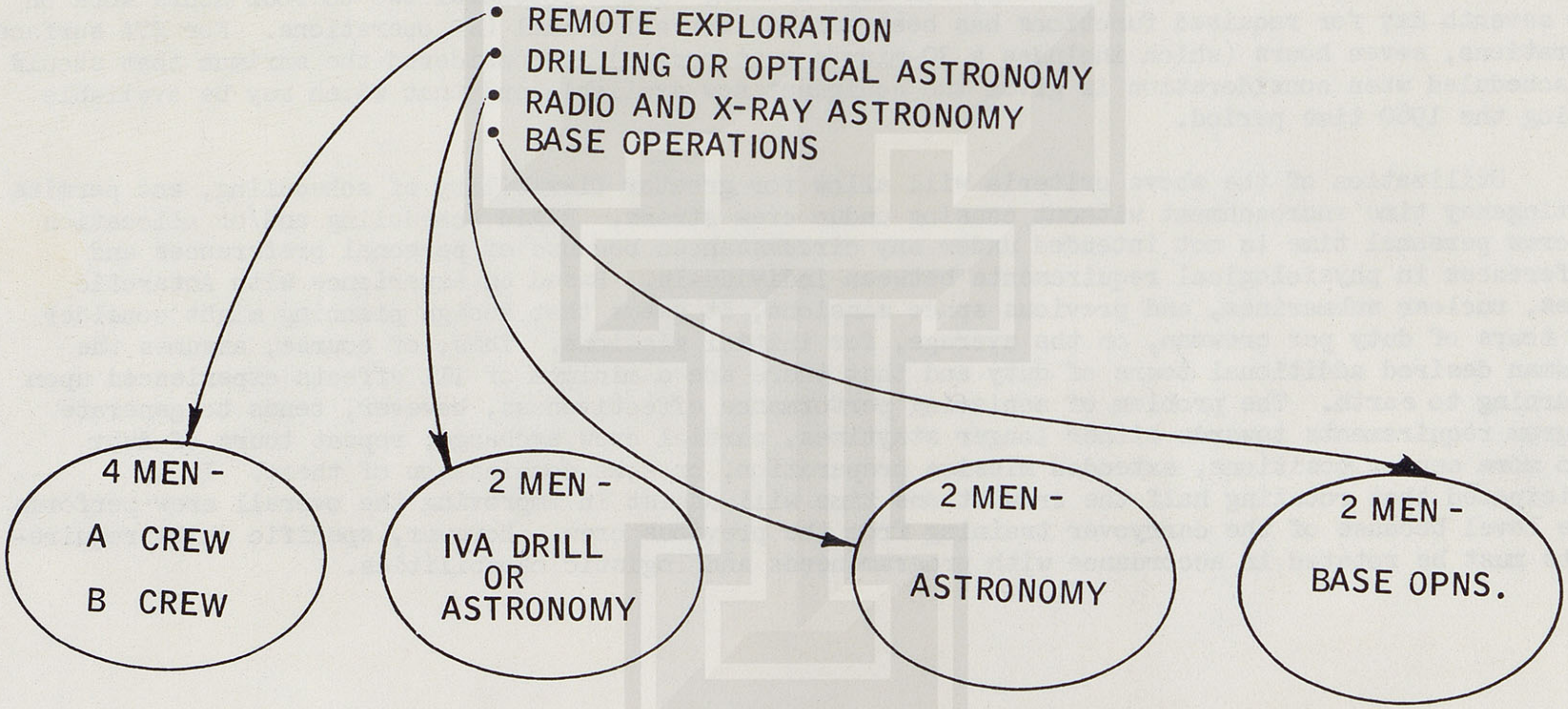
SAFETY CONSIDERATIONS

BUDDY SYSTEM

SIMULTANEOUS OPERATIONS

- REMOTE EXPLORATION
- DRILLING OR OPTICAL ASTRONOMY
- RADIO AND X-RAY ASTRONOMY
- BASE OPERATIONS



MINIMUM CREW SIZE = 10

MINIMUM SKILLS MIX

2 TUG PILOTS
ALL EVA
4 MOBILITY DRIVERS

MANPOWER DEVELOPMENT

The method utilized to outline the basic skill requirements and to develop the manpower loading for LSB operations is based on the proposed lunar surface experiment program. LSB stationkeeping operations were estimated from the data developed for the EOSS and amended for the LSB requirements. LSB base operations and experiment manpower estimates were compiled both by discipline and by experiment. A work shift of ten hours per day, six days a week, with a potential two to four hours work on the seventh day for required functions has been assumed for all normal LSB operations. For EVA surface operations, seven hours (which includes a 30-minute rest period) is considered the maximum that should be scheduled when consideration is given the equipment now available and that which may be available during the 1980 time period.

Utilization of the above criteria will allow for greater flexibility of scheduling, and permits contingency time encroachment without causing undue crew stress. Rigid scheduling and/or allocation of crew personal time is not intended under any circumstances because of personal preferences and differences in physiological requirements between individuals. Based on experience with Antarctic bases, nuclear submarines, and previous space missions, it seems that design planning might consider two tours of duty per crewman, on the average, for initial missions. This, of course, assumes the crewman desired additional tours of duty and that there are a minimum of ill effects experienced upon returning to earth. The problem of achieving performance effectiveness, however, tends to generate program requirements towards either longer staytimes, partial crew exchange, repeat tours of duty into more senior positions, extended mission preparation, or some combination of these. It is anticipated that rotating half the crew at one time will assist in improving the overall crew performance level because of the carryover training from the previous crew. However, specific skill requirements must be rotated in accordance with program needs and logistic capabilities.

MANPOWER DEVELOPMENT

- IVA
  - 10 WORKING - HRS/DAY
  - 6 DAYS/WEEK
  - 2 HOURS/SUNDAY
- EVA
  - 8 SUIT - HRS/DAY
  - 6.5 WORK - HRS/DAY
  - 6 DAYS/WEEK

ASTRONOMY

Table F-3. Experiments Manpower Requirements

Experiment Number	Equipment Number	Function	Total EVA Hours	Shirtsleeve Hours Total	EVA Hours Mainten. & Servicing	Shirtsleeve Hours - Servicing	Remarks	Operational Cycles	Cycle Time
X-RAY TELESCOPE									
4012	11092 11097	Installation Activation Maint. and film change Operation	120 40 720 880	720	1/day	60 cy.	Plus travel time	12/36	1 month
1.3 METER OPTICAL TELESCOPE									
4016 Time-sharing 4029	11095 11095	Installation Activation Servicing Operation Operation	90 10 720 400 200 1420	 5 360 1100 550 2015	1/day	1/day	Plus travel time 750 man hours/year	1 1	1 year 1 year
2.5 METER OPTICAL TELESCOPE									
4030		Installation Activation ECLSS Activ. Telescope Servicing Operation	325 10 75 720 1130	80 100 150 360 2180 2875	1/day	1/day 6/day		1	1 year
OPTICAL EFFECTS FROM ENVIRONMENT									
4017	90004 90005 90006	Set up-align-calib. Operate Test	184	42				1/10	8-day runs
NOISE SURVEY									
4021	15013 -	Installation Operation Observe	40	32 360 392	20	1 hr	Observe 1 hr/day for a year	1/2	1 month
RADIO PROPAGATION									
4022	15014 15019	Installation Calibrate Operate	40 16	75	4		4 cycles (10 hr calibration) minimum for year observation	4/32	1 week
IMPEDANCE MEASUREMENTS OF ANTENNA									
4023	15015 15016 15017 30005 11091	Installation Calibrate Operate	20 12	9	10 2				
LUNAR PLASMA EFFECTS									
[illegible]	15018	[illegible]							

LSB PERSONNEL SUMMARY

From the experiment, base buildup, and operations manpower requirements the crew size was determined based on the allowable workload requirements of EVA and IVA operations. These work rates require a 12-man equivalent crew throughout the mission and results in almost 100,000 man-hours of science time. This workload represents rather tight scheduling with no provisions for unanticipated tasks. The only potential contingency provisions which might be available were the use throughout the remote sortie planning of the maximum site science time estimates from the LSB site experiment plans.

LSB PERSONNEL SUMMARY

MISSION	EQUIVALENT PERSONNEL (MEN)	
	1st YEAR	2-4 YEARS
REMOTE SORTIES		
EVA	2.5	2.5
IVA	1.5	1.5
DEEP DRILLING		
EVA	0	0
IVA	2.0	0
OBSERVATORY		
EVA	0.6	1.3
IVA	1.5	2.5
SHELTER EXPERIMENTS		
EVA	0.3	0.3
IVA	0.7	0.7
SCIENCE SUBTOTAL		
EVA	3.4	4.1
IVA	5.7	4.7
BASE OPERATIONS	2.9	3.2
PROGRAM TOTAL	12.0	12.0

CREW SKILL/SPECIALTY REQUIREMENTS

The nominal LSB crew represents a range of scientific and technical disciplines which are utilized as an autonomous unit in much the same manner as naval vessels or remote expeditions such as the South Pole IGY Base which are resupplied periodically via logistics support. To achieve this autonomous independence, the LSB crew must include the skills and capabilities to conduct all normal base operations and maintenance functions and be able to cope with all the expected emergencies that may occur. In addition, the crew is expected to conduct a comprehensive scientific program whose objectives is to investigate and explore the total lunar environment.

Based on a gross analysis of LSB crew skills and specialties required for base and remote sortie operations and on the lunar surface science program, the skills/specialties shown in the chart appear to cover the basic requirements for LSB operations. These skills/specialties have been identified in terms of functional requirements, scientific, and support personnel for identifying skills needed within a particular job assignment.

It is the purpose of this chart to show the areas of greatest need. The skills/specialties are listed down the left-hand side of the chart with science and stationkeeping functions listed across the top. Stationkeeping is depicted by gross functions such as base operation, base experiment operations, etc. Each check mark identifies a need for experiments and/or stationkeeping function. Final crew selection will determine the level of training for a given discipline and the amount of cross-training each will need to fully support base requirements.

For a crew complement of 12, these 25 diverse and highly specialized skills presents a formidable crew training problem. Additionally, normal crew rotations and the potential temporary loss of an on-station crewman complicate the active skills mix available for LSB operations.

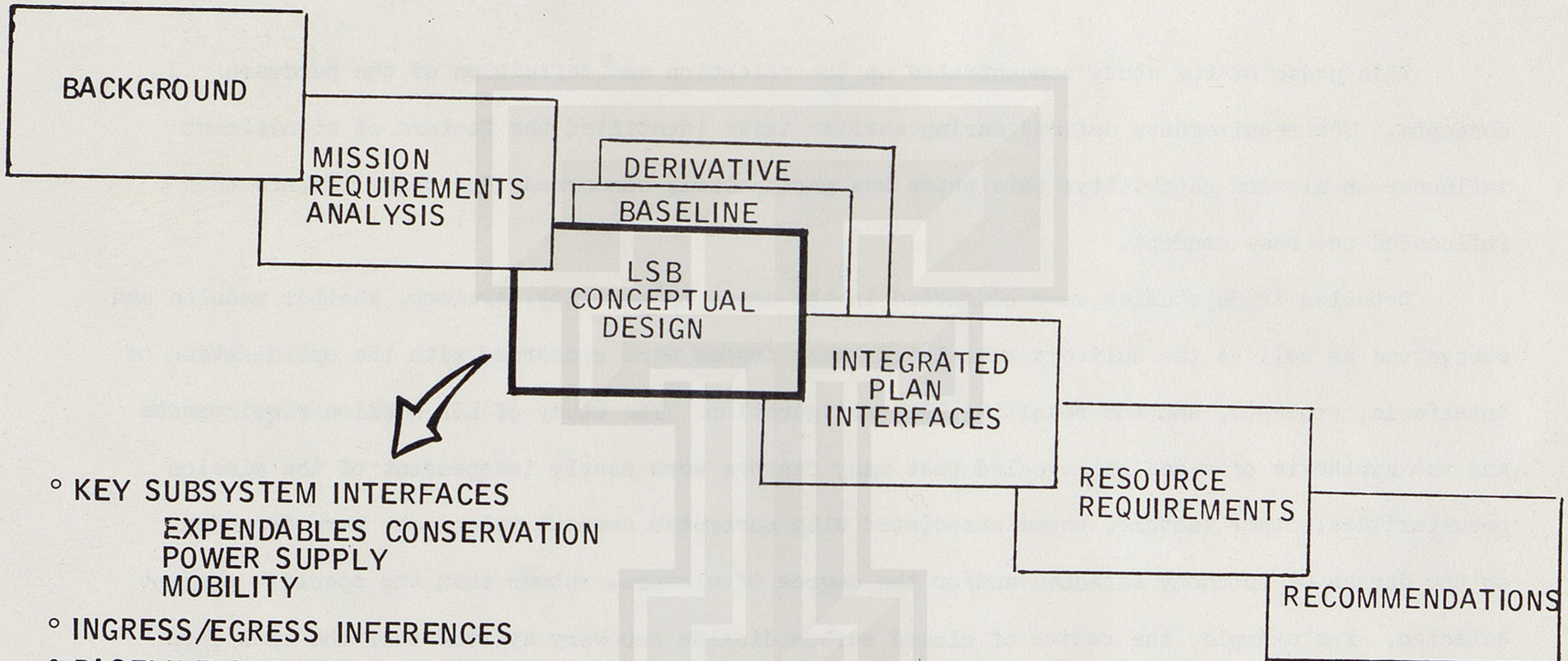
CREW SKILL / SPECIALTY REQUIREMENTS

SKILL/SPECIALTY	Experiments	STATIONKEEPING													
		Base Operations	Base Expmt. Operations	Base Maint. Operations	Base Housekeeping	Base Facility Operations	Base Buildup	Rover Operations	Rover Maint. Operations	Rover Expmt. Operations	Rover Housekeeping	Flyer Operations	Flyer Maintenance	Tug Operations	Tug Maintenance
COMMANDER/PLANETOLOGIST		X	X			X	X								
ELECTRONICS ENGINEER	X		X	X		X			X	X			X		X
AERONAUTICAL/MECH. ENGINEER	X		X	X		X	X		X	X					
ELECTRONICS TECHNICIAN	X		X	X		X			X	X			X		X
ELECTROMECHANICAL TECHNICIAN	X		X	X		X	X		X	X			X		X
PILOT ENG. - TUG FLYER		X	X			X						X		X	
MEDICAL	X	X	X		X			X			X				
COOK - DIETITIAN		X			X						X				
PHOTO LAB SUPPORT	X		X							X					
GEO/CHEM LAB SUPPORT	X		X							X					
OPTICAL LAB SUPPORT	X		X							X					
INSTRUMENT LAB SUPPORT	X		X	X					X	X			X		X
ASTRONOMER - OPTICAL	X		X												
ASTRONOMER - RADIO	X		X												
GEOLOGIST	X		X							X					
GEOCHEMIST	X		X							X					
GEOPHYSICIST	X		X							X					
MICROBIOLOGIST	X		X							X					
PLANT BIOLOGIST	X		X												
ZOOLOGIST	X		X												
HOUSEKEEPING SERVICES			X		X						X				
HEAVY EQUIPMENT OPERATIONS	X						X	X							
LOGISTICS SCHEDULING		X	X		X			X		X	X				
CIVIL ENGINEER	X	X					X								
SUIT TECHNICIAN		X	X	X		X	X	X	X	X		X	X	X	X

PRESENTATION OUTLINE

The next section presents the conceptual designs of the mobility and shelters which resulted from the application of the mission requirements and the tradeoffs of the subsystem options.

