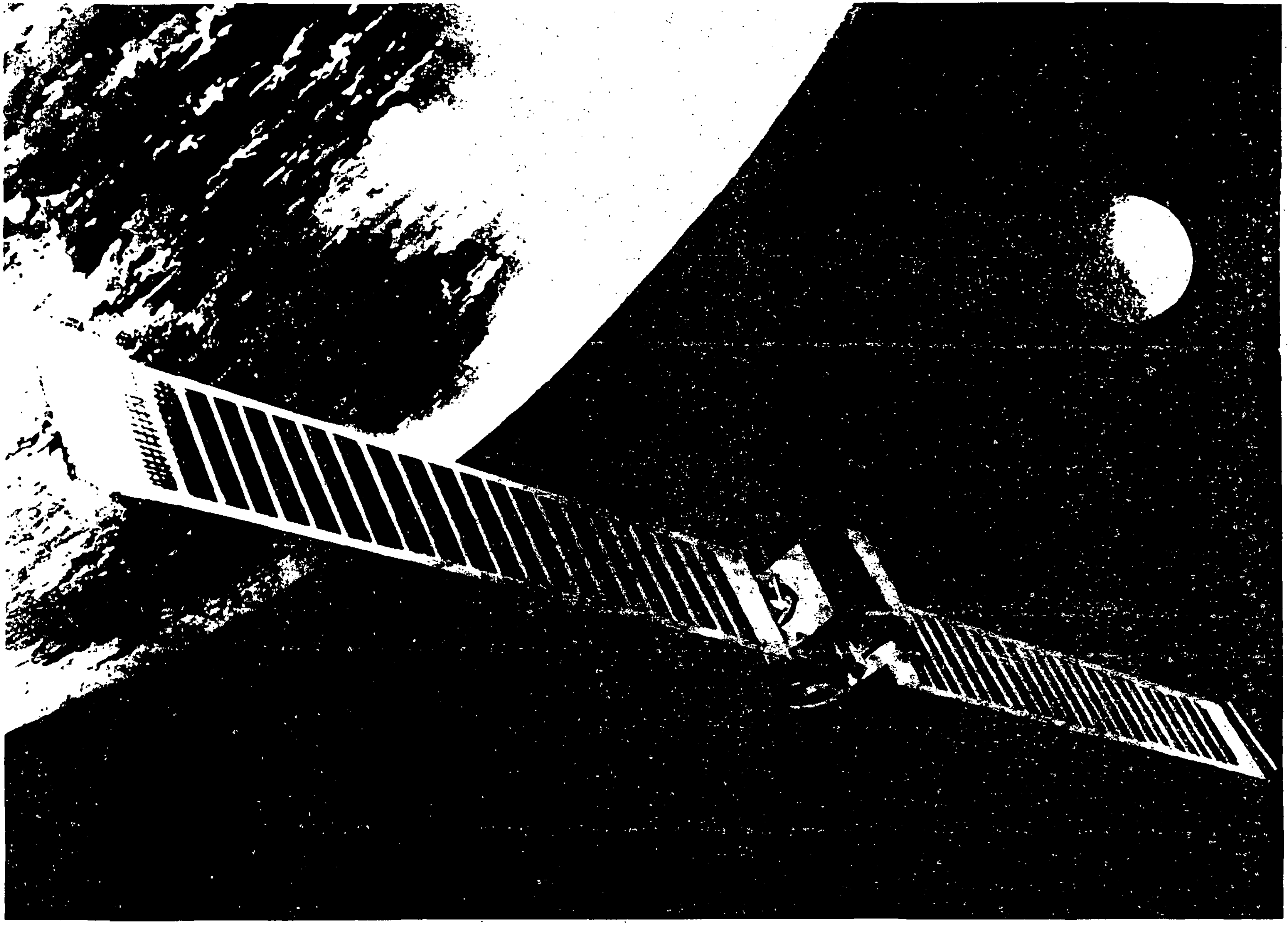

Figure 8. - Communications Technology Satellite.

