SD 71-499

LUNAR BASE SYNTHESIS STUDY
FINAL PRESENTATION

CONTRACT NAS8-26145

6 MAY 1971

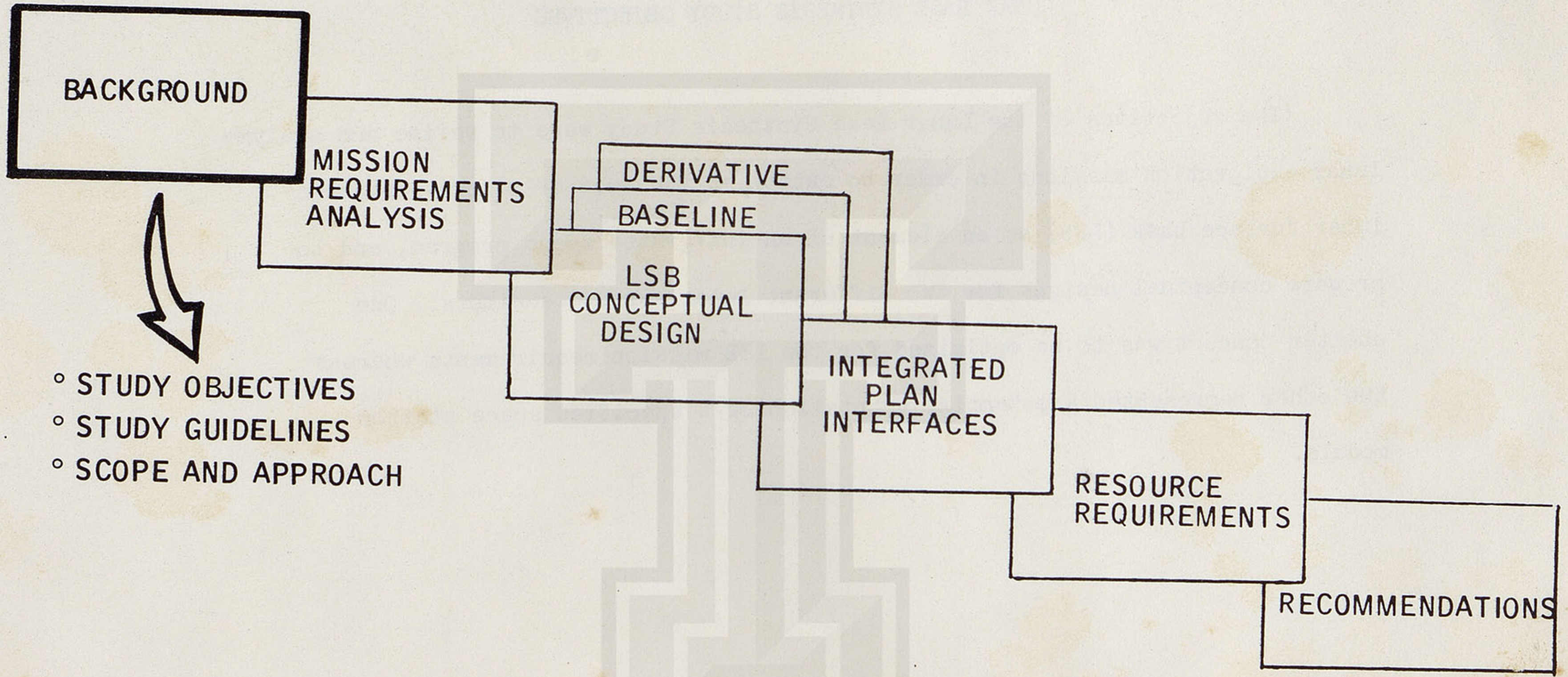
Space Division
North American Rockwell

PRESENTATION OUTLINE

This presentation is the final contract review of the Lunar Base Synthesis Study, Contract NAS8-26145. The briefing outlines all work accomplished during the contract period, gives the significant study results and conclusions, and presents some recommendations regarding future effort.

The first section presents the study background in terms of the objectives and approaches followed.

PRESENTATION OUTLINE



LUNAR BASE SYNTHESIS STUDY OBJECTIVES

The objectives of the Lunar Base Synthesis Study were to define and analyze lunar exploration missions in order to establish the role of a semi-permanent lunar surface base (LSB) as an element of an integrated space program, and to prepare conceptual designs for two different lunar surface shelters. One shelter concept was to be optimized for the LSB mission requirements whereas the other represented a potential adaptation of a specified space station module.

LUNAR BASE SYNTHESIS STUDY OBJECTIVES

ESTABLISH ROLE OF SEMI-PERMANENT LUNAR SURFACE BASE

- OBJECTIVES
- FUNCTIONS
- MANNING
- INTEGRATED PROGRAM INTER-ACTIONS

DEFINE LUNAR SURFACE BASE CONFIGURATION CONCEPTS

- OPTIMIZED
- SPACE STATION MODULE DERIVATIVE
- MOBILITY AIDS
- MAJOR SCIENCE ELEMENTS

PRINCIPAL STUDY GUIDELINES

The study was oriented towards a lunar surface base which would support a two- to five-year program of scientific and exploration activities in the 1980's by a crew of up to 12 men at any location on the moon which might be selected. The principal program option involved considering the operation of the LSB concurrently with an operational Orbiting Lunar Station (OLS) or without the existence of the OLS. The space station module which was designated as the candidate for adaptation to an LSB shelter configuration was the shuttle-launched modular space station as defined by North American Rockwell, Space Division (NR/SD) under Contract NAS9-9953 for the Manned Spacecraft Center and documented in NR report, SD 70-546-1, January 1971.

PRINCIPAL STUDY GUIDELINES

- CONSIDER - CONCURRENT OLS
  - NO OLS
- FIVE-YEAR LIFETIME DESIGN GOAL
- DESIGNATED SSM = NR SHUTTLE LAUNCHED MODULAR SPACE STATION
- OTHERS - SINGLE SEMI-PERMANENT LSB
  - MIDDLE 1980's
  - UP TO 12-MAN CREW
  - ANY LUNAR LATITUDE

} INFLUENCED STUDY APPROACH

SCOPE AND APPROACH

The basic approach adopted for the study involved the identification of scientific and exploration activities appropriate to a single, semi-permanent base on the lunar surface from an examination of the consensus of previous studies of lunar scientific missions. A typical distribution of these activities on the lunar surface was derived from a detailed examination of several potentially desirable areas and operational/design requirements were defined to accomplish the various classes of activities. It should be noted that it was not intended that the study would identify the site of program for the eventual lunar surface base. The intent was to identify rather a "typical" surface program such that mission concepts could be synthesized and a Phase A level conceptual design performed of a shelter which would be general and flexible enough to meet the eventual actual requirements.

A lunar surface base configuration which included a main shelter, major science elements, and surface mobility system elements was conceptually defined. The initial design considered the probable state of the art and operational and design requirements in arriving at a shelter configuration optimized for the spectrum of lunar surface missions. The potential emergency situations were considered and the implications delineated including a maintenance and repair philosophy. Maintenance, repair and housekeeping functions were described and typical tool requirements identified.

Following the definition of the optimized LSB shelter, a conceptual design of a lunar shelter derived from the specified space station module was developed. The degree of modification required, including specific additions for the lunar missions and environment, was identified.

Cost and resource estimates were prepared for the design and development of each of the shelter configurations and for the science, mobility, and power source elements of the LSB program. The shelter development costs were generated utilizing cost estimating relationships from other space programs. Cost estimates for the science, mobility, and power source elements were primarily derived by adjusting prior studies of these elements for the recommended concept modifications and the passage of time.

SCOPE AND APPROACH

- IDENTIFICATION OF SCIENTIFIC ACTIVITIES APPROPRIATE TO A SINGLE SEMI-PERMANENT SURFACE BASE
- DERIVATION OF TYPICAL DISTRIBUTION OF ACTIVITIES IN A LUNAR SURFACE AREA
- SYNTHESIS OF MISSION CONCEPTS TO ACCOMPLISH ACTIVITIES
- IDENTIFICATION OF PRECURSOR SURFACE AND ORBIT MISSIONS
- PHASE A CONCEPTUAL DESIGN OF SHELTERS
- RESOURCE REQUIREMENTS

    SHELTERS

    SCIENCE, MOBILITY, POWER SOURCE

STUDY SCHEDULE

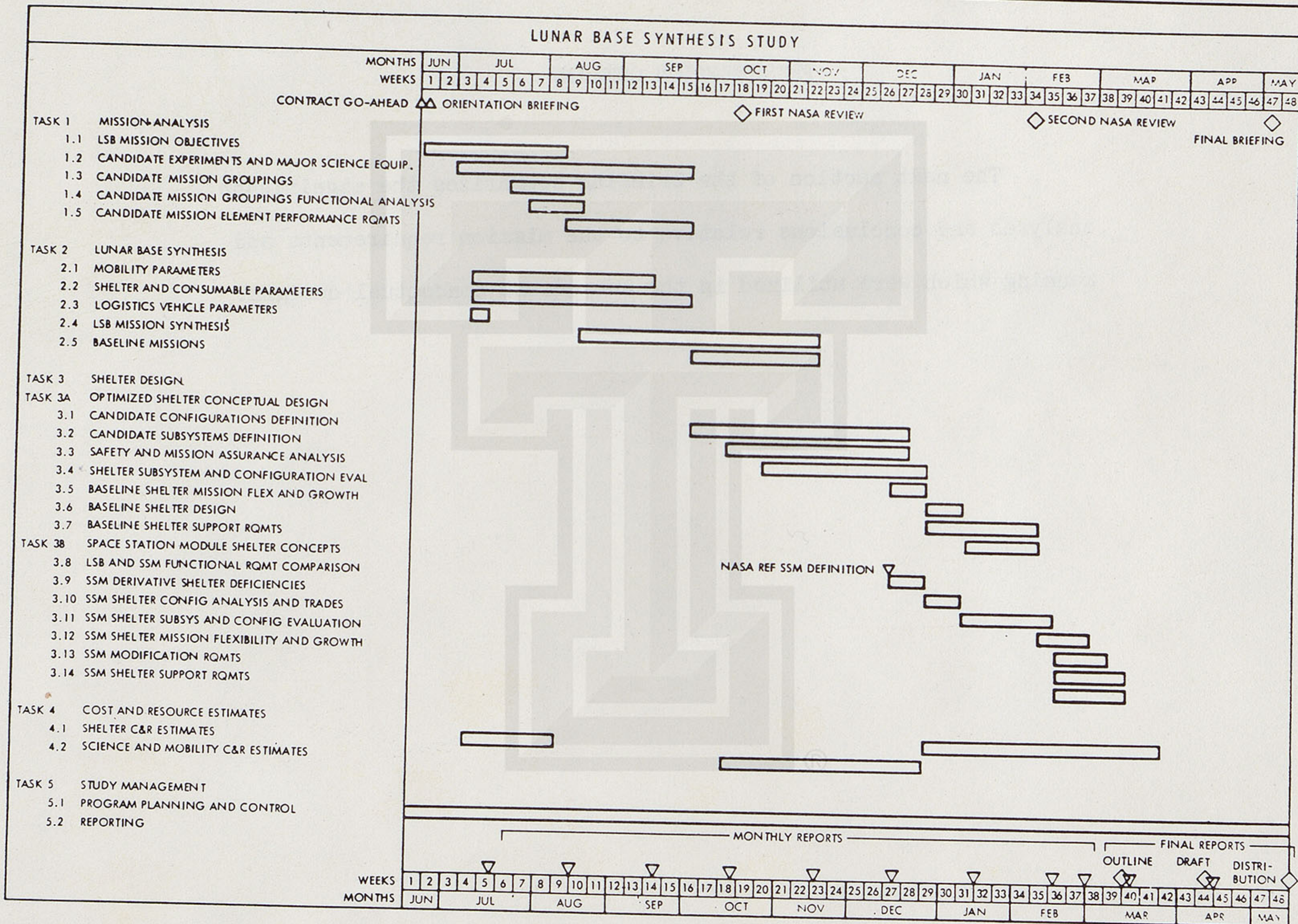
The study was accomplished and documented in an 11-month period between 15 June 1970 and 15 May 1971 as shown. The definition of a program encompassing the scientific and exploration activities, the associated operational and design requirements, the logistics operational concepts, and the precursor surface and orbit missions comprised study tasks 1 and 2, Mission Analysis and Lunar Base Synthesis, respectively.

The conceptual designs of the two shelter configurations and the definition of the mobility concept and its interfaces with the shelter comprised study task 3, Shelter Design.

Preparation of the cost estimates for the shelters, mobility, science, and power source equipments together with program schedules and milestone data comprised study task 4, Cost and Resource Estimates.

The study results are recorded in four basic volumes. Volume I is an executive summary which briefly outlines the objectives, summarizes the results, conclusions and recommendations; Volume II contains a comprehensive description of the analysis and synthesis results of tasks 1 and 2; Volume III presents the LSB configurations including the conceptual designs of the optimized and derivative shelters which resulted from study task 3; and Volume IV describes the cost estimates derived in task 4.

