~~TOP SECRET~~

IDA - TE - 1[illegible]

3 March 1959

Technical Evaluation of Mapping Satellite

by

Ad Hoc Panel on Satellite Mapping [redacted]

[redacted] Chairman

[redacted]

Approved by: [redacted]

Assistant Director

Advanced Research Projects Division, Institute for Defense Analyses
The Pentagon
Washington 25, D. C.

Under Contract to the Advanced Research Project Agency

Contract No. [redacted]

ARPA Log. No. ______

Copy No. ______

~~TOP SECRET~~

~~EYES ONLY~~

THIS IS A COVER SHEET

The information in this document is classified and as such will be treated according to OSD Security instructions. Writing on this cover sheet is prohibited.

For The

~~EYES ONLY~~

of

ARPA
Mr. Johnson
Adm. Clark -
[redacted]

ARPA/IDA
[redacted]

~~TOP SECRET~~

C52986

TOP SECRET

For The

~~EYES ONLY~~

of

ARPA

Mr. Johnson

Adm. Clark

[redacted]

ARPA/IDA

[redacted]

[redacted]

TOP SECRET

TABLE OF CONTENTS

[redacted]

I. **References**

1. [redacted]
2. [redacted]
3. [redacted]
4. [redacted]
5. [redacted]
6. [redacted]
7. [redacted]
8. [redacted]
9. [redacted]
10. [redacted]
11. [redacted]
12. [redacted]
13. [redacted]
14. [redacted]

[redacted]

15. [redacted]

16. [redacted]

17. [redacted]

18. [redacted]

19. [redacted]

20. [redacted]

21. [redacted]

22. [redacted]

23. [redacted]

[redacted]

II. Background Discussion of Problem

Reference 1 established and instructed the Ad Hoc Panel to undertake a technical feasibility study of a mapping satellite and a technical evaluation of the results which can be obtained with it. The problems associated with all elements of the Department of Defense were to be considered. In addition to the technical considerations, an engineering estimate of the fiscal requirements and a tentative firing schedule were to be included. Parallel with these studies, the Assistant Director for Policy and Planning, ARPA, was requested to prepare a requirement analysis on mapping. References 1 through 23 form the background working information for the Panel and each reference will be introduced as it applies to the discussion contained herein.

In the early stages of defining the technical approach for the mapping satellite it became readily apparent to the Panel that a detailed interchange of information between the technical and requirement phases of the problem must occur so that the proper technical approach could be specified. The building block to a sound research and development program is the requirement and without it or without a clear interpretation of it a sensible technical program is difficult to define. As a result of this situation the Panel report presented herein is complete in that it presents the technical and requirement phases of the mapping problem, together with a firing schedule and funding statement, as an integrated package.

Military reconnaissance has two basic problems. The first is to detect target objectives, and the second is to determine their location. Many methods of solution are possible, but in all cases they depend (to a greater or lesser degree) on aerial photographs or maps to provide a means of establishing and communicating the ultimate decision concerning the objective. A striking example of the problem is seen in new weapons systems (both those of the U. S. and those of her potential enemies) that are being developed to feature automatic guidance and high mobility. Once any intelligence sensor selects a target, it becomes necessary to determine with extreme speed and accuracy the exact target location, the location of the launching point, and the relative orientation of each point.

It is apparent, therefore, that a requirement exists for an extremely accurate reference system that will permit immediate determination of the coordinates of any point on the earth. To meet these requirements, any proposed system should include the following:

(a) The capability of surveying any area on the earth, including politically inaccessible territories where the survey must be completed without the benefit of established check points.

(b) The development of an automatic filing and retrieving system for pictorial background, permitting immediate and automatic tie-in of objectives located by any method.

The operational utility and feasibility of the new location concept represented by the above two general statements of performance has been proved in extensive exercises run by the Second and Eighth Air Forces of the Strategic Air Command (Monticello Program). Through the Monticello program, the USAF has developed a capability to survey vast areas with rapidity and without having access to an existing ground survey. However, this capability depends on aerodynamic vehicles overflying the territory to be surveyed at their operational altitude. This aspect, unless the decision to risk overflight with such vehicles at such altitudes is acceptable or becomes necessary due to imminence of war, keeps the system in abeyance for mapping politically inaccessible areas. Further, with the advent of advanced interceptor ground launched missiles, the vulnerability of such an aerodynamic system becomes highly questionable in the near future and the enemy will undoubtedly be in a position to deny us access to overflights. Therefore, from both the political and vulnerability point of view, it is desirable to consider satellites for overflight of territories dominated by hostile powers and thus avoid the politically sensitive part of this problem.

