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AFMDC-TR-63-1
Technical Report

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(U) LUNAR EXPLORATION SYSTEM (LES) LAND AREA RECOVERY RANGE AND ASSOCIATED COMMAND AND CONTROL SYSTEMS

SEPTEMBER 1963

TASKS 618207(24)
618207(80)

AIR FORCE MISSILE DEVELOPMENT CENTER

DEPUTY FOR FOREIGN TECHNOLOGY

AIR FORCE SYSTEMS COMMAND

HOLLOMAN AIR FORCE BASE

NEW MEXICO

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LUNAR EXPLORATION SYSTEM (LES) LAND AREA RECOVERY RANGE AND ASSOCIATED COMMAND AND CONTROL SYSTEMS

September 1963

Task 618207(24)
Task 618207(80)

Prepared by:

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(U) PREFACE

The information reflected in this Technical Report has been prepared primarily for the use of Foreign Technology personnel engaged in the analysis of the Soviet space effort. This is an Air Force Systems Command project, and this contribution will be of interest to those analysts concerned with Soviet land recovery areas and their associated requirements. This report serves as a technical support document for Project 6182, Tasks 618207(24) and 618207(80) assigned to the Air Force Missile Development Center. (~~S~~)

(U) PUBLICATION REVIEW

This Foreign Technology document has been reviewed and is approved for distribution within the Air Force Systems Command. (U)

FOR THE COMMANDER

Howard L Conkey

HOWARD L. CONKEY
Lt Col, USAF
Deputy for Foreign Technology

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(U) SUMMARY

Purpose

This Technical Report was prepared in accordance with requirements established by the Foreign Technology Division Technical Operational Project Specification (TOPS). Requirements are reflected on pages 28 and 91 of the Soviet Lunar Exploration Program TOPS. The results in this report fulfill the AFMDC portion of Tasks 618207(24) and 618207(80) pertaining to lunar exploration vehicle land recovery range. (S)

Conclusions

a. The design characteristics of a lunar return vehicle, its guidance capabilities, and geometrical mission constraints determine the final geographic boundaries of any recovery range. (U)

b. Using standard recovery site selection criteria, the area bounded by 56°N-60°E, 56°N-80°E, and 44°N-60°E, 44°N-80°E is best suited for the establishment of a Soviet lunar return vehicle recovery range. (S)

c. Logistic support bases (search/recovery staging areas) which would provide the most timely recovery of a downed vehicle are located in the northern sector of this area. This sector is

bounded generally by 48°N-60°E, 48°N-80°E and 56°N-60°E, 56°N-80°E. (S)

d. Assuming the use of a semi-ballistic lunar re-entry vehicle, the northeastern sector bounded nominally by 48°N-68°E, 53°N-68°E and 48°N-80°E, 53°N-80°E offers the maximum number of existing staging areas. The use of this sector could minimize the search and recovery time by using of a number of nominally equidistant staging areas. (S)

e. The recovery range currently being used for Soviet earth orbit recovery operations appears to fall within this sector and would serve equally well without modification for the recovery of a semi-ballistic lunar return vehicle. (S)

f. The recovery range for a lifting lunar return vehicle would most suitably be located in the low level arid southern sectors. The use of this type vehicle would also require the development of additional facilities for terminal tracking and guidance including:

(1) A complex terminal range tracking network.

(2) Terminal range command and control instrumentation.

(3) Terminal range control and logistics complex.

(4) Primary and secondary landing sites. (S)

Background Highlights

Due to a void in available information concerning planned site selection for a Soviet lunar return mission, information used in the preparation of this study consisted primarily of a review of current Soviet range recovery areas and their utility for use as lunar vehicle recovery sites. Although source material does suggest that the Soviets plan earth-moon-earth recovery operations, little or no information is available as to the type of vehicle to be used or what preparations may be underway to establish a land-based recovery range specifically designed for a lunar return mission. ~~(S)~~

The types of re-entry vehicles which are discussed briefly in this report stem from studies conducted in support of the U.S. lunar program and are used only as an aid in the site selection criteria. (U)

SECTION I

(U) LUNAR RE-ENTRY VEHICLE

In order to determine what site selection criteria should be used in selecting an optimum lunar recovery range, the design characteristics of the proposed re-entry vehicle must be defined. (U)

U.S. design studies related to the development of a lunar return re-entry vehicle have pointed out the complexity in the overall systems design for this type of mission. Ultimate vehicle design will be largely dependent on the superorbital velocities encountered upon re-entry into the earth's atmosphere. Velocities encountered will be near 36,000 fps as opposed to the nominal 25,000 fps encountered by a low earth orbit vehicle. The inaccuracy in tracking vehicles at superorbital velocities over long distances also becomes a serious problem during the return leg of the lunar trajectory as well as during entry into the earth's atmosphere. (U)

All space vehicles entering the earth's atmosphere at super-orbital velocities can be classed into two broad groups -- those with no lift (i.e., ballistic) and those whose lift-to-drag ratio ($^L/_D$) > 0. Re-entry vehicles in the latter group also fall into two classes -- those of a fixed design with a constant lift coefficient C_L for any given angle of attack, and a second class with a variable-geometry configuration. Fixed C_L designs have been tested in the U.S.; however, the variable-geometry concept has not received any appreciable study. One such variable-geometry design calls for folded wings on the leeward side of a relatively compact vehicle. After the vehicle has slowed down and reached a low altitude, the wings are unfolded to provide control and stability required for a soft landing. ~~(S)~~

In the design of a vehicle which re-enters the atmosphere from the moon, it is assumed that the objective of re-entry is to arrive at a particular point on the earth's surface. If it has no guidance system, the vehicle will depend entirely on the forces that act upon it during its precalculated trajectory. Thus, it may be best that the vehicle has no lift since unexpected variations in such parameters as density and wind velocity will more severely affect the trajectory of a lifting vehicle than they will of a ballistic or a semi-ballistic ($L/D \approx .5$) type. On the other hand, a guidance and control system can correct for any unexpected deviation of the vehicle from the prescribed descent path. (U)

Until a vehicle's maximum re-entry velocity and trajectory are specified, the exact form of the lifting surface cannot be accurately defined. As the velocity mounts, it becomes increasingly difficult to provide suitable lift because of the severity of heating conditions. In these circumstances, it is necessary to compromise control requirements and design a more compact vehicle with a lower $^L/_D$ ratio. (U)

Due to the tolerance limitations placed on the re-entry vehicle by the boundaries of a small lunar return re-entry corridor, it has been found that a lift vehicle with a small $^L/_D$ (on the order of .5) can enter the atmosphere at a steeper angle and lower trajectory approach than a ballistic vehicle and therefore increase the corridor depth by extending both the overshoot and undershoot boundaries (Figure 1). (S)

Inasmuch as the semi-ballistic ($^L/_D \approx .5$) re-entry vehicle provides structural simplicity, compactness, and relative lightness with respect to the entire lunar mission, it is assumed for the purposes of this report that this type of vehicle will be used by the Soviets for lunar return missions. Figure 2 shows the range and lateral displacement for a lifting body re-entry (maximum $^L/_D$ 0.5) assuming return velocity deceleration to 25,000 fps. (S)