PRESENTATION OUTLINE



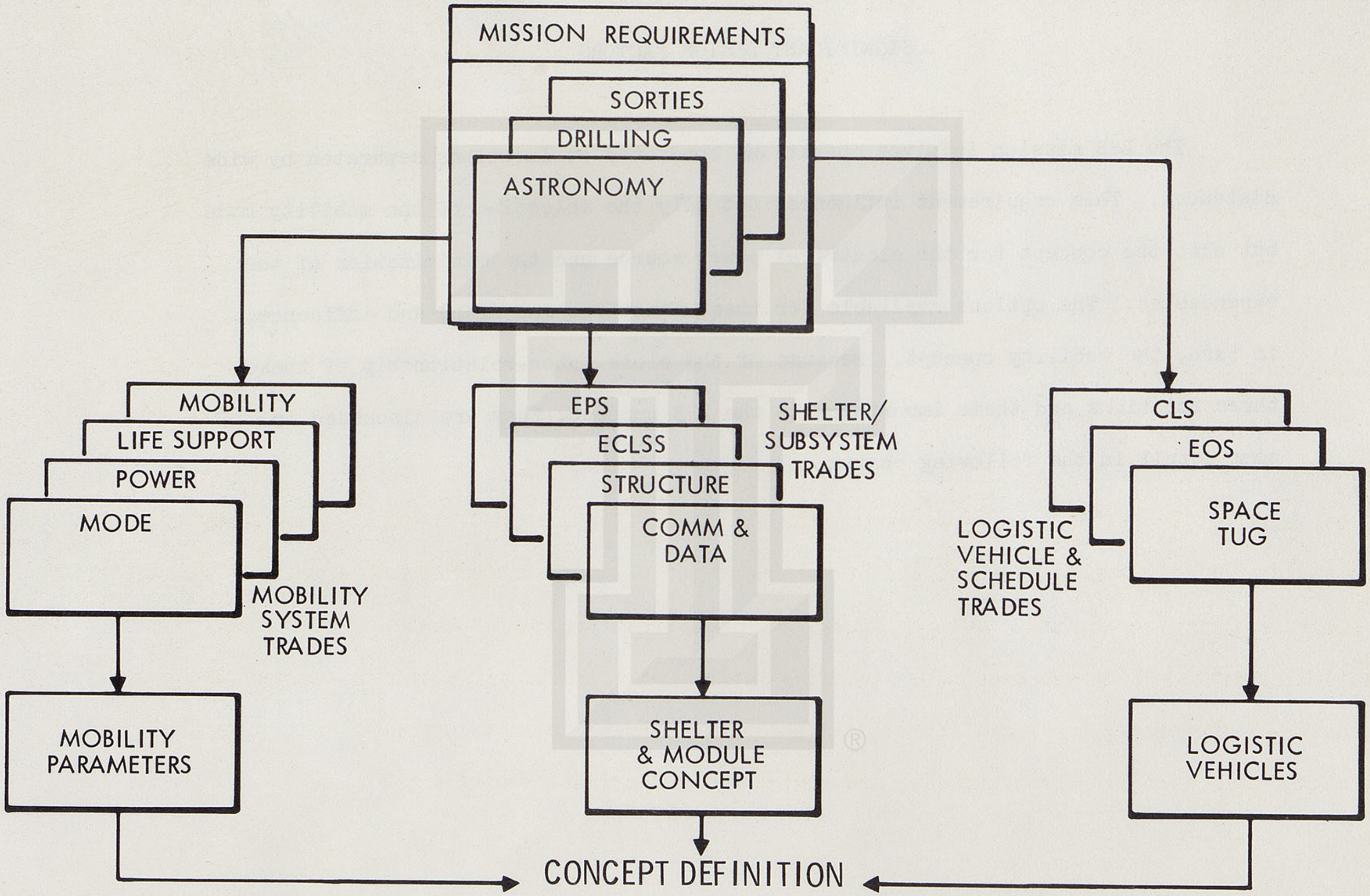
- KEY SUBSYSTEM INTERFACES
  - EXPENDABLES CONSERVATION
  - POWER SUPPLY
  - MOBILITY
- INGRESS/EGRESS INFERENCES
- BASELINE SHELTER CONCEPT
- BASELINE LUNAR SURFACE BASE
- SPACE STATION DERIVATIVE SHELTER

LSB CONCEPT DEFINITION

This phase of the study concentrated on the selection and definition of the hardware concepts. The requirements defined during earlier tasks identified the factors of significant influence on mission capability; this phase was particularly concerned with those factors that influenced the base concept.

Detailed trade studies were conducted in the areas of mobility, systems, shelter modules and subsystems as well as the delivery vehicles. These trades were concerned with the optimization of interfaces, concepts, and the resulting LSB configuration. The study of LSB mission requirements and the synthesis of a design revealed that many factors were nearly independent of the mission peculiarities; other factors, those associated with subsystem concept selection, were dependent on the degree of autonomy selected and/or the degree of closure, rather than the specific concept selected. For example, the choice of closed carbon dioxide recovery systems over the open loop lithium hydroxide beds was much more significant than selection of the Sabatier versus the Bosch reactors. Therefore, subsystem trade decisions are not presented herein except where they impact a significant factor. The trade data are contained in the final report.

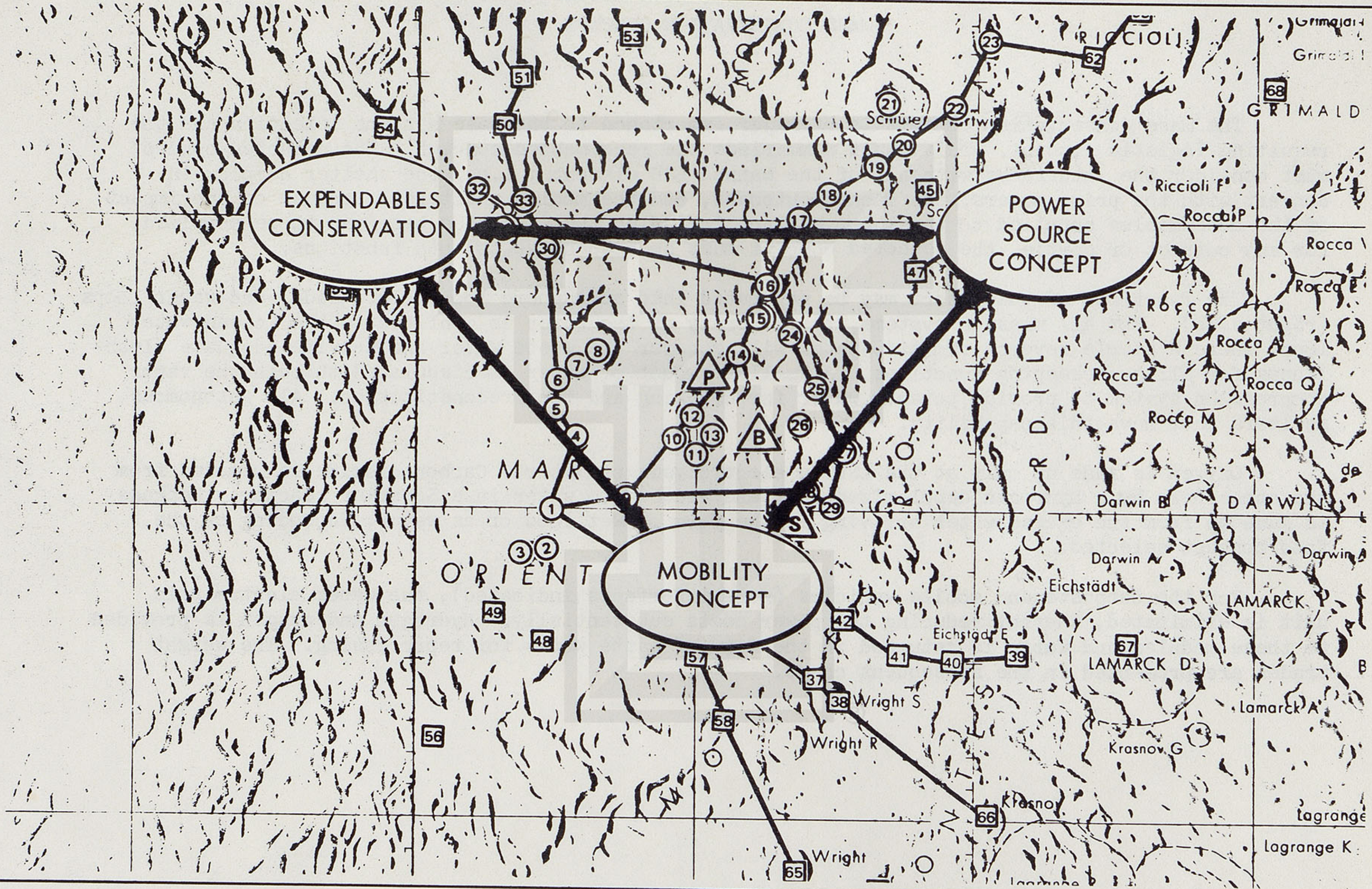
LSB CONCEPT DEFINITION



SIGNIFICANT DESIGN FACTORS

The LSB mission involves operations conducted at locations separated by wide distances. This requirement influences not only the selection of the mobility mode but also the concept for the electrical power source and the minimization of the expendables. The options available for these functions interface and influence, in turn, the mobility concept. Because of the close inter-relationship of these three functions and their importance to the LSB concept, they are discussed in some detail in the following charts.

SIGNIFICANT DESIGN FACTORS



MASS CONSERVATION CONCEPT

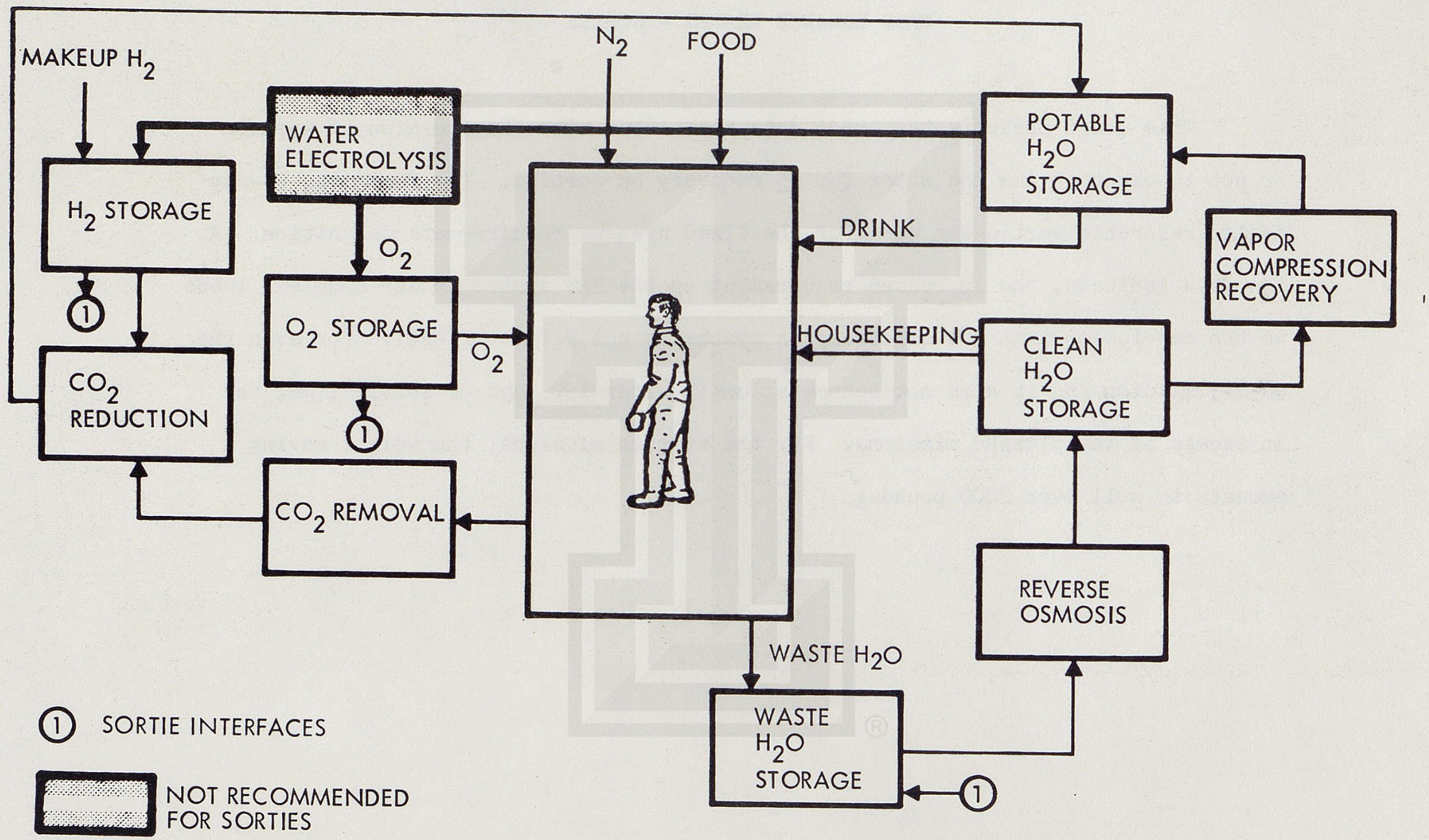
The mass conservation concept is of major importance to the base systems selection and the resulting logistic concept. This chart summarizes the recommended concept. The selected concept must consider the interfaces with all of the manned LSB elements; i.e., the shelter complex in concert with the prime movers, the manned outposts, and the mobile shelters. Because of the impact of the consumables supplied to the lunar surface including those for the base and those supplied for any outpost or sortie, the selected concept must be responsive to both functions.