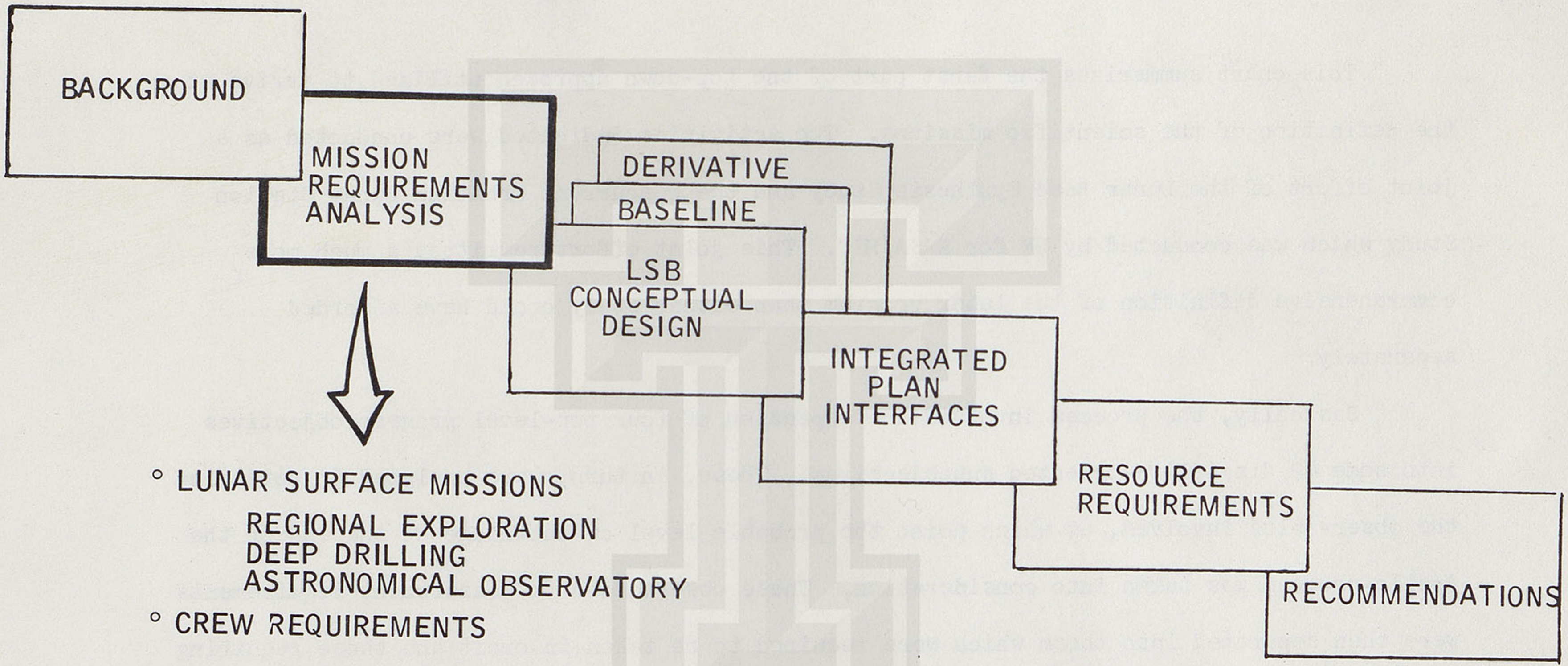
STUDY SCHEDULE



PRESENTATION OUTLINE

The next section of the briefing summarizes the significant analyses and conclusions relative to the mission requirements and manning which were utilized in the subsequent conceptual designs.

PRESENTATION OUTLINE

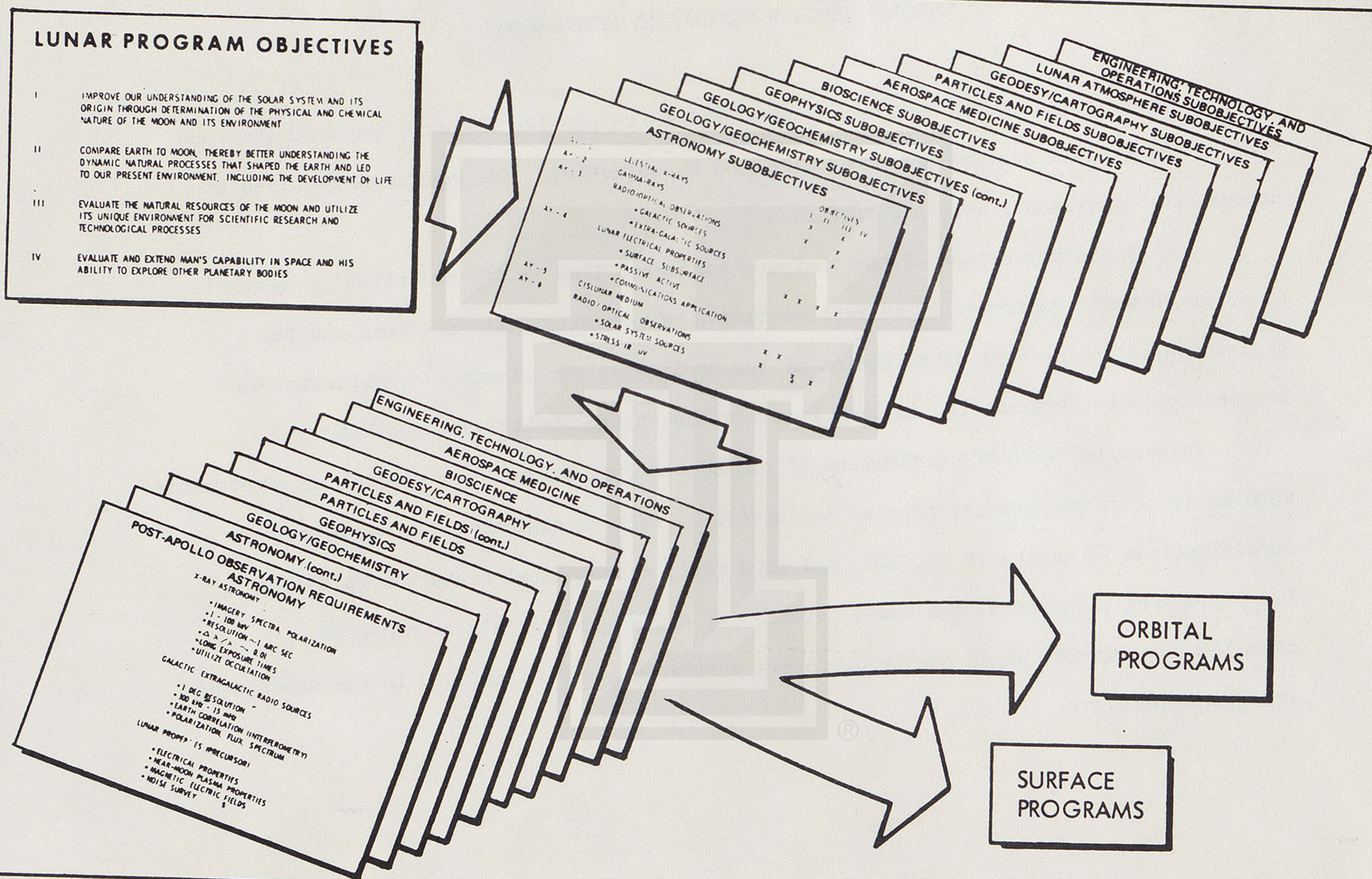


MISSION OBJECTIVES DEFINITION SUMMARY

This chart summarizes the first part of the top-down approach utilized to arrive at the definition of the scientific missions. The activities indicated were conducted as a joint effort of the Lunar Base Synthesis Study and the concurrent Orbiting Lunar Station Study which was conducted by NR for NASA/MSC. This joint effort permitted a much more comprehensive definition of the lunar program than either study could have afforded separately.

Basically, the process involved the expansion of four top-level program objectives into some 42 discipline-oriented subobjectives. These, in turn, were analyzed to determine the observables involved, at which point the probable level of knowledge at the end of the Apollo program was taken into consideration. These observation or measurement requirements were then separated into those which were required to be taken in orbit and those requiring surface activities. The detailed process is documented in Volume II of the final report.

MISSION OBJECTIVES DEFINITION SUMMARY



Space Division
North American Rockwell

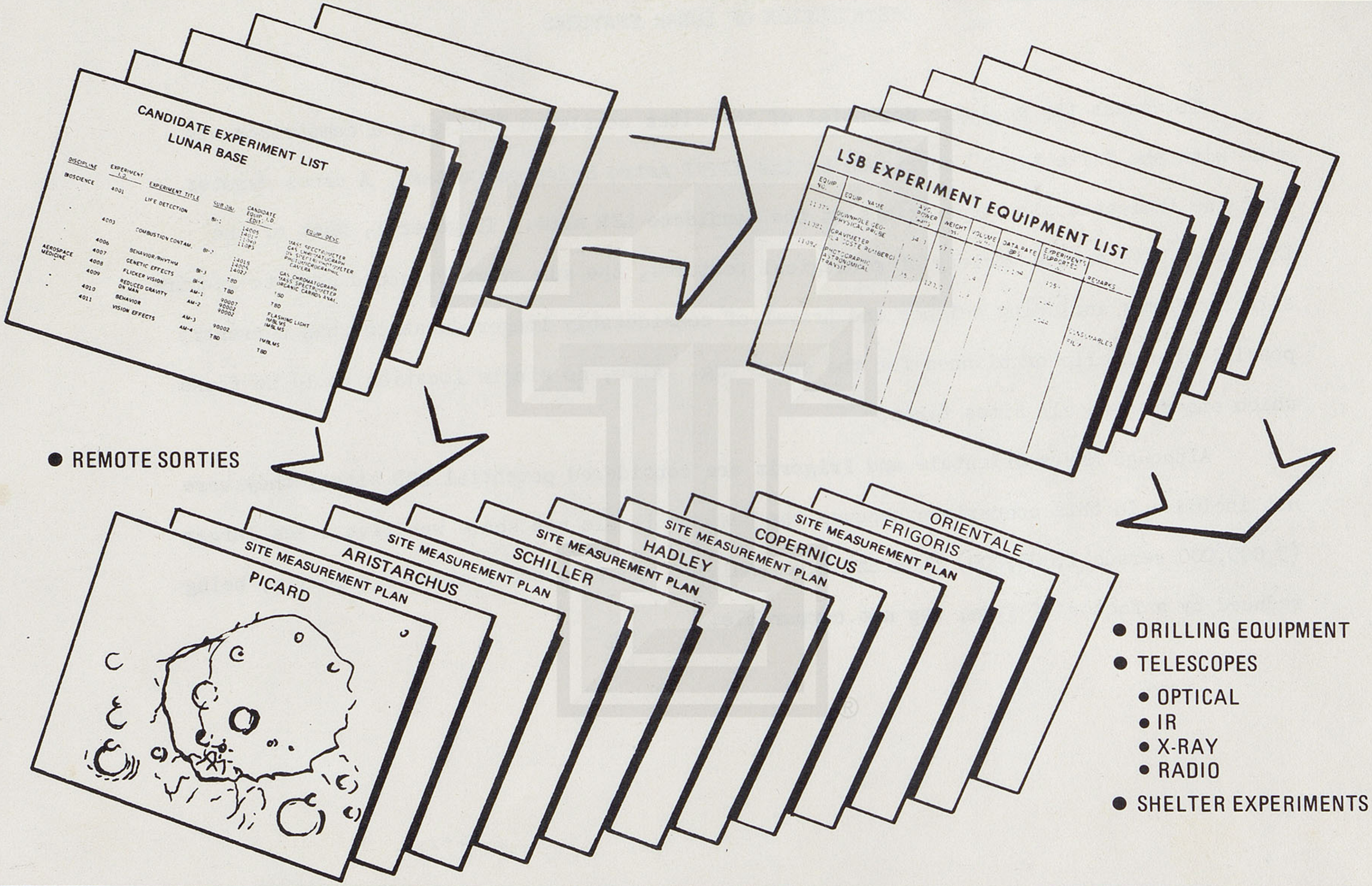
SURFACE PROGRAM DEFINITION METHODOLOGY

Some 52 experimental activities were defined to provide the data required for each surface observation requirement and associated subobjective. The equipment required to conduct the experiments were also defined.

One of the key points of the analyses conducted lies in the selection of several sites which were considered to be representative of potential LSB locations and the definition of the special distribution of the applicable experiments. These sites were then analyzed to abstract the implied requirements on the shelter and mobility.

In parallel with the definition of remote sorties, three other classes of experiments were analyzed in the surface program definition. Drilling equipment for stratigraphic investigations to depths of 10, 100, and 1000 feet; astronomical measurements utilizing X-rays, optical, infrared, and radio telescopes; and a wide variety of non-site dependent experiments which may be performed at the shelter are defined in the experiment and equipment lists.

SURFACE PROGRAM DEFINITION METHODOLOGY



DISTRIBUTION OF LUNAR FEATURES

To assess the geologic potential of the sites completed thus far, a comparison was made with the "site types" developed by the IITRI Astro Sciences Center. A cross denotes that the indicated site type exists at the candidate LSB site. In general, most of the LSB sites have a wide variety of geological features, the sum of which would seem to require site staytimes including science and travel of considerably longer duration than currently possible for Apollo or planned for the space tug. Also, no single location could be found which encompassed all sites types.

Although Mares Orientale and Frigoris are considered potential LSB sites, they were not included in this comparison because the best available map scale was five times larger (5,000,000 versus 1,000,000) than the five analyzed and thus the feature resolution, being reduced by a factor of five, was not comparable.