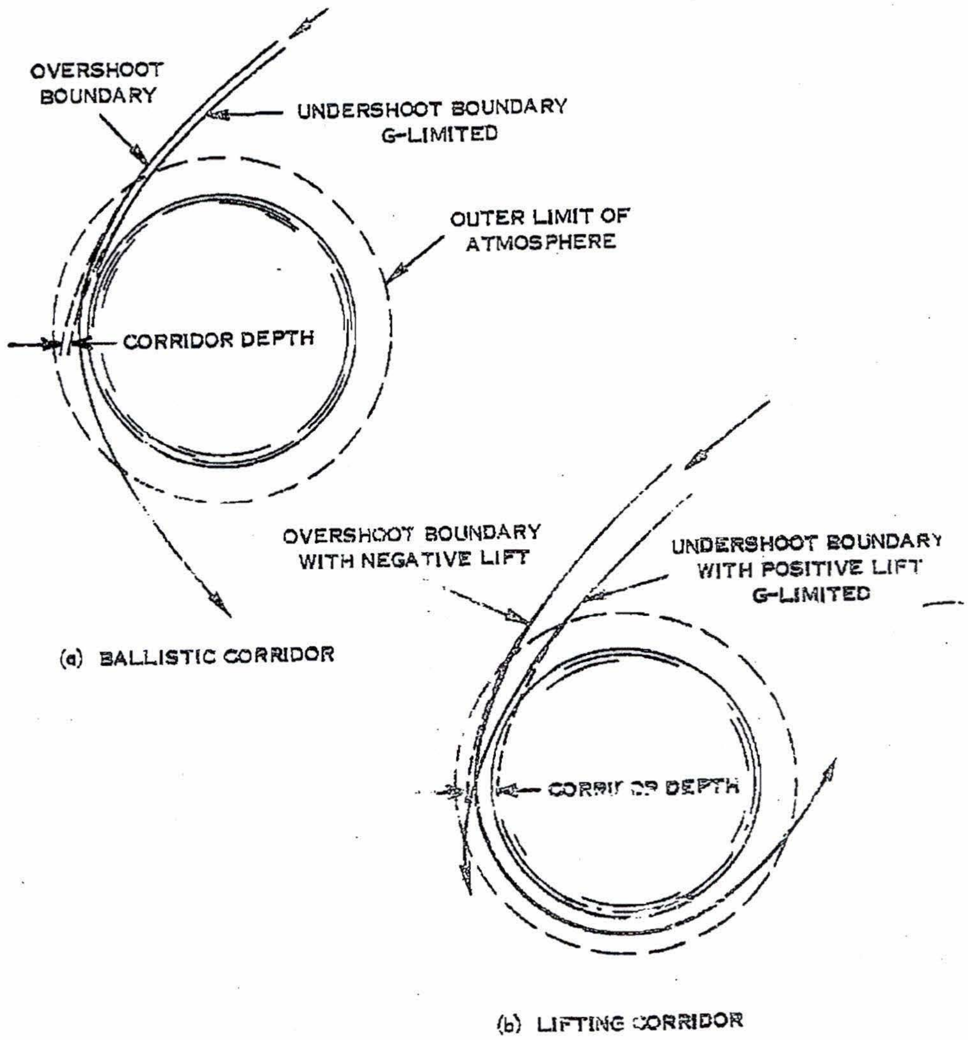

FIG. 1 (U) ENTRY CORRIDORS

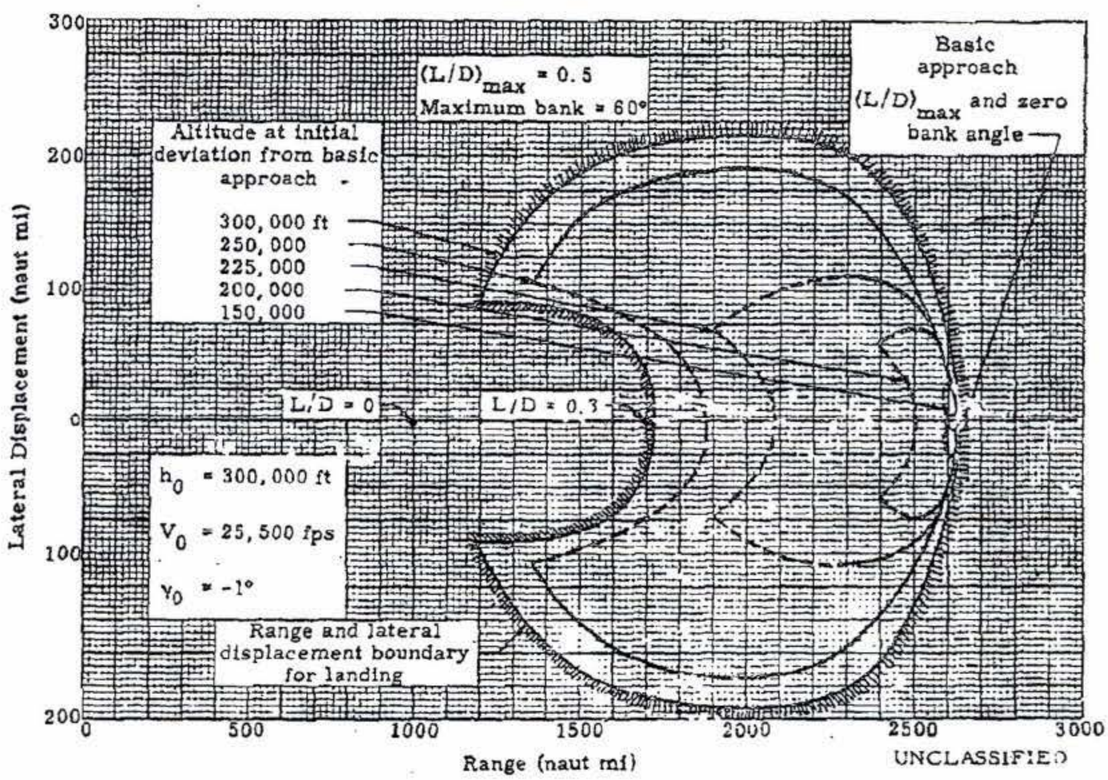

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Fig. 2 Range and Lateral Displacement for Lifting Body Re-Entry

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SECTION II

(S) USSR LUNAR RECOVERY SITE SELECTION

Prior to assessing the operational characteristics of a land area recovery range for returning Soviet lunar exploration vehicles, it is necessary to define the external parameters which influence site selection. (S)

Problems which affect the earth entry of a returning lunar vehicle are inherent in the entire system beginning with the powered flight phase of the trajectory. Accurate preprogrammed trajectory calculations which best fit the mission are initially controlled by geometrical constraints such as the location of the launch and recovery sites, azimuth of fire, declination of the moon, time elements involved, and velocity required to achieve the proper trajectory. Assuming that the prelaunch calculations can be determined accurately with respect to known conditions and the vehicle can follow the programmed trajectory, an accurate error analysis is necessary throughout the entire flight. By using inertial or ground radio command guidance systems the vehicle can then be corrected along its trajectory, making it possible to hit a precalculated earth re-entry window. This window constrains the allowable tolerances of the re-entry vehicle and governs the boundaries of the vehicle displacement with respect to the calculated landing site.

