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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AND

DEPARTMENT OF DEFENSE

A NATIONAL PROGRAM TO MEET SATELLITE AND SPACE VEHICLE TRACKING AND SURVEILLANCE REQUIREMENTS FOR FY 1959 AND 1960

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CONTENTS

PREFACE

On January 8, 1959, the Joint NASA-ARPA Committee on United States Satellite and Space Vehicle Tracking and Surveillance Requirements made the following presentation to the Administrator, National Aeronautics and Space Administration; the Deputy Secretary of Defense; the Director, Advanced Research Projects Agency; and the Chairman, Civilian-Military Liaison Committee.

This presentation reflects the results of a study by the Committee to determine the present capabilities of the U. S. to conduct tracking and surveillance of U. S. and foreign satellites and space vehicles, and to recommend a financial and development program to provide for future requirements as supported by the U. S. space program as visualized at this time.

It is recognized that future developments and requirements will probably change this picture, and the recommendations contained herein are considered to fulfill only a portion of the ultimate requirements.

Concurrent studies on national intelligence requirements in the space surveillance field were undertaken by another committee chairmanned by ARPA, and the methods of exchanging information among DoD scientific-military programs, NASA scientific programs, and the intelligence community were agreed upon.

As a result of this presentation, an agreement on the NASA-ARPA relationships in the fields of global tracking, data acquisition, communications, and data centers for space flight was reached between the Secretary of Defense and the Administrator, NASA.

The Joint NASA/ARPA Committee membership was as follows:

L. A. Kurtz, Cdr., USN ARPA	Frank Smith NASA
John S. Patton ARPA	Jack T. Mengel NASA
Clifford I. Cummings JPL/CIT	Homer J. Stewart NASA
Dr. Henry Richter JPL/CIT	E. M. Cortright NASA

A World-wide Tracking and Data Acquisition System for Satellite and Space Probes

Introduction:

A broad program of space exploration cannot be successfully undertaken without an adequate ground tracking and data acquisition network. Although such a system will be expensive, it actually represents a reasonable proportion of the total space program budget. While tracking and data acquisition is not a profitable area for skimping, cost savings may be effected by carefully coordinating the requirements of all potential users of such a system.

During the past year ARPA, with the aid of JPL, has conducted a study of the needs of the DoD for a world-wide network. In addition, they took under consideration the needs of other users with a view to providing service and minimizing duplication. A similar study has been underway within the NASA for the past several months and recently the two agencies and JPL have attempted to cut across jurisdictional lines, reconcile differences and develop a joint technical plan for immediate and longer range action. It is the preliminary results of this work which will be presented herein.

The reaction of most individuals, when first introduced to the problem of world-wide tracking and data acquisition, is one of confusion. In order to minimize this, a brief introduction to basic principles will be made. Following this introduction, the existing equipment will be reviewed and then the additional needs will be detailed. Lastly, joint recommendation for site development and construction to begin immediately will be made.

The first chart (Fig. 1) illustrates the basic components which go to make up a tracking and data acquisition system. The launching phase (1) makes use of somewhat specialized equipment which will not be generally available to serve orbiting vehicles or space probes and hence will not be discussed herein. Tracking (2) is accomplished by electronic means, such as the minitrack antennae complex which is shown, or by optical means with such equipment as the illustrated Baker-Nunn camera. Data acquisition (3) requires large parabolic self-tracking antennae such as the one shown, if large quantities of data are to be transmitted (large bandwidth). These antennae may also be used for tracking. The data collected must be transmitted to a central processing and computing center (5) by conventional means such as radio, landlines and cable (4) or by future communication satellites.

The question of how to assemble these components into a useful system is considered in the second chart of an idealized system (Fig 2). Ideally, we would like to make contact with our satellites once each orbit, particularly for data acquisition purposes and to a lesser extent for tracking. It is thus necessary to set up a line of coverage over which the satellite must pass on each circuit. The number of stations required to do this depends on the altitude of the satellite, as indicated by the coverage of a single station for 300 and 1000 mile satellites.

Most of our experience to date has been with low inclination orbits such as the illustrated 33° orbit. Complete coverage here could be obtained with the indicated vertical chain of stations. Our current interest has shifted towards polar type orbits. We must thus either extend our idealized chain of stations northward and southward to the poles or eastward and westward to a total arc of 180°. The latter is the natural choice since it does not require excessive stations and provides better geographic choices of location. It is apparent, however, that such a neat network is impossible due to land-ocean geography. Various types of "trades" may be made, however, For example, station C may be replaced with station C' with a displacement of 1/2 orbit in time. Also stations A and B could be replaced with A' plus B' at a higher latitude where a single station gives a greater percentage coverage of the polar orbits. Another point of interest is that replacing C by C' provides three stations separated by more than 180°. Utilizing the cross hatched stations for deep space probes permits continuous contact with the probe for all but the earliest portion of the flight.

However complex the real pattern of stations becomes in subsequent discussions, it is important to remember that the goal is simply to achieve the coverage described in this chart.

Let us imagine that each station of the chart contains a minitrack or equivalent antenna, and a large tracking antenna dish. Would such a system serve as a common system for all of our national space programs? Some indication of the answer may be seen in the third chart.

Our scientific satellite programs are well served by such a network provided the tracking system is sufficiently accurate for geodetic satellites. The research and development programs on communication, meteorological and navigation satellites are also well served provided sufficient bandwidth exists to collect and transmit to a computing center relatively large amounts of data in relatively short times.

Manned space flight developments are not completely served by the indicated system. Special equipment of the radar type are required to provide faster, more accurate, and more reliable orbit determinations in the launching and recovery areas. Reentry and recovery places special demands on this equipment.

Space probes could be served by the common system provided at least three stations with the indicated spacing were equipped with highly sensitive receiving equipment to detect the relatively weak signals spanning the many millions of miles.

Operational satellites are generally not well served by the basic system which is conceived as largely an R and D system. Communication, meteorological, and reconnaissance satellites in operational systems will generate huge volumes of data requiring both private and real time transmission to central computing and analysis facilities. In some cases this equipment will be controlled by other government agencies than those with current requirements (i. e., U. S. Weather Bureau) and in other cases they might be privately owned (i. e., a telephone company).

The equipment required in "silent" satellite detection is basically different than that described as part of the common system. Due to this factor, and the operational military aspect of silent satellite detection, it requires its own tracking, communication, and computing system.

Lastly, there are the special needs of the intelligence groups which will be discussed subsequently. Because of the sensitive nature of this work, separate equipment appears to be required although some slight possibility exists of receiving R and D service from this equipment, at least on an interim basis.

All of this network will not be developed at once. At the present time, R and D needs are paramount. A civil and military R and D network could share much equipment with the prototype operational military systems and could provide most of the private civil needs. In the future, however, although the amount of shared equipment may actually be expected to increase, the needs of military and civil operational satellites will require an increasing amount of equipment outside of the R and D network.

The remainder of the discussion, illustrated by the accompanying charts, will detail the existing equipment and the future requirements for a world-wide tracking and data acquisition system.

PRESENT FACILITIES

The present National capabilities for satellite and space vehicle tracking and data acquisition include a number of facilities and networks established primarily and only for this application, a number of facilities now a part of the National missile and test ranges that are available for this application on a shared basis, and some independent or private facilities that can be borrowed for this application on a temporary basis.

Chart 1 (Figure 3) provides a summary of the tracking and data acquisition facilities now available. The first item, the Minitrack network, will be described in some detail because it is the only permanent full-time network now in operation that provides all of the types of functions typical of a world-wide tracking and data acquisition network. The functions provided by this network are:

a. Tracking of the vehicle

b. Data acquisition and recording.

c. Ground command of vehicle functions.

d. Ground communications.

e. Network technical and administrative control.

f. Logistic support.

g. Orbital computation.

h. Continuous provision of station look angles, and of orbital elements and ephemerides.

i. Ground monitoring of the scientific measurements being made in the vehicles.

Chart 2 (Figure 4) is a map of the present Minitrack network. On all of the maps following, red indicates present facilities, green planned facilities which are included in the budget estimates following, and purple temporary or shared facilities. The red, or presently installed Minitrack network, includes stations in a vertical fence approximately along the 75th meridian, plus special stations to enhance signal recovery during the initial orbits fired south-east from Cape Canaveral, and to provide tracking data from locations equally positioned around the world.

Chart 3 (Figure 5) gives a detailed diagram of the communications system associated with this network. Basically, this system provides direct, private, full-time teletype lines to all of the domestic and Latin American stations, using both leased wire lines and a special radio teletype circuit provided by the Signal Corps as an off-net tributary to the Army ACAN system. Shared usage of Navy and Air Force military teletype communications is used to the Australian station, and commercial teletype is used to the South African station.

Chart 4 (Figure 6) gives an aerial view of the Minitrack station located at Batista Field, near Havana, Cuba. The inserts show an actual telemetry antenna (left) and tracking antenna (right).

Chart 5 (Figure 7) is a map of the Baker-Nunn stations, showing the location of the 12 Baker-Nunn precision optical cameras. These stations are located at sites offering good seeing conditions between 30° North to 30° South

Latitude around the world. This system provides the most precise tracking data now available; accuracies currently provided are a few seconds of arc, but with a greatly reduced number of observations and a long delay in data availability compared to electronic tracking systems.

Chart 6 (Figure 8) shows a Baker-Nunn camera, with an insert showing an idealized station layout.

Chart 7 (Figure 9) shows a map of the Microlock stations. These tracking and data acquisition facilities have been used for all previous satellite operations. This system features a technique for improving system sensitivity that makes it particularly applicable for telemetry and radio doppler measurements. Operations with U. S. satellites at 108 mc, primarily for the Explorer series, and at 40 mc for the Soviet satellites, have been provided by these stations.