III. The Military Requirement and Mission Assignment

The military requirements to fulfill the Geodetic and mapping need is spelled out in two basic documents. The first submitted by the Department of the Army to ARPA, reference 4 details a rather complete approach to the problem. The second, submitted by the USAF, reference 20, is a general operational requirement number 80-4. In both the Army and Air Force requirements the basic needs are essentially the same. Military Service responsibility for the Geodetic and mapping assignment is clearly stated in Joint Chiefs of Staff action dated 25 August 1949. This action assigns to the Department of the Army responsibility for procuring geodetic data for the common use of all three departments, and for compiling the large scale topographic bases of land areas for use by all departments. It assigns to the Air Force responsibility for procuring data for primary applications to aerial warfare, for procuring aerial photography, and for providing ground control which requires airborne electronic means (Hiran). The Navy is assigned similar responsibility with respect to naval warfare. J. C. S. action dated 25 August 1949 also, however, authorizes the Army to obtain aerial photography from other sources than the Air Force, if the latter does not satisfy its requirements. J. C. S. action dated 16 October 1956 assigns the procurement of one type of geodetic data, ocean gravity surveys, to the Navy. The Panel is of the opinion that the J. C. S. should review its original actions in 1949 to introduce the element of geodetic satellites and determine whether additional assignment of responsibility is desirable in view of the present overall war plan and order of priority of geodetic type data. This suggestion is in keeping with the intent expressed by the J. C. S. in reference 2. In any case, the technical program for satellite mapping can be defined independent of mission assignment since the satellite mapping payload can produce if properly defined the type of data needed for all known military requirements in this area.

IV. Existing Geodetic Data Status and Order of Importance

During the initial phase of the Ad Hoc Panel work, the group was verbally briefed by the Director, ARPA and Director for Policy and Planning, ARPA, to the effect that preliminary discussions between the Director, ARPA and other elements of the O. S. D. have lead to a serious questioning of the desirability of proceeding with a request for emergency funds for the subject program. The point of contention was not whether the mapping requirement was proper but rather the questions posed related more specifically to the need for the program in view of information being obtained through other sources which appeared to meet the mapping data needs as outlined in the military requirements.

Investigations by the Ad Hoc Panel of the various technical approaches and the types of data obtained from these sources has resulted in the Panel finding that these programs and other sources of data will not meet the military mapping needs as detailed in the requirements; therefore, the need for a mapping satellite program has been established by the Panel. The technical analysis of this situation is presented in section V of this report.

Once establishing the technical need for the program the Panel was faced with determining the importance of a satellite mapping program relative to our current and projected military missions. Where did this program fit? And could it be classed as a program requiring emergency funds. To obtain perspective on this problem it was important for the Panel to determine the country's present situation with respect to "on hand" or available geodetic data to meet the military need.

Now used for geodetic computations are fourteen major datums plus several independent local datums; for military purposes, there are four significant groups, of which three are blocks of datums which have been firmly tied together in recent years. The American block, consisting of the North American and South American datums; the Indo-European block, consisting of the British, European, Arc, Nahrwan, Indian, and Malayan datums; and the Far East block, consisting of the Tokyo, Hong Kong, and Luzon datums. The fourth militarily significant group is the heterogeneous scattering of disconnected datums in the Soviet Union, China, and Afghanistan. Geodetic control points in the Soviet Union on a "tie-in" from the North American datum (point to point) are known for about 15% of the land area of the Soviet Union to around 1250 feet. The remaining approximately 75% of the land area must be "tied-in" by bridging techniques. Considerable errors can occur, several miles or more, in attempting this approach from established "on hand" data. The long established methods of geodesy are capable of locating any two points on the same land mass within 100 feet or better with respect to each other, given enough time and access to the intervening ground. In the last fifteen years, methods have been developed utilizing aircraft to give accuracies of positions within 25 feet across water gaps up to 550 miles. All these methods, however, require access to any point so connected.

Any method to obtain geodetic data of inaccessible areas must utilize a vehicle which obtains the data without installations in the inaccessible area. This, in essence, is the conventional method used, for economic reasons, to obtain map detail by bridging with photography between ground control stations. In the case of the Soviet Union, however, the inaccessible area requires a much wider bridge than ever crossed by conventional methods, indicating that the system utilized must be optimized in flight altitude, and path, must have a minimum of distortion in obtaining and transmitting the data, and must have an observing pattern which has great redundancy and makes maximum use of existing data, and must utilize the most advanced techniques of data processing.

In addition to requiring greatly improved map coordinate fixes on known targets, information will be forthcoming shortly on new and important targets in the area north of Moscow and east of the Urals in the Soviet Union. In these areas militarily useful geodesy information is practically non-existent. Map coordinate data for these new targets must be obtained rapidly since they probably will pose a severe threat to the security of the United States. The problems of effectively programming to a major extent ICBM's or IRBM's on older and newer targets with the existing mapping information is for all practical purposes unsolvable. Therefore, accurate target map data is vitally needed to give our future Ballistic Missile force a truly effective and deterrent posture. Even with offset bombing techniques as used in manned aircraft the new areas in Russia presenting probably a variety of new and important targets may be difficult to reach without better target data than presently exists. The effective use of the 36" Sentry satellite surveillance vehicle will require good map coordinate fixes so that it can be efficiently and accurately programmed to carry out its assigned mission.

References [redacted] emphasize the military importance of rapidly obtaining mapping data. These references include a statement from the Joint Chiefs of Staff (reference 2) which indicates a need to move more rapidly in this area. The Panel finds the urgency and importance of obtaining mapping information is so great that emergency funding is justified to permit this nation to acquire geodetic mapping data as soon as possible. Background material supporting the information presented in this section of the report is contained in references [redacted] The detailed technical discussion covering the general statements made in this section of the report is presented in section V.

[redacted]

V. Technical Considerations

A. Capabilities of existing systems

The USAF General Operation Requirement for "A Strategic Reconnaissance Satellite Weapons System" [redacted] dated 16 March 1955 [redacted] that was in effect at the time W. S. 117L was started recognized topographic mapping as a requirement but did not spell out accuracy requirements for the data produced.