As discussed in Section I, a pure ballistic re-entry vehicle design for lunar return missions necessitates the use of a narrow re-entry corridor with low tolerances on guidance accuracy. The use of such a system would require an extremely accurate ground based tracking network providing finite data during the terminal leg of flight. (U)

The lifting vehicles ($L/D \geqslant 1$), although offering a wider re-entry corridor and more maneuverability, necessitates a more complex design criteria and mission control system. (U)

The use of a semi-ballistic lunar re-entry vehicle (nominal L/D .5) would offer a mean re-entry corridor, provide adequate range accuracy, and still incorporate design simplicity. Assuming that this type of re-entry vehicle will be chosen by the Soviets and that they will continue to utilize a south to north re-entry corridor, a site selection criteria can be defined and used to project the most likely recovery area within the USSR. ~~(S)~~

<u>Lunar Recovery Range Criteria:</u>

a. <u>Security</u>

In the USSR, as in the U.S., tolerable security constraints should be maintained during the re-entry and recovery phase of a lunar return mission. The recovery area chosen should minimize the opportunity for unauthorized persons to locate and examine the re-entry vehicle prior to exploitation by trained recovery forces. In order to accomplish this, the recovery area should either be sparsely populated or under continuous security control. ~~(S)~~

A review of current Soviet earth orbit recoveries indicates that the re-entry corridor lies between the longitudinal boundaries of the Tyura Tam and Sary Shagan rangehead areas with impact occurring just north of the range boundaries. The Soviet range areas lend themselves well to the maintenance of tight security during recovery operations without necessitating full-time security personnel. Due to the relatively low population density in the area, overshoots into the northern latitudes would require only minimal additional security restrictions. ~~(S)~~

Use of air or ground mobile forces could also provide the Soviets with a relatively low cost security force when needed. Ground mobile forces could be air transported to the planned recovery area prior to re-entry. ~~(S)~~

b. Safety

A primary consideration in laying out a land recovery range for a lunar re-entry vehicle is the safety and control of the population residing in the area. The site selected should ideally have a sparse population commensurate with the predicted accuracy and controllability of the spacecraft. In order to avoid a serious mishap during re-entry, the close supervision of the civilian and military population in the area is a necessary factor. (U)

Use of Soviet missile test range areas for recovery purposes would be well suited for such supervision of personnel. Military and civilian personnel located in the proposed recovery area could be alerted or removed during the recovery exercise and all air/ground movement could be controlled. ~~(S)~~

Population densities at latitudes under approximately 50°N on the existing range areas are almost exclusively under one person per square kilometer. Even at latitudes slightly north of the range areas to approximately 56°, the population density increases only slightly from one to ten persons per square kilometer. Only one city between 60° to 80°E and 44° to 52°N is known to have a population over 200,000 people. The remaining widely scattered cities in this region are all between 50,000 and 200,000 in population (Figure 3). ~~(S)~~

c. Terrain

One of the most critical factors associated with land recovery range planning is the general terrain characteristics. In order to