The functions of this chart may be separated into atmosphere loops (left side) and water loops (right side). For all mission systems, the majority of the water is confined to the "clean water loop" where a simple reverse osmosis system will recover the waste water and provide adequate cleanliness for all housekeeping functions. A smaller amount of water is circulated through the vapor compression system to provide potable water for drinking and food reconstitution. All autonomous shelters must have this capability.

Oxygen is made up only at the LSB by electrolysis of water. Carbon dioxide is removed from the atmosphere by a hydrogen depolarized cell and reduced to water in a Sabatier reactor. Leakage is made up from the excess water arriving in the form of wet food or as water, depending on the food concept selected.

For the outposts and mobile vehicles (note interfaces indicated), the water electrolysis unit is eliminated, thereby reducing the power costs substantially. Hydrogen and oxygen is provided to these modules and water is returned in the form of waste water for reprocessing. The weight trades are presented in the subsequent chart.

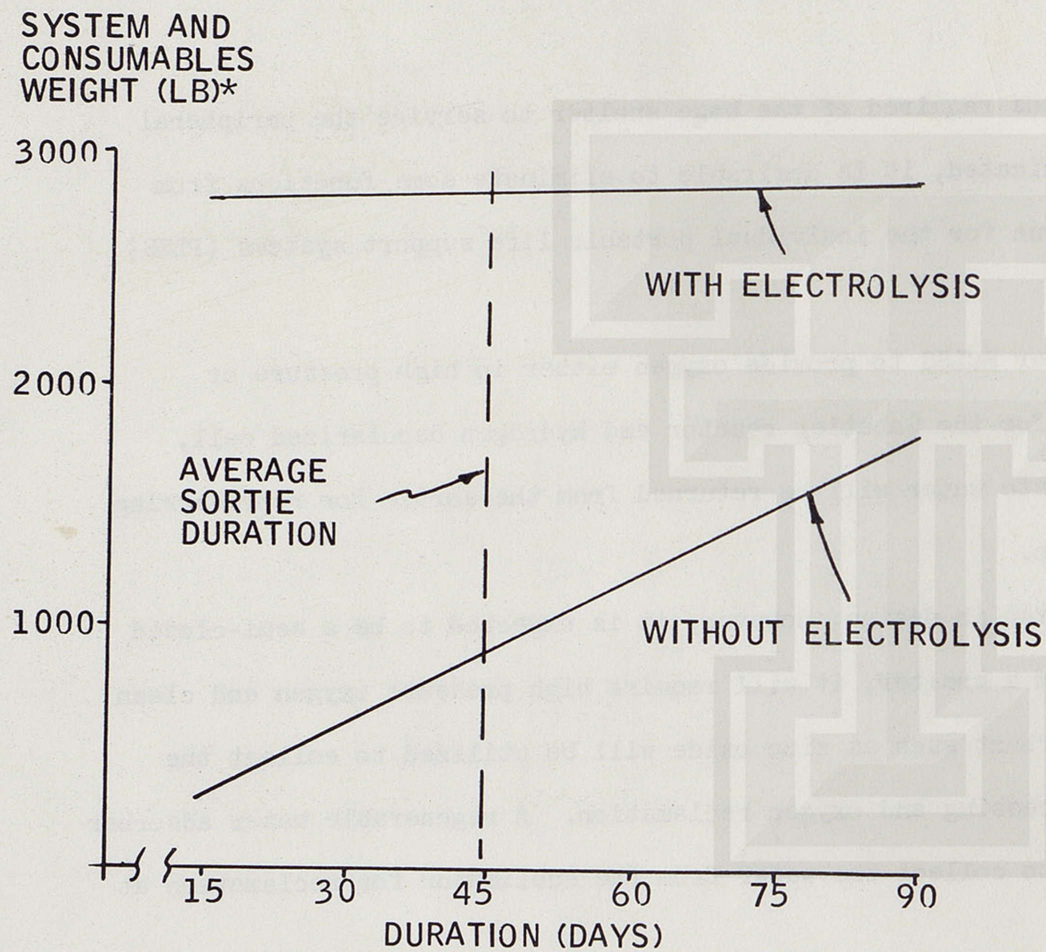
MASS CONSERVATION CONCEPT



MASS BALANCE TRADES - SORTIE

This chart presents the trade data associated with the decision as whether or not to electrolyize the water for O_2 recovery on sorties. The four-man, 90-day design reference sortie was used for the fixed systems requirements definition. As the data indicate, the increased requirement on the EPS system (power doubled) leads to the conclusion that the electrolysis system is not weight effective for even the 90-day mission and it does not become so until after 150 days of sortie time, far in excess of the planned missions. For the average missions, the weight saving amounts to well over 2000 pounds.

MASS BALANCE TRADES - SORTIE



REQUIRES:

- STORAGE OF WATER FOR REPROCESSING
- STORAGE OF O_2 FOR OUTGOING
- INTERFACE SYSTEMS AT LSB

*DOES NOT INCLUDE MOBILITY IMPACT ON VEHICLES AND MOTIVATING POWER

MASS CONSERVATION - BASE INFERENCES

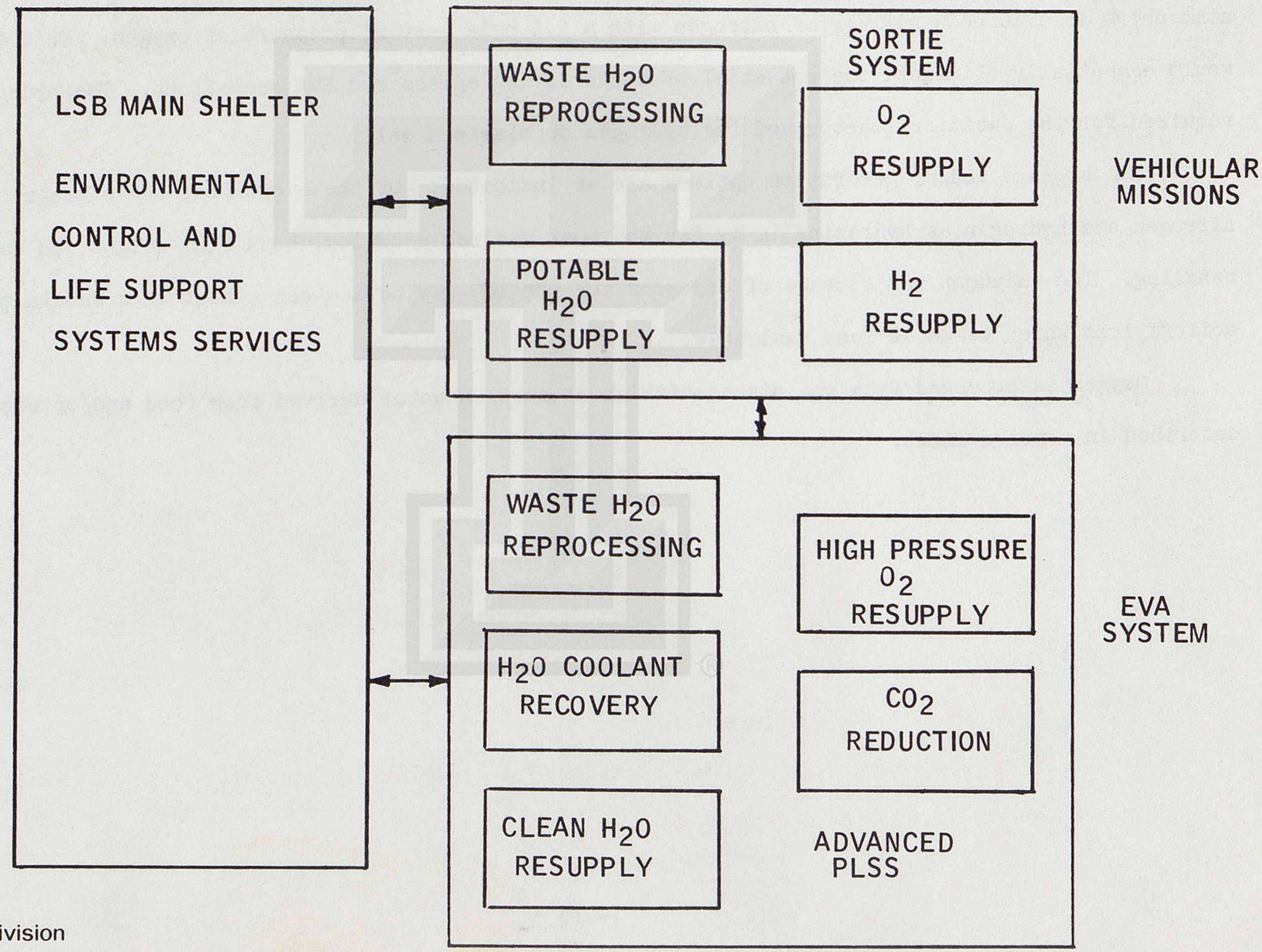
This chart illustrates the functions required of the base shelter to service the peripheral mission systems. As the former chart indicated, it is desirable to eliminate some functions from the sortie functions. It is even more true for the individual portable life support systems (PLSS) used for EVA.

The sorties require the base shelter ECLSS to provide oxygen either in high pressure or cryogenic form, hydrogen (high pressure) for the Sabatier reactor and hydrogen depolarized cell, and processed potable drinking water. Waste water will be returned from the sortie for reprocessing into hydrogen and oxygen for the next trip.

The advanced PLSS has not been frozen in design; however, it is expected to be a semi-closed loop, dependent system. At departure from a shelter, it will require high pressure oxygen and clean water. A regenerable carbon dioxide adsorbant such as zinc oxide will be utilized to collect the carbon dioxide for subsequent shelter processing and oxygen reclamation. A regenerable water adsorber such as lithium bromide will be utilized to collect the water from the sublimator for reclamation at the shelter after the EVA is completed.

The shelter will, therefore, have to provide the capability to desorb the carbon dioxide and water for subsequent reprocessing and reuse.

MASS CONSERVATION - BASE INFERENCES



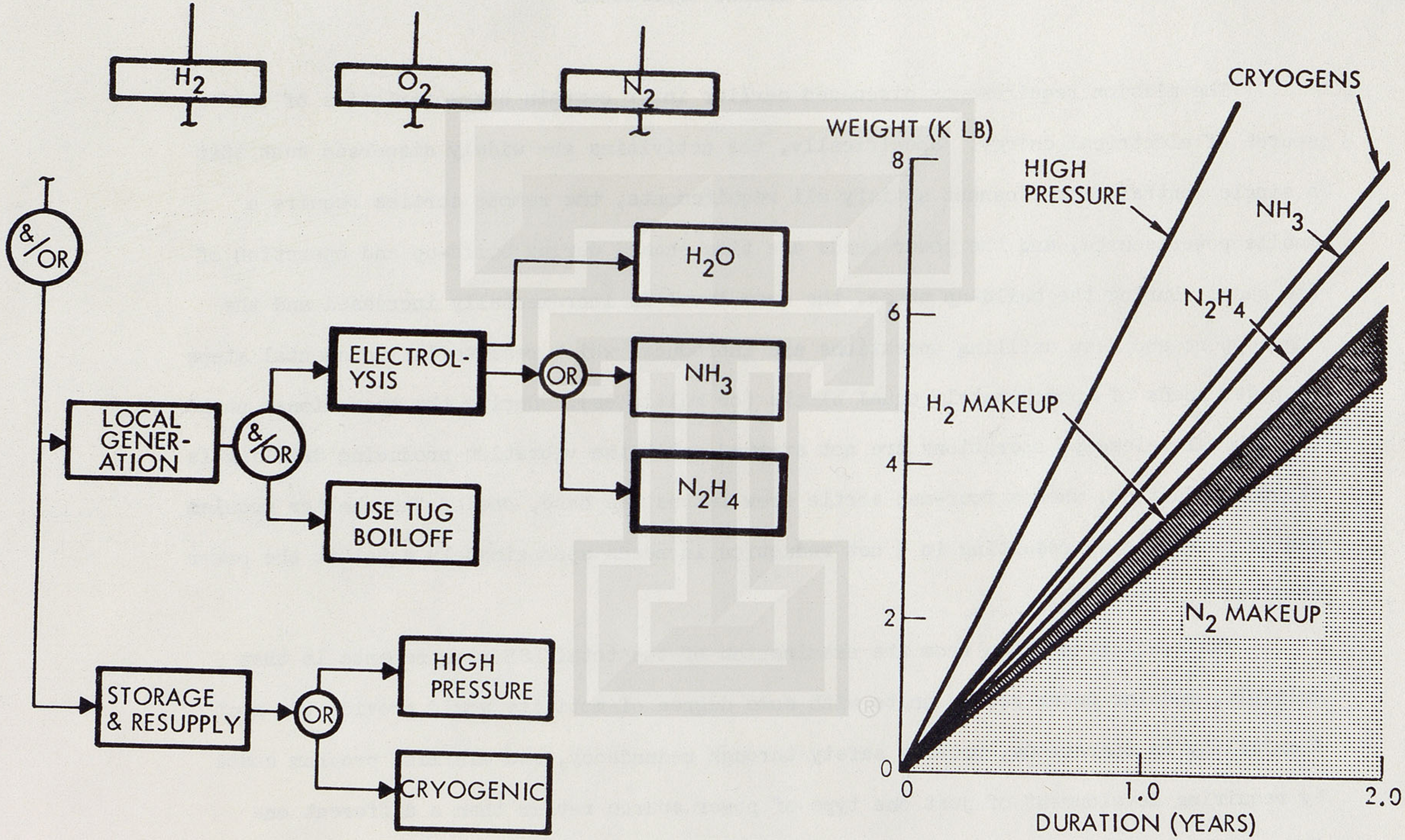
MAKEUP GAS SUPPLY OPTIONS AND TRADES (12 MEN)

Oxygen, nitrogen, and hydrogen are required in gaseous form for base operations. The recommended atmosphere is a 10 psia mixture of nitrogen with a 3.5 psia partial pressure of oxygen. This atmosphere would essentially eliminate the potential of bends during egress and EVA operations. The hydrogen is required for the Sabatier reactor and the hydrogen depolarized cell.