DISTRIBUTION OF LUNAR FEATURES

LUNAR FEATURES	ARISTARCHUS	PICARD/ MARE CRISIUM	SCHILLER	HADLEY	COPERNICUS
LAVA FLOW	X	X			
ASH DEPOSIT	X				
FAULT SCARP		X	X	X	X
CRATER WALL	X	X	X	X	X
CONE		X			
BULBOUS DOME	X				X
LOW DOME					X
LTP SITE	X				
MARE-UPLAND CONTACT		X		X	
DIATREME					
RIMLESS CRATER		X	X		
SOFT MARE CRATER	X				
GRID LINEAMENT	X	X	X	X	
RADIAL LINEAMENT	X	X			X
CONCENTRIC SCARP		X			
LINEAR RILLE	X	X	X	X	X
CRATER FLOOR	X	X	X	X	X
PATTERNED GROUND	X	X			
EJECTA BLANKET		X	X		X
RIFT AREA		X	X		
WRINKLE RIDGE	X		X		X
SINOUS RILLE	X		X	X	X
MARE	X	X		X	
CENTRAL PEAK	X	X		X	X
EXPOSED RING					
MANTLED RING					X
GHOST RING	X				
<20 Km SMALL YOUNG CRATER	X	X		X	X
>50 Km LARGE YOUNG CRATER	X	X	X	X	X
STREWN ROCK CRATER			X		

POTENTIAL LSB SITES ANALYZED

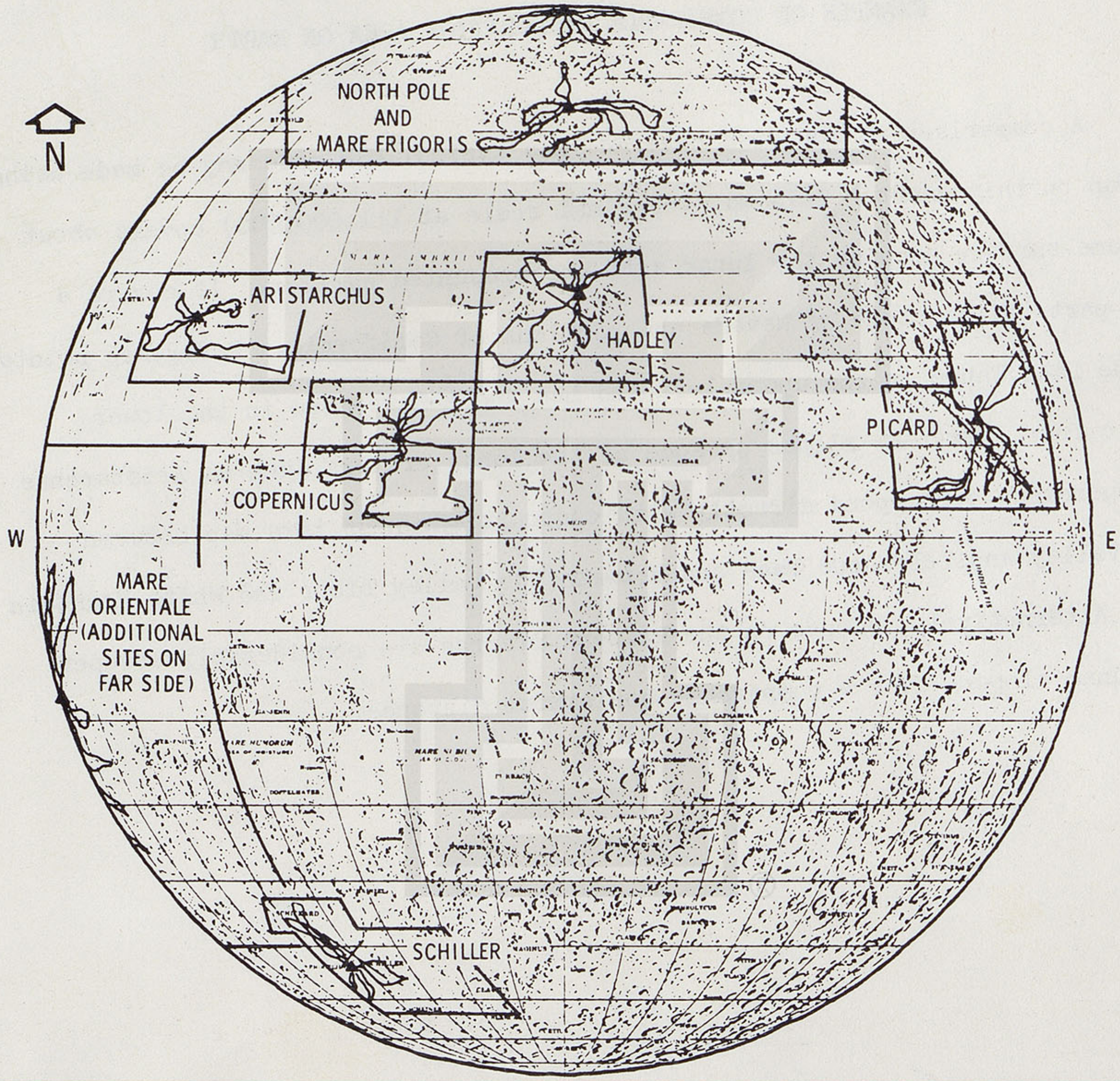
Since the objective of this study was to provide a preliminary design for an LSB to begin operations in the 1980's and capable of being located anywhere on the moon, concurrent, multi-site performance requirements were required. To accomplish this, seven potential LSB sites were analyzed to define requirements such as distance to be traveled by a flyer or a surface vehicle, mission duration, terrain to be encountered, payload characteristics, etc. From all these data, parameter distributions were developed to define a mathematical model of a "typical" LSB site. Mission performance requirements encompassing 95 percent of the performance envelope were taken from the model. Equipment sized to meet these requirements are expected to be capable of accomplishing the requirements of the surface missions at any site. A wide variety of LSB locations were deliberately selected to provide a broad range of inputs to the model. The location and extent of these sites are shown in the chart along with the approximate exploration around the shelter site. These sites generally lie on mare surfaces adjacent to highland terrain.

The approach for selection of the potential LSB sites was based on the availability at specific lunar locations of the geologic features which are related to providing answers to the primary scientific questions on the origin and evolution of the moon. Also, a centralized location for the shelter at these sites is desirable in order to support all three missions--remote sorties, deep drilling, and the observatory. For remote exploration sorties, the site criteria include features located within a reasonable distance from a centralized shelter location consisting of favorable rock exposures and special geological, geophysical, or geochemical formations. For suitable deep drilling locations, the site criteria are promising stratigraphic sections near the surface, suspected zones of subsurface permafrost, anomalous heat flow, and devolatilizing or geophysical features. The observatory site criteria will be described in detail later.

There are a multitude of sites which meet these criteria and are worthy of detailed, advanced study. Those of this study were chosen for a number of reasons, the most important being the presence of sufficient features or conditions or scientific interest accessible from the base to allow the maximum in scientific return from a relatively modest logistic effort.

None of the selected sites are on the farside since no concentrated site of distinguished lunar features could be discerned from the Lunar Orbiter photographs. The dark crater, Tsiolkovsky, interesting in itself, does not appear to contain the variety of features necessary to justify an LSB; however, it may warrant a tug exploration sortie.

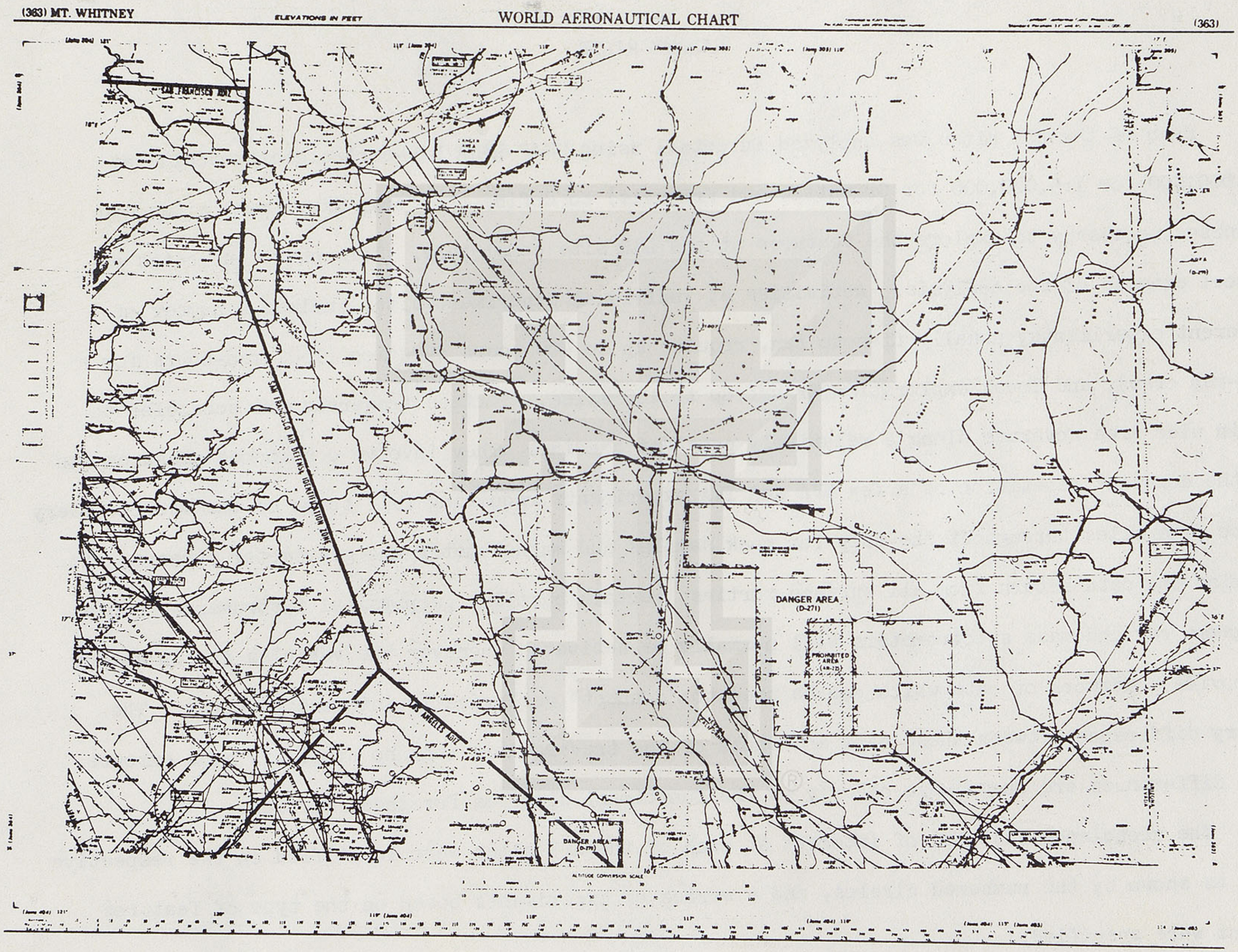
POTENTIAL LSB SITES ANALYZED



EXAMPLE OF COMPARABLE EXPLORATION AREA ON EARTH

A comparison of the area covered in a typical LSB site may be made using the map on this chart. This map (original scale at 1:1,000,000) covers about the same surface area as the lunar site map presented earlier. It covers a large part of the state of Nevada and portions of California. Reference points include Lake Tahoe in the upper left and Las Vegas-Lake Mead in the lower right corner. Extreme slopes on some of the lunar craters such as Aristarchus and Copernicus correspond directly with contours shown on this map between Death Valley and Telescope Peak and between the valley floor and White Mountain Peak. Alternatively, slopes on the eastern Sierras are considerably steeper than lunar slopes--over a comparable horizontal distance.

EXAMPLE OF COMPARABLE EXPLORATION AREA ON EARTH

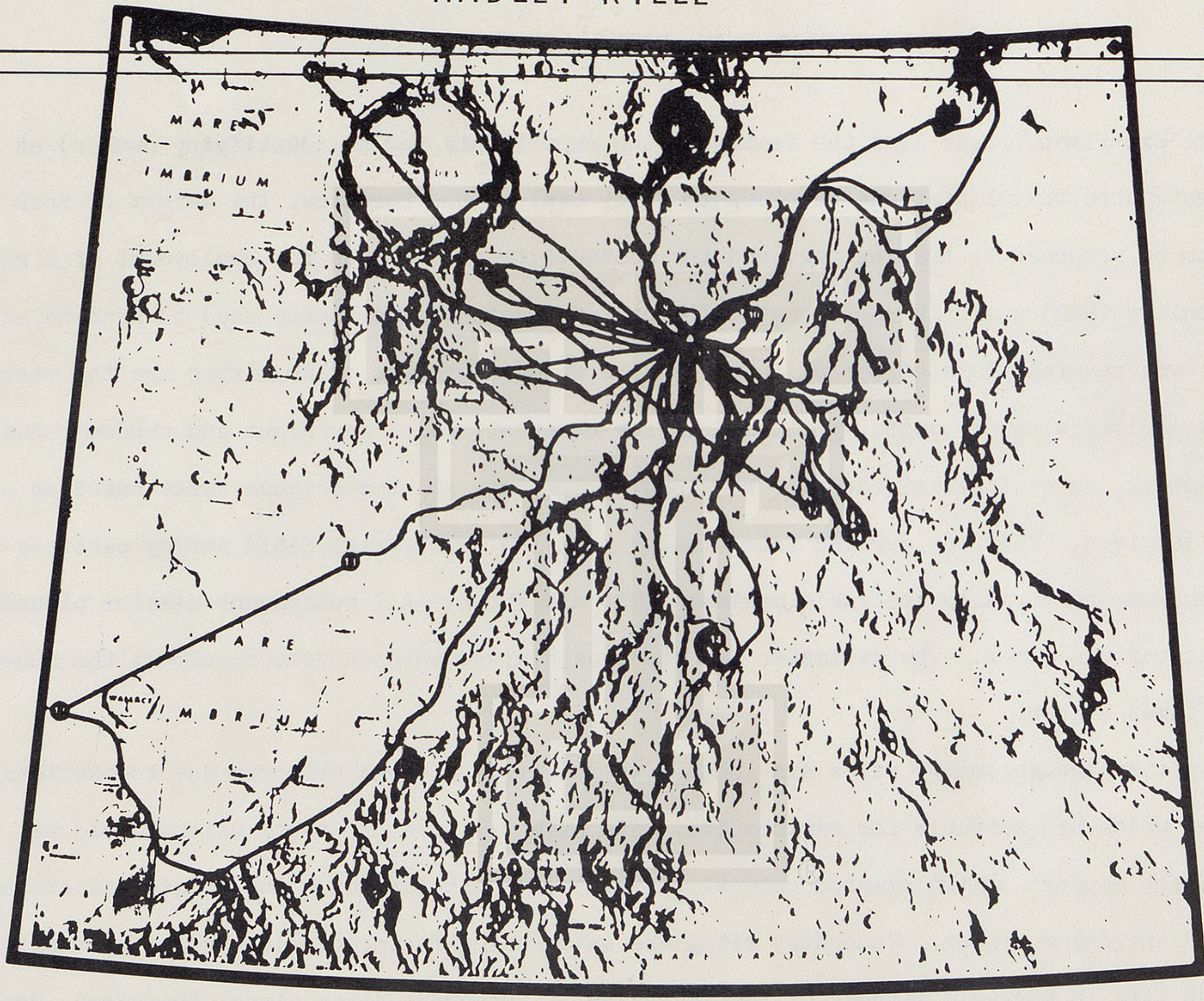


HADLEY RILLE

Each of the LSB sites was analyzed in detail using USAF-NASA LAC-series charts scaled at 1:1,000,000 (or 1:5,000,000 for Orientale and Frigoris) to define the local experiment sites and traverses necessary to explore the features at the LSB site completely. This chart indicates a typical example of the analysis. Activities at individual experiment sites include a number of different experiments, usually five to ten, require up to 400 hours duration (1600 man-hours for a four-man crew), and local exploration travel up to 100 miles. Surface traverses are scheduled to obtain wide area coverage along a relatively constant heading. They involve continuous measurements and the constant repetition of a few EVA and IVA experiments requiring full stops of the vehicle every one to five miles throughout the trip for rock samples and magnetometer and gravimeter surveys. To maximize the data return from all surface sorties, certain baseline geophysical instruments such as the gamma ray and mass spectrometers will normally be activated whenever the vehicles are in motion to provide a network of data which can be used to "connect" geologically interesting sites. The primary difference between these data and those of the traverse are that no stops are made enroute. These differences are shown more clearly on the functional diagrams for these sorties.