Chart 8 (Figure 10) shows a photo of the Goldstone 85' antenna station. This station was the primary tracking station used for the JPL moon probe, PIONEER III. Secondary, temporary stations at Cape Canaveral and Puerto Rico provided launch and initial orbital data, as well as data during the re-entry phase. This antenna is typical of the 85' antennas proposed for deep space operations by the NASA, and for wide-band data acquisition systems for satellites by both NASA and ARPA. A model of it is sitting at the center of the conference table. All operations using this dish have been at 960 mc, with the exception of a flash conversion to 183 mc required for tracking the Soviet lunar shot. This tracking operation was successful.

Chart 9 (Figure 11) shows a map of the stations used in the STL lunar probes, PIONEER I and PIONEER II. These shots utilized a 60-foot antenna at Hawaii, plus temporary installations at Cape Canaveral and at Singapore, and shared use of the Millstone Hill Radar and the Jodrell Bank Radio Astronomy antenna. Operations were at 108 mc, and coverage was also provided on the initial orbit phase by the Minitrack system.

Chart 10 (Figure 12) is a photo of the Hawaiian 60-foot dish used in this shot. This is a TLM-18 225 to 260 mc antenna converted to 108 mc. This same type of antenna, at the original frequency band, will be used with the ARPA DISCOVERER satellite series.

Chart 11 (Figure 13) shows a map of the DISCOVERER tracking stations, which all utilize SCR-584 Mod II radars, plus TLM-18 antenna installations at the Hawaii and Vandenberg Air Force Base stations.

Additional facilities that can be provided by the National Missile and Test Ranges on a shared basis for space and satellite operations are the TLM-18 antenna just shown, various photo theodolites, and precision tracking radars.

Chart 12 (Figure 14) shows a picture of an FPS-16 radar typical of these precision tracking radars, and also of the radars required for tracking the MERCURY satellites, which are included in the program proposals to be given by Mr. Smith (NASA).

Chart 13 (Figure 15) is a map showing the location of the satellite detection fence components across southern United States. Two types of equipment are currently in a development study status in this fence - the Doploc doppler detection system and the active Minitrack detection system. In these systems, a signal from a large ground transmitter is reflected from a satellite into ground tracking receiving stations. Because the signal reflected from a satellite is extremely weak, very high gain antennas are employed at these receiving stations, with a consequent reduction in beam width. As a result, although they are capable of receiving signals from satellites equipped with 108 mc transmitters, the duration of a signal is so short as to significantly decrease the precision of the data obtained from it. For this reason, and because of certain operational considerations, this detection fence is considered as a separate facility from the primary Minitrack network.

Chart 14 (Figure 16) shows an aerial view of the Brown Field Active Minitrack station, showing the supports for the three 1600 foot antennas. Also shown at the lower left is the Prime (IGY) Minitrack Station, which will be operated on a common, cooperative basis with the active Minitrack system at this site.

In addition to the tracking and data acquisition facilities given on Chart 1, (Figure 3), there are several support facilities applied to these operations on a full-time basis. These include the Vanguard Control Center and the Vanguard Computing Center associated with the Minitrack network, the SPACETRACK Data Filter and Coordination Center, and the Smithsonian Astrophysical Observatory Computer and Operations Control Center.

In summary, although there are about 35 full-time tracking and data acquisition facilities now in operation, and about 15 part-time or shared facilities, the needs of the presently scheduled satellite and space vehicle programs are not now being met.

In the area of satellite tracking, virtually no capability exists for polar inclination orbits and not over half of the requirements for 51 degree orbits can be met. Only for the original IGY orbits of about 35° can it be said that tracking facilities are adequate.

In the area of space vehicle tracking, only the Goldstone 85-foot antenna facility exists. This cannot meet over one-third of the present minimum space vehicle requirements, and less than that when the requirements for two-way transmission to provide velocity and range are considered.

In the area of data acquisition, only low information bandwidth requirements can now be met, by the use of ground magnetic tape recorders and physical transportation of the magnetic tapes from the stations to the user group. Real time data ground transmission capabilities can meet only the very lowest bandwidth requirements, using teletype circuits.

In consideration of these shortcomings, a program for the improvement of the National capability for tracking and data acquisition has been prepared.

Recommended Program 1959 - 1960

Representatives of the National Aeronautics and Space Administration and ARPA have met over a period of months in an effort to identify national space surveillance tracking requirements, the assets available to meet these requirements, and from these, by a process of subtraction, to identify additional requirements essential to the national space program.

It would be incorrect to report that a completely satisfactory solution to all problems has been reached. However, the two agencies concerned have agreed on certain additional facilities to be developed as a matter of national priority, and on the inescapable premise that no space program is feasible without an adequate ground environment.

We, therefore, unanimously recommend that the program for FY 59 and FY 60 include at a minimum the following components:

1959

Referring to this chart for Fiscal Year 1959, (Figure 17) we believe the national tracking effort must include the following additional facilities.

a. Space Probe Tracking and Wide Band Data Acquisition: This includes two 85-foot diameter antennae located in Australia and Spain, 'an 85-foot" diameter antenna located in South Africa, and a transportable data station initially located in Japan. The 85-foot antennae will serve the dual purposes of providing wide band data acquisition for the Meteorology Program, the Communications Program, the Early Warning Program, and the Mercury (Man in

Space) Program. In addition, these antennae can serve the intelligence community on a time available basis to track and readout data from foreign satellites and space vehicles. The 85-foot antenna to be located in South Africa will serve the same programs and provide coverage in that part of the world. The United States is in need of general purpose tracking and data acquisition equipment in the Far East, which will also support the intelligence community surveillance of foreign satellites. A transportable type of tracking equipment is considered to be satisfactory to meet this requirement.

b. High Inclination Orbit Tracking: The high inclination orbit tracking equipment consists of Minitrack stations located in Alaska, North central U.S., Newfoundland, and Spain. This equipment is needed to provide the basic tracking capability necessary for light-weight scientific satellites in high inclination and polar orbits. The equipment in Spain is also necessary to provide target acquisition information needed to position the 85-foot antenna. The figure indicated to cover the costs for these stations is considered minimum but adequate.

c. Mercury (Man In Space) Program: The additional equipment needed in FY 1959 for support of the Mercury Program consists of high-precision, pulse-type tracking radars and computers located on Bermuda, and Hawaii; plus additional tracking data acquisition and communications equipment located on a ship operating in the Atlantic. The Bermuda equipment is necessary for injection and for a rapid determination of the orbit, as well as for tracking during the later passes. (This equipment is also needed for the earlier non-orbital shots Southeastward from Wallops Island). The Hawaiian equipment is needed for rapid re-determination of the orbit immediately after firing the retrorocket so that the exact landing point can be predicted. The shipboard instrumentation is needed to provide communications and data acquisition in those areas where no land masses are available for location of this equipment. These stations are considered the minimum necessary for safety of the pilot.

The requirements of the DYNA-SOAR Program have not yet been thoroughly defined but will be reviewed in order not to duplicate the Mercury Program equipment.

d. The Satellite Detection Fence Program: The Satellite Detection Fence Program was authorized in May of 1958 and construction is essentially complete on this system. Experience to date indicates that additional work must be accomplished on this system in order to obtain maximum benefit from the stations now available. These stations consist of modified Minitrack equipment and a Doppler system. The stations already in operation have contributed to the intelligence community and to the U.S. capability in determining the existence of satellites passing over the United States. Plans have been approved to integrate this system with Project Space Track at the Air Force Cambridge Research Center in order to develop an interim filter center for all satellite and space vehicle information.

e. The Interim Filter Center: The interim filter center development is considered to be a research and development tool to provide information on an immediate basis to all satellites and space vehicle activities and to serve as a means for determining the ultimate type of activity which can best serve the U.S. interests. This is considered to be based primarily on the national defense requirement to provide information of this nature but it is expected that it will be useful to all other agencies concerned with the Space Program. It is not intended that the filter center will replace computing and data reduction activities, separate requirements of the scientific community.

f. Money: The total cost of these programs for FY 1959 amounts to $41 million. It should be noted that this includes the procurement, installation, and supporting research and development for these programs. It is quite clear that the United States must now invest money in a capital outlay for tracking and data acquisition equipment, and their necessary logistical systems during 1959 in order to have the capability of supporting its currently approved satellite and space vehicle projects commencing in 1960. To date, $18.7 million of the required total amount of $41 million is available and the necessary additional 1959 funds amount to $22.3 million.

1960

The 1960 program (Fig. 18) is essentially an extension of the requirement as laid down in the 1959 program.

a. Space Probe Tracking and Wide Band Data Acquisition: The item for Space Probe Tracking and Wide Band Data Acquisition as indicated on the FY 1960 chart includes: (1) an additional 85-foot antenna to be located in the eastern United States, (2) a 60-foot antenna in Bermuda, (3) an interplanetary control net with additional equipment to be located in Australia, Spain, and Goldstone Lake, California, and (4) a transportable data acquisition and tracking station to cover areas of space vehicle surveillance not foreseen. The costs of these items are consistent with the costs as noted in 1959.

b. High Inclination Orbit Tracking: The high inclination orbit tracking stations require improvements. These include real time data readout for positioning of tracking antennae, a change of the operating frequency to permit accuracy comparable to optical tracking in addition to providing a capability to cover the polar orbits.

c. Mercury (Man in Space) Program: The additional facilities needed in FY 1960 for continuance of the Mercury Program include an additional pulse-type tracking radar in Texas which will precisely fix the vehicle's landing projectory, additional data acquisition and communication facilities at the existing Australian and South African stations, and additional ship modifications.

d. Satellite Detection Fence: Satellite detection fence as seen now will require continued research and development on both the active Minitrack and Doploc systems to meet the ultimate design requirement to detect non-radiating satellites of an effective radar cross sectional area of one square meter at 1,000 miles, and to provide for development of the optimum data presentation method. The object is to coordinate the various station outputs concurrently with the interim filter center development.

e. Interim Filter Center: During FY 1960, the research and development phase of the interim filter center at Space Track will reach full scale. This is necessary in order to complete the research and development phase of this important component by July 1, 1960, at which time it is expected that a blueprint for establishing an operational National Coordination Center will be available. Typical of the R & D activities at Space Track during FY 60 are: (1) studies and experimental operations to test incoming and outgoing communications, (2) tie-ins and data processing from the Satellite Detection Fence and other sources, (3) specialized techniques such as multi-dimensional displays and advanced ephermeris calculation methods, and (4) quick reaction procedures for handling a large satellite population.