The storage and/or generation options are as indicated. Of these options, the storage of nitrogen and hydrogen as hydrazine is by far the most desirable option, both from weight and ease of handling. The shipment and storage of cryogens for the 180-day period can result in a substantial boiloff loss which makes it less desirable.

Oxygen is produced from the disassociation of surplus water derived from food and/or water as described in a prior chart.

MAKE-UP GAS SUPPLY OPTIONS AND TRADES (12 MEN)



ELECTRICAL ENERGY INFERENCES

The mission requirements discussed earlier infer certain characteristics of the source of electrical energy. Specifically, the activities are widely dispersed such that a single central source cannot satisfy all requirements, the remote sorties require a mobile power source, and the power needs are time phased during build-up and operation of the base. During the build-up phase, the crew level is incrementally increased and the tug support and deep drilling operations are introduced which results in incremental steps in power needs of approximately equal blocks (or multiples). During the operational phase the optical telescope operations are not started until the vibration producing drilling is stopped. Further, when a four-man sortie crew leaves the base, one of the shelter modules can be powered-down resulting in a net reduction in needs approximately equal to the power required for the sortie.

The conclusion drawn from the examination of the total LSB requirements is that multiple, modular power source units with some degree of mobility would provide the most flexibility in operations, provide safety through redundancy, and minimize program costs by requiring development of just one type of power source rather than a different one for each application.

ELECTRICAL ENERGY INFERENCES

CHARACTERISTIC REQUIREMENTS

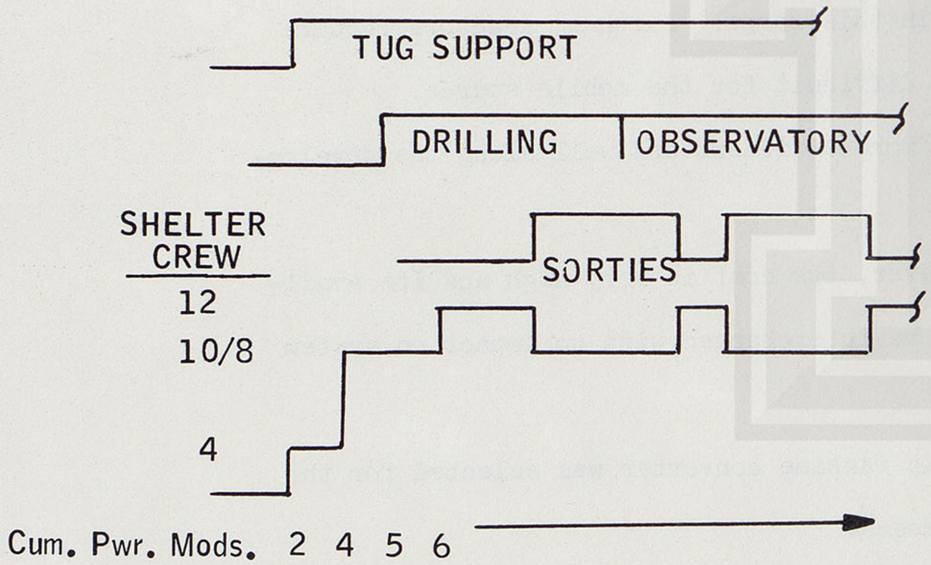
WIDELY DISPERSED

TUG SUPPORT	(1 - 5 KW)
DRILLING	(~3.4 KW)
OBSERVATORY	(~4 KW)
MAIN SHELTER	(~1 KW/MAN + 1.2 KW)
REMOTE SORTIES	(~3.6 KW)

MOBILE

REMOTE SORTIES

TIME PHASED



MULTIPLE
MODULAR MOBILE
POWER SOURCE

- FLEXIBILITY
- SAFETY
- SINGLE DEVELOPMENT

ELECTRICAL POWER SOURCE TRADES

This chart presents the options and significant trade data that influence the EPS source selection. The long lunar night and the resulting impact on either the system weight or the consumables resulted in the elimination of all but the nuclear source options. The regenerative fuel cells are the closest competitors but were eliminated because of the large volume of reactants required to power the system and the impact on storage requirements.

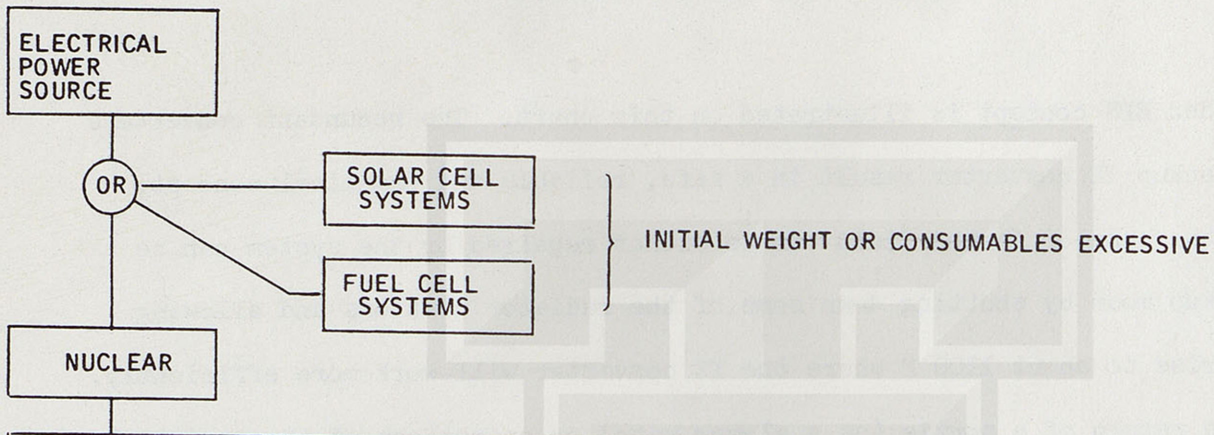
Isotopes are recommended over reactors because of the need for the smaller flexible power sources and the inefficiency of a reactor in this range. Further, reactors require much heavier shields which would be particularly difficult for the mobile source.

The organic rankine converter is somewhat more efficient and well along the development cycle.

The Pu-238 would be the best isotope; however, its cost is very high and its availability is questionable. If available, it could be interchanged with no impact on system design.

The Po-210 isotope together with an organic rankine converter was selected for the baseline system as a feasible and achievable approach.

ELECTRICAL POWER SOURCE TRADES



3.5 KW MODULE OPTIONS	SYSTEM WEIGHT (KLB)	VOLUME (FT^3)	CONSUMABLES (180 DAYS) (KLB)	HEAT REJECTED (KW)	SHIELD WEIGHT (LB)	OTHER CONSIDERATIONS
RADIOISOTOPE						
Pu 238 - Brayton	2.0	230	0	14	20	Isotope may not be available
Pu 238 - Rankine	1.6	200	0	20	20	
Pu 238 - TE	4.9	200	0	70	25	
Po 210 - Brayton	2.1	235	0.9	27*	150	Isotope resupply required @<180 days
Po 210 - Rankine	1.7	205	1.0	29*	150	
Po 210 - TE	4.3	200	2.8	135	200	
REACTOR						
Rankine	6.1	400	0	20	19K	Inefficient size
Brayton	7.0	450	0	15	15K	Inefficient size

*AVERAGE OVER SORTIE LIFE

ADDITIONAL CONSIDERATIONS

- Reliability
- Operability
- Maintainability
- Development Status
- Integrated Program Plans
- Safety

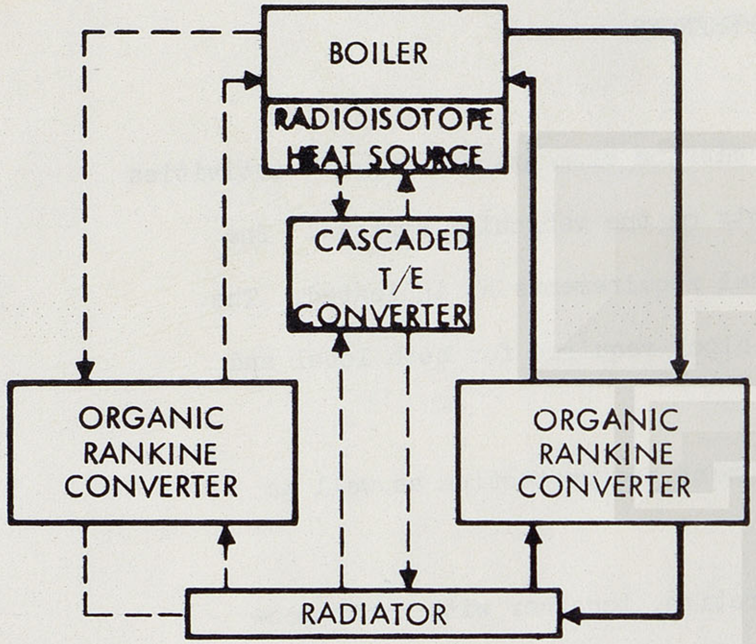
ELECTRICAL POWER MODULE CONCEPT

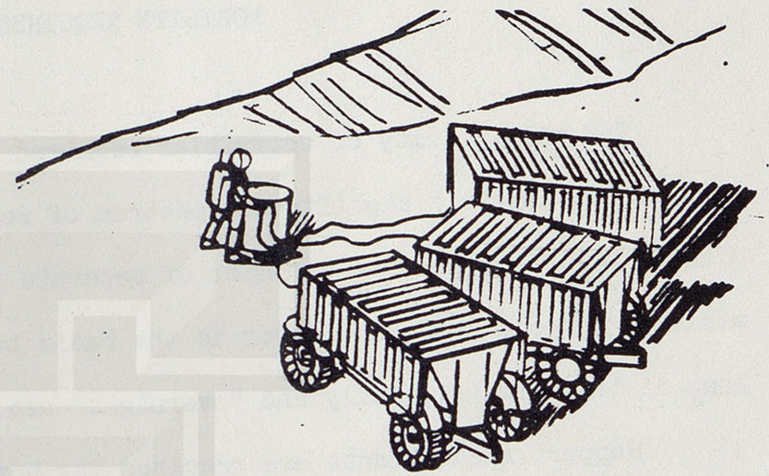
The recommended EPS concept is illustrated on this chart. The redundant converters together with the backup TE converter result in a safe, reliable and practical concept. Failures either at the base or in the field can be either repaired or the system can be operated in the backup mode by shutting down some of the radiator sections and allowing the temperature to rise to about 1100 F where the TE converter will work more efficiently. This will permit the return of a sortie (at a slower rate) or operations of the essential base functions.

Supplementary radiator sections are hinged along the sides and can be raised to the horizontal and brought on-line when additional heat rejection is required; e.g., low power requirements and/or beginning of Po-210 half-life. The system is basically sized for operation at approximately 3.5 kwe with batteries for peak load conditions but can be operated at over 7 kwe, if required, by running both converters simultaneously.

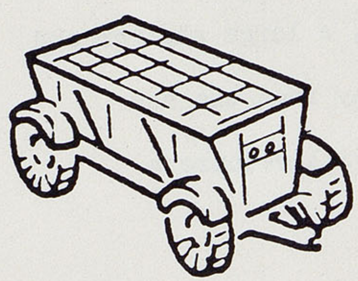
The base may be powered with two or three of these in parallel. Changes in power requirements or the redistribution of these requirements will result in the reassignment of these carts from one point to another. No more than six are expected to be required for the total program.

ELECTRICAL POWER MODULE CONCEPT





BASE APPLICATION



MOBILE UNIT

- AVERAGE POWER ~ 3.5 - 7 KW
- EMERGENCY POWER ~ 1.2 KW
- FUEL Pu-238 or Po-210
- WEIGHT ~ 3670 LB
- 10K AMP-HRS BATTERIES
- RADIATOR AREA ~ 200 FT^2

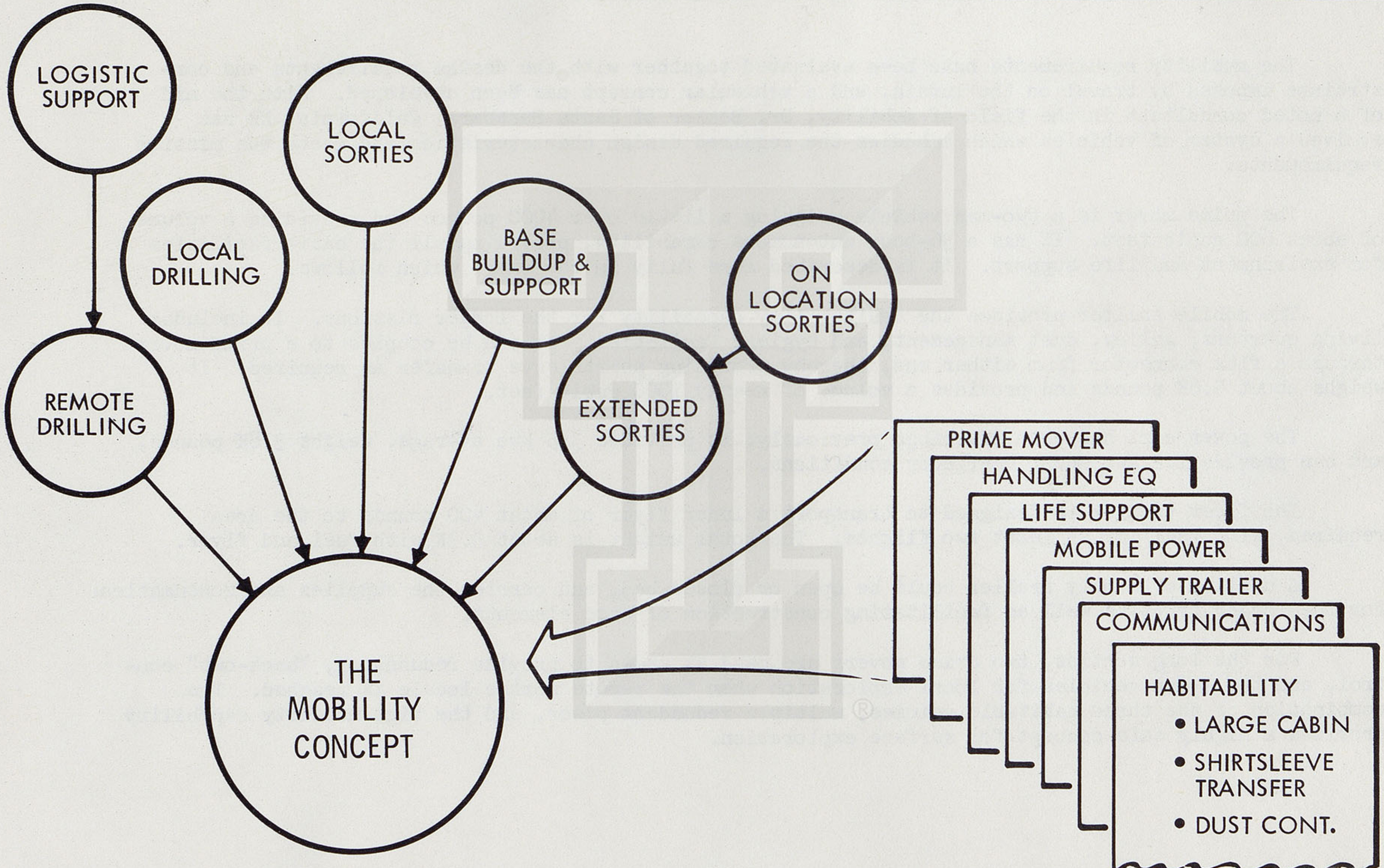
MOBILITY REQUIREMENTS INFERENCES

The multiplicity of activities required for the mission elements and support activities for the LSB impose a significant spectrum of requirements on the vehicular systems. The mission activities impose a number of separate functional requirements as indicated. The mobility function or prime mover is the basic building block required for both local and long distance travel, daily and "overnight" use.