The first phase of the program that resulted was based on the use of a strip camera with a lens that stressed resolution rather than distortion, a tracking system that permitted position uncertainties up to one-half mile and the data was returned to the earth by electronic readout. The contract statement of work specified that "The location of any point on any photograph shall be determinable with an error no greater than one mile."

It was recognized early in the program that the approach being followed was not suitable for mapping and charting purposes and a new [redacted] dated 26 September 1958 was issued. The -4 section of this document dealt specifically with Mapping and Charting and the detailed requirements were made compatible with the task to be performed. [redacted]

The 36" focal length visual reconnaissance system that resulted from the recent reorientation of the Sentry program continues to use a strip camera with electronic readout and makes no attempt to meet the mapping and charting requirements of [redacted]

The results of USAF project "Shoelace" were reviewed to determine their application to the solution of the Mapping and Charting problem. This project consists of using existing aerial photography in conjunction with data recently obtained on geodetic datum check points in Asiatic Russia to establish coordinates on target areas uncovered by this photography. By bridging techniques certain target areas have been located and checked with relation to datum within an accuracy of 750'. The application of the results of this program to the overall Targeting problem is very limited. The amount of photography on hand is very limited and the means of obtaining it can be denied us at any time.

The possibility of using Project C photography in conjunction with Shoelace geodetic datum check points was also explored and the results of the study were very discouraging for the following reasons.

The instrument used in the Project is of the Panoramic type. A scan angle of $\pm$ 35° from the vertical is used to obtain suitable ground coverage. When operating in a 138 statute mile orbit, a ground swath width of 200 statue miles is covered. The longitudinal distance along this path covered by each scan is 10 statute miles.

The scan speed used provides a 10% overlap at the center for each exposure. This overlap is inadequate to provide stereo height information for position rectification purposes. As an example, an object at the outer edge of a particular photograph that is 1000' higher than a similar object in the center of the photograph will be offset 700' from its true plan position. If a similar altitude differential prevailed on the opposite side of the photograph, a total error between two objects in the same photograph could be 1400' per thousand feet per 100 miles slope across the track.

If a known datum control point is located in a particular photograph, coordinates for other objects in the same photograph are subject to this altitude error without recourse.

If objects of interest are located in photographs that do not contain datum control points, bridging must be resorted to to refer these objects back to the nearest known datum point. Current practice in aerial photography where bridging is involved is to provide a 60% overlap between exposures to permit accurate matching for cantilevering purposes. The extent to which this bridging technique can be applied to photography without altitude rectification and with only 10% overlap is not known. Detailed studies are being made by both the CIA and the USAF but the result is not expected to be encouraging.

If the ability to bridge for any appreciable distance proves to be negative, the best locational accuracy that can be expected on any single photograph that does not contain an identifiable datum check point is (1) Position of satellite in orbit within one mile. (2) Uncorrectable error due to tilt of ±.1 in all planes of ±1300 in any one plane. 1800' for combined pitch and roll and an approximate 2800' when yaw is added. (3) Errors due to altitude gradient of 1000' per 100 miles, 1400'.

All of these considerations add up to a system that is far from meeting the accuracy requirements of USAF GOR-80-A or U. S. Army map service for mapping and charting purposes, a locational accuracy of 1000' with relation to local datum. In general it is expected that the existence of data of the type expected from the Project will add to the urgency for the establishment of a Mapping and Geodetic Satellite System, rather than satisfy the requirement.

B. Proposals for Mapping & Geodetic Satellite Systems

The two most promising proposals for accomplishing the Mapping and Geodetic task as laid down by current requirements have been presented by the USAF - BMD and the U. S. Army Corps of Engineers.

The USAF Sentry Development plan dated 30 January 1959 provides for the development of a Recoverable Reconnaissance Satellite System, with one version to meet the requirements of [redacted] A detailed technical presentation on this phase of the program was made to ARPA on January 15, 1959 [redacted]. Additional technical and fiscal data on the camera and ground data handling system planned were presented on February 5, 1959 [redacted]

The U. S. Army Corps of Engineers proposal to accomplish this mission with Project SALAAM was presented to ARPA by memorandum dated December 4, 1958 [redacted] Assignment of responsibility and allocation of funds were requested.

Comparative data on the two proposals are shown in the following table:

	USAF SENTRY	ARMY SALAAM
Booster	Atlas	Thor/Able
Added Stage	Sentry	New
Altitude of Orbit	150 NM	200 NM
Camera Focal Length	6"	4"
Ground Resolution	165'	300'
Angular Coverage	74° x 74°	59° x 59°
Ground Coverage	225 NM	225 NM
Overlap	60%	60%
Distortion	150' to 50' 5 microns	90' to 35' 5 microns
Format - Ground Camera	9" x 9"	4.5" x 4.5"
" - Star Camera	4.5" x 4.5"	1" x 2.25"
Film Size	Ground 9.5" Star 5"	Total 5"
Film Quantity	----------	2060'
Film Weight	195 lbs.	48.6 lbs.
Film Duration	64 Passes	64 Passes
Camera Weight	140 lbs.	34 lbs.
Stabilization Limits	± 3°	± 1°
Orbit Life	30 days	7 days

[redacted]

Space borne payloads & Vehicles

Both the USAF and U. S. Army proposals provide for obtaining raw photographic film data from the satellite by means of a recovery capsule. Each plans to use a between-the-lens shutter pulsed for single frame exposures at a rate providing 60% overlap per frame. The ground swath covered by each system is the same -- 225 N miles. Both plan the use of a star camera as a vertical reference indicator to determine tilt to within one minute of arc. Both groups claim to have chosen an optical system designed to give an optimum compromise between resolution and distortion as required by the G.O.R. The detailed solution to the problem in this area has led to a rather wide divergence in the end result as far as payloads and vehicles are concerned. Since both solutions either equal or better the accuracy requirements of the G.O.R. the evaluation must be made on the basis of cost and schedule implications of the two approaches.