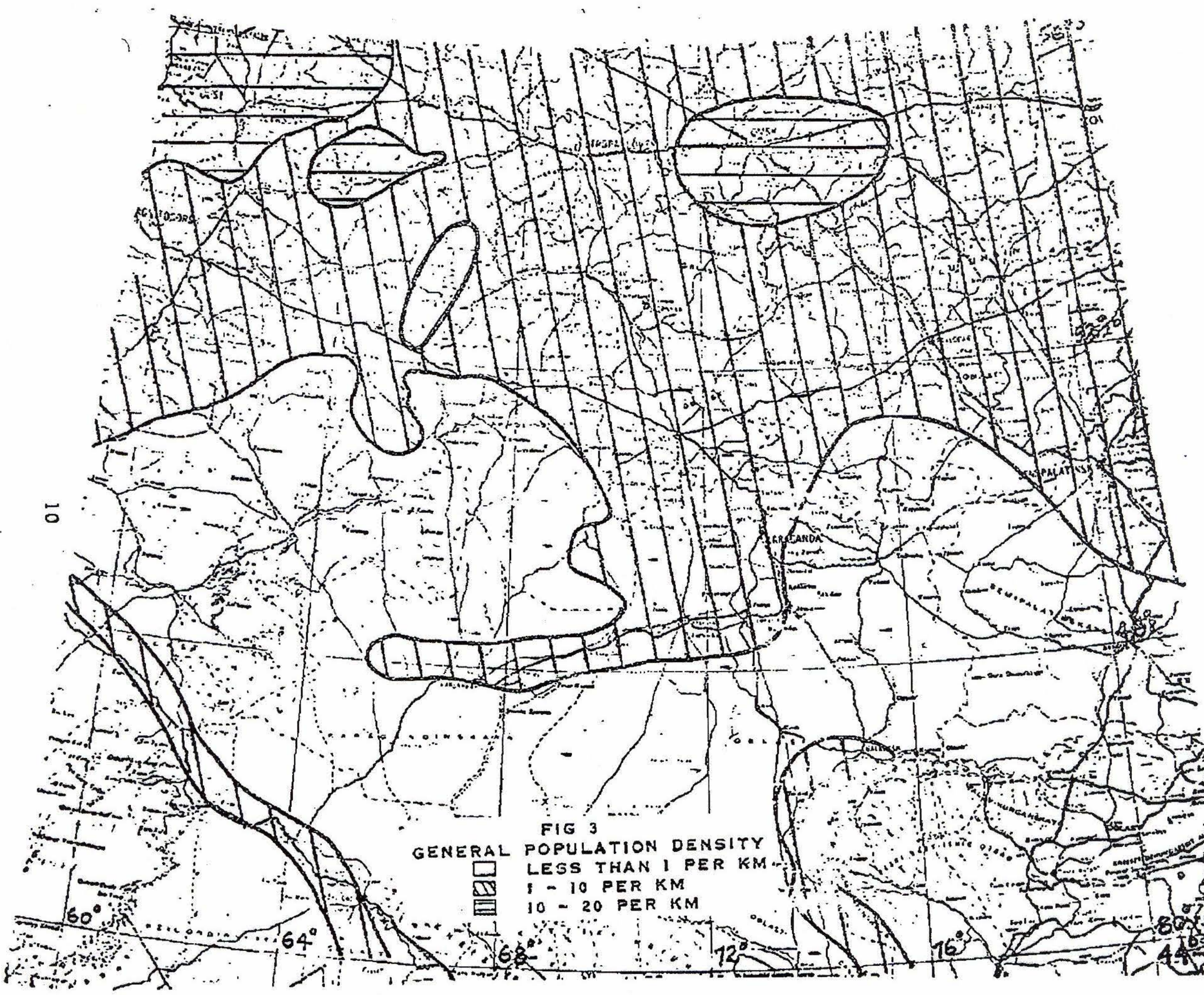

FIG 3
GENERAL POPULATION DENSITY

optimize location and recovery of a downed vehicle, the landing site should offer the least number of hazards to the incoming vehicle as well as the recovery force. If possible, mountainous areas, heavy forest areas, and water areas should be avoided. Use of a lifting type re-entry vehicle would require an expansive flat terrain area suitable for an aerodynamic type landing. This type of re-entry would also require additional flatbed areas for abort and overshoot conditions. The use of a semi-ballistic re-entry vehicle employing parachute drag devices would ideally also require a large flatbed area for impact. This type of vehicle, however, could suitably land on relatively low flat or rolling hill type terrain with negligible effects on the re-entry vehicle. This type of terrain would also still offer good accessibility by helicopter for expeditious physical recovery. The extent of the area needed for a semi-ballistic lunar re-entry vehicle is dependent largely on tracking and guidance accuracies achieved prior to and during re-entry. (U)

Assuming that the Soviets will continue to use the current recovery range in the development of a lunar program, the area should prove quite adequate. The range area bounded by the Tyura Tam and Sary Shagan rangeheads is an arid lowlands region. The area on the northeastern border of the Sary Shagan range is an arid plains type region with low rolling hills to the southeast and northwest of the city of Karaganda. Assuming that a lateral re-entry dispersion of between 60° and 80°E was possible, the Ural mountain range to the northwest and the mountain range directly east of 80° should present no problem in landing or recovery. ~~(S)~~

Since terrain surrounding the current recovery area is one of the most suitable areas (if not the most) in the USSR for landing and recovery, it seems likely that this area would be projected for use in a programmed lunar mission. ~~(S)~~

The southern boundaries of the available range area would probably be the 44°N latitude providing entry well within the USSR. The northern boundary would be restricted to an area generally below 56°N latitude due to population density and higher elevations in the terrain. ~~(S)~~

d. Climatology

The general weather conditions of a proposed recovery range play an important role in site selection. Since visual observation is an important factor in search recovery operations, the area chosen should be relatively free from overcast, ground fog, rain, and snow during as much of the year as possible. (U)

Although the recovery forces should be equipped to handle search/recovery operations during bad or hazardous weather, the efficiency with which the operation is carried out is dependent on the general weather characteristics of the area. (U)

Climatic conditions at the nominal 51°N range now being used for recovery has full seasonal weather varying from -10°F in January to 90°F in July. The snow line dips down into the recovery zone in the winter months but is much less critical than at any of the more northern latitudes. The present recovery range and its areas toward the southern boundaries of the USSR make use of one of the best climatic regions in the USSR. ~~(S)~~

e. Logistic Support

Functions of the recovery support bases located on or near the recovery range for a lunar mission are again dependent on the type vehicle utilized. By using a semi-ballistic re-entry vehicle, with guidance accuracies on the order of ± 200 NM in downrange and lateral displacements, ground support facilities could be held to a minimum. ~~(S)~~

Ground mobile recovery teams could be staged from bases around the recovery area with little additional workload on the existing bases. Primary considerations would be the housing of personnel and vehicle maintenance. (U)

If expeditious physical recovery of the downed lunar vehicle is a requirement in the USSR (as in manned flights), helicopter recovery teams equipped with special pickup gear would be the best recovery method to use. If this type recovery is designed for the pickup of a lunar vehicle, the prime logistics problem would be staging areas in close proximity to the planned impact area which would be capable of handling refueling operations. The northeastern and northwestern sectors of the re-entry range currently being used would appear to have airfields large enough to handle refueling operations for this type of craft. Due to limited range and speed capabilities of helicopters, staging would probably be programmed from three or four areas on the recovery range. The exact number of helicopters staged from each location would be dependent on the accuracy of the search aircraft in locating the downed vehicle. (~~S~~)

The search aircraft located in or near the recovery range presents a more complex logistics problem. Assuming that light cargo type aircraft will be used for search operations, landing strips and refueling points will have to be established on or near the planned impact area. Having established the area bounded by 44°N-60°E, 56°N-60°E and 44°N-80°E, 56°N-80°E as being one of the most suitable areas in the USSR for recovery airfield [illegible] problem. The majority of the airfields in this area are concentrated along the northern latitudes and are most strategically located in the northeastern sector of the range. Based on the Tass-announced recovery points for Vostoks V and VI, this general recovery sector was used for these operations. Utilization of this area provided the Soviets with the most suitable aircraft and helicopter staging sector on the recovery range. The northwestern sector, combined with the sectors along the northern border, appear to offer the second best aircraft staging area for recovery within the range boundaries (Figure 4). ~~(S)~~

f. Recovery Associated Command and Control

An essential element in the success of any recovery operation is the effectiveness of its command and control network. As noted earlier, the scope of instrumentation required for this phase of the lunar mission is a direct function of the type of re-entry vehicle utilized. (U)

(1) Semi-Ballistic Vehicle

(a) U.S. Program:

The current proposals for the Apollo lunar spacecraft point up the plans to incorporate the semi-ballistic design in the U.S. moon program. U.S. intentions for command and control equipment for Apollo currently call for the use of the Deep Space Instrumentation Facilities (DSIF) network with stations