Support requirements are required for base deployment and protection as well as setting up the deep drill module.

The variations in sortie and drilling mission duration, together with their geographical locations are the major contributors to the diverse environment and life support requirements. In general, when the distances exceed one day's travel, life support functions are required. Since some of the sorties could approach 90 days duration, a large shelter and a supply trailer are needed. Any mission in excess of about 36 hours away from the base requires a mobile power trailer. Power consumption for extended travel will require a power source providing an average of 3.5 kwe.

MOBILITY REQUIREMENTS INFERENCES



MOBILITY CONCEPT CHARACTERISTICS

The mobility requirements have been evaluated together with the design requirements and constraints imposed by travel on the lurain, and a vehicular concept has been developed. With the aid of a noted consultant in the field of mobility, Dr. Bekker of Santa Barabara, California, NR has evolved a system of vehicles which embodies the required design characteristics and meets the mission requirements.

The prime mover is a two-man vehicle weighing a little over 4000 pounds and providing a volume of about 600 cubic feet. It has a 36-hour autonomous capability, providing all the basic facilities for environment and life support. It is described more fully in the chart which follows.

The mobile shelter provides the habitability capability for the longer missions. It includes living quarters, galley, dust management, and hygiene facilities. It can be coupled to a prime mover through a flex connector from either end, thereby providing shirtsleeve transfer as required. It weighs about 5.6K pounds and provides a volume of nearly 1000 cubic feet.

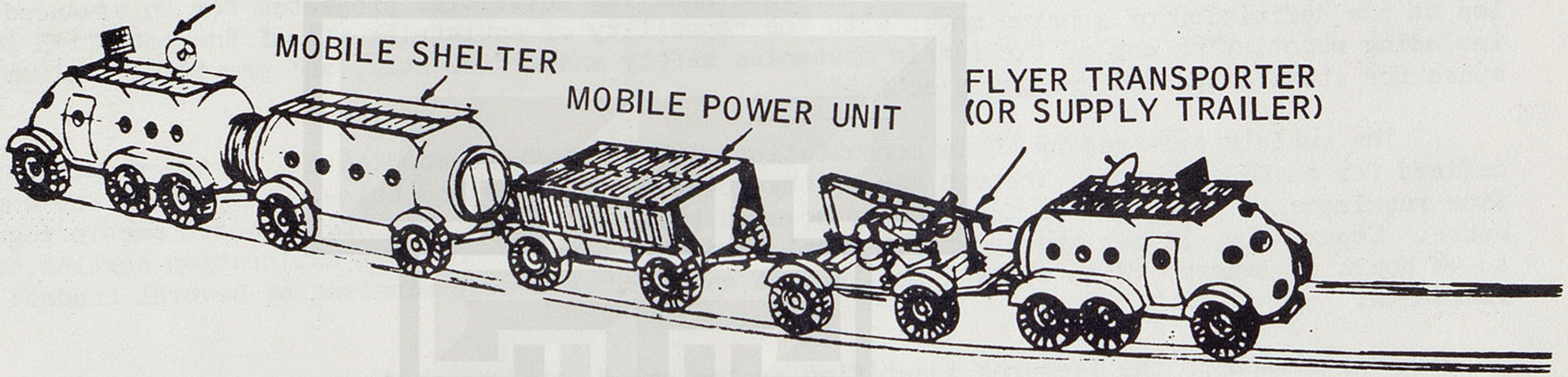
The power cart has been described previously; it provides 3.5 kwe average, weighs 3.8K pounds, and can provide 1.2 kwe under emergency conditions.

The flyer trailer is designed to transport a lunar flyer of about 400 pounds to the area required, with fuel for at least two flights. The total weight is about 3.3K with fuel and flyer.

A utility or supply trailer could be open or closed bed, and carries the supplies and consumables for the longer trips as well as facilitating construction of base elements.

For the long sorties, two prime movers are used as shown to provide redundancy, "back-out" control, and two 2-man vehicles for local exploration when the remote sortie locale is reached. The combination of the three habitable volumes, multiple redundant power, and the high mobility capability provides a highly safe concept for surface exploration.

MOBILITY CONCEPT CHARACTERISTICS



- 0 - 90 DAYS AUTONOMOUS OPERATION
- RATE OF TRAVEL ~ 3.5 MPH
- DAILY TRAVEL ~ 8.0 HRS / DAY
- SHIRTSLEEVE TRANSFER BETWEEN VEHICLES
- SAFETY FEATURES:
  - TWO PRIME MOVERS
  - MULTIPLE LIVING QUARTERS
  - MULTI-REDUNDANT POWER
  - REPAIRABILITY

PRIME MOVER AND ATTACHMENTS

The variety of transportation and material handling activities projected for an advanced LSB led to the definition of a prime mover with the capability of satisfying all of the potential functions including negotiating any of the lurain obstacles safely and efficiently, and providing minimum living space for short trips and emergency actions.

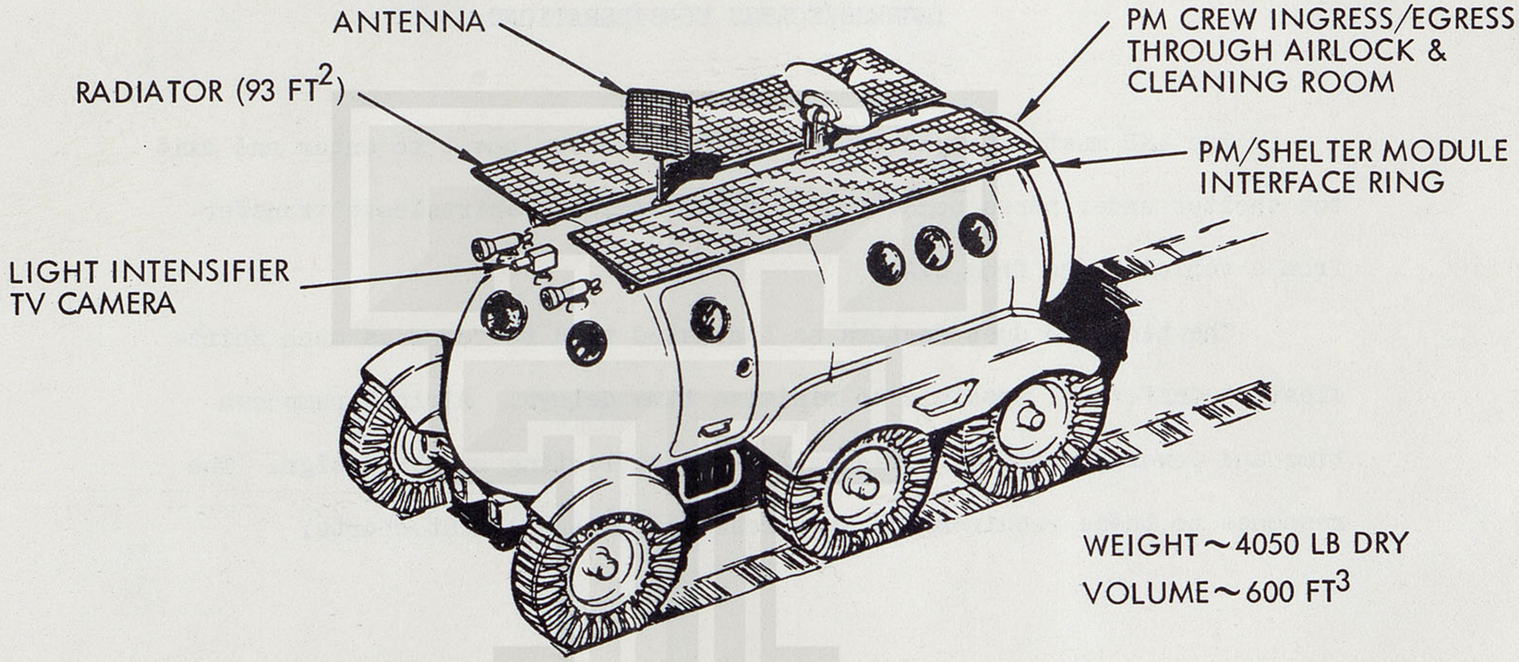
The vehicle selected by NR in consultation with Dr. Bekker embodies all of the requirements defined for an LSB mission. Through use of the attachments described below, it can meet the construction requirements and with the addition of powered trailers it can meet the extended sortie requirements. Separately, it can transport personnel to a work site or on short exploration sorties of up to 48 hours in length. With a power trailer, it can perform rescue missions of several hundred miles in length.

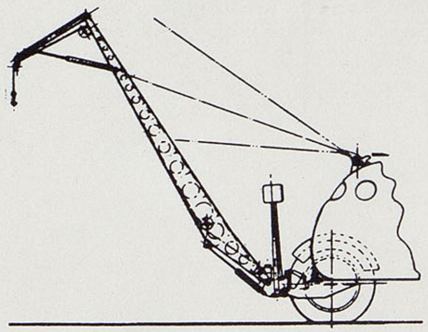
In addition to the features identified on the chart, the large wheels provide over 60 degrees of clearance, front and rear. It has a short turning radius and permits shirtsleeve transfer of the crew into a shelter module by use of the docking interface.

Attachments

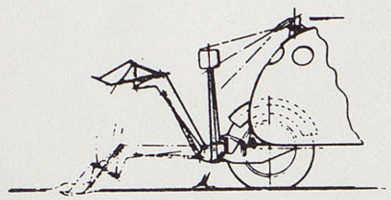
Base installation and the supporting logistic operations impose a requirement to provide the capacity to move both large pieces of equipment and soil in large quantities at the LSB site. A study was made of all of the activities required to install, operate and service an advanced lunar base. From these activities, various options for accomplishing these tasks were identified as well as the associated equipment requirements. A selection of support equipment requirements was made on the basis of commonality, weight, flexibility, and crew participation requirements. The crane and skiploader were found adequate for meeting all task requirements.

PRIME MOVER & ATTACHMENTS





GENERAL PURPOSE: WINCH-HOIST-CRANE



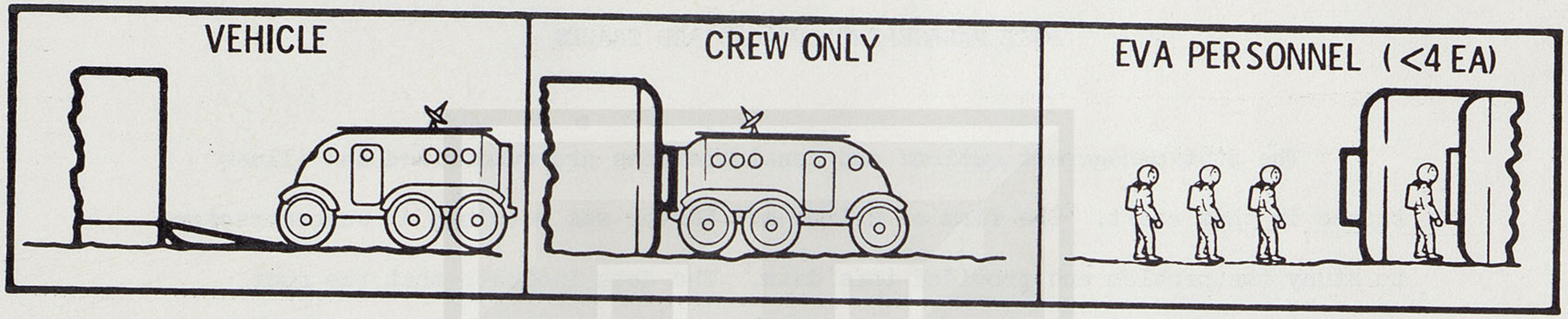
GENERAL PURPOSE: SKIP LOADER-GRADER

INGRESS/EGRESS CONSIDERATIONS

The LSB must make provisions for men and equipment to enter and exit the shelter under three conditions: total vehicle, shirtsleeve transfer from a vehicle, and from EVA.

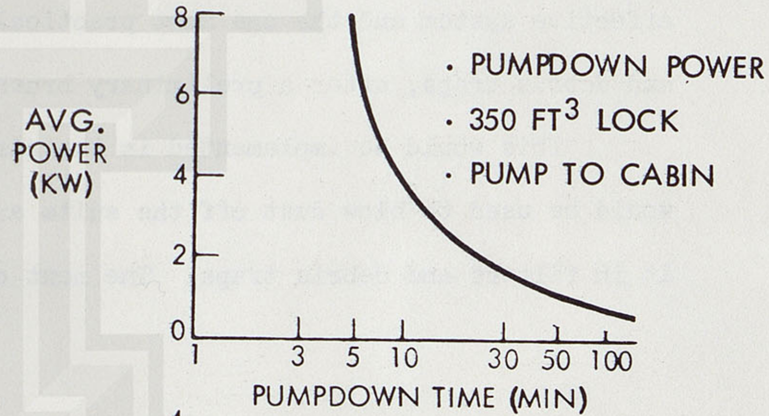
The time and dust factors as indicated tend to force as much shirt-sleeve transfer as possible to minimize time delays. Airlock pumpdown time and power present significant factors reflecting on LSB design. The response to these requirements are presented in subsequent charts.