The capital cost for technical equipment procurement, installation, necessary facilities costs, and supporting research and development amounts to $30.8 million for the above items. This is exclusive of the costs of operation and logistical support for all stations of the U. S. satellite and space vehicle surveillance program.

f. Operational Support: It has been estimated that $33.3 million will be required for operational support, including the current DISCOVERER Program and SENTRY Program. It should be understood that the SENTRY Program is still under review and final decisions have not been made to date as to the extent of this program, and a figure of $10 million has been included to cover the possible needs for SENTRY. $25 million has been spent to date on tracking, data acquisition, computing, communications, and logistics for the DISCOVERER Program, and that these facilities will contribute to whatever operational SENTRY Program is approved. It is also planned to use the DISCOVERER tracking facilities in support of all other programs. These facilities will be under Pacific Missile Range management since they are considered as part of the total national capability. The over-all national cost estimate for FY 1960 is $64.1 million.

In conclusion, the programs presented for 1959 and 1960 are considered to be only a portion of what the future United States requirements will be in space. The developments to date have indicated an entirely new field of endeavor for the scientific and military agencies of this nation. It is still too early to see the total picture and this program, as presented, represents the minimum implementation as conceived, now supported by valid requirements.

THE MANAGEMENT PROBLEM

The purpose of this part of the presentation is to make a few remarks about the management problem associated with the formation and operation of what we have chosen to call the National Ground-Based Surveillance Complex. The plans for this complex have been outlined to you in general form today and these represent a great deal of study by many individuals with a heavy concentration of effort in the last few months. There is some air of vagueness still associated with this plan, and this is because the structure of a world complex depends strongly on the management structure over the complex. This plan is far from unique; it would look much different if both ARPA and NASA installed and operated completely separate equipments for only their own programs. It would be even more complicated if each program installed and operated its own network. Some management had to be presupposed in order to formulate the plan you have heard; this presupposition was not in the charter of this planning group. If joint participation of both ARPA and NASA in the complex does not come about, then this plan will have to be revised. In any case, this plan will have to be re-examined as to its long-range plans and goals after a detailed management arrangement exists.

The Jet Propulsion Laboratory was requested to study and recommend a National Complex. To date, two reports resulted from this study: JPL 140 and 146. It became obvious that, at best, the latter report could only collect the over-all technical requirements to be placed on such a complex, and to use this to define the management problem. It was felt that if technical agreement could be reached on what the complex should do and might look like, then a management decision could be made on this basis. The plan today is in general agreement with the complex suggested in 146, but represents the minimum implementation. The over-all complex recommended by this report amounts to a continuing capital investment of about the same as you see for 1959 and 1960, namely $40-$50 million per year. It appears that this is still the right order of magnitude to expand the complex to match our growing space program for several years. Not only will there be an increasing number of vehicles, but the data transmission will become more complicated as vehicles increase in size.

It is realized that a complete management decision will probably not be made in the immediate future, but it is essential that some fundamental agreements be reached so the installations can be started and longer range technical plans be made in greater detail. Numerous plans for the complex have been made, only to be discarded when the presupposed management never came into being.

The management of the complex includes several functions. This is true whether the complex is an integrated national one, or whether it consists of two sets of installations, operated by different agencies. The management plan must reach through all levels of the complex, from the local operation of each equipment through the top level planning required. There are two classes of management which must be represented in all levels of the operation. These are the technical and administrative supervision which may or may not be separate.

The people operating the equipment must have a clearly defined local administrator, who insures their welfare, logistic support, and other similar items. On the other hand, they must have a clear understanding of the source of their technical supervision. This latter could come from different organizations at different times, depending on the particular circumstances of operation.

The technical and administrative supervisors of each installation must also have a clear understanding as to the source of their support, and from whence they get their guidance and decisions. This level of management is a very critical one at those locations where different types of equipments will be located, and which will be assigned different tasks at different times. Some of the operation will involve routine tracking and data collection as a service function; others will involve the installation and operation of special equipment by organizations doing R&D on the site.

The top level management has an obvious responsibility for over-all operation and planning. This includes allocation of specific equipments, and formation of networks within the complex, as well as participation in the program planning stage, to insure compatability of ground-based and vehicle equipments.

Six management plans are suggested in publication 146. As a result of the study work by JPL, as well as others that have studied this subject for their own agencies, it is clearly apparent that some decision must be made very soon to begin those facilities indicated for 1959. Even if begun today, many of these facilities could not be placed in operation until months after they are first needed for programs soon to launch their first experiments.

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AGREEMENT

between

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

and

DEPARTMENT OF DEFENSE

on

Global Tracking, Data Acquisition, Communications, and Data Centers for Space Flight

1. The separate requirements of NASA and the Department of Defense for space tracking and data acquisition are recognized. The NASA requirements are primarily for research and development flights and the DOD requirements are primarily for research, operational flights and intelligence support.

2. Immediate and vigorous action is required in both agencies to implement the agreed-on national program.

3. It is agreed that the following actions be started in the current year:

a. Provide tracking and data acquisition stations for deep space probes at Woomera, Australia and South Africa using one of the existing 85-foot dishes. This will complete a three-station net including the existing NASA Goldstone facility for 24-hour coverage of deep space flights. These stations will be operated by NASA. High capacity data acquisition equipment will be required at these sites by the Department of Defense in the near future. These stations will provide for DOD requirements until the load increases so that parallel DOD equipment is required.

b. Provide one of the existing 85-foot dishes in Spain and a secondary acquisition antenna with high capacity in Japan. These stations will be operated by the Department of Defense. These stations will provide for NASA requirements until the load increases so that parallel NASA equipment is required.

c. Provide facilities required for project Mercury, including those for injection, tracking, data acquisition, and re-entry command. The NASA will provide and operate these facilities.

d. Add four stations to the Minitrack network and modernize remaining stations to provide coverage for polar flights. NASA will provide and operate these stations.

4. The need is recognized for two closely cooperating data reception and analysis centers, one operated by NASA as a continuation and expansion of the Vanguard center and one operated by the Department of Defense under Spacetrack management at the Cambridge Research Center. These two centers will exchange data freely and provide mutual support for the national program.

5. The world-wide communications networks now in existence shall be shared equally by DOD and NASA.

6. A technical committee with representation from NASA and DOD shall maintain a continuing study and monitoring of the global tracking, data acquisition, and communications problems and periodically report their findings for action to the Secretary of Defense and the Administrator of NASA.

/s/
Neil H. McElroy
Secretary of Defense

/s/
T. Keith Glennan
Administrator, NASA

Washington, D. C.
January 10, 1959

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APPENDIX NO. 1

GROUND FACILITIES NEEDED FOR SCIENTIFIC APPLICATION OF SATELLITES, SPACE PROBES, AND MANNED SPACE FLIGHT

All presently anticipated space programs have been reviewed by NASA and ARPA representatives to determine what ground facilities are needed to support the national program during the next two years.

In determining what new stations should be established an attempt was made to use existing facilities wherever possible and to choose new station sites to serve as many different programs as possible.

The major programs to be considered by this paper are scientific and application satellites, space probes and manned earth satellites.

EARTH SATELLITES (Unmanned)

No firm schedule exists for launching satellites into equatorial orbits during the next two years. For this reason coverage for zero-degree inclination orbits was not considered to be a prime requirement at this time.

During 1959-60, 12 to 15 satellites are scheduled for launching into low-inclination (30^{o}-35^{o}). The existing IGY electronic and optical tracking stations furnish adequate coverage for these vehicles---at least insofar as tracking is concerned.

During the same period, 15 to 20 satellites are scheduled for high-inclination (51^{o}) orbits and an additional 15 to 20 satellites will be launched from the Pacific Missile Range into polar orbits.

For these vehicles, the existing networks do not provide adequate coverage---especially for lightweight scientific vehicles which cannot carry a heavy radar beacon and power supplies.

This is illustrated on Chart 1 (Fig. A-1) which shows polar orbits. It can be seen that a few passes which occur near the 75th meridian will be thoroughly covered but most other passes would be missed entirely. To remedy this situation it is proposed that four additional stations be located at Alaska, N. Central U.S., Newfoundland, and Spain. These stations form a rough east-west fence which will catch most of the polar orbits.

A proposed further modification for polar orbit coverage is to add east-west antenna arrays to the existing Minitrack stations.

The other two "new" stations indicated on the map, Florida and Bermuda, are relocations of the Cuban and Ft. Steward stations. The

Florida station serves the same function as the Cuban station and the Bermuda station will provide needed additional coverage for vehicles launched from AMR and Wallops Island.

The next Chart 2 (Fig. A-2) shows the existing IGY stations provide rather poor coverage for 51° orbits and illustrates how the proposed new stations provide the needed additional coverage. Note especially the N. Central U.S., Newfoundland, and Spain stations.

SPACE PROBES AND DATA ACQUISITION

Another area where the existing facilities are inadequate is the reception of wide bandwidth data transmitted from meteorological or experimental reconnaissance satellites. This is illustrated on Chart 3, (Fig. A-3) Explorer and Vanguard satellites launched in 1958 transmitted a data bandwidth in the order of a few hundred cycles per second. The meteorological satellite will transmit a few hundred thousand cycles per second and a reconnaissance vehicle may transmit 50 to 60 million cycles per second.