The geoscience features of interest at each of the LSB sites were identified on the respective maps, as shown by the numbered circles, and a series of experiments based on the type of features present were specified.

HADLEY RILLE



HADLEY RILLE

SCALE 1 1 000 000

LAC 41

EXPERIMENT PLAN, HADLEY LSB SITE

The Site Experiment Plans list the features, the experiments (by an identifying number) at each feature, the estimated travel distance required to fully explore the features, the weight of rock and soil samples to be returned to the shelter, and the suitability of the site for deployment of a remote geophysical monitor (RGM) which is an automatically operated set of experiments used to measure and transmit data over several years of operation on passive seismic events. Also listed are the recommendations for additional site visits, particularly for observations of day/night and random transient phenomena. Finally, an estimate of the time required to complete all the science tasks based on a four-man crew is given. This was derived from similar tasks on terrestrial field survey parties. A contingency minimum and normally desirable maximum limit are shown. All subsequent mission planning is based on the maximum times. The estimates are shown as elapsed science time required; the man-hours would be four times higher.

Primary sites and secondary sites are identified for Orientale and Frigoris due to the larger number of sites which are suitable for exploration. The primary sites are those which should be explored in direct support of the mission objectives related to understanding the origin and evolution of the moon and the solar system. Secondary sites are interesting features which should be visited once at the LSB site in possible support of the objectives. Secondary sites alone, therefore, would not justify an LSB mission.

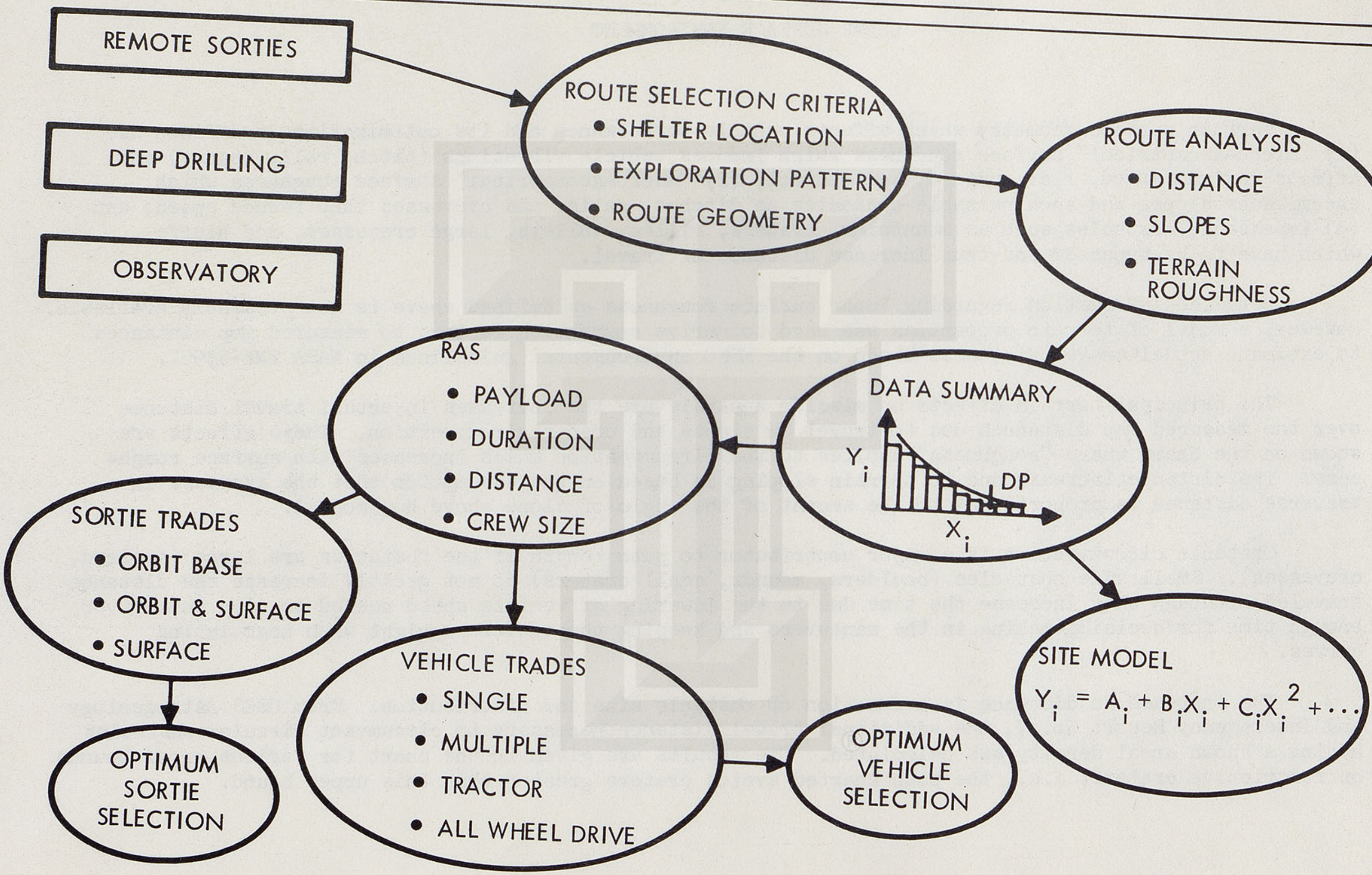
EXPERIMENT PLAN, HADLEY LSB SITE

Experiment Site	Features	Preferred Experiments (Critical Experiments Underlined)	Experiment Site Mobility (SM)	Rock Sample Pickup (LBS)	Deploy RGM	Return Visits	Duration of Experiment Operation (Based on 3-4 Man Field Crew)
1	Rima Hadley (sinuous rille)	4001, 4032, 4038, 4039, 4057	None	200	No	Optional for LTA	Minimum: 20 hrs Maximum: 200 hrs
2	Terminations of Rima Hadley	4032, 4033, 4038, 4039, 4045, 4046, 4057, 4058, 4059, 4088	31	120	No	No	Minimum: 48 hrs Maximum: 250 hrs
3	Mt. Hadley & Range & Geol. traverse up valley from (2)	4001, 4032, 4039, 4044, 4053, 4057	62	200	Yes	No	Minimum: 60 hrs Maximum: 200 hrs
4	Front ridge, west of Rima Hadley	4032, 4033, 4038, 4044, 4057	25	50	No	No	Minimum: 20 hrs Maximum: 60 hrs
5	Structural features: linear ridges & fracture patterns	4032, 4033, 4038, 4045, 4057, 4058, 4088	62	150	No	No	Minimum: 40 hrs Maximum: 140 hrs (2 sites)
6	Caucasus Range, General geology and structure	4001, 4032, 4038, 4045, 4047, 4057, 4058	19	120	Yes	No	Minimum: 10 hrs Maximum: 60 hrs
7	Caucasus Range. Fault to the north	4001, 4032, 4038, 4045, 4057, 4058	19	75	No	No	Minimum: 10 hrs Maximum: 60 hrs
8	Mare rocks & stratigraphy NW Mare Serenetatus	4001, 4032, 4033, 4038, 4044, 4045, 4046, 4088	None	100	No	No	Minimum: 80 hrs Maximum: 230 hrs
9	Palus Putredinis, Mare rocks & stratigraphy	4001, 4032, 4033, 4038, 4044, 4045, 4046, 4088	None	100	No	No	Minimum: 80 hrs Maximum: 230 hrs
10	Rilles, straight, structural features	4001, 4032, 4038, 4045, 4058	None	75	No	No	Minimum: 80 hrs; Maximum 200 hrs each site (NOTE: 3 sites)
11-11'	Small mascon, geophysical traverse	4032, 4038, 4044, 4045, 4046, 4047, 4053, 4058	None		Yes	No	Stop every 1 Km for IVA. Emplace passive seismic station at 11. RGM at SE end of Traverse
11 & 11'	At traverse end points	4033, 4039 (Two 100-ft drill holes on traverse) 4088				No	Minimum: 50 hrs; Maximum 70 hrs for EVA

REMOTE SORTIE DEFINITION

Given the LSB site location and its distributed experiments sites, the next steps which are required in the analysis of remote sorties, are the outbound and inbound route selection and analysis of these routes to define the surface distances, slopes, and terrain to be encountered, the payload characteristics, and other variables. These data are summarized in a series of histograms to be described later. Design points are selected from these histograms to define performance requirements for the typical remote sortie mission and the transportation vehicles. Requirement Analysis Sheets (RAS) define additional performance requirements derived from the mission functional flow diagrams. Sortie trades and vehicle trades were performed on concepts which satisfy the requirements. From these studies a sortie concept and a transportation vehicle for the sortie were defined.

REMOTE SORTIE DEFINITION



LUNAR SURFACE ENVIRONMENT

Terrain surface geometry which affects vehicle performance and its optimization is defined as: (1) "micro-geometrical" surface roughness which induces vehicle vibrations (pitch, roll, bounce) and affects maximum speed, ride comfort, and control; (2) "macro-geometrical" surface roughness which encompasses slopes and such passable obstacles as ditches, walls, and crevasses that reduce speed; and (3) impassable obstacles such as mountains, craters, rilles, valleys, large crevasses, and bluffs which have to be bypassed and thus increase distance of travel.

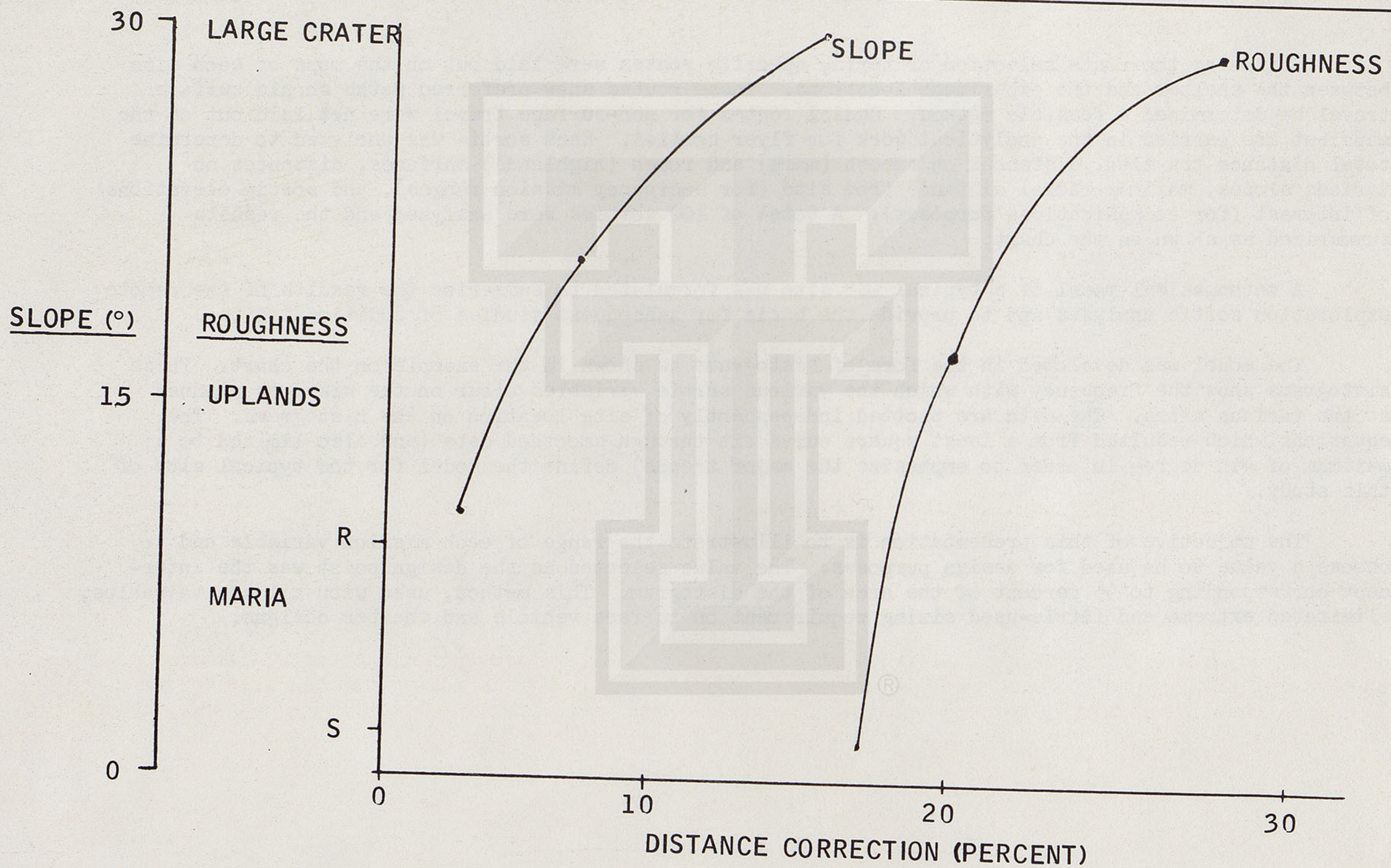
Detailed information regarding lunar surface roughness as defined above is not presently available. However, a model of terrain properties was used to derive correction factors to measured map distances to estimate actual travel distances based on the MSFC environmental guidelines in NASA TMX-53957.

The principal terrain effects on mission analysis are the increases in actual travel distance over the measured map distances due to travel on slopes and crater circumvention. These effects are shown on the chart where "roughness" applies to the circumvention which increases with surface roughness. The distance increase due to terrain sloping is based on the assumption that the increase in traverse distance is proportional to the secant of the angle of slope above horizontal.

Obstacle circumvention is a major contributor to path length if the obstacles are large (craters, crevasses). Small size obstacles (boulders, mounds, small craters) do not greatly increase the distance traveled although they increase the time due to the lowering of vehicle speed needed to give the driver enough time for decision-making in the maneuvers and keeping the vehicle upright when negotiating curves.