INGRESS/EGRESS CONSIDERATIONS



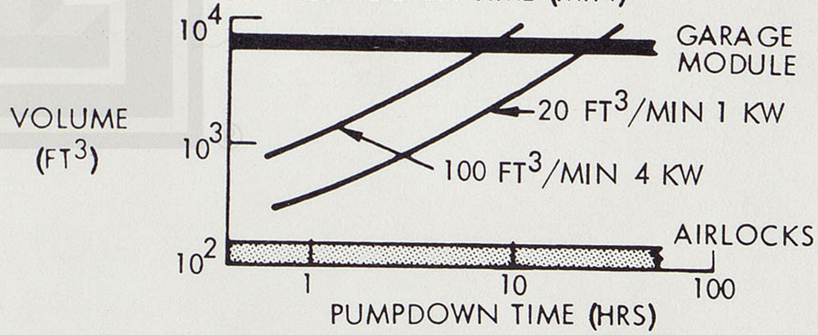
TIME FACTOR

- EGRESS ~0.9 HRS
- INGRESS ~0.8 HRS



DUST FACTOR

- SIGNIFICANT ELEMENT
- CLEANING TIME ~0.4 HRS



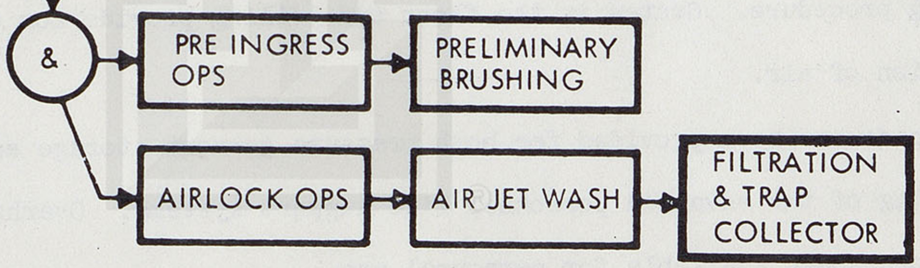
DUST MANAGEMENT OPTIONS AND TRADES

The dust management options and considerations are summarized and illustrated in this chart. The firm of Holmes and Narver was retained as subcontractors to study the problem and provided this data. The data indicate that the most effective system and the one most practical is the air jet wash with multifiltration and debris traps, after a preliminary brushing.

This would be implemented in the airlock where the repressurizing gas would be used to blow dust off the suits and rapid recirculation would trap it in filters and debris traps. The next chart indicates the design impact.

DUST MANAGEMENT OPTIONS AND TRADES

OR	VOLUME (FT^3)	WEIGHT (LB)	POWER (WATTS)	CONSUMABLES (GAL. H_2O/USE)	EFFECTIVENESS ORDER
VENTURI SCRUBBER	22	73	1.6 K	6	4
CENTRIFUGE ELEC PRECIPITATOR	7.0	116	0.3 K	4	3
CENTRIFUGE FILTER	4.4	31	0.3 K	0	2
AIR JET WASH & MULTI-FILTRATION	7.5	32	0.6 K	0	1



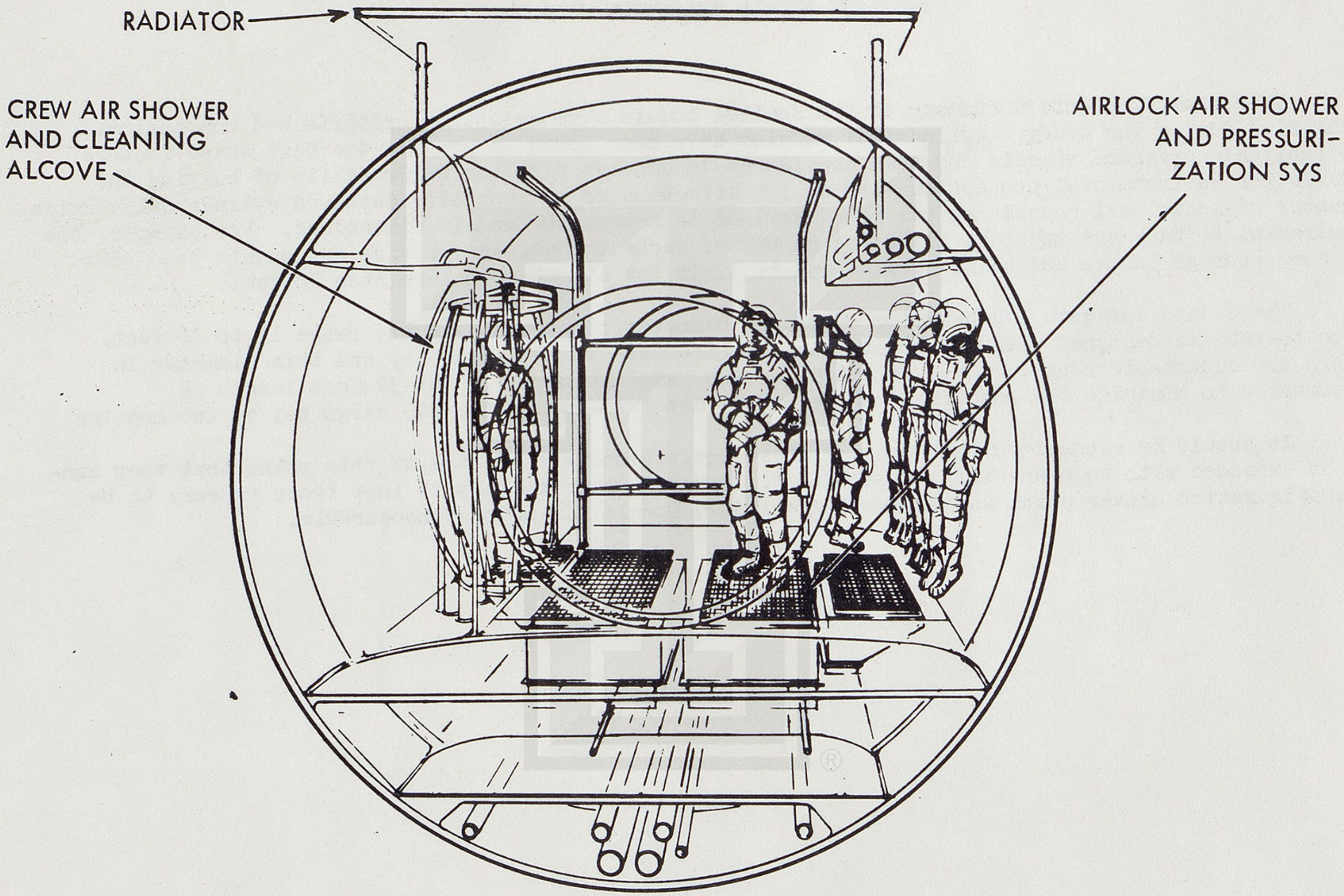
DUST MANAGEMENT DESIGN IMPLICATIONS

The need for dust removal and collection function that is effective during the ingress procedure influences the design of the airlock and/or introduces the need for a cleaning room. The use of an integrated airlock/cleaning room design permits use of the time normally "wasted" during the repressurization process. Further, since an airshower concept was selected, the incoming air can be used in the shower assembly.

The design presented on this chart embodies the features required of both an airlock and the dust management subsystem. The airshower assembly is to one side, in a semi-enclosed area where air recirculated at a high rate can carry the dust to the filters and traps. The airlock is large enough to accommodate from four to six men, each of which can undergo the dedusting procedure. Grates in the floor and ceiling provide for collection and rapid recirculation of air.

Space has been provided for both pressure garment storage and for the storage and reservicing of the advanced personnel life support systems. Overhead storage of hatches leaves more space available for personnel use.

DUST MANAGEMENT DESIGN IMPLICATIONS



BASELINE MODULE SELECTION SUMMARY

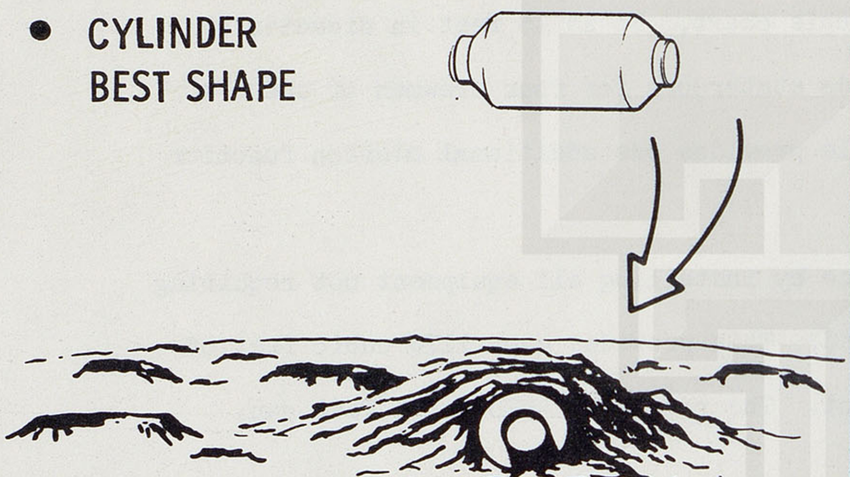
This chart presents a summary of the shelter module size selection criteria and constraints identified during the study. Cylindrical modules have been found to provide the best shape factors for habitable pressure vessels and when considered in concert with the desirability of burying the modules for environmental protection, led to the selection of horizontally deployed cylindrical modules. A number of additional considerations were examined to select the module dimensions. For example, the requirement to bury the modules, limit the number of decks to one, and provide reasonable head room and some storage (above and below) would tend to limit the diameter to less than 16 feet.

These data indicate a bracketing of module diameter constraints to the range 13 to 16 feet. Since the EOS is designed with a 15-foot diameter clearance in the cargo bay and this diameter is within the acceptable range, it was selected for the baseline module. The 30-foot length is recommended to minimize the handling problem and permit full use of the EOS cargo bay by two modules.

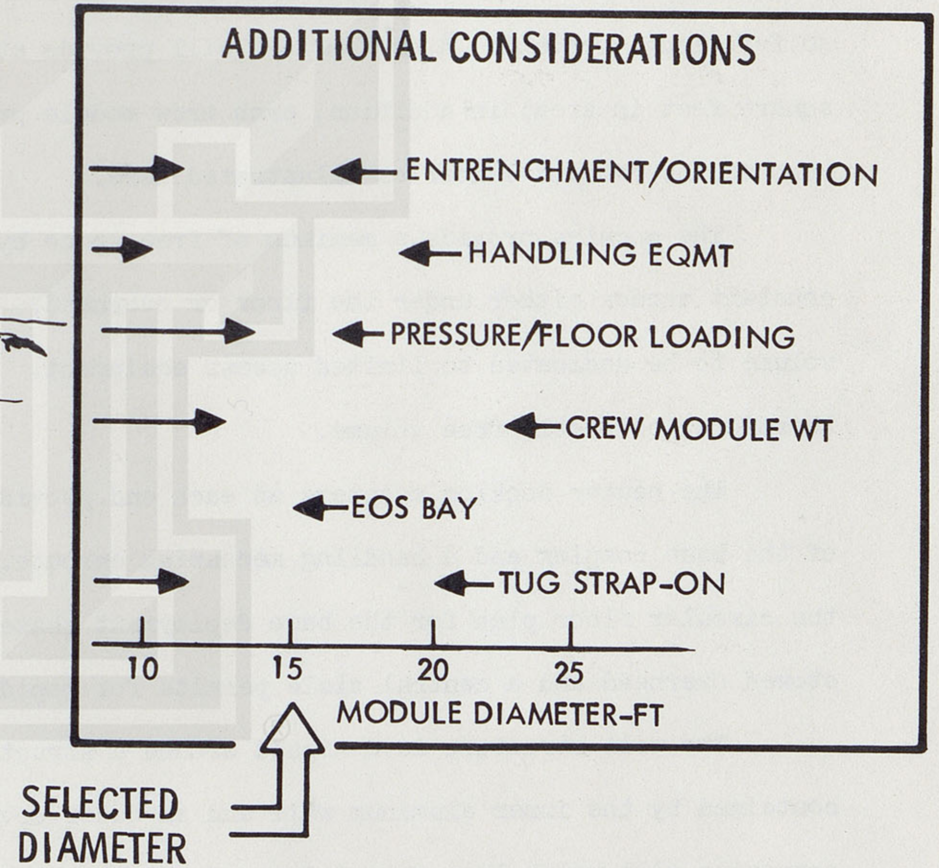
It should be recognized that none of these constraints are so firm at this point that they cannot be exceeded with some special design effort. However the corollary is that there appears to be no configuration driver which would make the selected module dimensions undesirable.

MODULE SELECTION SUMMARY

- CYLINDER BEST SHAPE



- LONGITUDINAL DEPLOYMENT FOR BURIAL



- CONSTRAINED TO ~30 FT LENGTH BY SURFACE HANDLING EQMT.