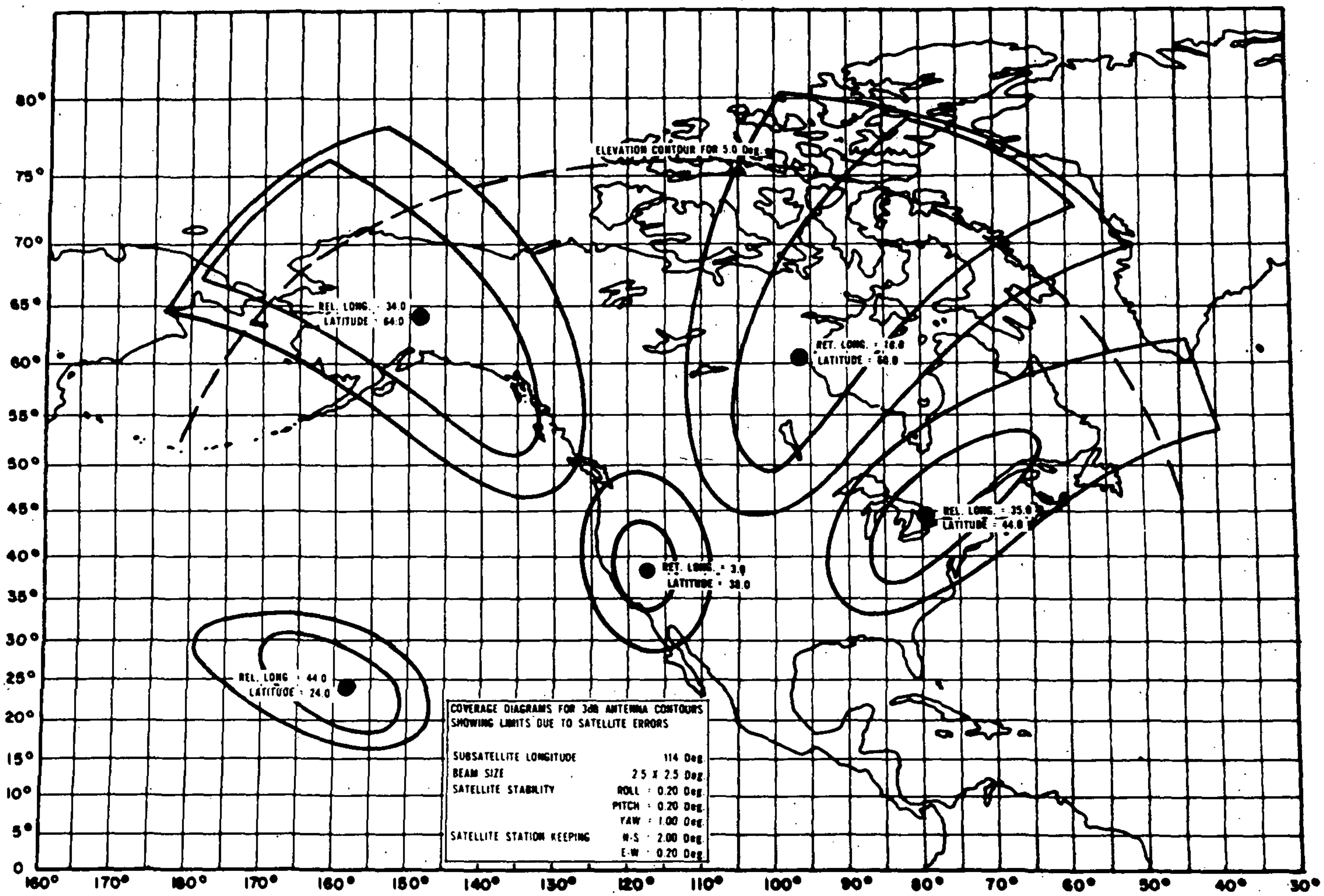

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Figure 9. - Typical antenna beam coverage of CTS for North America.