The increase in distance is a function of obstacle size and distribution. From USGS Astrogeology and Interagency Report No. 7, the additional travel distance necessary to circumvent circular obstacles having a known areal density was calculated. The results are given in the chart for various upper bounds on restrictive craters; i.e., the path charted avoids craters greater than this upper bound.

LUNAR SURFACE ENVIRONMENT



SORTIE DISTANCE HISTOGRAM

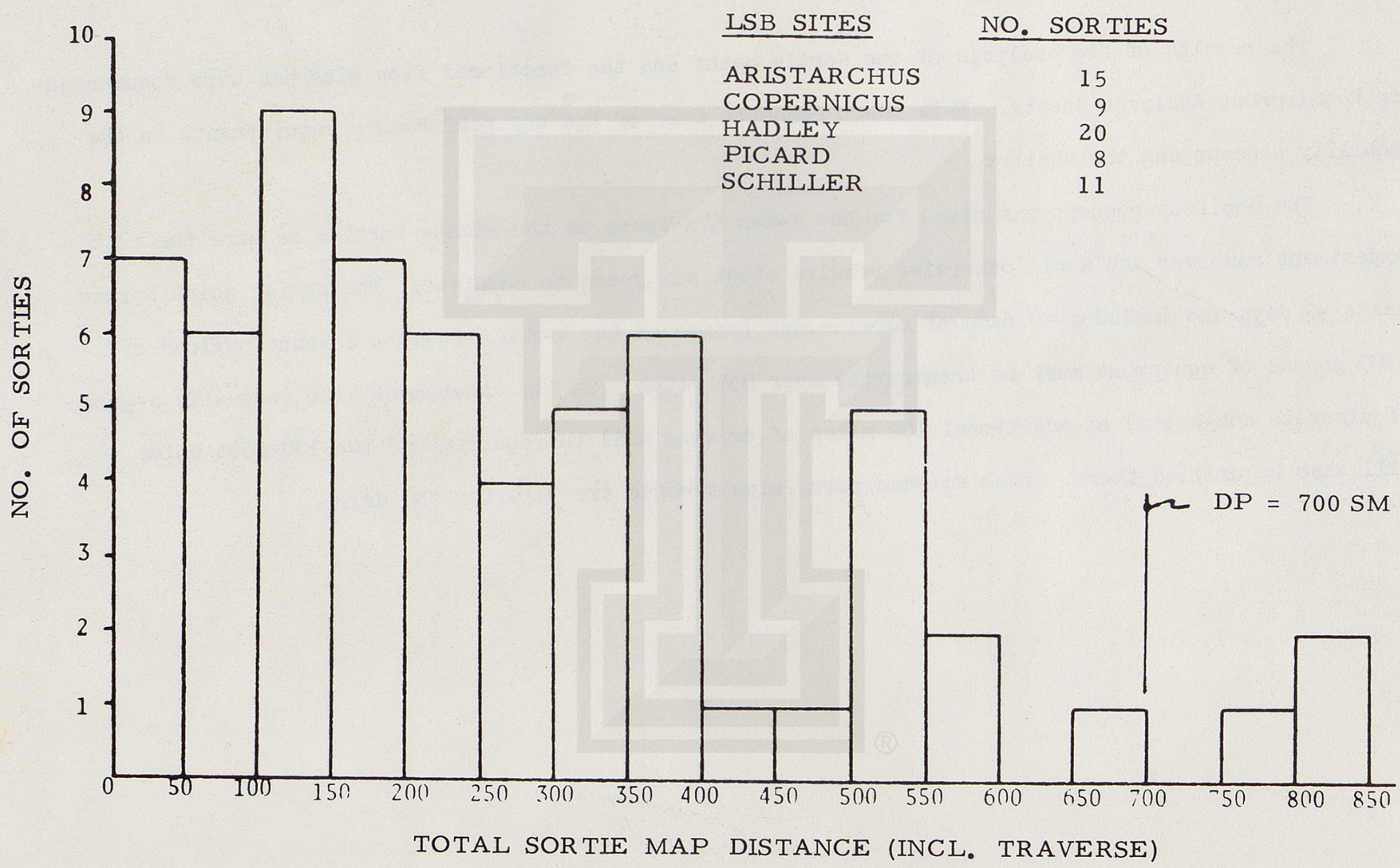
Utilizing the route selection criteria, specific routes were laid out on the maps of each site between the shelter and the experiment locations. These routes show preferred paths should surface travel be determined a feasible method. Radial routes for non-surface travel were not laid out on the maps but are carried in the analytical work for flyer sorties. Each sortie was analyzed to determine total distance traveled, distances on smooth (mare) and rough (highlands) surfaces, distances on various slopes, maximum radial distance from site (for emergency mission ranges), and sortie elevations of interest (for communications purposes). A total of 100 sorties were analyzed and the results summarized as shown on the chart.

A mathematical model of a typical LSB site was formulated to summarize the results of the remote exploration sortie analyses and to provide the basis for subsequent studies of additional sites.

The model was developed in the form of histograms as shown in the example on the chart. These histograms show the frequency with which the various sortie variables occur on the missions planned at the various sites. The data are plotted independently of site location on the histograms. The equations which resulted from a least square curve fit through smoothed data (and also limited to a maximum of 4th degree in order to emphasize the major trends) define the model for the typical site of this study.

The objective of this presentation is to illustrate the range of each mission variable and to choose a value to be used for design purposes. The value selected as the design point was the intercept corresponding to 95 percent of the area of the histogram. This method, used with all the vairables, eliminated extreme and little-used sizing requirement on surface vehicle and shelter designs.

SORTIE DISTANCE HISTOGRAM



REMOTE SORTIE PERFORMANCE REQUIREMENTS

The results of the analysis of the sortie paths and the functional flow diagrams were documented in Requirement Analysis Sheets. This chart presents some of the key performance requirements on the mobility concept and the shelter.

The mobility concept was sized for two 2-man EVA teams as the remote sorties require the most experiment manpower and would otherwise require about six years to complete. The design point sortie lasts 90 days and includes 40 days of experiments (based on the 4-man crew). A science payload of 1500 pounds of equipment must be transported over 855 miles. At the experiment site (actually a group of discrete sub-sites) an additional 100 miles of driving will be required and two 100-foot holes will also be drilled there. Peak science power requirements are 3 kw for the drill.

REMOTE SORTIE PERFORMANCE REQUIREMENTS

ON MOBILITY CONCEPT	ON LSB SHELTER
• 4 MEN	• VEHICLE MAINTENANCE FACILITIES - 168 HRS/SORTIE
• 40 DAYS SCIENCE	• MODULAR POWER SOURCES
• 90 DAYS TOTAL	• 10^4 BPS DATA LINK (< 230 SM)
• 855 MILES	• WAREHOUSING (10K LB/180 DAYS)
• W_P = 1500 POUNDS	• SYSTEMS AND PERSONNEL SERVICES (~240 MAN-DAYS/180 DAYS)
• 100 MI ON SITE	• 1150 DAYS MISSION DURATION
• 100' HOLES - 2	
• 3.6 KW	

REMOTE SORTIE CONCEPT SELECTION

For the remote exploration sorties on the lunar surface, three primary modes can be visualized:

1. Fly both crew and equipment to and from the site to minimize the enroute travel time
2. Fly the crew only and send the heavy equipment by unmanned surface vehicle to the site in which case, the crew would not leave the base until the equipment arrived at the experiment site
3. Utilize surface transportation both ways

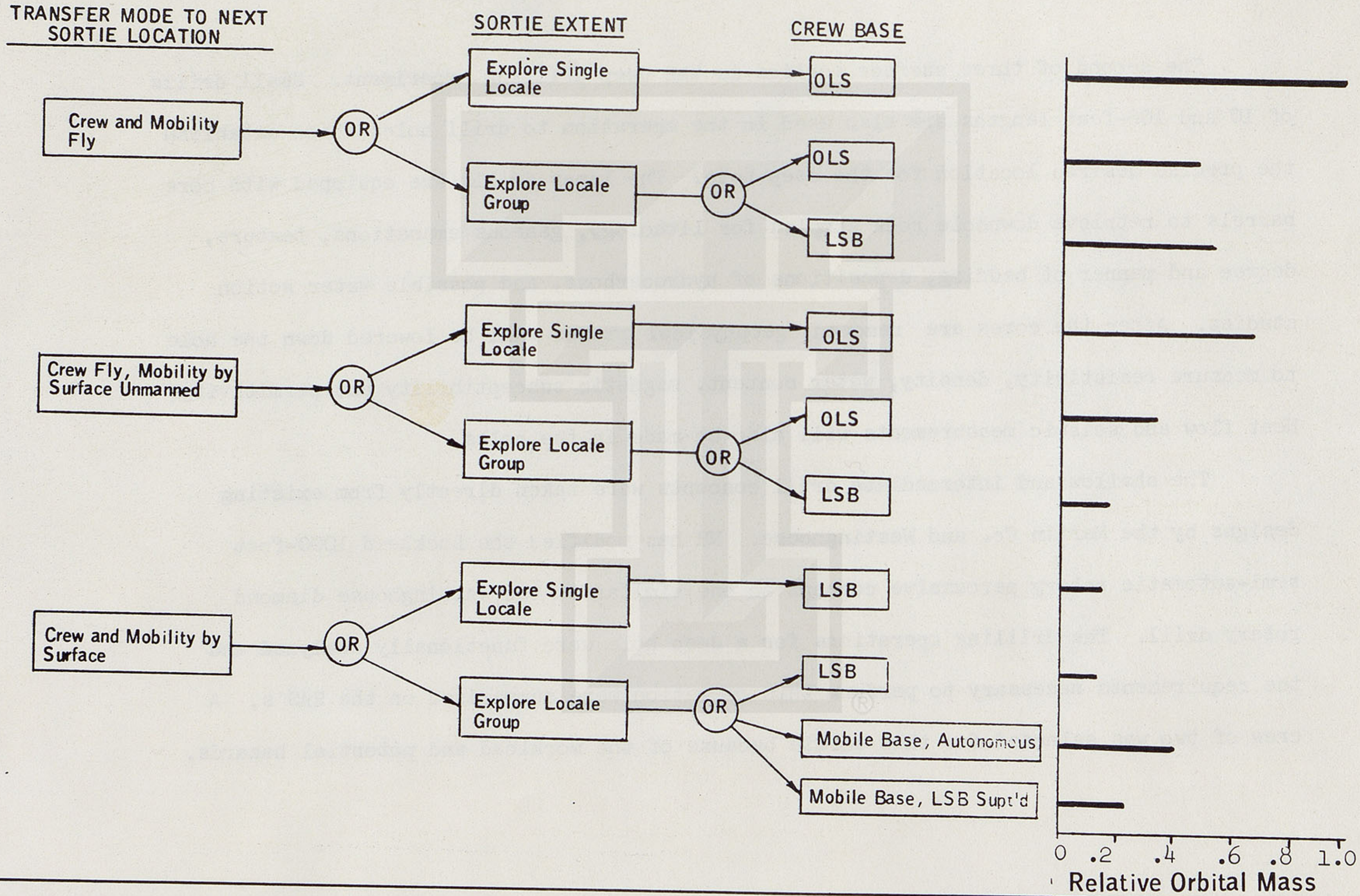
In addition to the choice of the transfer mode, the scope of the sortie can be varied. Here, the alternatives are to either explore a single experiment site or explore a group of sites during the sortie. In general, it would be preferable to always explore more than one locale per sortie in order to get the most benefit from the investment in transportation time and consumables. However, this approach may not be possible if the sortie duration achievable with a particular mission concept is less than the time required to complete the exploration of one locale, transfer to the next, and complete exploration there.

Finally, the remote exploration sorties can be accomplished by crews based at an OLS, at LSB or in a completely mobile base. The chart summarizes the above discussion of mission concept options in a trade tree format and indicates the relative mass required to be delivered to lunar orbit.

The conclusion reached from an examination of the data is that while use of the tug and flyer can reduce the program duration due to their lower travel times, the large mass of the propellant required increases the program mass delivered to lunar orbit and, therefore, results in a presumably higher program cost. Based on this premise and for the assumptions outlined above, it appears that a central LSB concept utilizing surface mobility equipment for transportation to explore the immediate region is the optimum way to perform the remote exploration mission.

It should be noted that this conclusion only applies to those locales that are within a feasible driving range of the selected LSB site. As indicated in the earlier discussion, not all lunar features of interest can be expected to be available at any one LSB site and some alternative concept will have to be adopted in order to achieve the scientific objectives associated with the missing features. Whether this alternate involves a second LSB, an OLS/tug, or some concept other than those described above, can only be determined after a future, more detailed site selection study is made and the missing elements identified.