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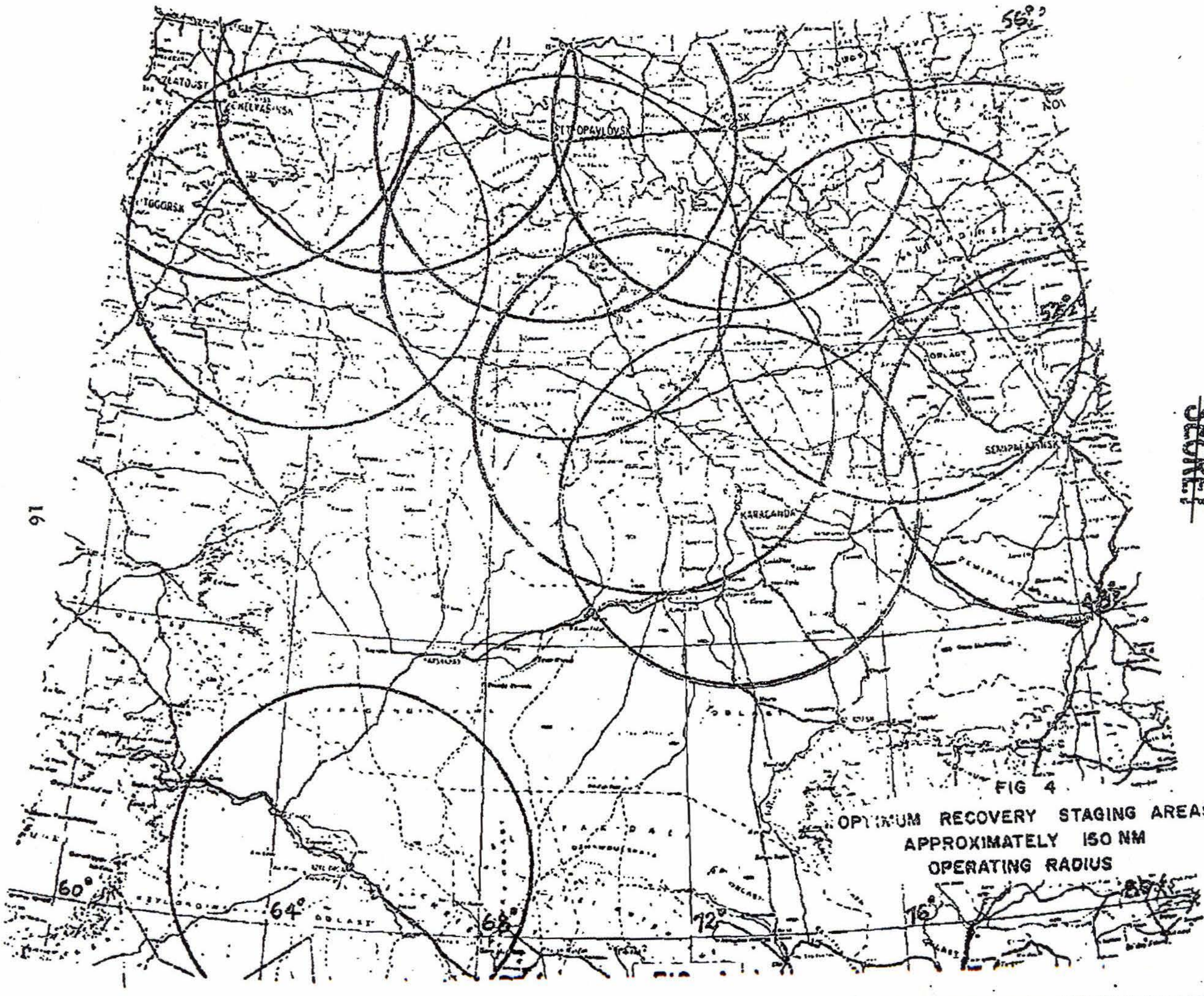

FIG 4
OPTIMUM RECOVERY STAGING AREAS
APPROXIMATELY 150 NM
OPERATING RADIUS

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at the Jet Propulsion Lab (JPL), Goldstone Facility, California; Woomera, Australia; Johannesburg, South Africa; and at least one mobile station located near mission injection points. Each of these stations is located at approximately equal longitudinal intervals around the globe; each is equipped with 85-foot diameter reflectors capable of precision tracking and communications; and each station can provide coordinated tracking, command, and telemetering functions for deep space probes. The Apollo program will also use existing Mercury control stations encompassing the Pacific and Atlantic Range instrumentation sites. Data collected from the combined sites is fed into the Goddard Space Flight Center for real-time analysis. ~~(S)~~

(b) Soviet Program:

By using a semi-ballistic re-entry vehicle, the Soviets could utilize tracking and recovery techniques very similar to those now in use for their earth orbit recoveries. A south to north re-entry corridor similar to that presently used by the Soviets is assumed for the returning vehicle; however, this corridor is also dependent on the original launch azimuth, the number of guidance corrections made through the flight, and the accuracy of these corrections. The use of the same re-entry corridor would provide the Soviets with versatility through their

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ship-based tracking network, and would therefore not necessitate a worldwide fixed land tracking network as is planned for U.S. programs. (S)

Minimum requirements for a Soviet recovery range command and control system include the establishment of a recovery control center, three or more beacon tracking stations, search aircraft staging areas, and recovery forces staging areas. The recovery range control center will probably control the entire recovery operation under the auspices of the central mission control and space track center. (S)

The recovery range control center should be located in close proximity to the planned impact area maintaining contact with the mission control center and its subordinate recovery forces on secure HF, UHF, or VHF communications links. (S)

Initial impact predictions and calculations would probably be forwarded from the central mission control and spacetrack center to the recovery phase of operations. The recovery range controller would then dispatch and control search aircraft via radio communications channels. Simultaneously, the recovery range controller would receive real-time data on the downed vehicle from recovery range associated beacon tracking stations.

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These stations would provide accurate impact location information derived from standard radio D/F methods. The number of beacon tracking stations could be limited to three stations aligned to give accurate triangulation data. The Soviet Krug network of high-frequency radio direction finding stations currently located at some twenty-six operational sites through the USSR could easily serve this function. By using this network of stations, the Soviets could cut cost on range instrumentation required and still maintain tolerable impact location requirements. (~~S~~)

The Krug system reportedly has a bearing accuracy of plus or minus 1.7 degrees at extreme ranges (8,000 NM) with accuracies approaching one-tenth of a degree at short ranges. Existing stations located in close proximity to the proposed recovery zone include: Krasnodar, Tbilisi, Shuraabad, Alma Ata, and two stations at Tashkent (Figure 5). (~~S~~)

Data received from the beacon tracking stations is fed into the central mission controller for correlation with calculated impact data and at the same time is sent to the recovery control center which dispatches the search aircraft to the recovery zone. This exercise could be handled on normal two-way HF or UHF communications links (Figure 6). (~~S~~)