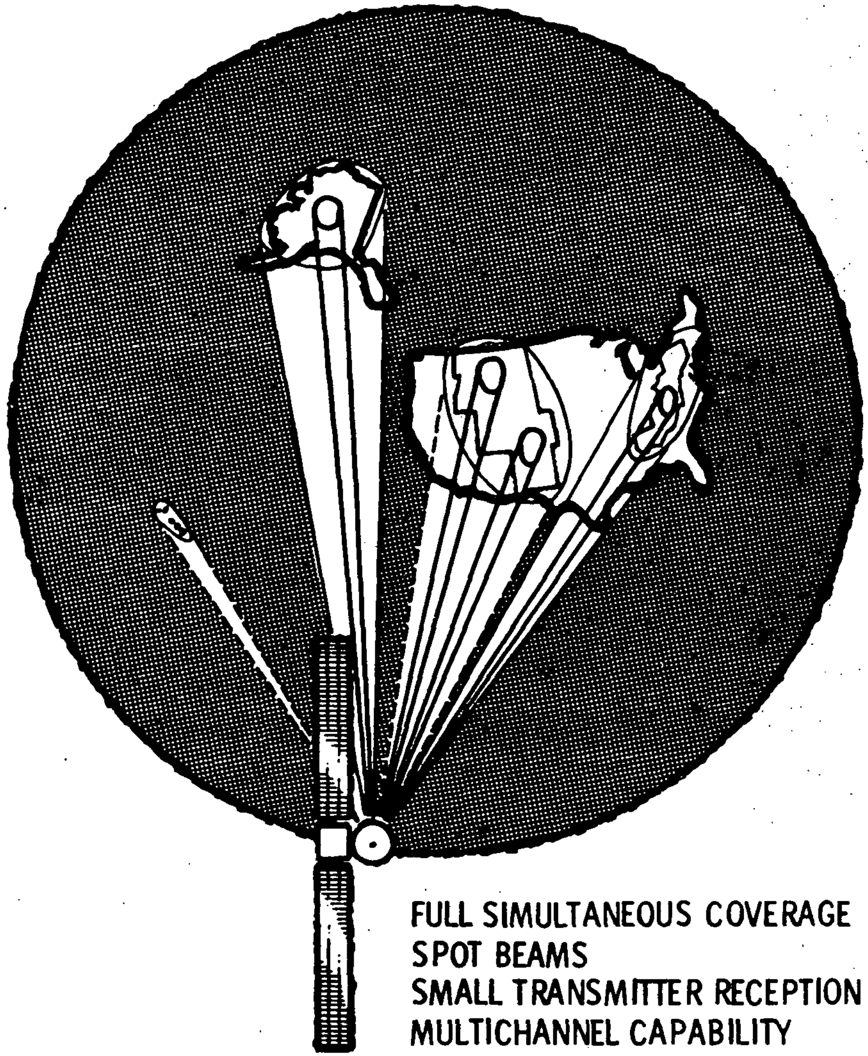

Figure 10. - ATS H/I coverage capability.