REMOTE SORTIE CONCEPT SELECTION

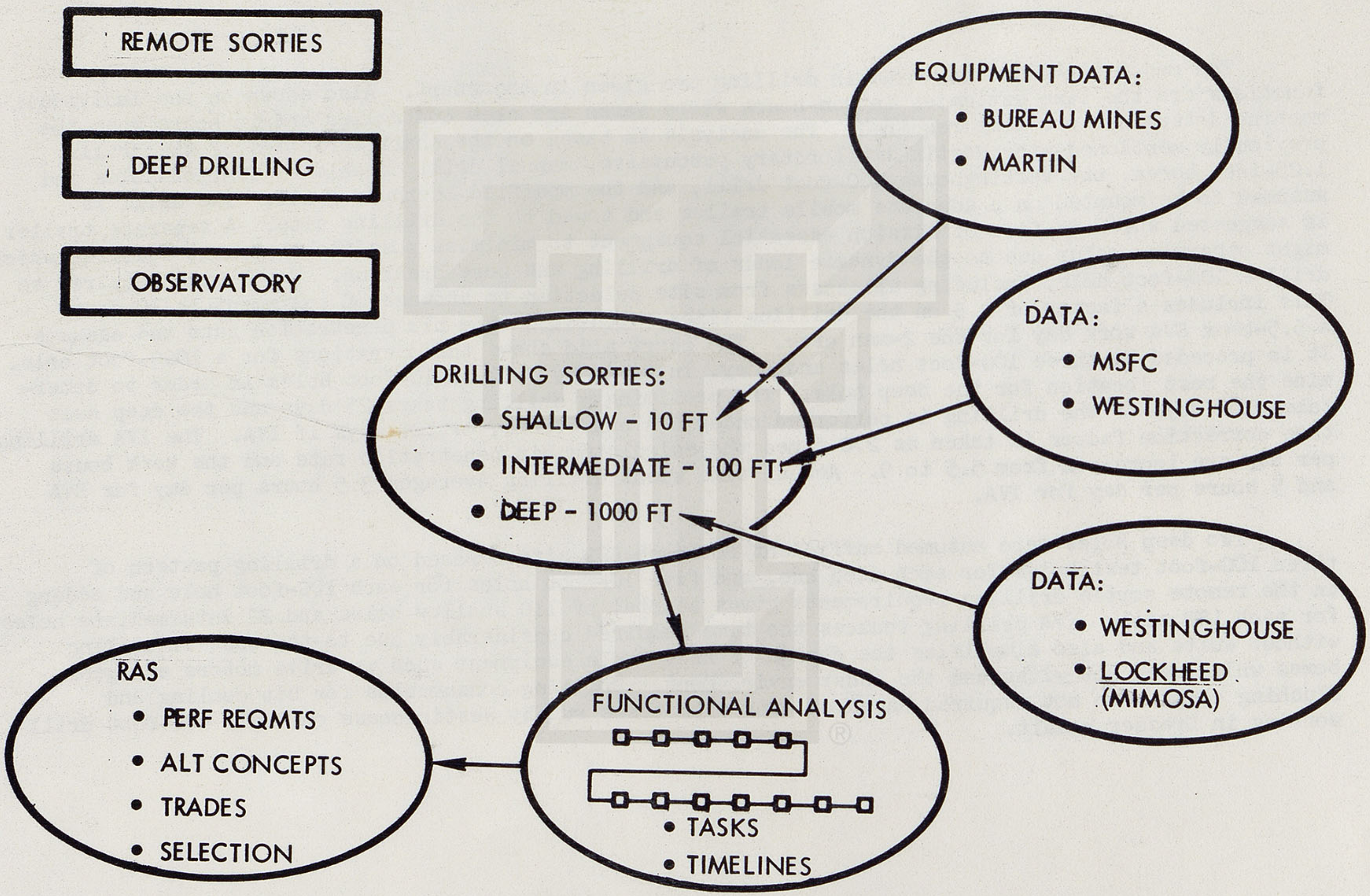


DEEP DRILLING SORTIE DEFINITION

The second of three surface sorties is the deep drilling experiment. Small drills of 10 and 100-feet lengths are also used in the operation to drill holes which establish the precise desired location for the deep hole. The lunar drills are equipped with core barrels to retrieve downhole rock samples for lithology, gaseous emanations, texture, degree and manner of bedding, depositions of hydrocarbons, and possible water action studies. After the cores are removed, geophysical probes will be lowered down the hole to measure resistivity, density, water content, magnetic susceptibility and permitivity. Heat flow and seismic measurements will also be made in the holes.

The shallow and intermediate drill concepts were taken directly from existing designs by the Martin Co. and Westinghouse. NR has modified the Lockheed 1000-foot semi-automatic rotary percussive concept to one similar to the Westinghouse diamond rotary drill. The drilling operations for a deep hole were functionally analyzed and the requirements necessary to perform this operation were summarized on the RAS's. A crew of two was selected for this sortie because of the workload and potential hazards.

DEEP DRILLING SORTIE DEFINITION

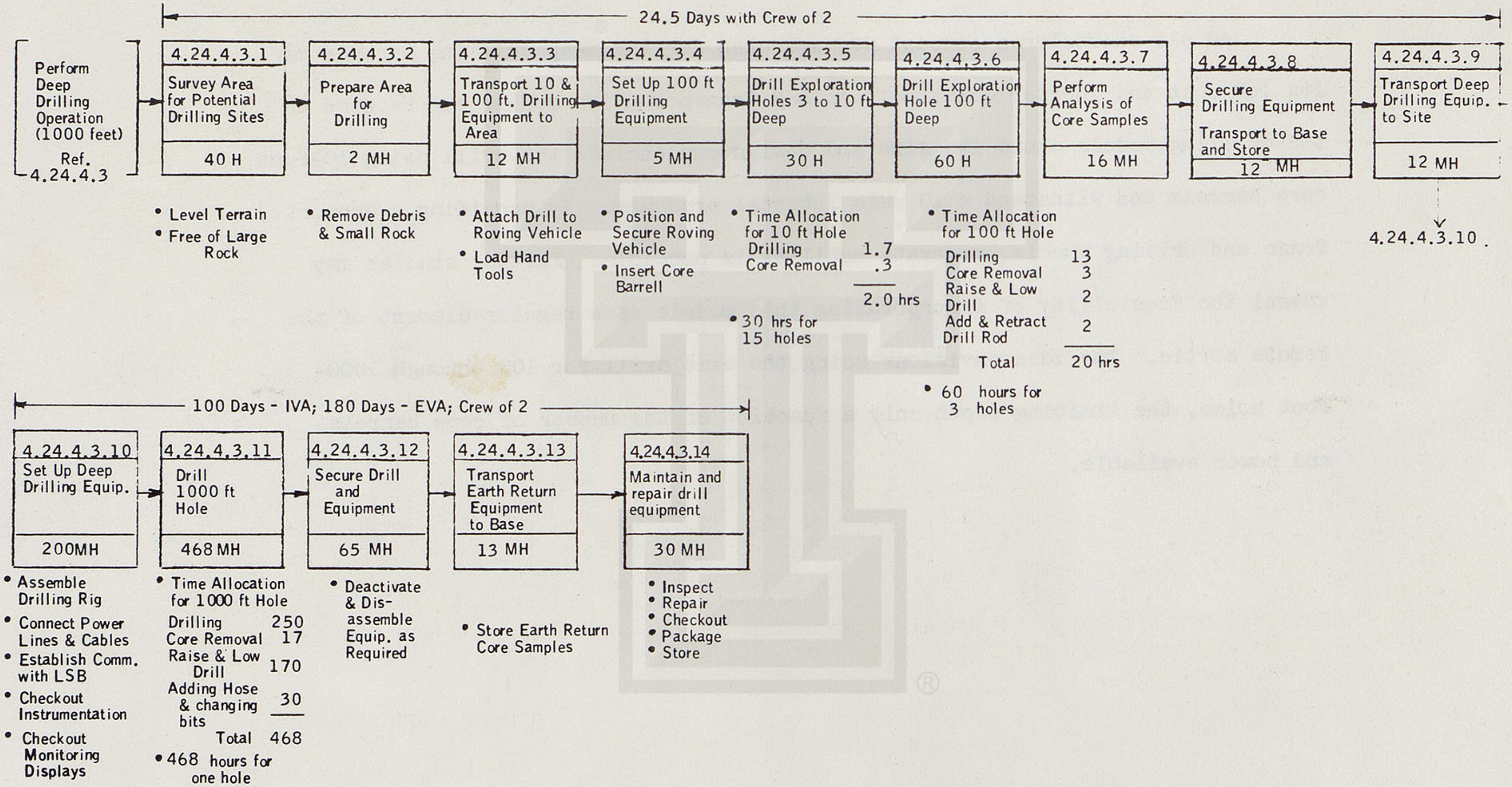


DEEP DRILLING FUNCTIONAL ANALYSIS

The major functions involved in drilling are given in the chart. Also shown on the individual functions are the time estimates in man-hours where tasks are crew controlled and in hours when the machine determines the time required. The analysis is based on the characteristics of the drills previously mentioned--the Martin small rotary percussive, manual drill capable of 10-foot holes and 1.25-inch cores, the Westinghouse 100-foot drill, and the modified Lockheed drill. The drill is assumed to be mounted on a separate mobile trailer and towed to the drilling site. A separate trailer is suggested which is free of mission essential equipment to minimize possible equipment failures which might otherwise occur due to the dynamic loads of drilling and core breaking. Total time required to drill a 100-foot hole, including all tasks from site selection to stowage of equipment is 10 days. This includes a factor of 2.5 on the drilling times calculated from bit penetration rate and assumes a 5.5-hour EVA work day for the 2-man crew. The chart also shows the operations for a 1000-foot hole. It is preceded by three 100-foot holes and they, in turn, by fifteen 10-foot holes in order to determine the best location for the deep hole. The preliminary drilling takes 25 days and the deep hole takes 180 days if the drilling is performed under EVA conditions, or 100 days if IVA. The IVA drilling time correction factor is taken as 2.0 times the calculated bit penetration rate and the work hours per day are increased from 5.5 to 9. Actual time spent drilling averages 3.5 hours per day for EVA and 5 hours per day for IVA.

Two deep holes were assumed sufficient for each LSB site. Based on a drilling pattern of three 100-foot test holes for each deep one, and five 10-foot holes for each 100-foot hole and adding in the remote sortie drilling requirements gives a total of 110 shallow holes and 22 intermediate holes for each LSB site. IVA drilling reduces the time required considerably due to the ease of working without suits and also simplifies the design of above-hole equipment such as drive motors and gear boxes which need not withstand the lunar environment. Drilling consumables for bit cooling and flushing chips were not required based on data from tests run by Westinghouse on their 100-foot drill working in Dresser basalt.

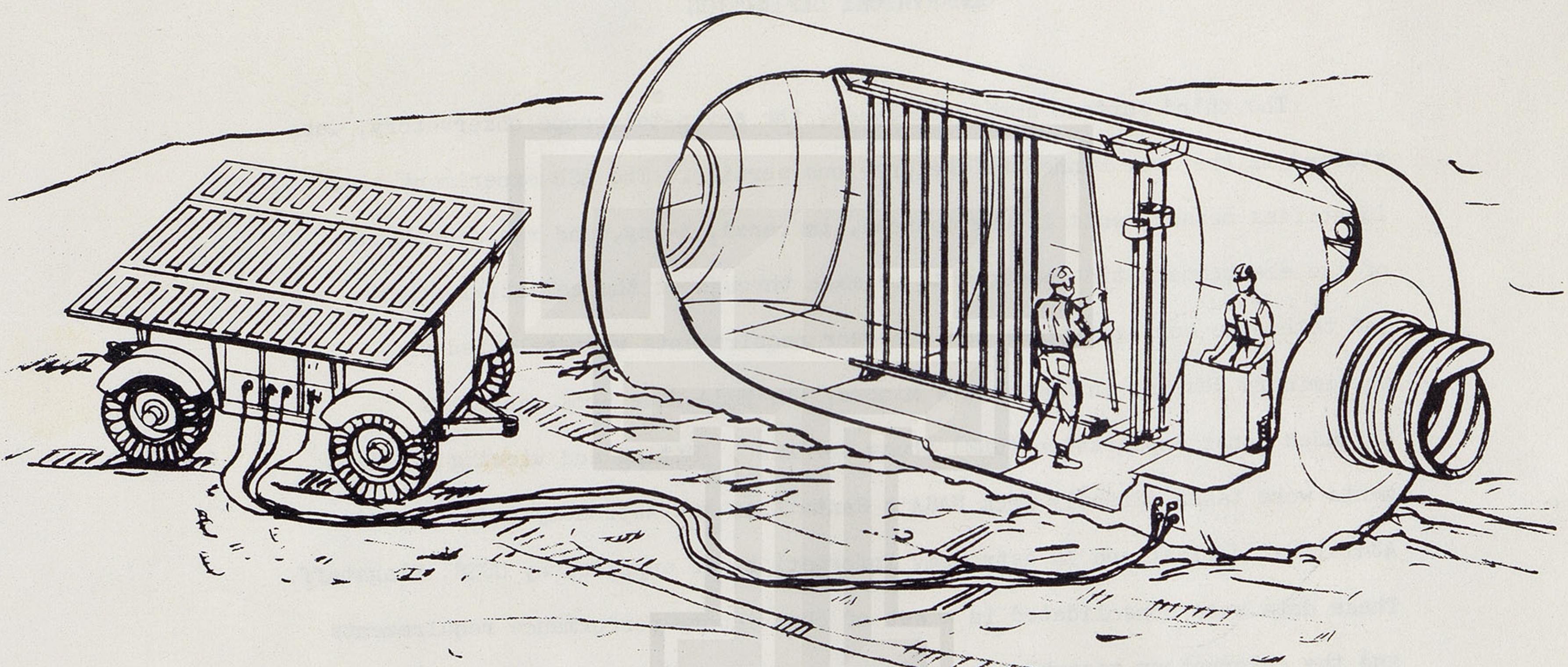
DEEP DRILLING FUNCTIONAL ANALYSIS



SELECTED DRILLING CONCEPT

An all shirtsleeve concept was selected for the deep drilling because of its low cost and shorter duration. An LSB transportation module can be used as the drilling module since its size and design can enclose the drill using 10-foot core barrels and withstand a 10 psia internal pressure. By providing a support frame and driving wheels, moderate mobility is possible. Further studies may reveal the feasibility of incorporating this module as a regular element of the remote sortie. The idea envisions using the same drill for 100 through 1000-foot holes, the limiting depth only a function of the number of core barrels and power available.