The USAF proposal uses a 6" focal length lens in a camera providing a format size of 9" x 9". When operated at an altitude of 150 N miles this combination gives a resolution of 165' on the ground with a maximum distortion of 5 microns. A separate star camera was used having a 3" focal length lens with a 4½" x 4½" format. The weight of the combined cameras was 140 lbs. Two separate rolls of film were required, one 9½" wide for the ground camera and one 5" wide for the star camera.

The U. S. Army's SALAAM proposal uses a 4" focal length lens for the ground camera and a 3" focal length lens for the star camera. Both are combined into a single camera unit using a single roll of 5" film. The format for the ground camera is 4½" x 4½" and the star camera 1" x 2½". When operating at an altitude of 200 N miles the ground camera lens, film combination gives a resolution of 300" on the ground with a maximum distortion of 5 microns. The weight of the camera in this proposal is 34 lbs. and the film supply for a four-day operation is 48.6 lbs.

The film weight required by the USAF proposal to cover the same land area as the SALAAM proposal would be:

$$\frac{(9 \times 9)}{(4.5 \times 4.5)} + \frac{(4.5 \times 4.5)}{(1 \times 4.5)} \times 48.6 = 195 \text{ lbs.}$$

This is an increase of 146 lbs. A corresponding increase would be required in the cassette weight to house this added film.

The recovery system to return this added film weight to the ground based on Discoverer configuration would be:

$$146 \times 5 = 730 \text{ lbs.}$$

The combined added payload weight for the USAF approach to cover the same ground area as SALAAM would be:

Camera	140	-	34	=	106
Film	195	-	48.6	=	146
Recovery System					700 lbs.
			Total		952 lbs.

It is clear from the above that an entirely different type of vehicle is required for the USAF approach than for the SALAAM proposal. The USAF proposal provides a new Atlas boosted recoverable vehicle to be ready for initial flight test in January 1961. The vehicle is the pacing element in the proposal as the lead time for the camera is quoted as 12 to 15 months.

The U. S. Army SALAAM proposal provides for the development of a new stabilized satellite stage to fit on top of a Thor-Able that can be available for flight one year from go-ahead. The lead time on the camera and ground handling equipment is compatible with the date quoted on the stage.

The proposed new stage for SALAAM uses the same air borne and ground based recovery system as Discoverer, and the space allocated to the camera is essentially the same. Figure 1.

A comparison of payload requirements for SALAAM and the Discoverer project is as follows:

	Project	SALAAM
Camera	80.3	34
Cassette	12.5	8.8
Film	20.0	48.6
	112.8	91.4

If the Discoverer vehicle could be used for this project in essentially its present configuration major saving in time, money and reliability could be realized as compared to developing a completely new stabilized stage as proposed by SALAAM. The principal problem in adopting this vehicle to the problem is its operating altitude of 120 N miles.

This is the maximum altitude at which the vehicle is capable of handling the payload required. If the SALAAM camera were to be flown at this altitude the ground swath would be reduced to 135 miles which would radically reduce the coverage for a four-day operation.

Even though a payload weight margin exists as shown above, and plans are underway to increase this margin by the introduction of larger propellant tanks on Discoverer vehicle # 12 and up, there would still not be adequate performance to increase the operating altitude past the next node in the coverage curve as shown in Figure 2. These nodes occur as a function of the ratio of orbit period to earth's rotational rate. An orbit altitude of 150 N miles as proposed by the USAF cannot be tolerated in this type of mission.

A comparison of the lens characteristics of the two proposals reveals that the angular coverage of the SALAAM lens is 59° while the USAF proposed lens is 74°. If a 74° lens could be used with the SALAAM format size the ground swath at 120 N miles could be increased from 135 N miles to 181 N miles, or 208 S miles which is comparable to the "Project" and would develop an equivalent four-day coverage of 90% of the area above 40° latitude. (Figure 2.)

The above could be accomplished in a practical fashion by reducing the USAF lens design to ½ scale. This would reduce the focal length from 6 to 3 the format size from 9" x 9" to 4.5" x 4.5". The resolution at the new altitude of 120 N miles would be approximately:

$$(165 \times 2) \cdot \left(\frac{120}{150} \right) = 265$$

which is slightly better than the 300 quoted for the original SALAAM lens at 200 N miles altitude. The distortion would be the same as originally quoted by the USAF of less than 5 microns.