This increased bandwidth can be handled by increasing the power transmitted by the satellite in direct proportion to the amount of data to be transmitted---which is of course unpractical---or by increasing the gain of the ground receiving antenna. To get the required antenna gain on the ground necessitates the use of big parabolic antennas which must be "aimed at", or must track, the satellite continuously during the data readout period.

Another program which requires the use of high-gain antennas is the space probe program. For tracking of space vehicles, 3 antennas located on the equator and spaced 120° apart in longitude would be ideal, as illustrated on Chart 4, (Fig. A-4).

To approach this situation practically, two additional 85-foot antennas are proposed for location in Australia and Spain, which, along with the existing 85-foot antenna in Goldstone, California will provide the needed space probe tracking capability. Another 85-foot antenna is proposed for the eastern U.S., so that the Goldstone antenna, which is actually an R&D prototype, can be worked on for R&D purposes.

These proposed additional station locations ~~(Figure 11-A)~~ are 85-foot antennas in Goldstone, Spain, eastern U.S., and Australia; 60-foot antennas in Bermuda and S. Africa, and a 10-foot antenna in Japan, which, in addition to the existing 60-foot antennas at Hawaii, PMR, and Florida will provide the data acquisition and space probe tracking capability needed for the 1959-60 national space program.

MANNED SATELLITE PROGRAM REQUIREMENTS

Present plans for the Manned Satellite (MERCURY) Program call for launching northeastward from Cape Canaveral in a 33° inclination and recovery in the Atlantic after the second or third pass, as illustrated on Chart 6. One of the primary considerations in the choice of this orbit was that it makes possible maximum use of existing ground instrumentation facilities at the Atlantic Missile Range, Pacific Missile Range, White Sands Missile Range, Eglin Air Force Base, etc.

Additional facilities needed include pulse-type, tracking radars and computers in Bermuda, Hawaii, and Texas; some additional communications equipment at Woomera and South Africa; and shipboard equipment to provide crude tracking, data acquisition, and communications for those areas where no land masses are available.

The Bermuda equipment is needed for injection and for rapid determination of the orbit as well as for tracking during the later passes. (It is also needed for tracking non-orbital vehicles and satellites launched southeastward from Wallops Island or northeastward from the Atlantic Missile Range.)

The Hawaiian equipment is needed for rapid redetermination of the orbit immediately after firing the retro-rocket so that the exact landing point can be predicted. The equipment in Texas is needed to supplement existing WSMR, Eglin, and AMR radars in precisely fixing the trajectory during the landing phase.

The shipboard equipment will be installed on ships owned by the AMR, by PMR, and the Navy, and the ships will be operated in the Atlantic, the Indian Ocean, and the Pacific. Several additional ships and planes, which will be available from the AMR and the Navy, will be required for the actual recovery operation.

ELEMENTS OF GLOBAL TRACKING AND DATA ACQUISITION NETWORK

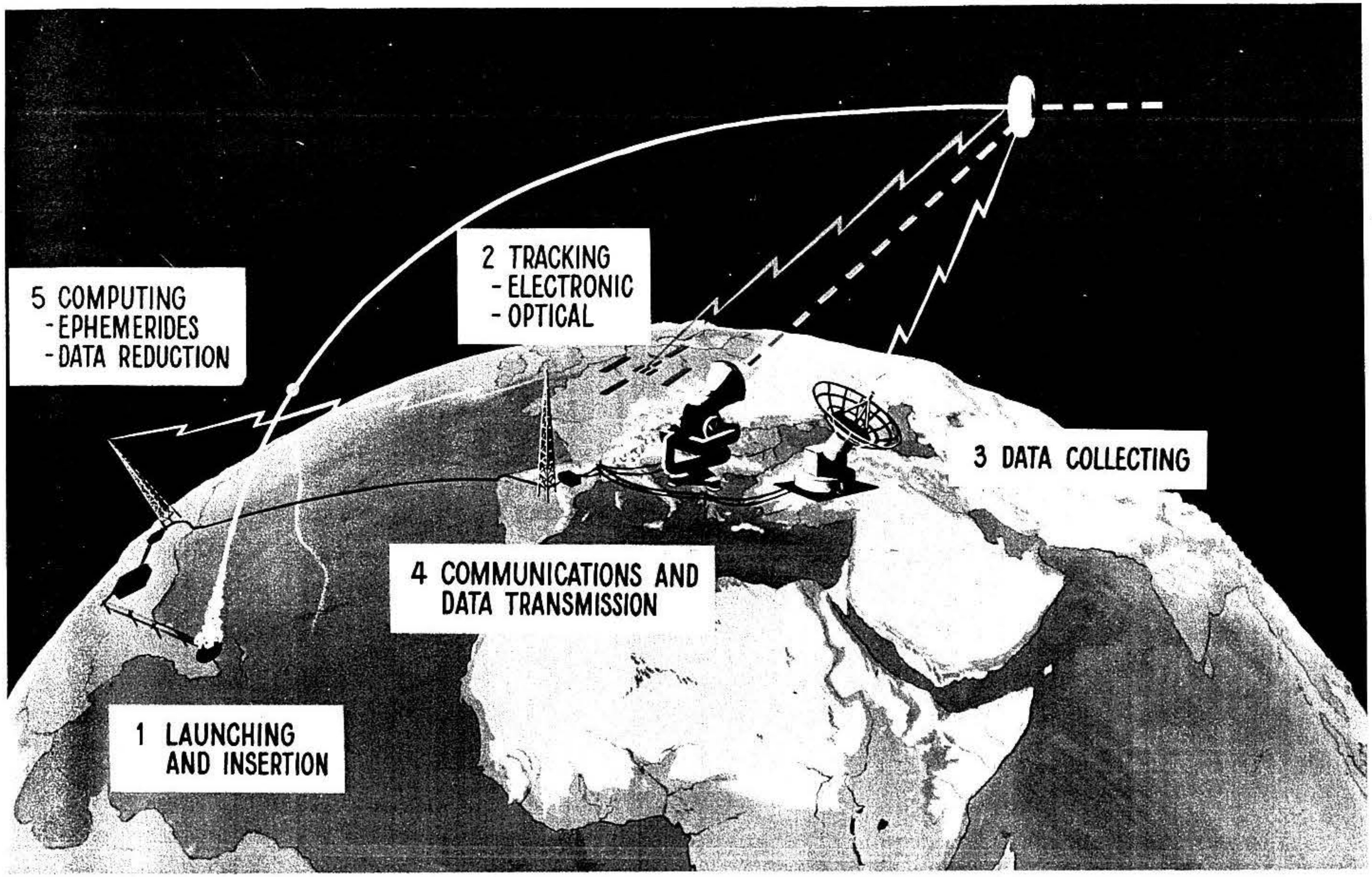


FIGURE 1

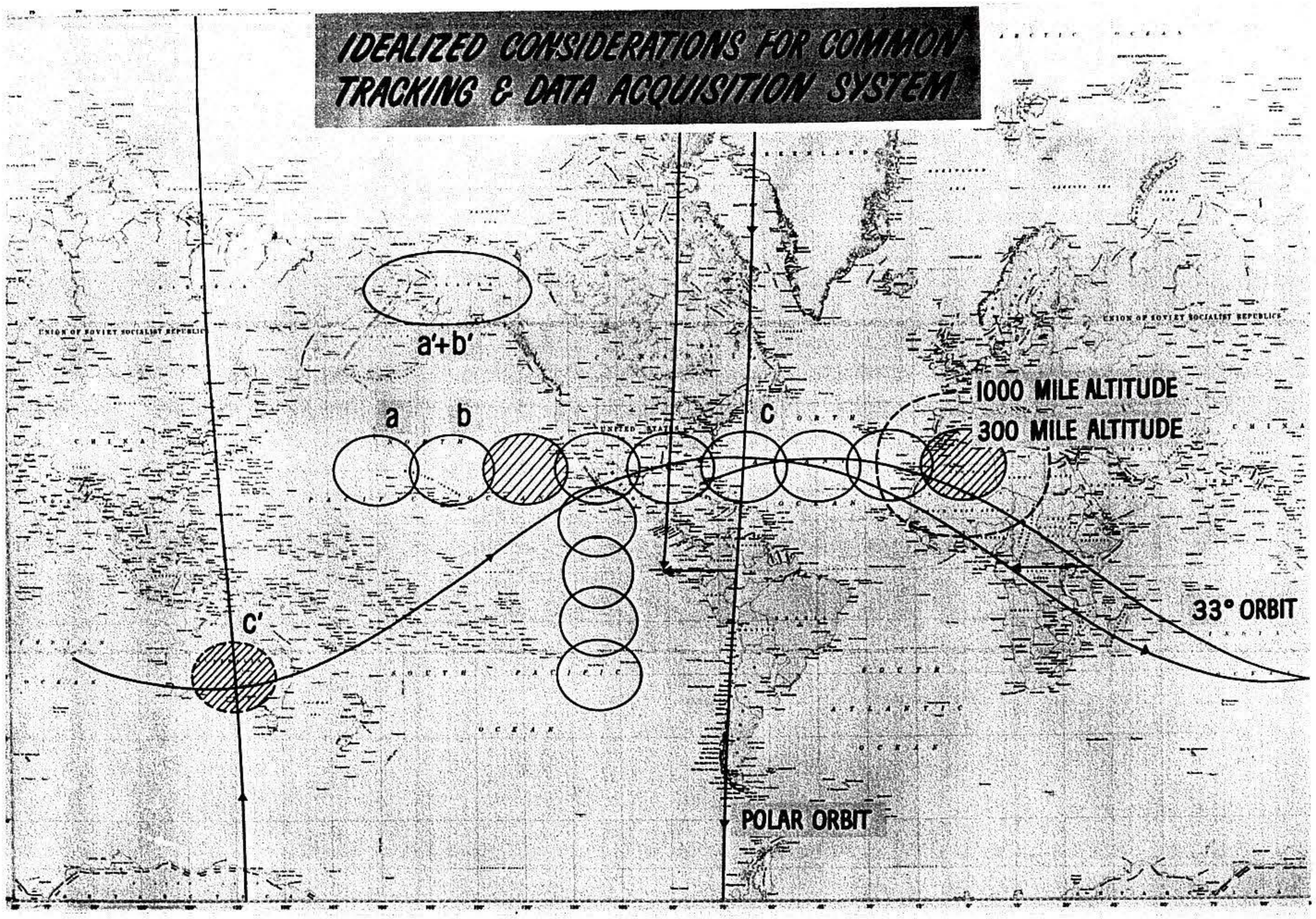

IDEALIZED CONSIDERATIONS FOR COMMON TRACKING & DATA ACQUISITION SYSTEM
a'+b'
a
b
c
c'
1000 MILE ALTITUDE
300 MILE ALTITUDE
33° ORBIT
POLAR ORBIT