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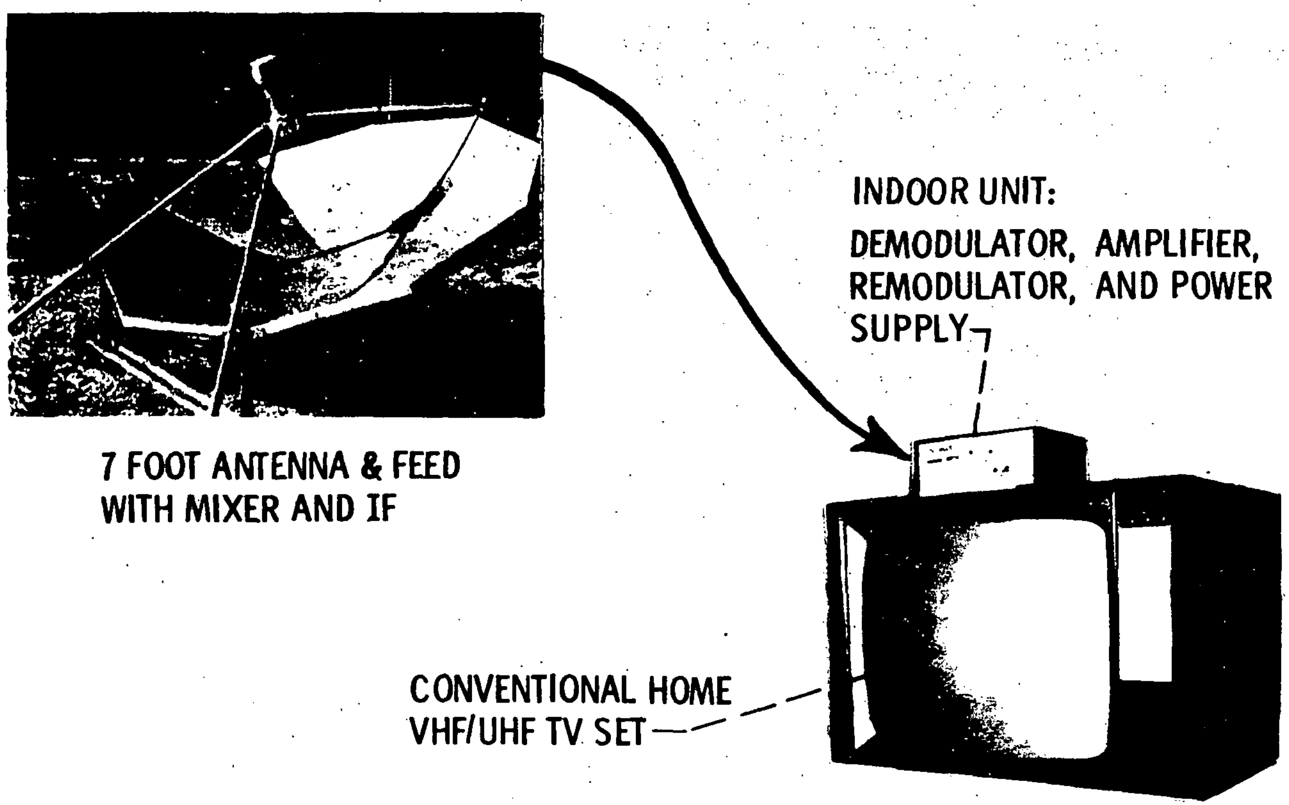