Ground Base Data Processing

Air Force: The Air Force proposal for ground base data processing equipment requires handling the output from the 6" focal length ground camera with a 9" x 9" format and the output from a 3" focal length stellar camera with a 4½" x 4½" format, and horizon recording on the mapping film. The ground base data processing system would be capable of producing the following items: (1) Target Coordinate, (2) Geodetic data sheets, (3) Target elevations, (4) Offset reference point coordinates, (5) Missile data sheets, (6) Target mosaics, (7) Photo maps. The equipment type required consists of the following: (1) Precision Measuring Device, this instrument would be capable of making accurate linear measurements within ± (2 to 5) micron tolerance. The readout would be automatic and recorded on tape. The instrument would have to accomodate film widths varying from 70 mm to 9½ inches; (2) Digital computers; (3) Analog computers; (4) Electronic Frame Rectifier, this instrument would be capable of rectifying photography of any tilt, format size, and scale to appear as if it was vertical photography. The instrument would electronically scan the tilted photograph and then represent the image increments in correct positions for rephotographing. Correct positioning would be determined by a computer which is an integral part of the rectifier; (5) Electronic Panoramic rectifier. This instrument would be capable of rectifying panoramic photography for tilt within ± 10 minutes of arc and scale adjustment to approximately 5%; (6) Area Matches, this instrument provides an additional method of determining latitude and longitude of the Nadir Point of an individual rectified aerial photograph. It would statistically reduce random error but will not handle systematic error; (7) Chart Revision Instrument. This equipment will facilitate addition of planimetric detail on the base chart using rectified panoramic prints and frame prints; (8) Analytical Plotter complex. This equipment would have a dual function in that it would be capable of automatically delineating contours within a stereo-scopic model and to automatically produce an orthophotograph of the same area; (9) Rapid Reproduction Equipment, provides rapid automatic reproductions of target charts, photomaps and mosaics for rapid distribution.

Items No. 2, 3, 6 and 7 are available now but must be adjusted to increase their capacity. These items total [redacted] for the re-adjustments necessary. Items 1 and 4 are presently available but would require some product improvement to adequately perform their function. The cost of 1 and 4 is approximately [redacted] and delivery could be expected in approximately twelve months. Items 5, 8 and 9 would require development time and estimated delivery is about eighteen months. The cost of these items is approximately [redacted] An additional cost of approximately [redacted] would be required for equipment integration. The total equipment cost of the Air Force proposed system for ground handling comes to about [redacted]. No operations costs are included in these figures. Estimates run around [redacted] for this which would result in a total of around [redacted]

Army: The Army SALAAM proposal for ground base data processing equipment requires handling the output from the 4" focal length ground camera with a 4.5" x 4.5" format and positioned on the same film is the output from a 3" focal length star camera with a 1" x 2.25" format. In addition, the altitude, frame number, aggregate time, and frame calibration is placed on the same 5" wide film. The ground base data processing system would be capable of producing essentially the same information as listed under the Air Force proposal and that discussion will not be repeated here. The equipment required consists of the following: (1) Five ground Matches, [redacted] (2) Five Star Matches, [redacted] (3) one least mean square analog computer, [redacted] (4) three optical rectifiers, [redacted] (5) three viewers, [redacted] (6) Filing Systems, [redacted] Operations, [redacted] The total cost including operations would be around [redacted] Of this total, a possible cost reduction resulting from related Government-supported effort of around [redacted] could be obtained. The use of [redacted] equipment bought under the Monticello program is involved in this cost saving.

After film processing (development) the following input data will be available as required for the ground handling system:

(1) Photographic recordings of the ground with 60 per cent or more overlap along orbital flight paths and any available overlap between orbital paths.

(2) Photographic recordings of the stars to fifth order of magnitude taken synchronously on the same optical axis but in direction opposite to the ground record.

(3) Time recorded to $\frac{1}{1000}$ of a second.

(4) Interior orientation of the camera.

(5) (5) Altitude recordings as obtained from the infra-red horizon sensors.

(6) A matchable record of acceptable positional accuracy (750 feet) of a ground survey in accessible territory.

(7) A matchable record of star positions to the fifth order of magnitude.

(8) The best available dimensions of the earth.

(9) The best known mathematical condition of orbital performance.

With these defined inputs the survey of the earth and of its denied territories is accomplished through the following steps:

(1) The photographic records showing surveyed territory are matched directly into a prepared reference of a matchable pictorial representation of the ground (photographic, map, radar), thus determining the initial principal point positions.

(2) The synchronous celestial recordings are matched into a prepared reference of the celestial background, thus determining the spatial point of the optical axis of each (corresponding) ground photograph. This spatial point and the center of the earth determine the orientation of the optical axis in space. Time and the initial principal-point position determine the orientation of the tangential plane of the principal-point position. The angle between the perpendicular to the tangential plane (local vertical) and the optical axis is the initial tilt of the photographic record.

(3) The satellite position obtained from step (2) in space is now established from which an improved tangential plane on the surface of the earth is obtained resulting in an improved tilt. This process is reiterated until the results become stable at the exact tilt and exact Nadir positions of the satellite at the time of the exposure.

(4) The altitude recordings provide an independent though a less accurate means of finding the Nadir positions of the satellite on the earth's surface. A rapid determination of tilt from the altitude recordings will provide a check on the results of the automatic reiterative computation and will permit an early judgment of the system's general performance in space.