FIGURE 2

INDIVIDUAL PROGRAM REQUIREMENTS

PROGRAM	EXAMPLE	ORBIT	ARE BASIC NEEDS MET BY COMMON SYSTEM ?				SPECIAL OR ADDITIONAL REQUIREMENTS
			TRACKING	DATA ACQUISITION	COMMUNICATIONS	COMPUTING	
SCIENTIFIC SATELLITES	FIELDS PARTICLES RADIATION	30° TO 90°	YES	YES	YES	YES	PRECISION TRACKING FOR GEODETICS.
R&D OPERATIONAL SATELLITES	EXPERIMENTAL METEOROLOGICAL COMMUNICATION NAVIGATION	0° TO 90°	YES	YES	YES	YES	HIGH CAPACITY DATA ACQUISITION AND TRANSMISSION.
MANNED SATELLITES	"MERCURY"	INITIALLY 33°	NO	YES	NO	NO	FASTER TRACKING, COMMUNICATION AND COMPUTING IN SELECTED AREAS, (RADAR TYPE). REENTRY AND RECOVERY CAPABILITY.
SPACE PROBES	LUNAR PLANETARY SOLAR	–	YES	YES	YES	YES	HIGHLY SENSITIVE DATA ACQUISITION AND TRACKING FOR MILLION TO BILLION MILE RANGE.
OPERATIONAL SATELLITES	METEOROLOGICAL COMMUNICATION RECON	90°	YES	NO	NO	NO	VERY HIGH CAPACITY AND HIGH VOLUME PRIVATE DATA COLLECTION AND TRANSMISSION TO PROCESSING CENTERS. NOT ALL GOVERNMENT CONTROLLED.
SILENT SATELLITE DETECTION	NON-RADIATING FOREIGN	0° TO 90°	NO	–	NO	NO	SPECIAL PURPOSE DETECTION FACILITIES. HIGH SPEED PRIVATE DATA TRANSMISSION TO SPECIAL PROCESSING CENTER.

FIGURE 2A

TRACKING & DATA ACQUISITION FACILITIES NOW AVAILABLE

FACILITY	APPLICATION	NUMBER/TYPE	FUNCTIONS
MINITRACK NETWORK	ALL SATELLITES USING 108 OR 40 MC	11	RADIO TRACKING & DATA ACQUISITION NETWORK
BAKER-NUNN STATIONS	SATELLITES	12	PRECISION OPTICAL TRACKING & COMPUTING SYSTEM
MICROLOCK STATIONS	ALL SATELLITES	6 TO 12	40 & 108 MC RADIO DOPPLER & TELEMETRY STATIONS
JPL MOON PROBE STATIONS	PIONEER III	1 - 85' ANTENNA 2 - SMALL, TEMPORARY	960 MC LUNAR PROBE TRACKING & DATA ACQUISITION STATIONS
STL MOON PROBE STATIONS	PIONEER I & II	1 - 60' ANTENNA 2 - SHARED 3 - TEMPORARY	108 MC LUNAR PROBE TRACKING & DATA ACQUISITION STATIONS
DISCOVERER STATIONS	DISCOVERY SATELLITES	6 - SCR 584 MOD. II 2 - 60' ANTENNAS	240 MC TRACKING & DATA ACQUISITION STATIONS
APOGEE MOONWATCH STATIONS	ALL SATELLITES	6	VISUAL OBSERVATION STATIONS
MISSILE AND TEST RANGE INSTRUMENTATION	ALL SATELLITES	TLM-18 ANTENNAS, TRACKING RADARS, PHOTO-THEODOLYTES	TRACKING & DATA ACQUISITION ON SHARED BASIS
SATELLITE DETECTION FENCE	NON-RADIATING SATELLITES	4 - ACTIVE MINITRACK 4 - DOPLOC 3 - TRANSMITTERS	DETECTION OF NON-RADIATING SATELLITES BY REFLECTION OF GROUND TRANSMITTER SIGNALS

FIGURE 3

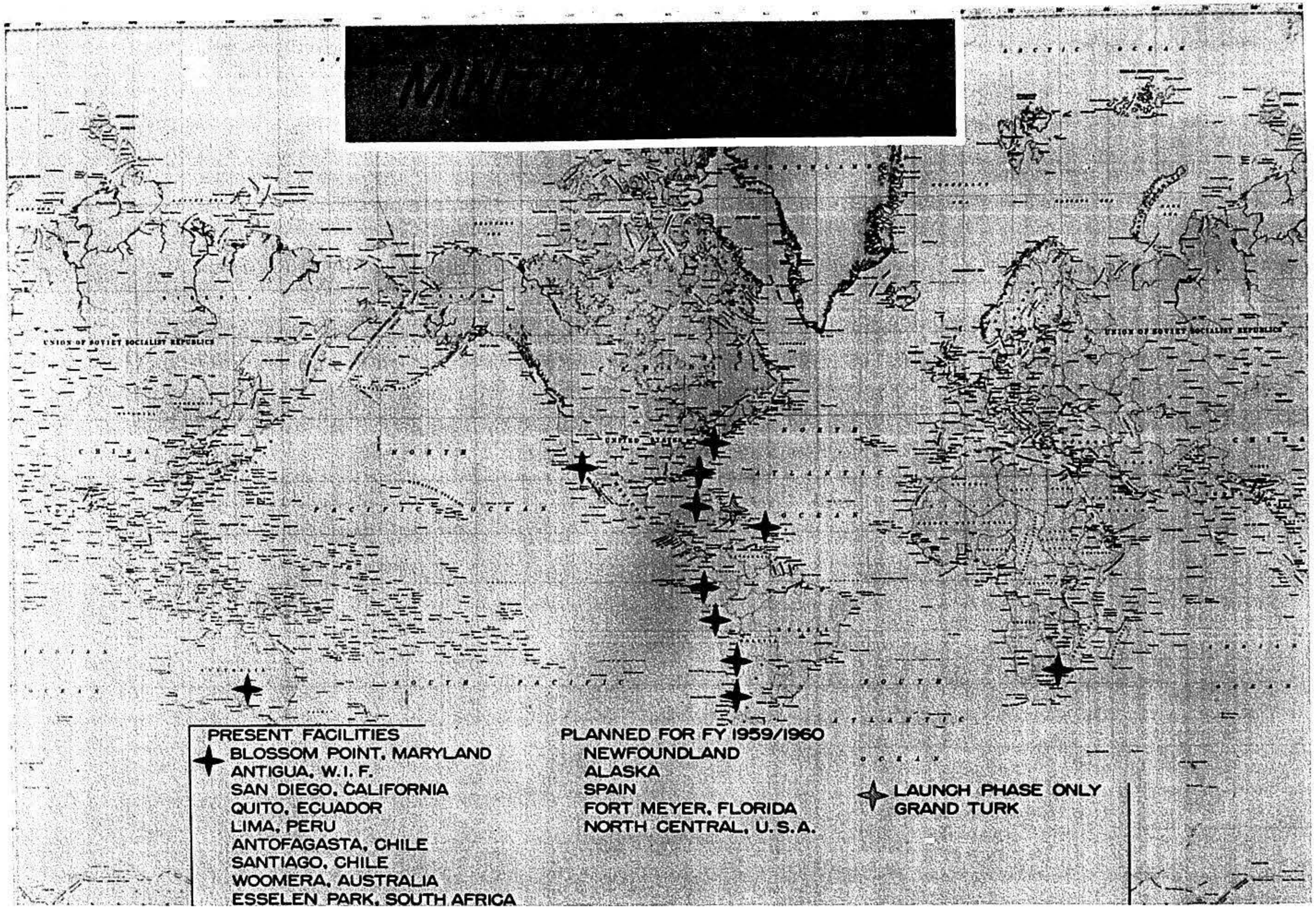

[redacted]
ARCTIC OCEAN
UNION OF SOVIET SOCIALIST REPUBLICS
UNION OF SOVIET SOCIALIST REPUBLICS
CHINA
NORTH
PACIFIC OCEAN
UNITED STATES
NORTH
ATLANTIC
OCEAN
SOUTH PACIFIC
SOUTH
ATLANTIC
OCEAN
PRESENT FACILITIES
BLOSSOM POINT, MARYLAND
ANTIGUA, W. I. F.
SAN DIEGO, CALIFORNIA
QUITO, ECUADOR
LIMA, PERU
ANTOFAGASTA, CHILE
SANTIAGO, CHILE
WOOMERA, AUSTRALIA
ESSELEN PARK, SOUTH AFRICA
PLANNED FOR FY 1959/1960
NEWFOUNDLAND
ALASKA
SPAIN
FORT MEYER, FLORIDA
NORTH CENTRAL, U.S.A.
LAUNCH PHASE ONLY
GRAND TURK