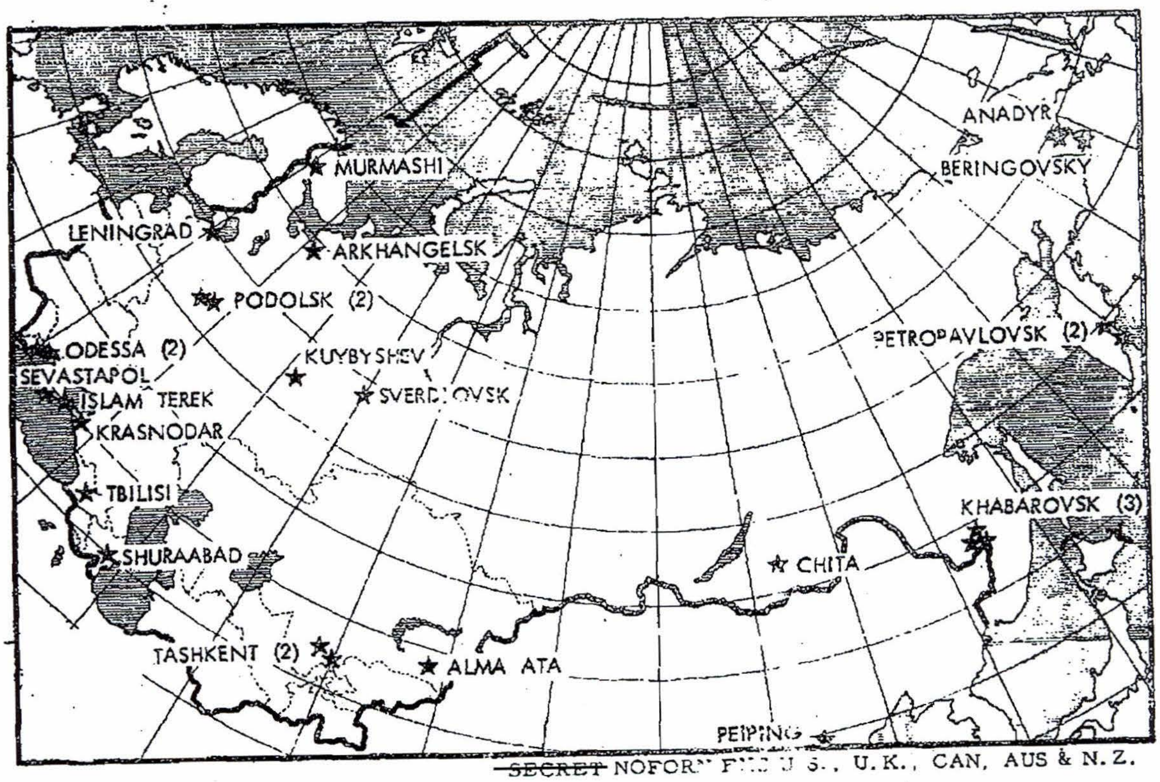

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Fig. 5 ~~(S)~~ Krug Sites

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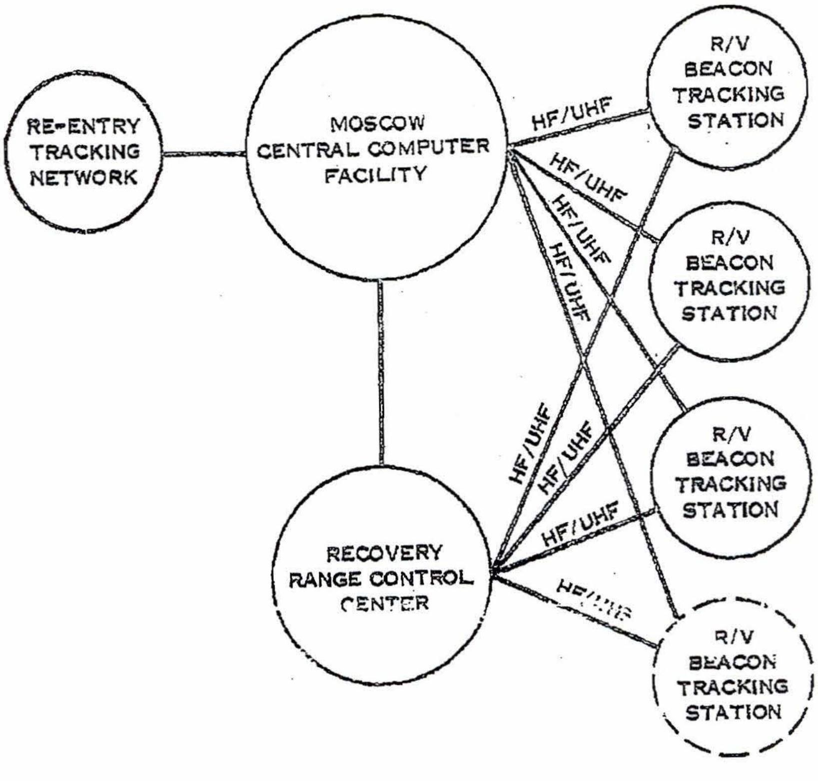

FIG. 6 (U) RECOVERY TRACKING NETWORK

(2) Lifting Re-Entry Vehicle

For a relatively high lift ($^L/_D$ > 1) lunar re-entry vehicle, the equipment requirements increase substantially for both orbital corridor stations and the recovery site. Continuous tracking will be required from the deboost point to the impact site which will normally result in an initial need for at least eight tracking stations along the orbital corridor. This arrangement will provide continuous tracking from deboost to landing. In the recovery area the probable instrumentation requirements include C and S band radars, radio D/F equipment, airborne radars, precision doppler radars (for velocity measurement), mobile ground radars (for immediate off-range coverage), angle and distance measuring equipment, tracking telescopes, and ballistic cameras. Absolute minimum instrumentation requirements for recovery purposes are a tracking and acquisition radar, and radio D/F equipment; however, this situation, while simple and economical, is an extremely rough approach to a very sophisticated problem. Safety considerations and the desire to obtain refined and accurate mission information will most probably dictate the use of the greater equipment requirements postulated above if the lifting re-entry vehicle is actually utilized by either the U.S. or the Soviets. (~~S~~)

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g. Search and Recovery Techniques

Although the search and recovery techniques currently being used by the Soviets are unknown, it has been established that the most effective recovery methods include the use of search aircraft for vehicle location combined with helicopter or ground mobile systems for physical recovery. Proposals for the U.S. Apollo program include the combined use of these vehicles during the recovery exercise. ~~(S)~~

The number of aircraft involved in the search activity is dependent upon the precalculated impact accuracy of the re-entry vehicle. To minimize the number of aircraft required for search operations, the range would probably be divided into search sectors with the bulk of the aircraft deployed in the primary precalculated impact zone. This zone could then be broken down into search sectors employing one or more aircraft per sector dependent on the size of the area to be covered. The range control center would maintain constant voice communications with the search forces and provide all vector information. (U)

Once the spacecraft was sighted, the geographic coordinates could be forwarded to the recovery range controller who in turn would dispatch the physical recovery vehicles to the impact site. Pickup of the re-entry vehicle would probably be carried out by conventional means, dependent on its physical characteristics, and then transported to a predetermined checkout or transhipment area. (U)

Since this method is adequate and yet employs nothing more than standard search techniques, it may be assumed that the Soviets would use equal simplicity in a planned lunar recovery mission. (Figure 7). ~~(S)~~