(5) The exact tilt is then used to eliminate distortions produced by perspective. The rectified photographic ground record is then matched to the ground reference. This match determines the exact scale and the exact ground position of the record. With this infor-

[redacted]

mation and previous information obtained in early steps the spatial positions of the satellite when the photographic record was taken is established. The orbital position thus determined is used as an "assumed position". Each ground picture taken over surveyed territory thus leads to an "assumed (orbital) position". All assumed orbital positions obtained are used to determine the "best orbit" through least square adjustment procedures.

(6) Secondary parameters of the mathematical equation, such as the flattening factor, can be determined independently through the recessional motion of the extreme points of the orbit and from the precessional rotations of the orbital plane in space. An important by-product of the orbital computations is the tie-in between various geodetic datums. The large number (over 100) of observations from each datum should easily show systematic discrepancies between datums of different surveyed territories down to as low as 100 feet. The orbital survey will thus produce its own world-wide datums.

(7) The best orbit resulting from the adjustment of all assumed orbital positions corrected for datum discrepancies to the mathematical condition of orbital performance becomes the "tape-measure" for the survey of inaccessible territories.

(8) The scale and tilt data are used to rectify all ground recordings taken over unsurveyed territory.

(9) The rectified photographs lead to surface positions establishing a new reference surface as that rotational ellipsoid from which all discrepancies of surface positions determined from the records and the interior camera orientations form a least sum of squares.

(10) On that surface the positions of all fiducial mark centers are established. These, then, are the assumed positions in a Monticello type network of measurements.

(11) The measurements of the network themselves are obtained through matching adjacent rectified ground recordings.

(12) From the data obtained in steps (9) and (11) a regular Monticello type survey is conducted for the area, leading to an adjustment principal point positions and to North orientations for each photograph.

<u>Tracking and Recovery Ground Base System:</u>

The ground based tracking, communications and recovery network is the same for both the Air Force and Army proposal. The film is recovered and the basic ground tracking network and recovery system is the system being used for the Discoverer program. This same system would be used with no additional requirements introduced.

[redacted]

VI. Recommended Program

Technical Approach

As a result of the above described study and knowledge of other associated programs the Ad-Hoc Panel has decided that the most expeditious, low-cost, and most likely to succeed approach to the Mapping and Geodetic Satellite program is to use the Discoverer Project vehicle operating at its current design altitude of 120 N miles equipped with an alternate payload nose section in which the Project instrument has been replaced with a special mapping camera with a lens which is a ½ size scale down of the T-11 lens proposed by the USAF. A star camera should be incorporated in the same basic camera frame with both cameras recording the SALAAM type format on a single 5" wide film.

The ground based tracking communications and recovery network associated with the Discoverer program is considered adequate for the mapping satellite program and it is recommended that it be used with no additional requirement introduced.

The ground based data handling equipment should be that specified in project SALAAM with maximum use being made of equipment being bought and paid for under the Monticello I and II programs.

A total of four launchings should be planned in the program with the first to take place in approximately mid-May 1960. Six total payloads should be provided to allow some flexibility for interchange with Project firings if the military situation dictates.

Schedule

By the spring of 1960 the Discoverer program should have progressed to the point where one satellite can be fired every three weeks from each available launch pad. Assuming an operational season of from mid-April to mid-September, it should be possible to attempt 12 to 14 satellite launchings from the two pads available. This will permit the addition of the four mapping shots to the overall program without interference with the eight planned Discoverer firings during this time period.

Funding

The total estimated cost for such a four-shot program would be as follows:

4 Discoverer Vehicles less Payload
6 Cameras including R & D
6 Integrated Payload assemblies
Additional Data processing eqpt.
Data processing handling & Analyses

[redacted]

[redacted] TOP SECRET

As a portion of this program will be accomplished in FY 1960 a possible breakdown by fiscal years is as follows:

	FY 1959	FY 1960
Vehicle	[redacted]	[redacted]
Cameras	[redacted]	[redacted]
Paylords	[redacted]	[redacted]
Equipment	[redacted]	[redacted]
Data Processing	[redacted]	[redacted]
Total	[redacted]	[redacted]

Management:

The technical approach outlined previously in itself suggests the specific areas of management responsibility as derived from the hardware supplier.

The following are the three major areas of management responsibility:

1. Overall systems integrations

2. Vehicle, launch, tracking, and recovery of film

3. Camera, ground base data equipment, processing, and analysis

The Air Force or the Army would be designated by ARPA to act as their agent for this program. The Joint Chiefs of Staff should be consulted before taking action in this assignment.

Lockheed presently has responsibility in area 2 above in the Discoverer program. The panel recommends they continue this responsibility as it applies to the mapping satellite project.

The panel recognizes the contributions made by the General Electric Company in providing extensive engineering information and systems analysis leading to the establishment of the recommended program. The panel recommends that General Electric be assigned responsibility for area 3 above. Area 1 and 2 should be assigned to Lockheed.

A solution to the agent selection problem representing what the panel feels to be a happy and acceptable service compromise would be as follows: The Air Force would be appointed as ARPA's agent for areas (1) and (2). The Army would be appointed as ARPA's agent for area (3).

The approach outlined above is a direct parallel to management approach currently being followed in the Discoverer Project "C" with the Army substituting in the role of CIA. This approach appears to be working very well to date.

[redacted]

Covert Program Phase:

The panel recommends that the mapping project be covertly integrated into the "Discoverer Project C" program because of the operational time for the program and its use of the "Discoverer" vehicle.