FIGURE 4

VANGUARD MINITRACK AND ASSOCIATED COMMUNICATION NETWORK

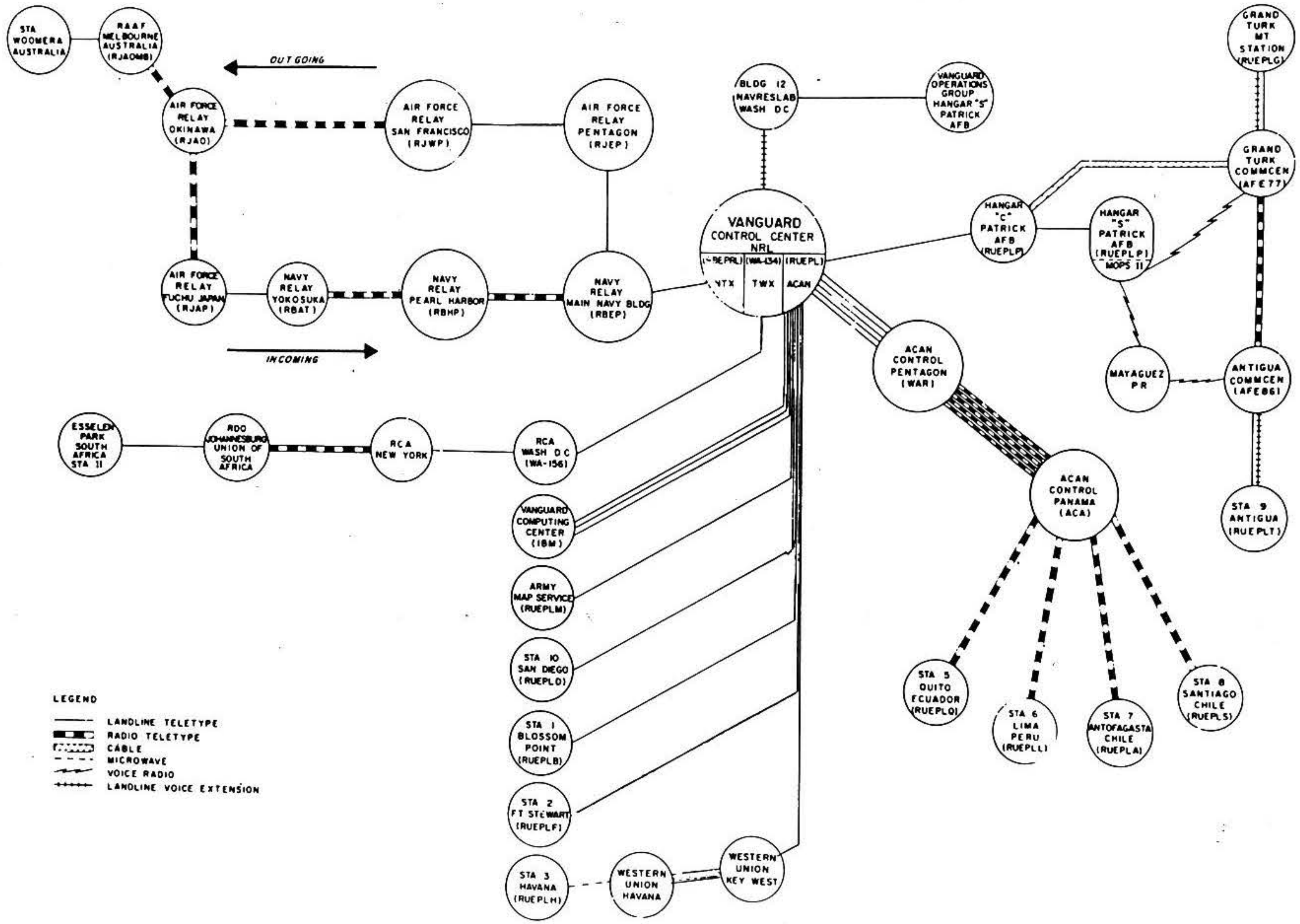


FIGURE 5

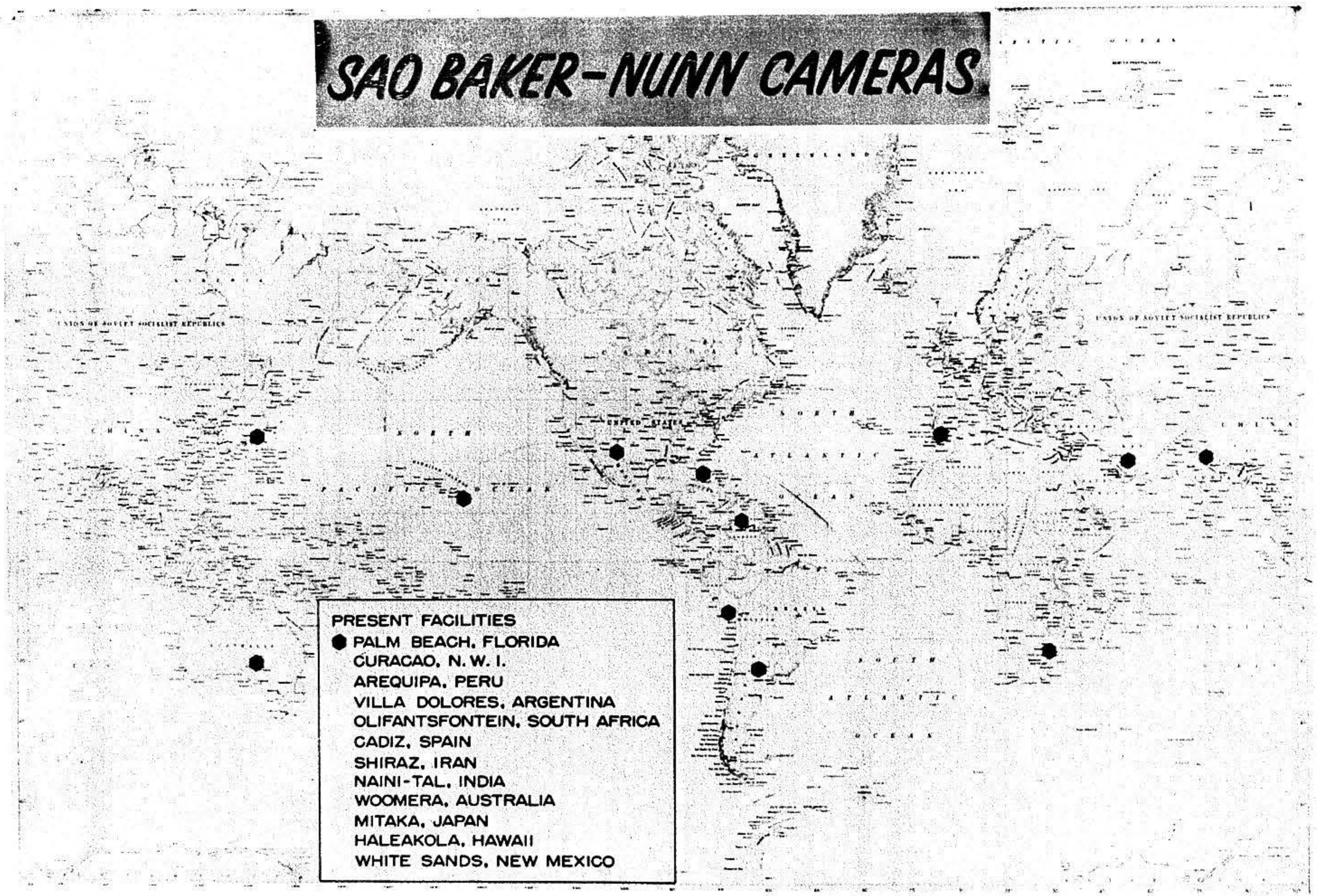

SAO BAKER-NUNN CAMERAS
PRESENT FACILITIES
PALM BEACH, FLORIDA
CURACAO, N. W. I.
AREQUIPA, PERU
VILLA DOLORES, ARGENTINA
OLIFANTSFONTEIN, SOUTH AFRICA
CADIZ, SPAIN
SHIRAZ, IRAN
NAINI-TAL, INDIA
WOOMERA, AUSTRALIA
MITAKA, JAPAN
HALEAKOLA, HAWAII
WHITE SANDS, NEW MEXICO