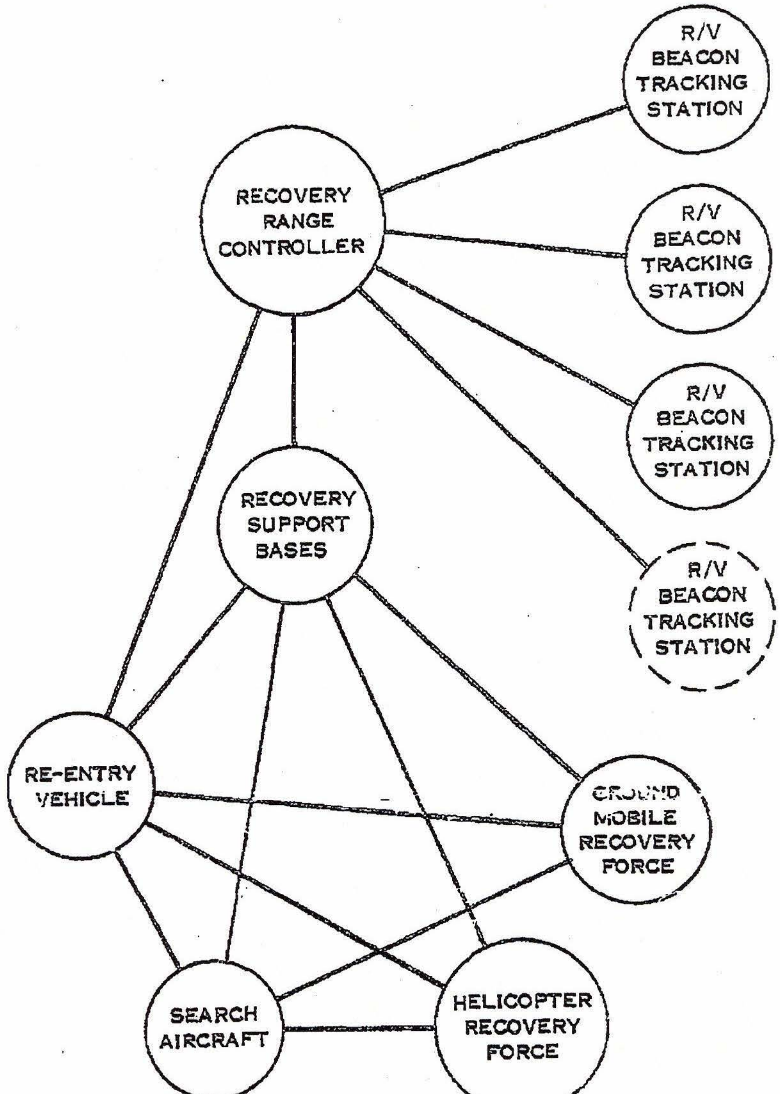

FIG. 7 (U) SEARCH RECOVERY NETWORK

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SECTION III

~~(S)~~ MODEL OF USSR LUNAR RECOVERY RANGE

The proposed lunar recovery range outlined in this section includes those areas of the USSR which best fit U.S. standard recovery range site selection criteria. The earth orbit recovery areas currently being used by the Soviets fit well within the proposed boundaries of the lunar recovery range and could continue to be used, dependent on the external constraints of the chosen lunar mission and its re-entry vehicle characteristics. It should be remembered, however, that these are limiting site selection factors and the area proposed is made with no knowledge of USSR lunar recovery mission technology. ~~(S)~~

The broad boundaries of the proposed recovery range include an area bounded by 44°N-60°E, 44°N-80°E and 56°N-60°E, 56°N-80°E. Within this broad land mass, the area bounded nominally by 54°N-60°E, 48°N-60°E and 54°N-80°E, 48°N-80°E appears to include the largest number of logistic support areas. Although this area is believed to be the most suitable for the recovery of a semi-ballistic type re-entry vehicle, the entire area still presents good possibility. Utilization of more southerly sectors of the proposed range would suggest the use of a high lift vehicle or the construction of logistic support bases designed specifically for the support of a lunar program. Past Soviet philosophy suggests that maximum use will be made of existing facilities for such a program rather than the development of an entirely new range. ~~(S)~~

Figure 8 includes the primary, secondary, and tertiary landing areas which would probably be used by the Soviets in a programmed lunar return mission. ~~(S)~~

Figure 9 illustrates a functional lunar recovery mission control network which could be used assuming a semi-ballistic re-entry vehicle. This diagram incorporates control techniques which are proposed for the U.S. lunar recovery program and includes certain Soviet command and control techniques which are believed to be used in current earth orbit operations. ~~(S)~~