Letters should be initiated to all parties (USAF and Army) which essentially indicate that the mapping program will be conducted under the Sentry project. This action would be consistent with the recent development plan submitted by the USAF on subject Sentry and would therefore constitute the framework for the cover story. Care should be exercised in the Sentry program to insure that the portions dealing with specific hardware directed only at the mapping payload be not permitted to develop since the real mapping job will be undertaken in the current program and only the cover insurance is maintained in Sentry. As a part of this procedure the ARDC [illegible] laboratory should be notified to proceed with the 6" camera design and approach compatible with the Atlas re-entry vehicle identified in the USAF Sentry Development Plan. This requires no funds from ARPA but does require ARPA concurrence that ARDC expend [redacted] of their own monies which are already identified by the USAF for this purpose. The long term technical returns from carrying out the R & D prototype construction of their 6" camera will be useful to the longer range military mapping needs and therefore is a fruitful expenditure of funds.

ARPA orders concerning the real program as outlined herein should then be issued covertly.

VII. Conclusions

The following conclusions are made by the panel:

1. Geodetic mapping data is needed covering the Soviet Union to location accuracies of about 800-1000 feet with relation to the U. S. datum.

2. Existing programs and approaches for obtaining photographic reconnaissance data will not provide the required geodetic mapping data.

3. A Satellite Approach to the geodetic mapping need is the best and only practical way to obtain the desired information.

4. The importance of acquiring the geodetic mapping data is considered high enough to justify emergency funds in order to start the program immediately.

5. The program should be conducted in a covert manner as part of the ARPA Discoverer program.

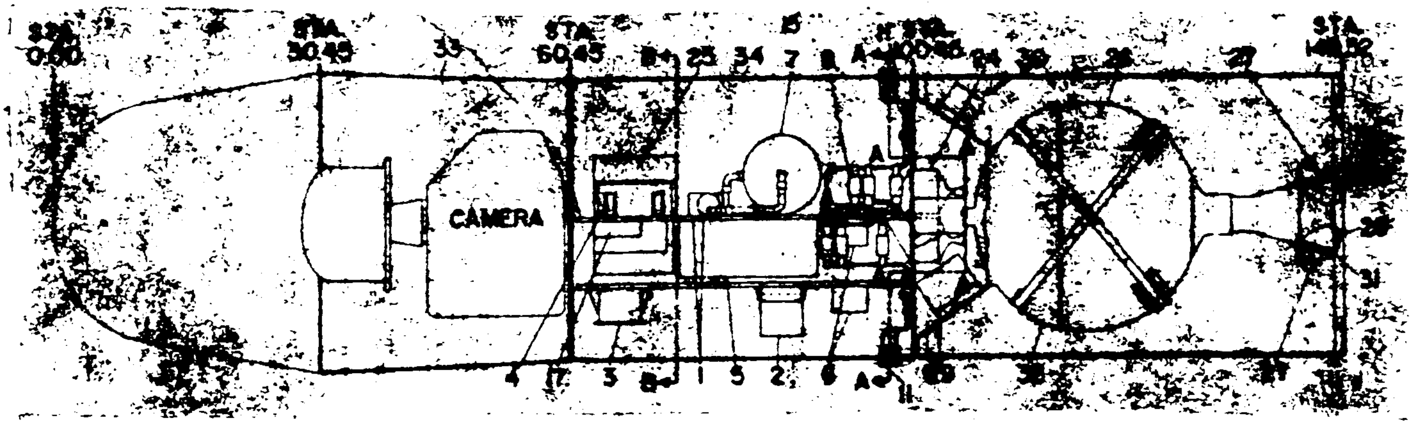
6. The program as discussed in detail in section V of this report should be carried out by ARPA and will provide the required geodetic mapping data at the earliest time for a minimum cost.

7. The Joint Chiefs of Staff should be requested to further clarify their 1949 mission assignment in geodesy and mapping to the Army, Navy, and Air Force in view of the program recommended herein.

~~TOP SECRET~~

~~SECURITY INFORMATION~~

[redacted]



[redacted]