SELECTED DRILLING CONCEPT

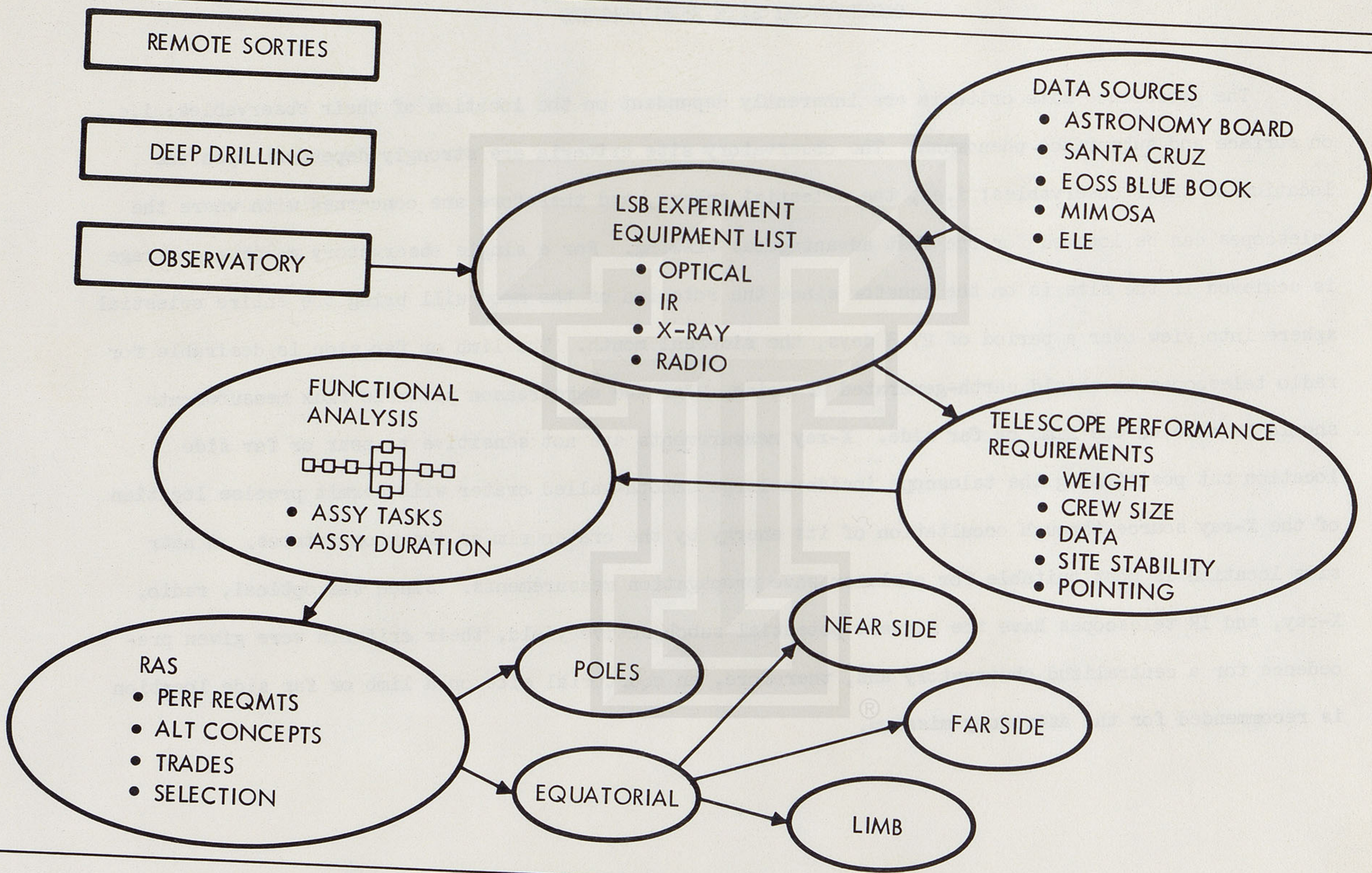


- TWO MAN CREW
- IVA
- POWER FOLLOWS MODULE
- MODERATE MOBILITY

OBSERVATORY DEFINITION

The third surface sortie analyzed, the seven-telescope observatory, was studied in the same manner as the previous sorties. The LSB experiment list identifies measurements in the optical, infrared, X-ray, and radio portions of the electromagnetic spectrum to be made throughout the celestial sphere. The telescope configurations and manpower requirements were selected from preliminary designs in Lockheed's Mimosa, the NASA Blue Book, and NR's Extended Lunar Exploration (ELE) study for MSFC. Siting and viewing requirements were taken directly from NASA's Santa Cruz and Astronomy Board reports. Additional optical and IR astronomy information was supplied by USGS, Flagstaff. These data were consolidated in a set of observatory performance requirements and the observatory assembly operations were functionally analyzed. RAS's summarized these requirements and the options for location of the observatory were identified.

OBSERVATORY DEFINITION



OBSERVATORY SITE REQUIREMENTS

The geoscience site criteria are inherently dependent on the location of their observables; i.e., on surface and subsurface phenomena. The observatory site criteria are strongly dependent upon the location of their observables; i.e., the celestial sphere, and therefore are concerned with where the telescopes can be located for the most advantageous viewing. For a single observatory maximum coverage is achieved if the site is on the equator since the rotation of the moon will bring the entire celestial sphere into view over a period of 27.3 days, the sidereal month. The limb or far side is desirable for radio telescopes to shield earth-generated RF noise. For the same reason particle flux measurements should be made on the limb or far side. X-ray measurements are not sensitive to near or far side location but positioning the telescope inside a large smooth-walled crater will permit precise location of the X-ray source through occultation of its energy by the crater rim as the moon rotates. A near side location is most suitable for cislunar wave propagation measurements. Since the optical, radio, X-ray, and IR telescopes have the highest potential subobjective yield, their criteria were given precedence for a centralized observatory and, therefore, an equatorial site on a limb or far side location is recommended for the astronomy mission.

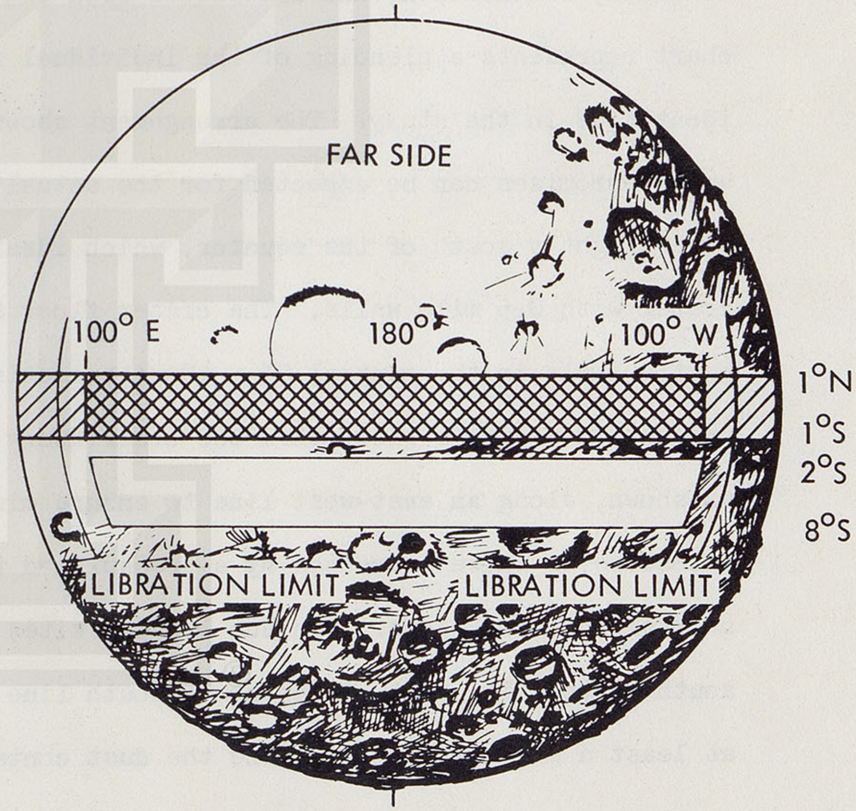
OBSERVATORY SITE REQUIREMENTS

OBJECTIVE

- MAX COVERAGE OF CELESTIAL SPHERE
- MAGELLANIC CLOUDS
- EARTH RF NOISE AVOIDANCE
- X-RAY OCCULTATION
- MAX EXPOSURE TIME
- MIN SKY BRIGHTNESS

LOCATION

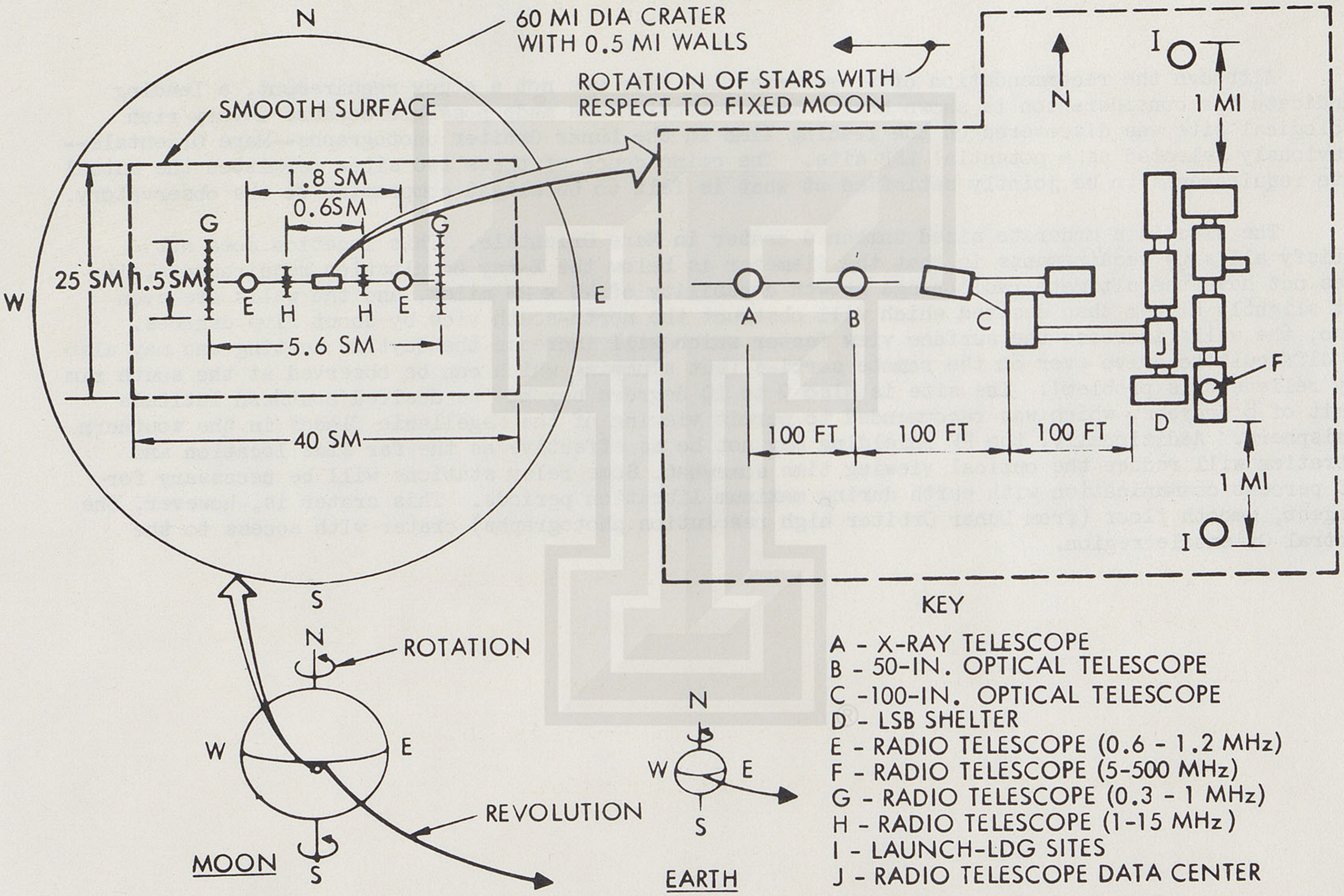
- OPTICAL & IR
- X-RAY
- RADIO



SITE ORIENTATION REQUIREMENTS

Each of the observatory elements has a set of requirements relative to its location, orientation, and interfaces with the LSB. The layout depicted on the chart represents a blending of the individual requirements of the experiments identified in the study. The arrangement shown presents a near optimum condition and compromises can be expected for the actual site. The figure indicates the site slightly south of the equator, which ideally contains a 60-mile diameter crater with 0.5 mile walls. The crater floor should be as smooth as possible, particularly in the central 25 x 40-mile section. If these features were all present in a single site, then the observatory and LSB elements could be colocated, as shown, along an east-west line to ensure minimum mutual shadowing. The 100-inch telescope is shown connected by a pressurized tunnel to the LSB shelter to allow shirtsleeve operations. The tug landing sites should be located either north or south of the site east of the north-south line through the 100-inch telescope and at least a mile away to minimize the dust contamination.

SITE ORIENTATION REQUIREMENTS

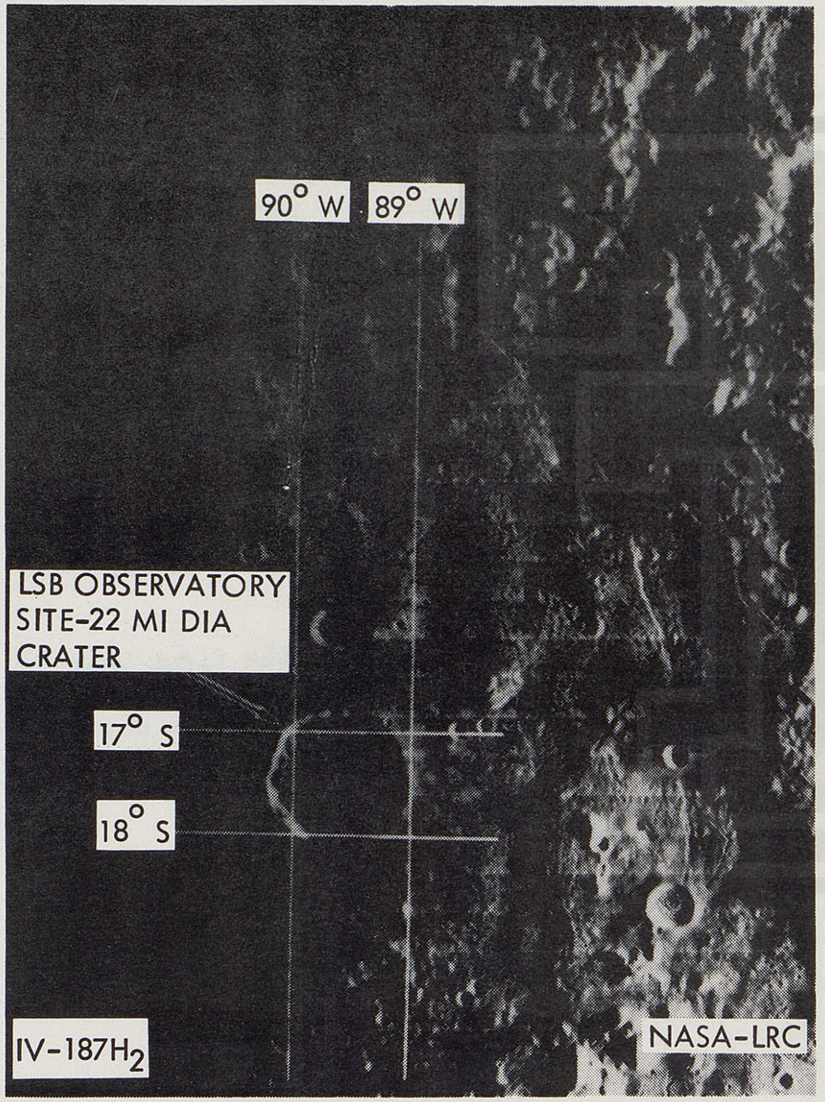


LSB OBSERVATORY SITE SELECTION

Although the recommendation of a preferred LSB site was not a study requirement, a leading candidate for consideration is shown here. This selection was made possible because a very rich geological site was discovered on the leading limb in the Lunar Orbiter photographs--Mare Orientale--previously selected as a potential LSB site. The coincidence of these two sites permitted the mutual site requirements to be jointly satisfied at what is felt to be slight compromise to the observatory.