FIGURE 7

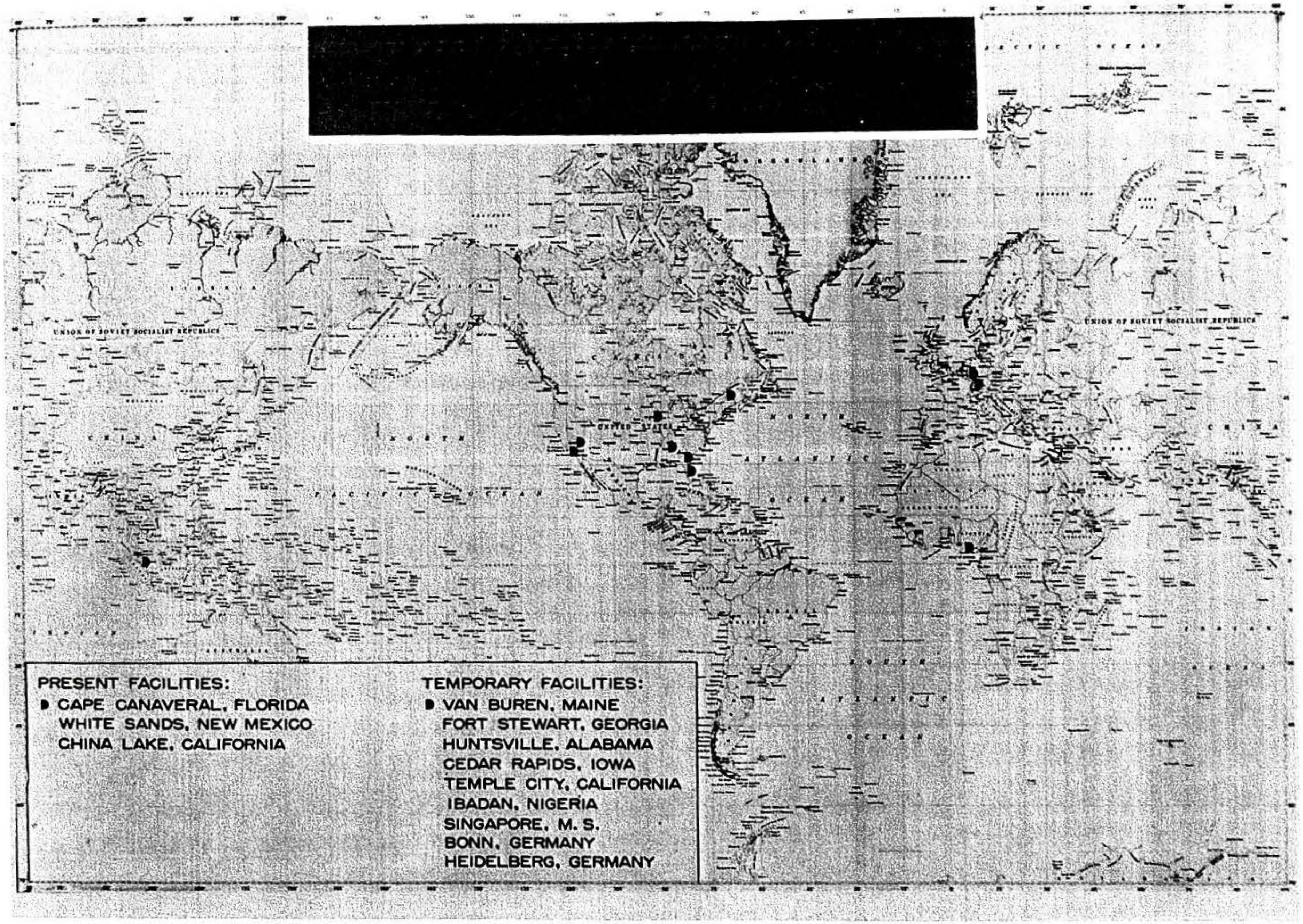

[redacted]
ARCTIC OCEAN
UNION OF SOVIET SOCIALIST REPUBLICS
UNION OF SOVIET SOCIALIST REPUBLICS
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
CHINA
UNITED STATES
PRESENT FACILITIES:
CAPE CANAVERAL, FLORIDA
WHITE SANDS, NEW MEXICO
CHINA LAKE, CALIFORNIA
TEMPORARY FACILITIES:
VAN BUREN, MAINE
FORT STEWART, GEORGIA
HUNTSVILLE, ALABAMA
CEDAR RAPIDS, IOWA
TEMPLE CITY, CALIFORNIA
IBADAN, NIGERIA
SINGAPORE, M. S.
BONN, GERMANY
HEIDELBERG, GERMANY

FIGURE 9

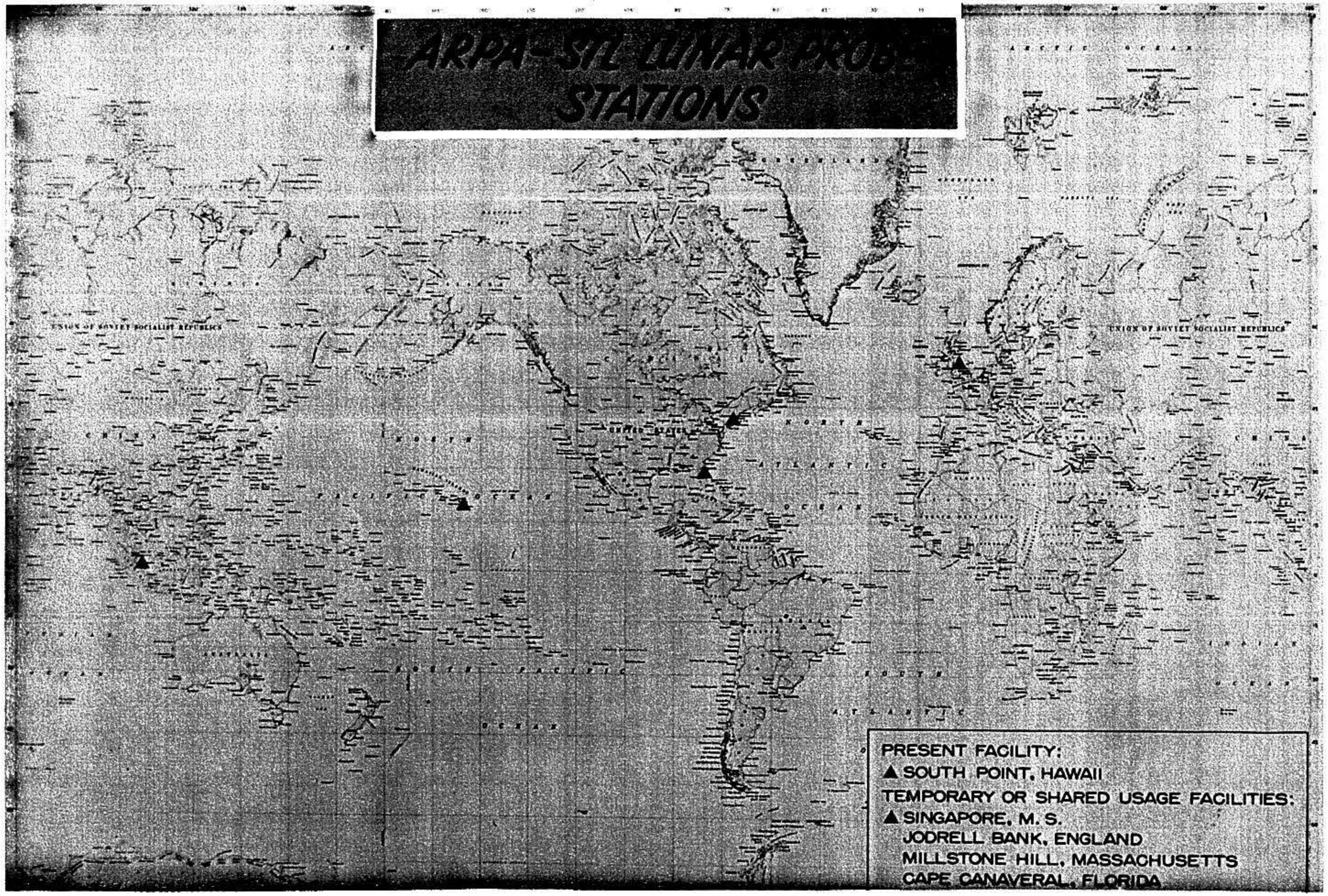

ARPA-STL LUNAR PROBE STATIONS
PRESENT FACILITY:
▲ SOUTH POINT, HAWAII
TEMPORARY OR SHARED USAGE FACILITIES:
▲ SINGAPORE, M. S.
JODRELL BANK, ENGLAND
MILLSTONE HILL, MASSACHUSETTS
CAPE CANAVERAL, FLORIDA

FIGURE 11


HIGH GAIN ANTENNA STATIONS
UNION OF SOVIET SOCIALIST REPUBLICS
PRESENT FACILITIES
GOLDSTONE CALIF. (85')
MALABAR FLA. (60')
VANDENBERG AFB.
HAWAII
PROPOSED FACILITIES
AUSTRALIA (85')
BLOSSOM POINT
SPAIN
SO. AFRICA (60')
BERMUDA
JAPAN (10')