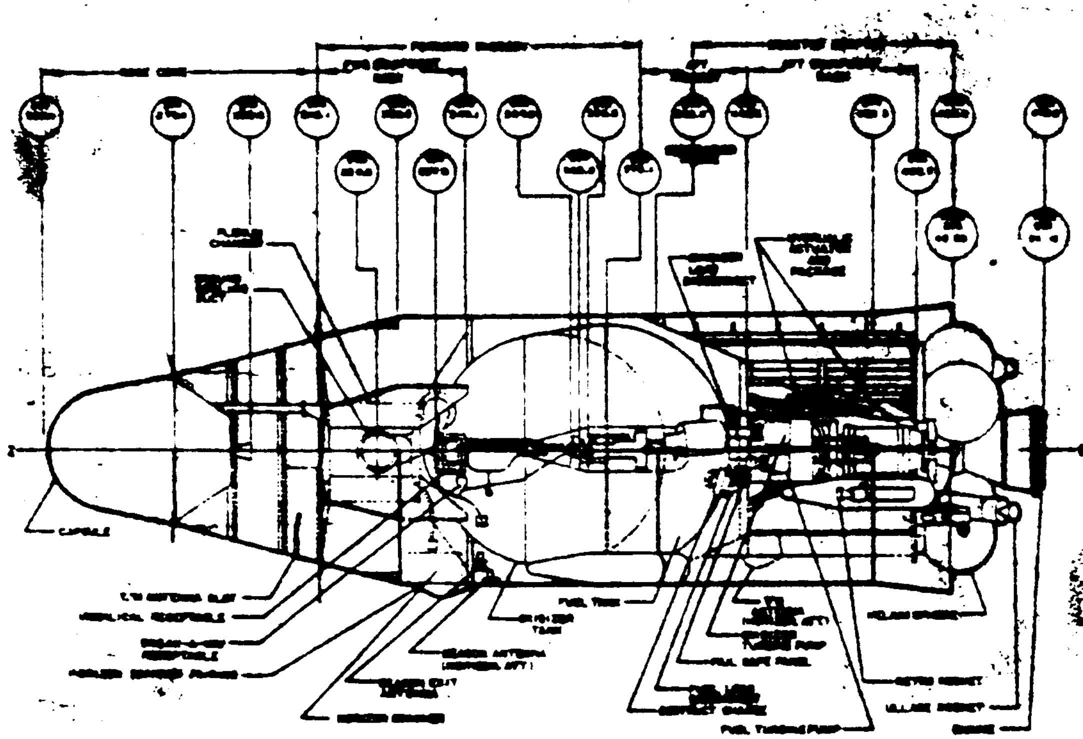
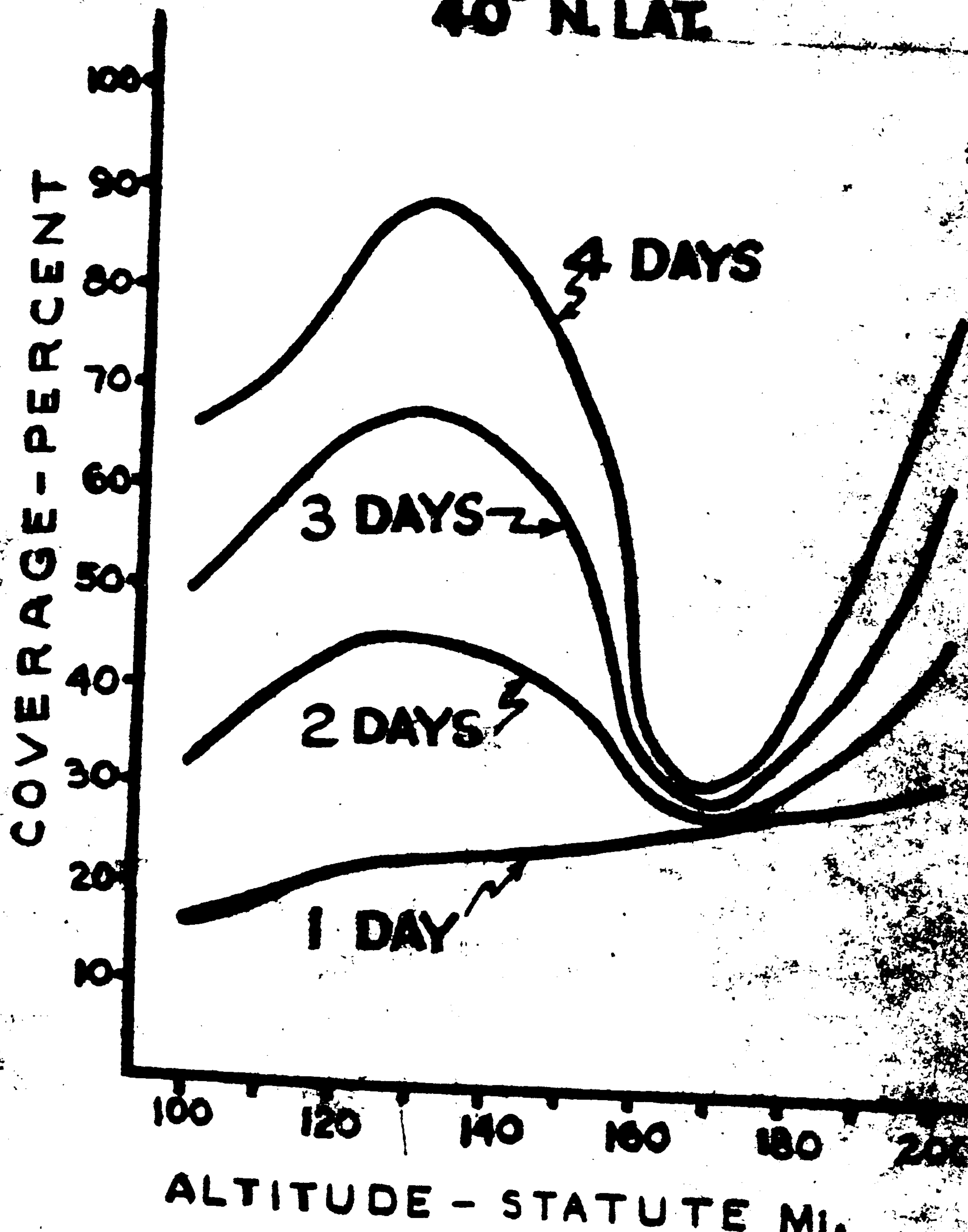


Figure 1

Copy [redacted]

TOP SECRET
SECURITY INFORMATION

40° N. LAT.



COVERAGE Vs ALTITUDE

Copy [redacted] copies