Figure 11. - Low cost receiving system. CS-64279

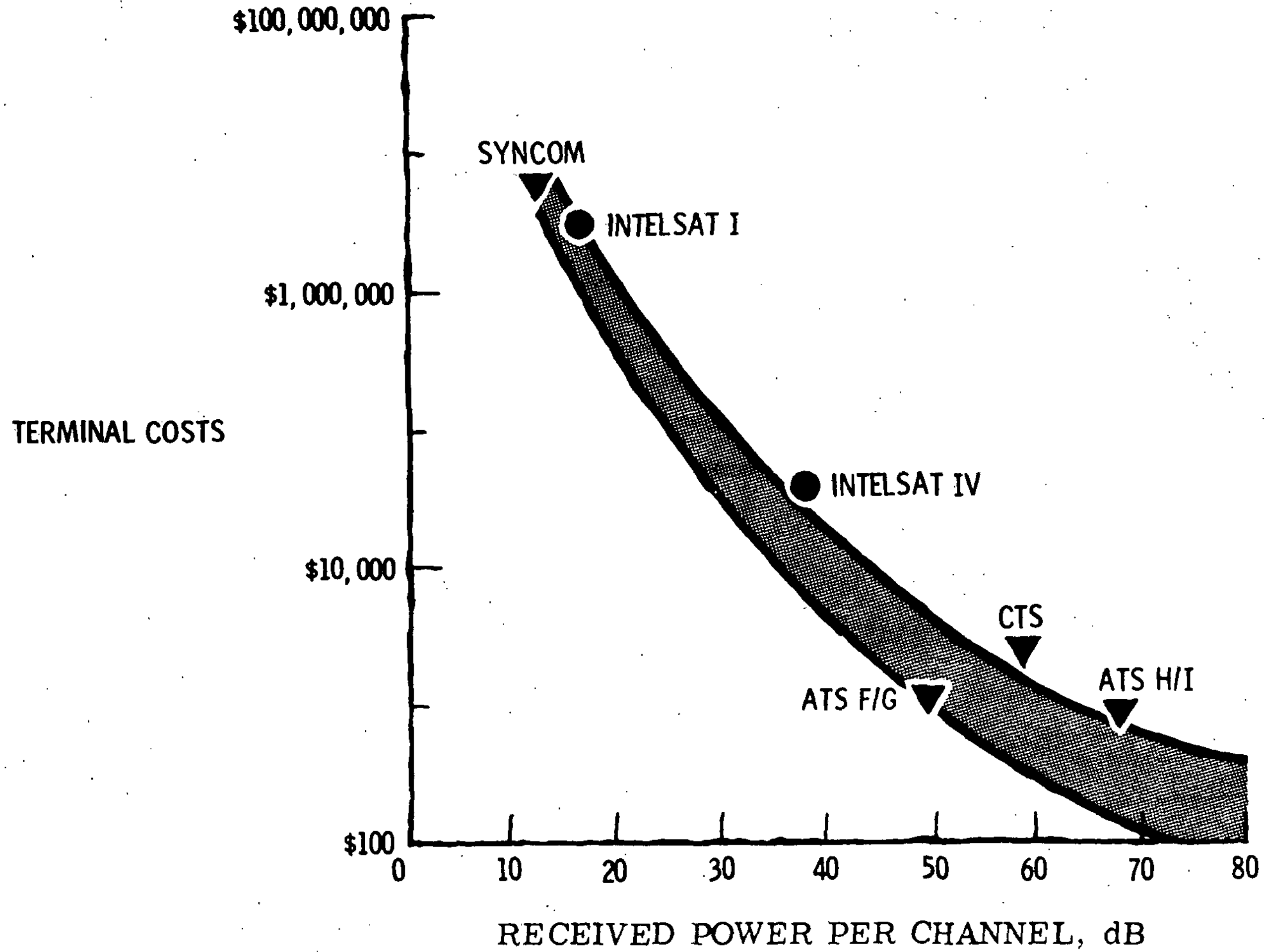

Figure 12. - Trends in receiver costs.