BASELINE MODULE FEATURES

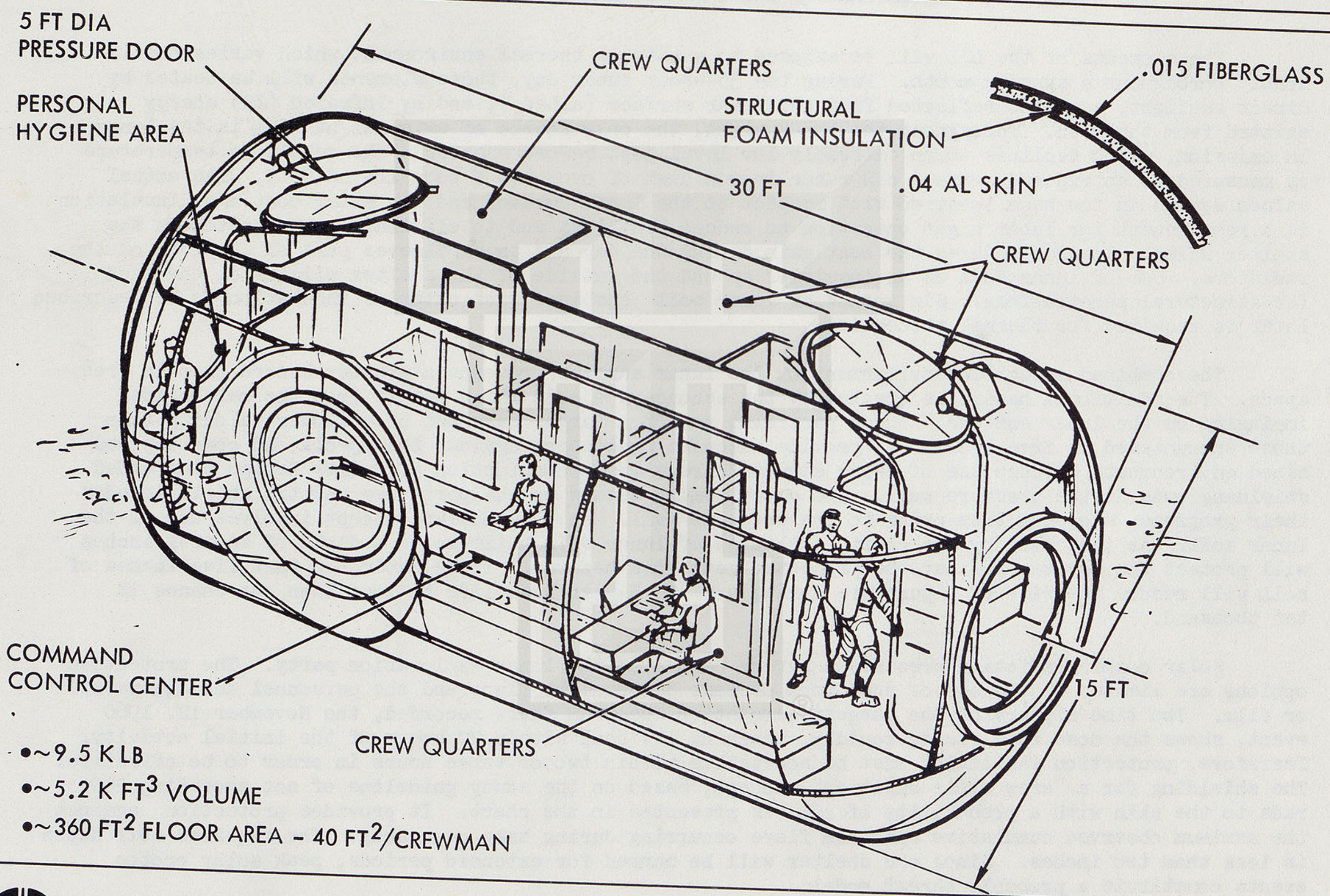
A typical baseline module is depicted on this chart. It is 15 feet in diameter by 30 feet long, overall. A crew module will provide staterooms for four crewmen of about 40 square feet in area; in addition, each crew module provides one additional mission function such as the command center as illustrated here.

The modules provide a maximum of free space by installing all equipment not requiring constant access either under the floor or overhead. This provides over 1170 cubic feet of volume to be dedicated to limited access equipment. The remaining 4030 cubic feet can, therefore, be mostly free volume.

The neuter docking adapters at each end provide both a coupling for the construction of the base complex and a handling mechanism enroute. The docking port on the side facilitates the circular floor plan for the base deployment phase and provides for growth. Hatches are stowed overhead and a central aisle permits for rapid movement from one module to another.

The wall structure is designed around a structural foam concept. One inch of foam is contained by the inner aluminum wall and an outer covering of two layers of fiberglass. The composite will weigh less than 0.5 pound per square foot. The primary structure weighs about 3600 pounds and less than 9500 pounds each, fully equipped.

BASELINE MODULE FEATURES



- ~9.5 K LB
- ~5.2 K FT^3 VOLUME
- ~360 FT^2 FLOOR AREA - 40 FT^2/CREWMAN

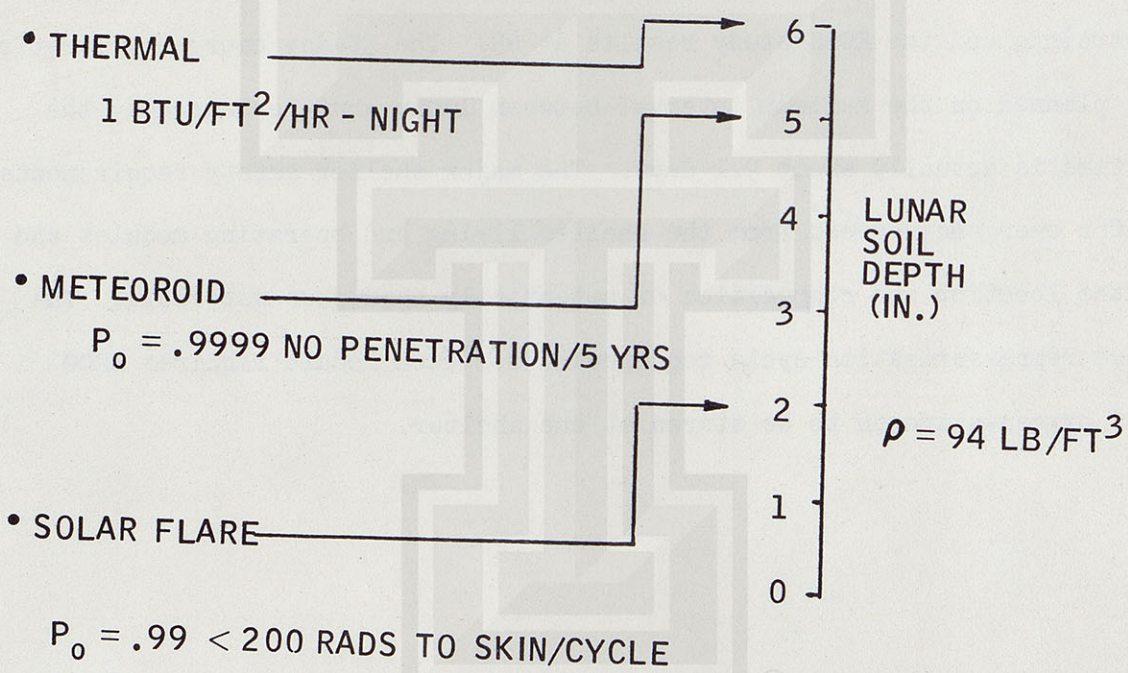
ENVIRONMENTAL REQUIREMENTS AND PROTECTION

The elements of the LSB will be exposed to a natural thermal environment which varies considerably throughout a synodic month. During the 354-hour lunar day, these elements will be heated by direct sunlight, sunlight reflected from the lunar surface (albedo), and by infrared (IR) energy emitted from the moon. Throughout the lunar night, the only source of external heating is the lunar IR emission, which declines to an extremely low level just before sunrise. The resulting temperature as measured on an exposed surface can range from a high of over 400 K to a low of 90 K. The actual values depend on the base location with respect to the lunar equator and its outer coating. Insulation is a requirement for lunar night operation to reduce heat loss and to eliminate condensation on the shelter walls. It also reduces the heat gain during the day and thus relieves part of the load on the radiators. Use of lunar soil as an insulator around the outside of the shelter eliminates the need for structural penetrations. Six inches of lunar soil combined with exterior insulation to be described later is required for thermal protection.

The combined meteoroid environment on the lunar surface presents a greater hazard than in free space. The additional hazard is created by the secondary ejecta which result from the meteoroids impinging on the lunar surface. These particles are of a larger mass but of a slower velocity than those encountered in free space. To provide adequate protection against the ejecta and cometary combined environments through use of basic structure requires a combination of bumper design plus added shielding outside the pressure wall. The outer bumper breaks up the particles and the shield impedes their progress, stopping them prior to the pressure wall. An alternative concept involves use of the lunar soil. As indicated by the chart, a blanket of lunar soil built up to a depth of several inches will protect the shelter against the projected meteoroid hazards. It is estimated that five inches of soil will reduce the risk of a puncture during a 2- to 5-year base life to less than one chance in ten thousand.

Solar cosmic radiation presents a severe hazard to the lunar exploration party. The protective options are limited to the use of some form of mass between the flare and the personnel and equipment or film. The time history of the largest cumulative spectrum flare recorded, the November 12, 1960 event, shows the dose rate rising rapidly, reaching its peak within 20 hours of the initial activity. Therefore, protection facilities must be accessible within two or three hours in order to be effective. The shielding for a "crew cycle duration" concept, based on the study guideline of not exceeding 200 rads to the skin with a probability of .99, is presented in the chart. It provides protection against the maximum observed cumulative spectrum flare occurring during base occupancy. The required soil depth is less than two inches. Since the shelter will be manned for extended periods, peak solar proton events constitute a probable threat model.

ENVIRONMENTAL REQUIREMENTS AND PROTECTION



SAFETY REQUIREMENTS SUMMARY

This chart presents a summary of safety requirements applicable to the crew and the shelter design. These requirements are taken from the LSB RFP guidelines and constraints and the EOSS study results at NR. The 30-day emergency duration limit is planned on the maximum interval between lunar shuttle launches; the minimum time is actually about 9.1 days. The major shelter safety requirements provide for emergency egress from the shelter living and operating modules and control the location and composition of potentially hazardous materials. The atmosphere repressurization cycle requirement for each module requires 1200 pounds of oxygen-nitrogen to be stored at the shelter.

SAFETY REQUIREMENTS SUMMARY

CREW

- BUDDY SYSTEM FOR ALL EVA
- SURVIVAL OF FULL CREW + 1/2 CREW FOR 30 DAYS WITHOUT RESUPPLY
- PROBABILITY = .99 OF NOT EXCEEDING 200 RADS TO SKIN IN ANY CREW CYCLE
- EMERGENCY FIRST AID BY MEDEX FOR SICK OR INJURED CREWMAN FOR UP TO 30 DAYS

SHUTTLE

- SHELTER DIVIDED INTO SEPARATE ISOLATABLE VOLUMES
- DUAL ROUTES FROM EACH PRESSURIZABLE VOLUME
- AT LEAST TWO SEPARATED AIRLOCKS
- PRIMARY STRUCTURE NONFLAMMABLE -- SECONDARY STRUCTURE SELF-EXTINGUISHING
- ISOLATE HAZARDOUS MATERIALS FROM CREW QUARTERS
- ONE REPRESSURIZATION CYCLE CAPABILITY FOR EACH MODULE

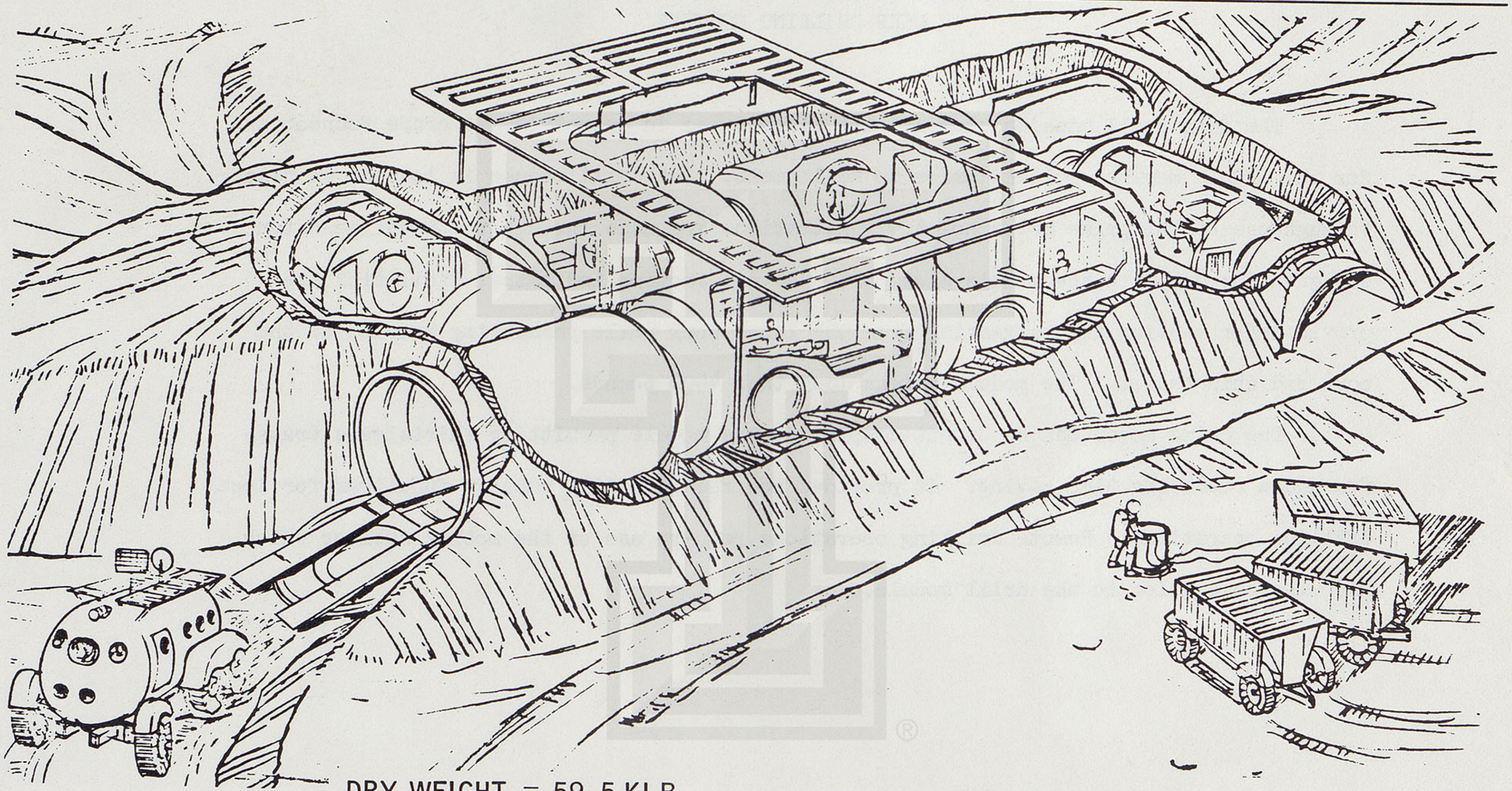
BASELINE SHELTER DESIGN

The baseline shelter is configured from eight of the foregoing modules arranged into a closed or circular floor plan. Two airlocks (two to six men) are provided, one at each end, each with a dust management facility and provisions for docking the vehicles to the entrance/docking port. Shirtsleeve transfer to vehicles and/or the mobile shelter is, therefore, possible. Three crew modules (four men each) operating autonomously or in concert, provide all the required crew services. In addition, each crew module provides one service to the base mission. These include a command center, a medical facility, and a backup galley. Other modules are dedicated to a laboratory and backup command center, a galley and recreation area, a drive-in warehouse, a maintenance facility, and a garage for the shirtsleeve maintenance of base vehicles.