FIGURE 11A

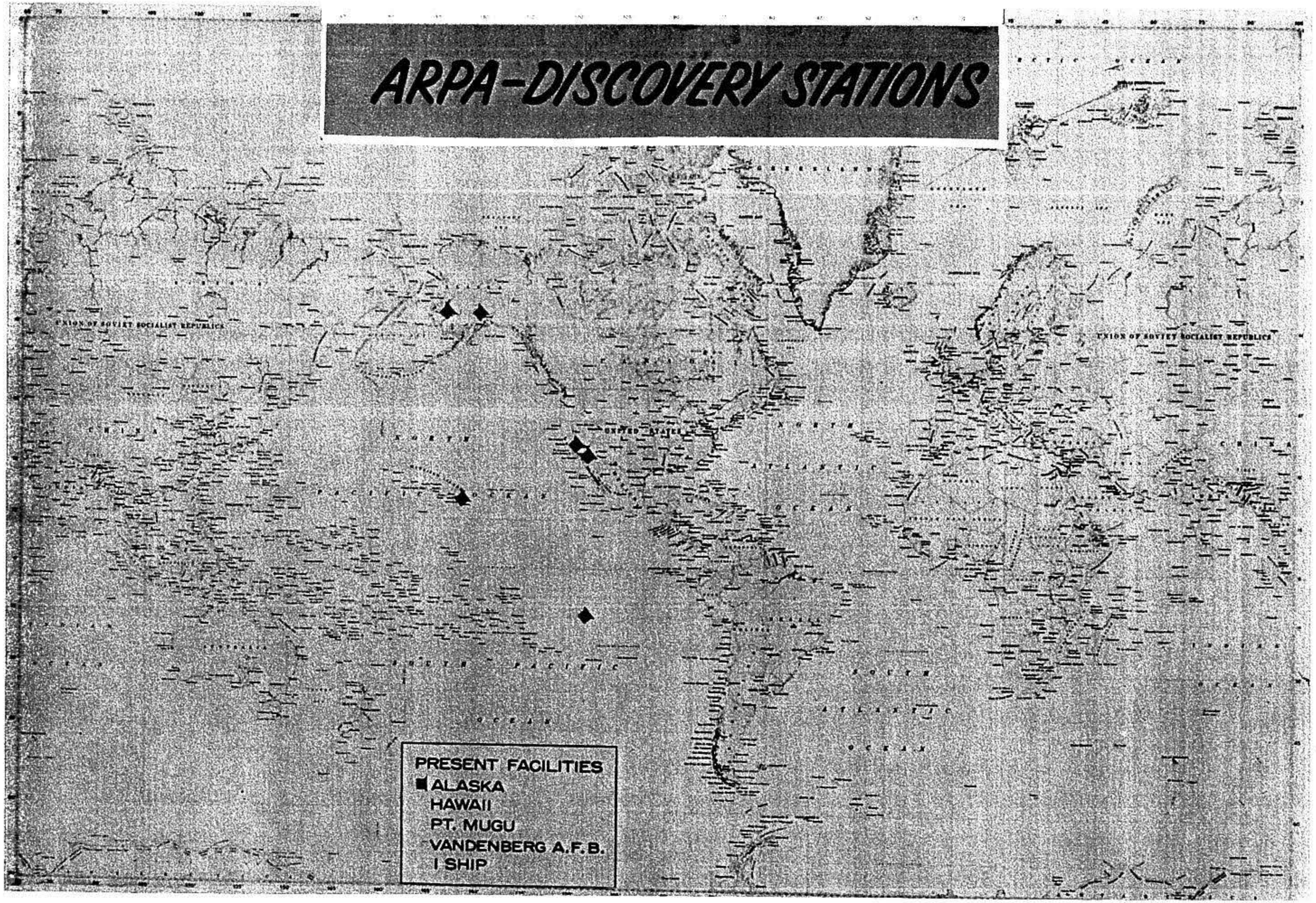
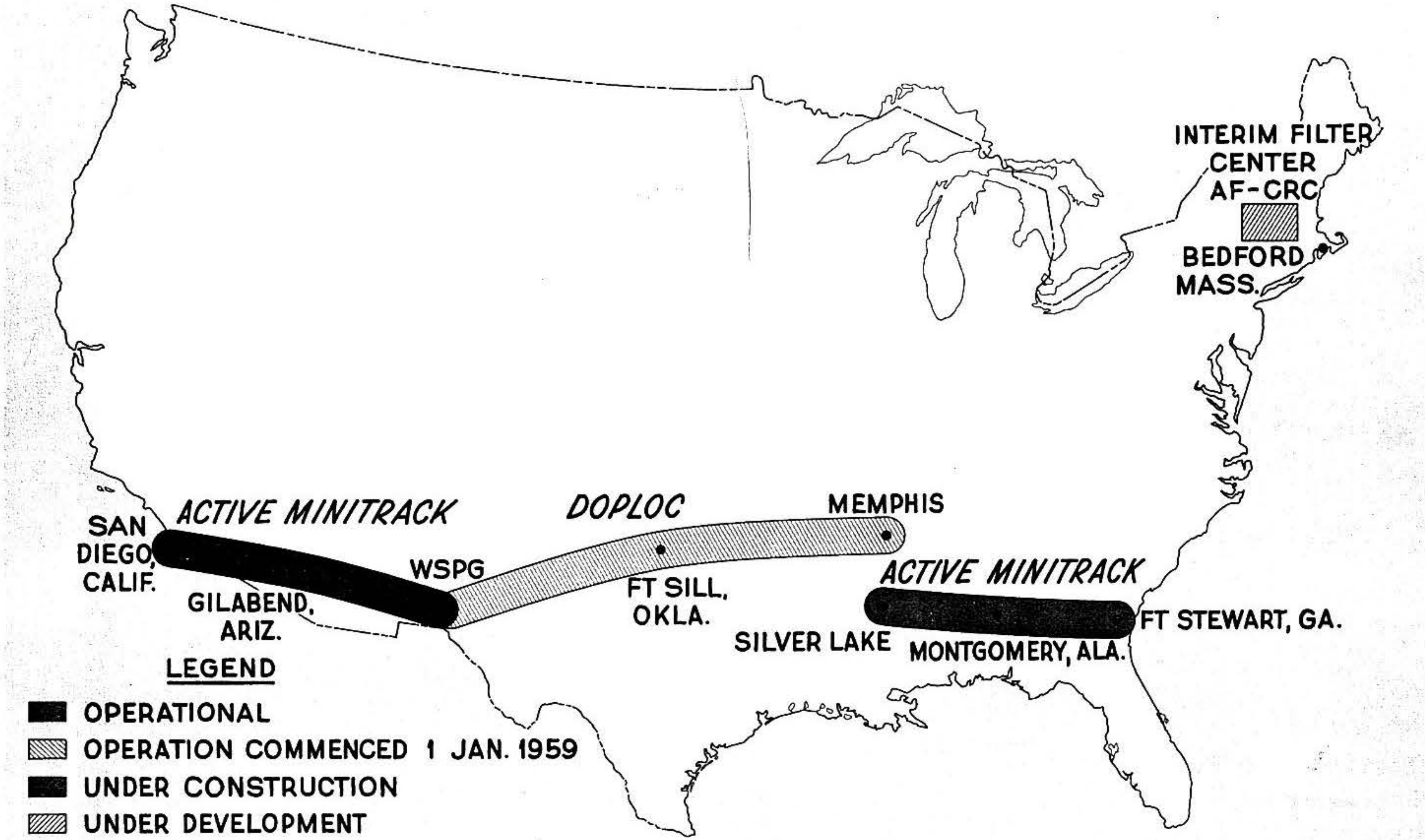

ARPA-DISCOVERY STATIONS
UNION OF SOVIET SOCIALIST REPUBLICS
UNITED STATES
PRESENT FACILITIES
ALASKA
HAWAII
PT. MUGU
VANDENBERG A.F.B.
1 SHIP

FIGURE 13A

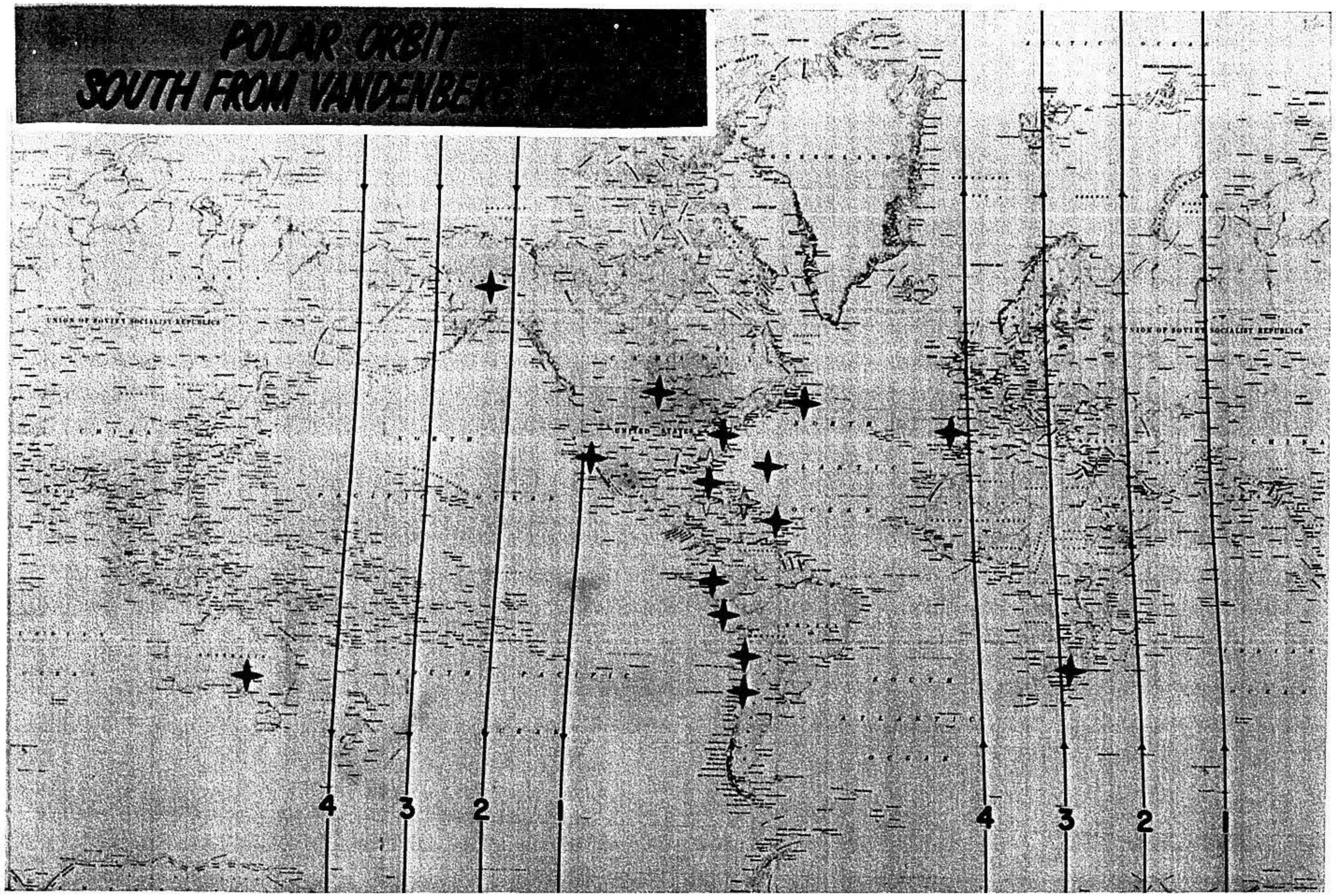
SECRET

DARK SATELLITE DETECTION FENCE



SECRET

FIGURE 15


POLAR ORBIT
SOUTH FROM VANDENBERG
UNION OF SOVIET SOCIALIST REPUBLICS
CHINA
UNITED STATES
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
4
3
2
1
4
3
2
1

INFORMATION TRANSMITTED FROM SATELLITES