CS-64284

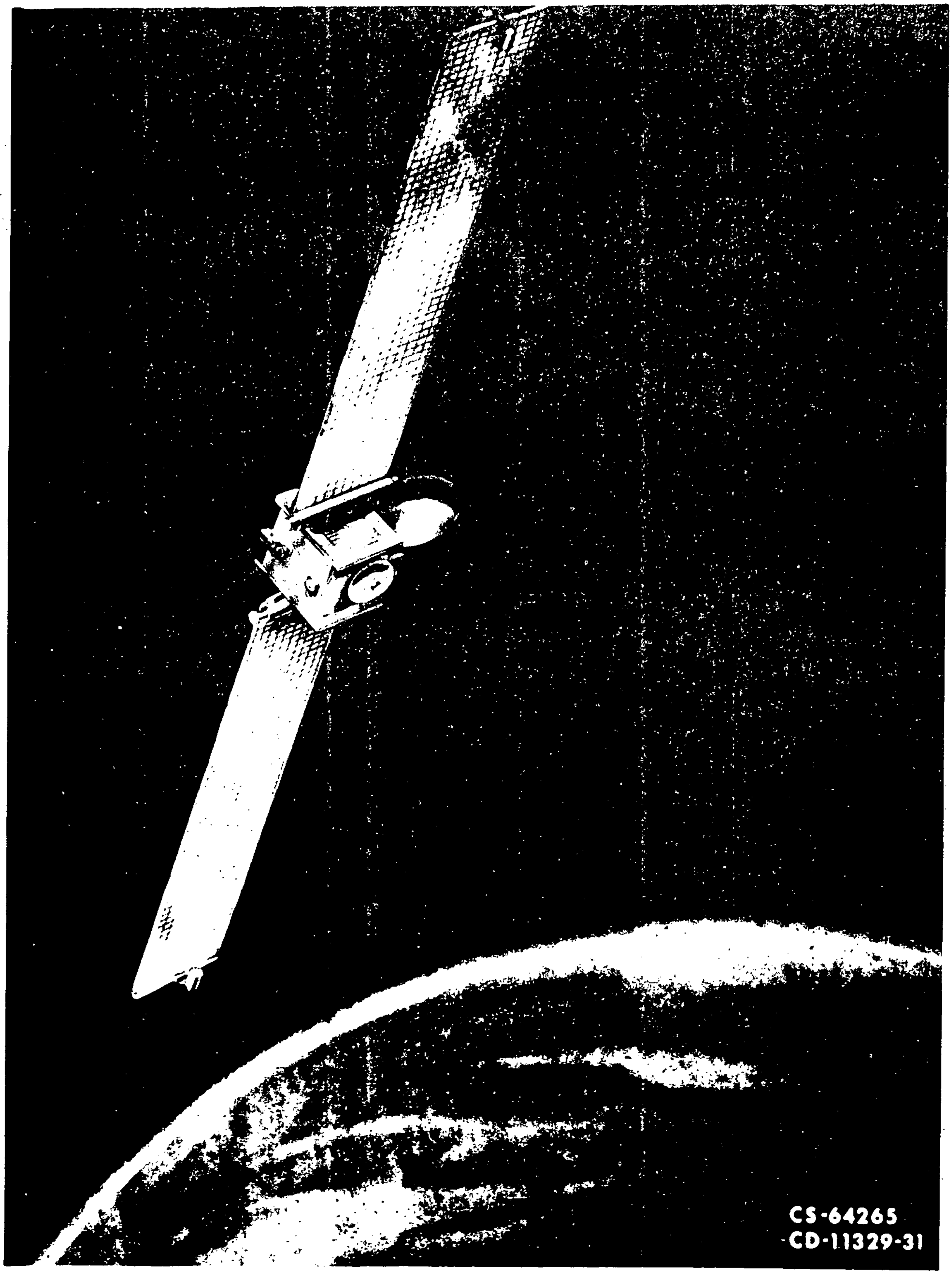

Figure 13. - Applications Technology Satellites - H/I.

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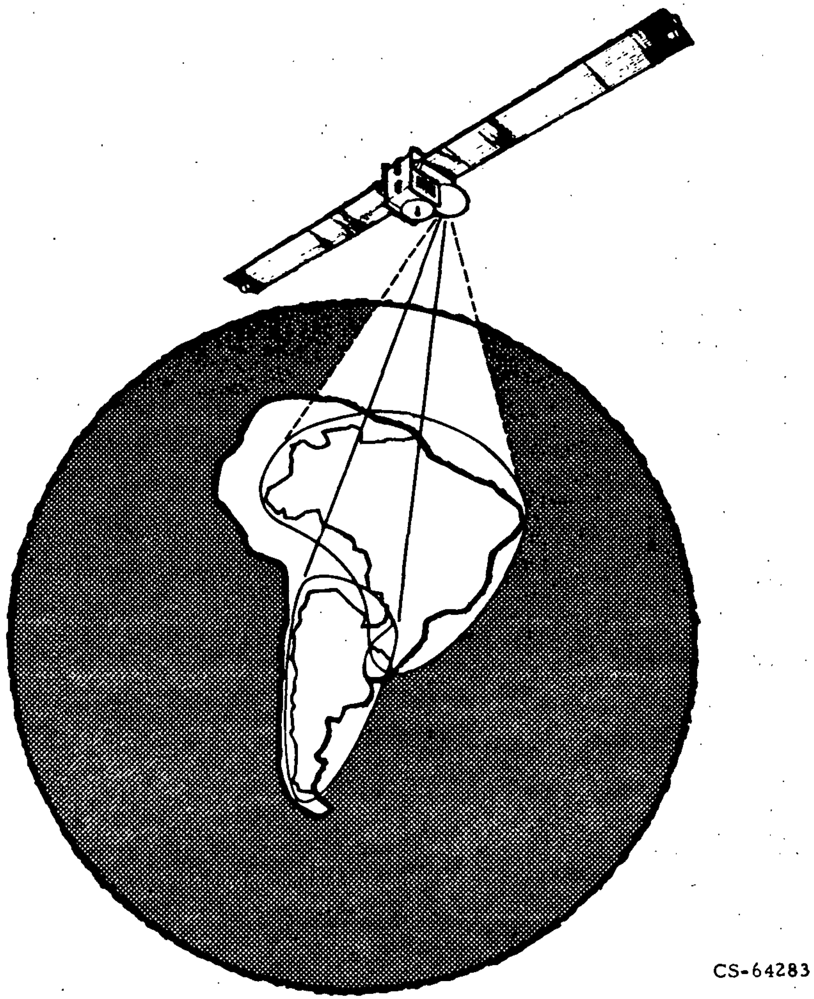

Figure 14. - International application - independent, simultaneous communications in Brazil and Argentina.