The site is a moderate sized unmanned crater in Mare Orientale. This location does not satisfy all site requirements in that the diameter is below the X-ray occultation requirements, it does not have the ultimate radio range growth capability of 40 x 25 miles, and the walls are even but slightly higher than desired which will obstruct the north-south view by about five degrees. Also, the walls increase the surface view factor which will increase the daytime heating and may also be difficult to drive over on the remote sorties (but slumping which can be observed at the south rim may relieve this problem). The site is also 9 to 10 degrees beyond the desired southern latitude limit of 8 degrees, which was recommended to permit viewing of the Megellanic Clouds in the southern hemisphere. Additionally, the RF shielding may not be as effective as the far side location and libration will reduce the optical viewing time somewhat. Some relay stations will be necessary for 100 percent communication with earth during maximum libration periods. This crater is, however, the largest, smooth floor (from Lunar Orbiter high resolution photographs) crater with access to the Central Orientale region.

LSB OBSERVATORY SITE SELECTION



SHELTER EXPERIMENTS PROGRAM

The main purpose of the shelter is to provide a habitable environment and facilities for the crew. Tasks to be performed by the crew at the shelter are data analysis, housekeeping operations, shelter and experiment management, logistics planning, data transmission, preparation of equipment, data, and samples for return to earth, storage of cargo, and vehicle and equipment maintenance and repair. In addition, the shelter and environs can be used as a laboratory to perform non-site dependent experiments. This approach is particularly conducive to experiments which require numerous repetitions over a long duration. The great variety of bioscience, lunar atmospheres, particles and fields, aerospace medicine, and the engineering, technological, and operational experiments are not site dependent but can best be conducted in the vicinity of the shelter, regardless of its location.

A plan for such an experiments program is given in the chart which lists the experiments by identifying number, their minimum and maximum number of repetitions, the duration of a single repetition, and the IVA and EVA crew support times required (note that these are not necessarily equal to the experiment duration). These data were used to determine the shelter experiment weight, volume, and power requirements, to size the laboratory area, and to determine the science manpower required to support this plan.

The experiments identified for the shelter will gradually decrease from 43 in the first year to 7 which continue while the shelter is manned. One equivalent man is required to perform these experiments although diverse skills will be required. Undoubtedly, other experiments will be devised to replace those completed. A special experiments area outside the shelter in an uncontaminated zone is necessary to complete several experiments.

SHELTER EXPERIMENTS PROGRAM

- NON-SITE DEPENDENT
- CREW SIZE - 1 EQUIV.
- WEIGHT - 2140 LB
- DURATION - 4 YEARS

Discipline	Experiments	Lmtd to LSB Site?	Repetitions Min	Repetitions Max	Duration of Experiment Operation	IVA (per man)	EVA in LSB Area
Bio-Science	4001	no	75	250	40 hrs	1/2 hr/sample	(per man - 2 men req'd per EVA)
	4003	yes	300	1200	150 hrs	1/2 hr/sample	
	4006	yes	140	1400	duration of base	1/2 hr/test	
	4008	yes	3	10	duration of base	1/2 hr/test	
	4009	yes	6	36	duration of base	1/2 hr/test	
	4011	no	250	800	duration of base	1/2 hr	
Astronomy	4012	yes	12	36	720 hrs	72 hrs	60 hrs
	4014	yes	12	36	960 hrs	96 hrs	72 hrs
	4015	yes	12	36	1 yr	40 hrs	35 hrs
	4016	yes	1	5	1 yr	500 hrs	40 hrs
	4017	yes	1	10	1 yr	10 hrs	12 hrs
	4021	yes	1	2	1 mo	32 hrs	20 hrs
	4022	yes	4	32	4 mo	4 hrs/mo	24 hrs
	4023	yes	3	5	6 days	3 hrs/day	12 hrs
	4024	yes	30	90	30 days	1 hr/day	2 hrs
	4025	yes	10	20	10 days	1 hr/day	3 hrs
	4026	yes	1	2	1 yr	0.5 hr/day	20 hrs
	4027	yes	12	36	1 yr	50 hrs/mo	40 hrs
	4028	yes	15	45	30 days	54 hrs	16 hrs
	4029	yes	1	5	1 yr	700 hrs	48 hrs
Geology-Geochemistry	4032	no	1	300	As required	13 hrs per EVA	6.5 hrs per EVA
	4037	yes	50	1000		1 hr/sample	
	4038	no	10	50			0.5 hr per sample
	4048	yes	1	2	500		[illegible]
	4057	no	25	50	2 days		traverse
	4059	no	1	10	[illegible]		
	4060	yes	200	15[illegible]			
	4061	yes	20[illegible]				
Geophysics	4045						
	4046						
	40[illegible]						

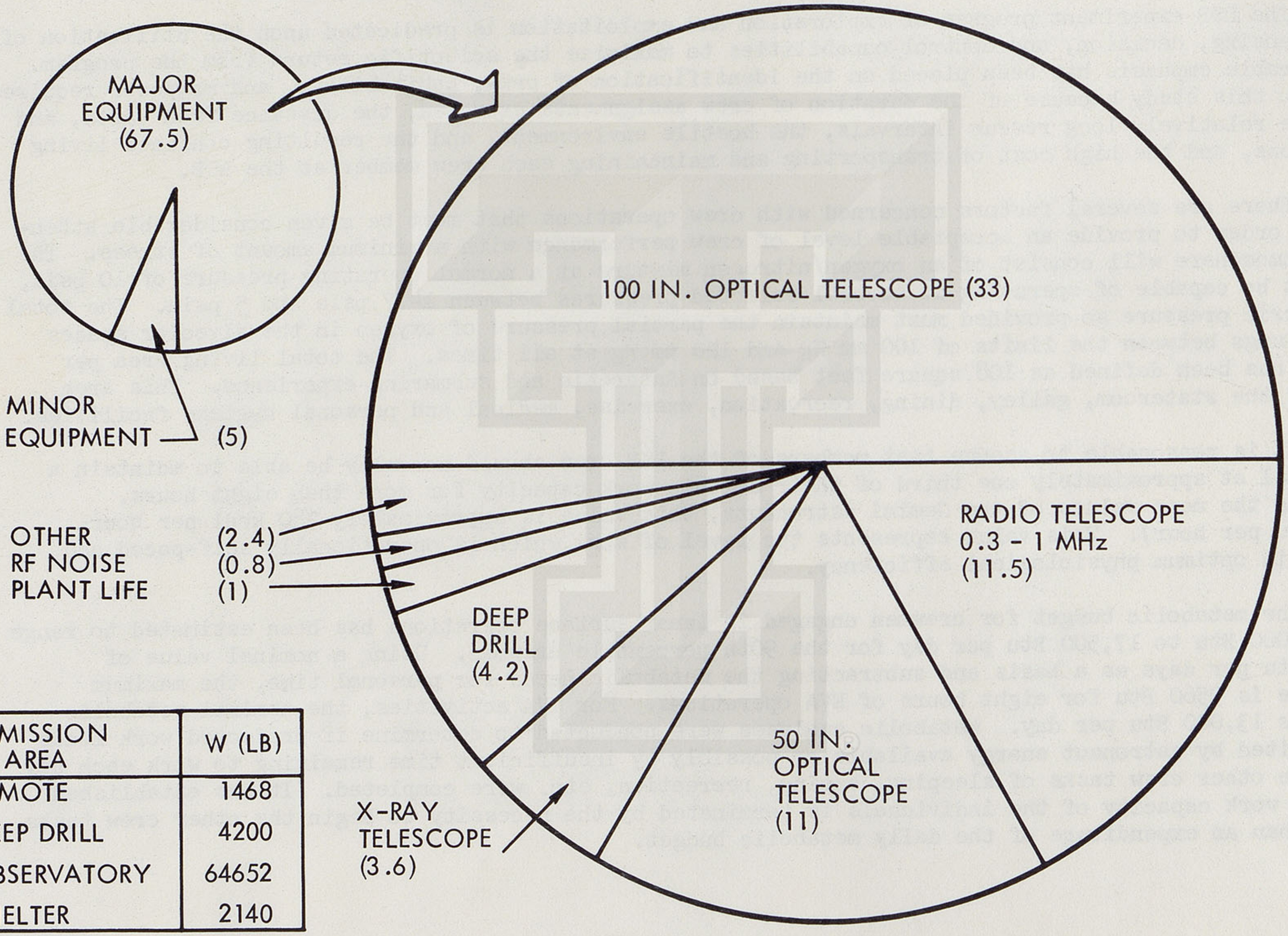
SCIENCE EQUIPMENT WEIGHT

Comparisons are shown on this chart of major versus minor science equipment weight, the weights of the individual pieces of major science equipment, and the science payload distribution among the surface sorties, including the shelter experiments program. The science equipment total weight of 72,460 pounds is composed of 90 pieces of science equipment. Major science equipment, defined as hardware weighing in excess of 100 pounds, includes only 18 percent of the pieces (10) but 93 percent of the weight. Subsequent analyses need only concentrate on these major drivers to size vehicles, shelters, logistics systems, and crews with adequate precision for preliminary studies.

The 100-inch optical telescope, already optimized for lunar surface use and considerably lighter than similar terrestrial telescopes, constitutes almost half of the total science equipment; the complete observatory takes up 90 percent of this total. The maximum remote sortie payload is about 1500 pounds while the deep drill weighs 4200 pounds, not including the drill module structure or power supply. All weights are given in earth pounds; weights shown in parentheses are in thousands of pounds.

SCIENCE EQUIPMENT WEIGHT

(WEIGHT IN THOUSANDS OF POUNDS)



MISSION AREA	W (LB)
REMOTE	1468
DEEP DRILL	4200
OBSERVATORY	64652
SHELTER	2140

CREW REQUIREMENTS

The LSB experiment program of exploration and exploitation is predicated upon the utilization of man's sensing, decision, and control capabilities to maximize the scientific return from the program. Considerable emphasis has been placed on the identification of crew, habitability, and manpower requirements in this study because of the duration of crew assignments expected, the distance from earth, and thus the relatively long rescue intervals, the hostile environment, and the resulting confined living conditions, and the high cost of transporting and maintaining each crew member at the LSB.

There are several factors concerned with crew operations that must be given considerable attention in order to provide an acceptable level of crew performance with a minimum amount of stress. The cabin atmosphere will consist of an oxygen/nitrogen mixture at a normal operating pressure of 10 psia, but must be capable of operating at several selected pressures between 14.7 psia and 5 psia. The total atmospheric pressure so provided must maintain the partial pressure of oxygen in the alveolar spaces of the lungs between the limits of 100 mm Hg and 120 mm Hg at all times. The total living area per crewman has been defined as 108 square feet based on Antarctic and submarine experience. This area includes the stateroom, galley, dining, recreation, exercise, medical and personal hygiene facilities.

It is reasonable to assume that members of the LSB crew should normally be able to maintain a work level at approximately one third of their aerobic work capacity for more than eight hours. Utilizing the mean values of the Gemini astronauts, this value is approximately 380 kcal per hour (1120 Btu per hour). This value represents the level of work which is operationally self-paced and results in optimum physiological efficiency.

The metabolic budget for crewmen engaged in lunar surface operations has been estimated to range from 14,000 Btu to 17,500 Btu per day for the 90th percentile crewman. Using a nominal value of 16,000 Btu per days as a basis and subtracting the metabolic needs for personal time, the maximum available is 9560 Btu for eight hours of EVA operations. For IVA activities, the nominal metabolic budget is 13,000 Btu per day. Metabolic analyses were conducted to determine if projected work loads were limited by astronaut energy available or possibly by insufficient time remaining to work each day after the other crew tasks of sleeping, eating, recreation, etc. were completed. It was established that the work capacity of the individuals is terminated by the necessity to begin the other crew tasks rather than an expenditure of the daily metabolic budget.

CREW REQUIREMENTS

TASK ALLOCATION

- REAL TIME ANALYSIS, DECISION, AND CONTROL
- DRILLING AND TELESCOPES SEMI-AUTOMATED

HABITABILITY

- SHELTER ATMOSPHERE - 10 PSIG O_2-N_2
- 108 FT^2 / MAN

WORK CAPACITY

- 16K BTU / MAN-DAY EVA
- 13K BTU / MAN-DAY IVA
- 1100 BTU / HR CONTINUOUS
- TIME LIMITED - NOT ENERGY LIMITED

SAFETY CONSIDERATIONS

Personnel and equipment safety is one of the primary design elements of the LSB and this provided the basis for the first iteration on crew size. To satisfy the assumed requirements of dual manned operations for all EVA tasks--the buddy system--and the simultaneous conduct of the various surface sorties, a minimum crew size of 10 men is initially necessary. Of these, four men are assigned to remote sorties--two 2-man teams, two men are required for deep drilling (which is completed after the first year), two men are required for radio astronomy which can be performed concurrently with drilling, and two men are used for base operations tasks such as management and administration, flight operations support, maintenance and repair, housekeeping, and the shelter experiments program. This crew of 10 must include a minimum skills mix of two tug pilots in the "no-OLS" case where tugs are stationed at the shelter between missions, all four remote sortie personnel should be checked out on the surface vehicles, and all LSB personnel must also be EVA-qualified to support rescue operations or mission aborts.