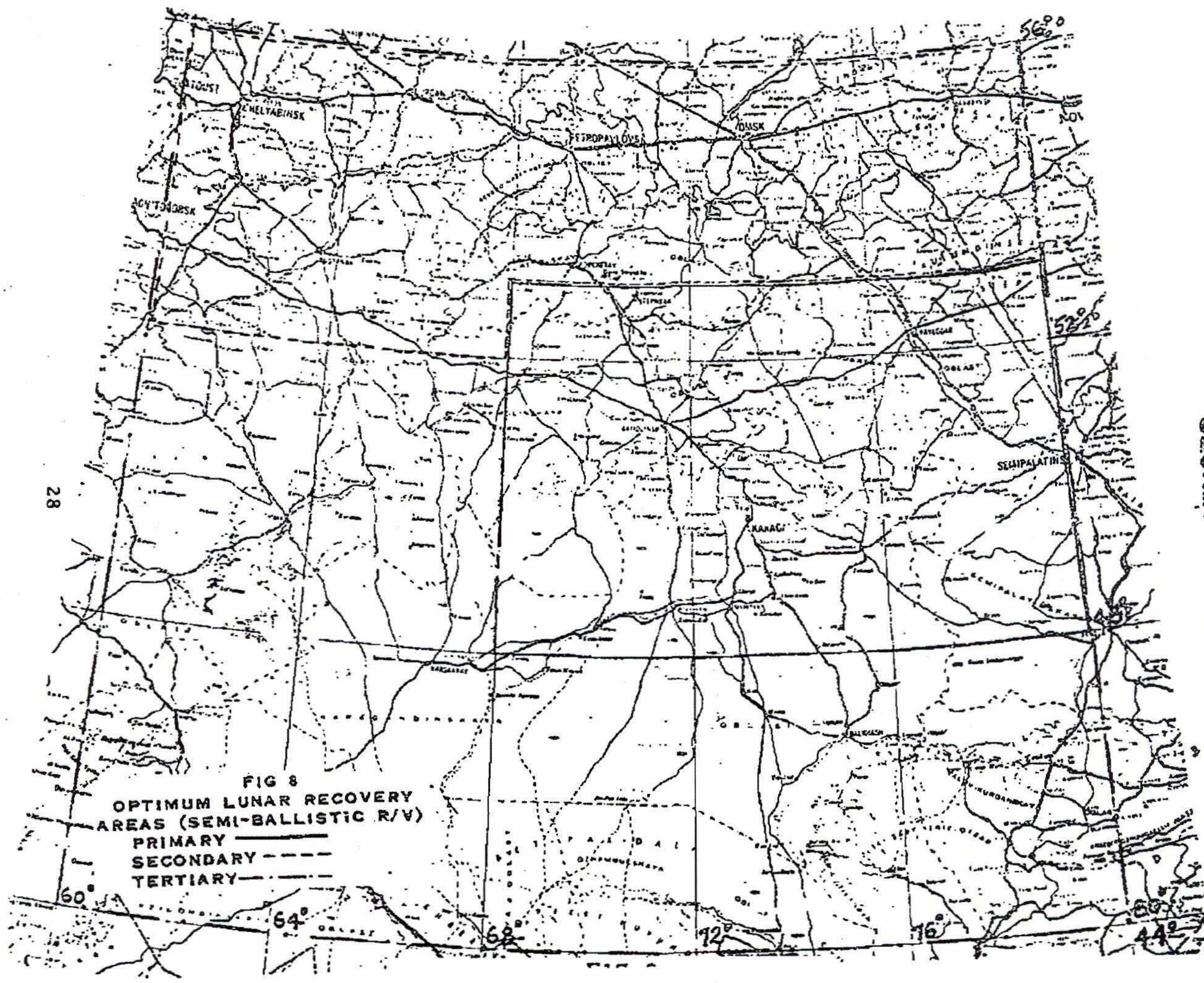

FIG 8
OPTIMUM LUNAR RECOVERY AREAS (SEMI-BALLISTIC R/V)
PRIMARY
SECONDARY
TERTIARY

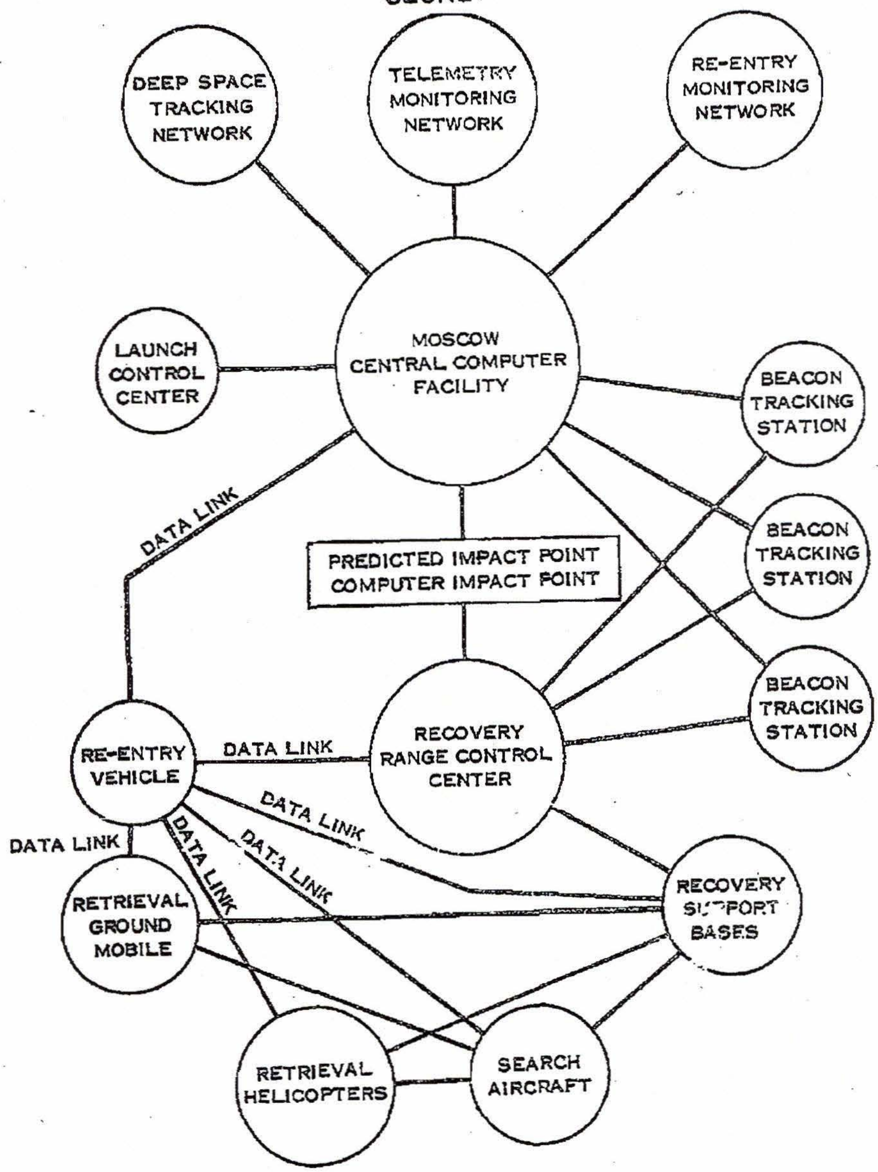

FIG. 9 (U) MISSION CONTROL NETWORK

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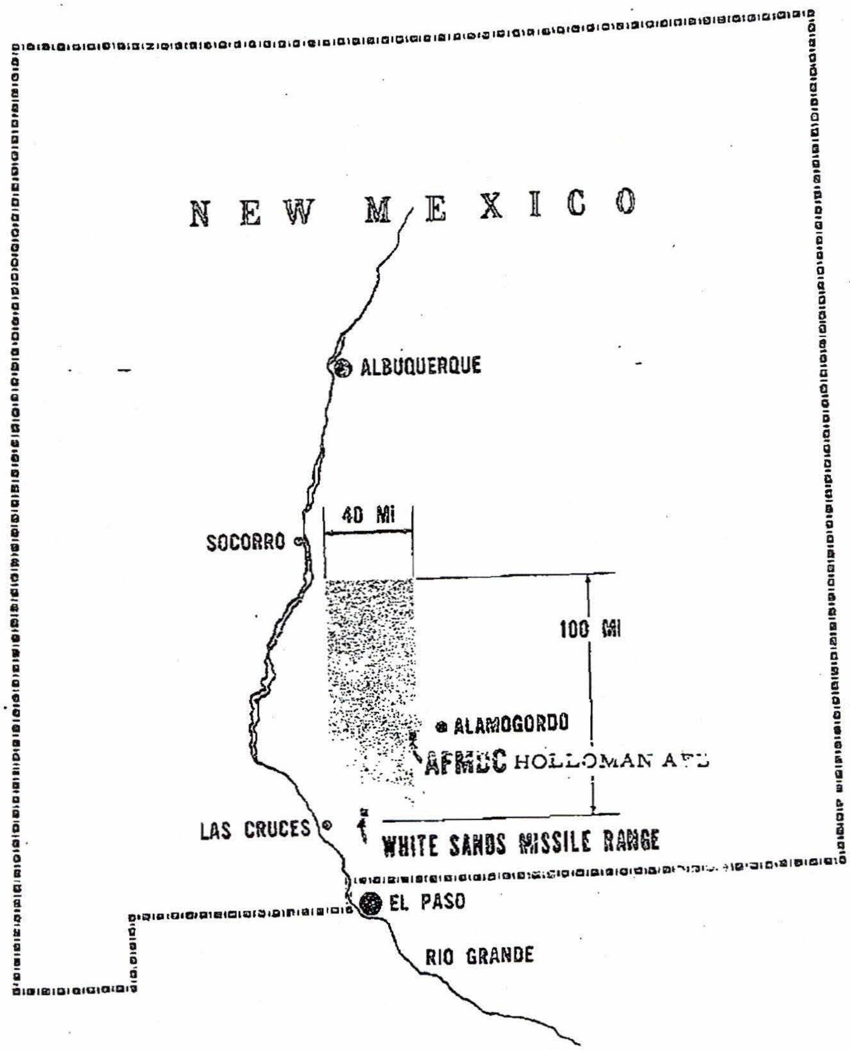

AREA MAP SHOWING LOCATION OF AFMDC