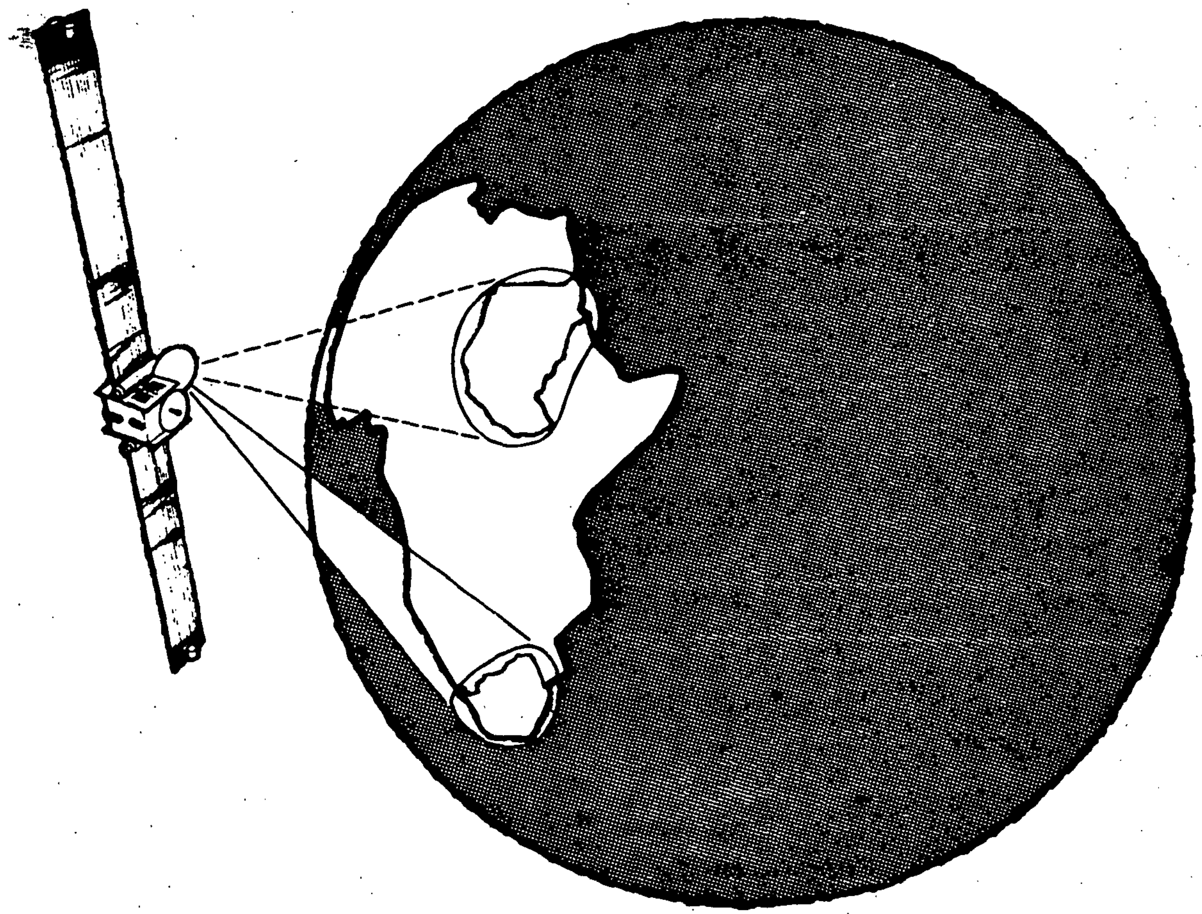

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Figure 15. - International application - independent, simultaneous communications in Sudan and South America.