The whole shelter complex is covered by not less than six inches of lunar soil which provides thermal isolation, a radiation shield and meteoroid protection sufficient to eliminate all but the catastrophic occurrence of large meteoroids ($>$ one inch in diameter).

The mobile power trailers are connected in parallel through a central J-box to all modules. They may be removed for service in the garage (by removing isotopes first) or to provide power for the sorties and other dispersed operations.

BASELINE SHELTER DESIGN



DRY WEIGHT = 59.5 KLB
VOLUME = 41.6 K FT^3
FLOOR AREA = 2.8 K FT^2

TWO CREW AIRLOCKS
TWO VEHICLE HOUSINGS

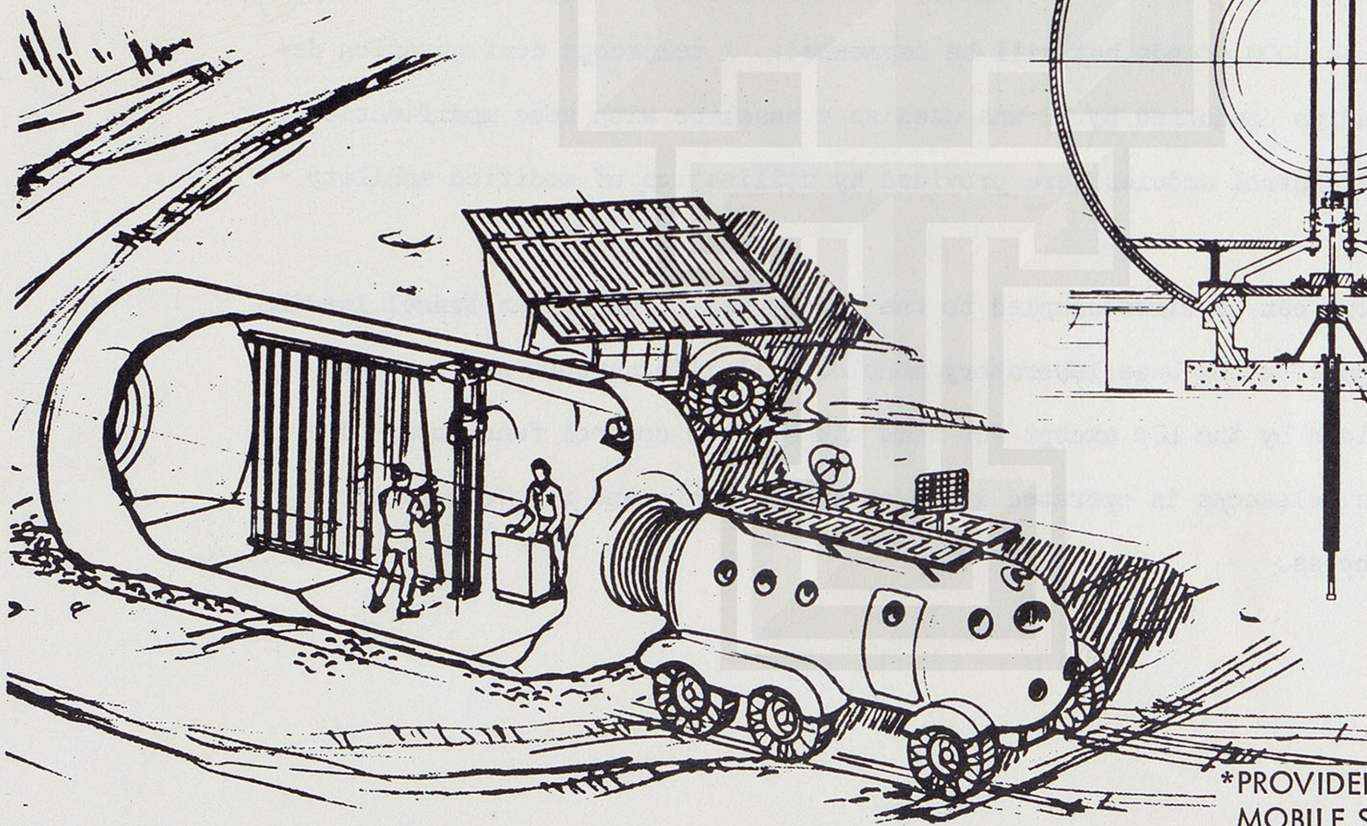
DEEP DRILLING CONCEPT

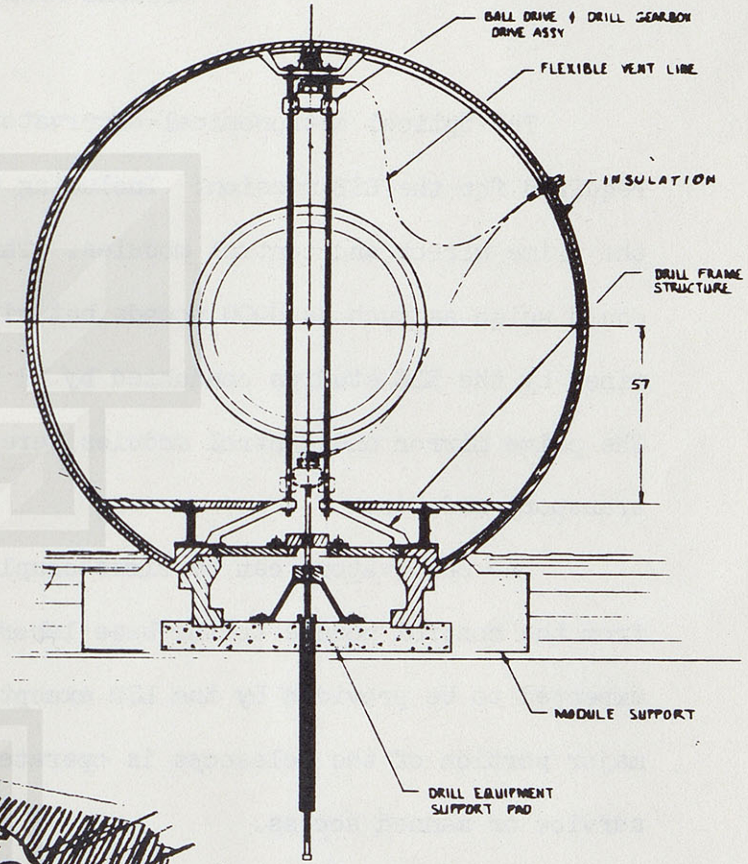
The deep drill mission elements are illustrated in operation. A crude foundation for the module may be emplaced prior to deployment. The drill module is lowered in place through use of the prime mover hoist. Penetrations are made through the modified hatch designed for use with the module side port. As the section indicates, facilities are provided for venting any outgassing from the lunar rock while permitting removal of the core and chip basket. The module weighs less than 4400 pounds.

The prime mover can be direct-coupled to the module permitting shirtsleeve transfer and a resulting time saving. It provides the required life support functions for local drilling operations. Remote drilling operations require use of the mobile shelter which may also be coupled to the drill module.

DEEP DRILLING CONCEPT

- LOCAL OR REMOTE OUTPOST – TRANSPORTABLE
- USES STANDARD MODULE – SHIRTSLEEVE OPERATIONS
- AUTONOMOUS ATMOSPHERIC CONTROL/DEPENDENT LIFE SUPPORT*





*PROVIDED BY PRIME MOVER. MOBILE SHELTER OR BASE SHELTER

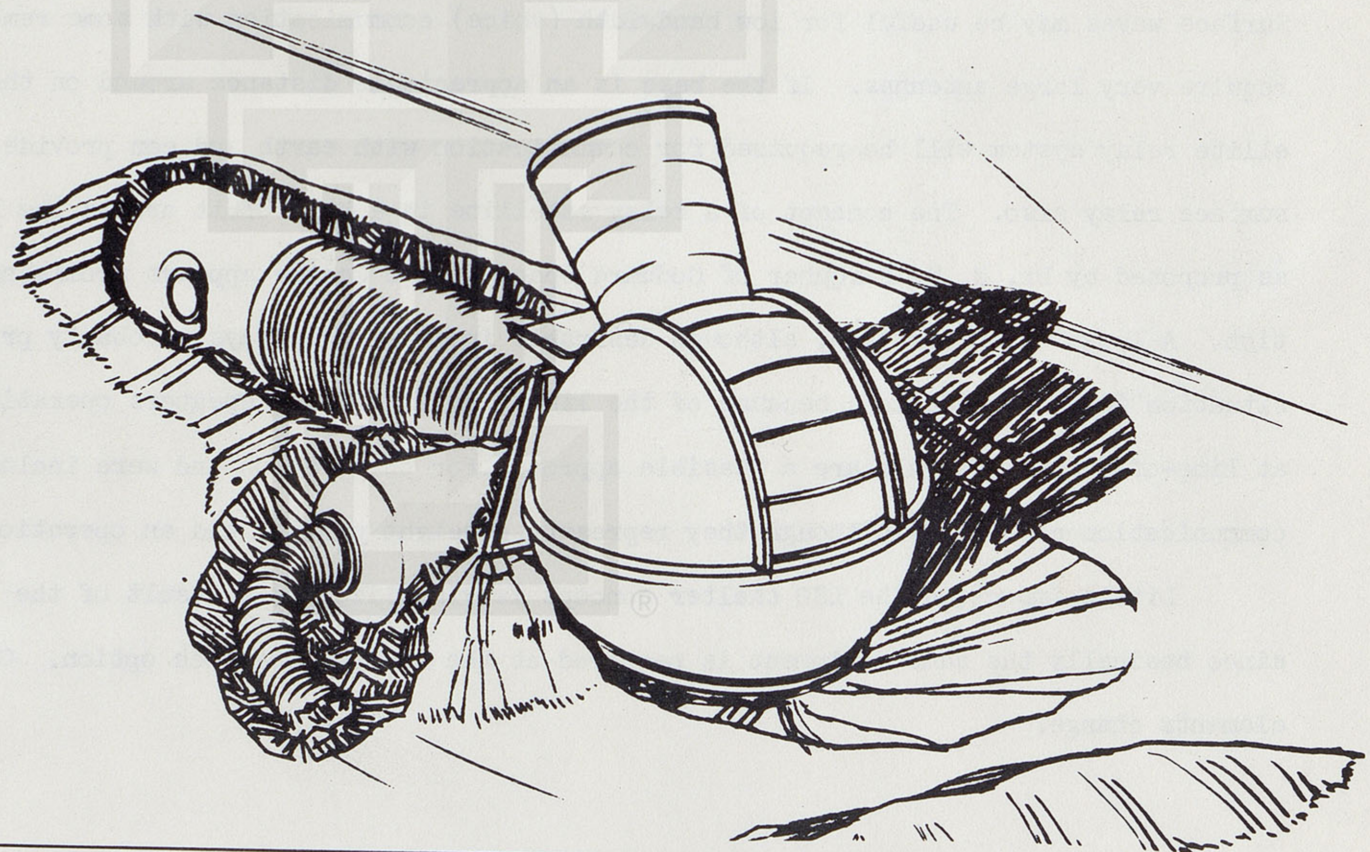
OPTICAL ASTRONOMY IMPLEMENTATION

The optical astronomical observatory is the largest single science element required for the LSB mission. Including the dome, it weighs about 33,000 pounds without the prime mirror and control modules. The largest element, the 200-inch siderostat mirror, could weigh as much as 8000 pounds but will be segmented. A telescope configuration defined by the ELE studies conducted by NR was used as a baseline with some modifications. The prime mirror and control modules were provided by utilization of modified mobility transport modules.

The observatory can be close-coupled to the LSB by use of an access tunnel leading from the control module to the base laboratory module. All life support services are expected to be provided by the LSB except for some atmospheric control functions. The major portion of the telescope is operated in an evacuated state and requires little service or manned access.

OPTICAL ASTRONOMY IMPLEMENTATION

- DIRECT COUPLED TO BASE SHELTER
- REQUIRES TWO STANDARD MODULES PLUS SPECIAL TUNNEL
- LIFE SUPPORT PROVIDED BY MAIN SHELTER



COMMUNICATION OPTIONS

Four basic options can be visualized for communications between the elements of the LSB beyond the horizon: (1) surface waves, (2) repeaters at line-of-sight intervals, (3) satellite relays, and (4) earth relay. Earth relay is a clear choice if LSB operations are confined to the near side. Surface waves may be useful for low bandwidth (voice) communication with some remote elements but require very large antennas. If the base is an appreciable distance around on the back side, a satellite relay system will be required for communication with earth and can provide the surface-to-surface relay also. The concept of a relay satellite in a halo orbit around the L_2 libration point as proposed by Dr. R. W. Farquhar of Goddard Space Flight Center appears promising for this application. A location on the limb, although desirable in many other ways, probably presents the worst situation for communications because of the libration effects. Repeaters operating in the VHF band at line-of-sight intervals are a feasible approach for this region and were included in the LSB communication concept even though they represent a weight penalty and an operational complication.

Little impact on the LSB shelter concept is visualized as a result of the selected options since basically the same equipment is required at the shelter for each option. Only the supporting elements change.

COMMUNICATION OPTIONS

LSB LINK TO	LSB LOCATION		
	FRONTSIDE	BACKSIDE	LIMB
EARTH	√ DIRECT	√ SATELLITE RELAY	√ SURFACE RELAYS SATELLITE RELAY
SURFACE ELEMENTS	√ EARTH RELAY SATELLITE RELAY SURFACE RELAYS	√ SATELLITE RELAY SURFACE RELAYS	√ SURFACE RELAYS SATELLITE RELAY

√ OPTION SELECTED, PLUS VLF SURFACE WAVES FOR LOW BANDWIDTH (VOICE) SURFACE-TO-SURFACE LINK

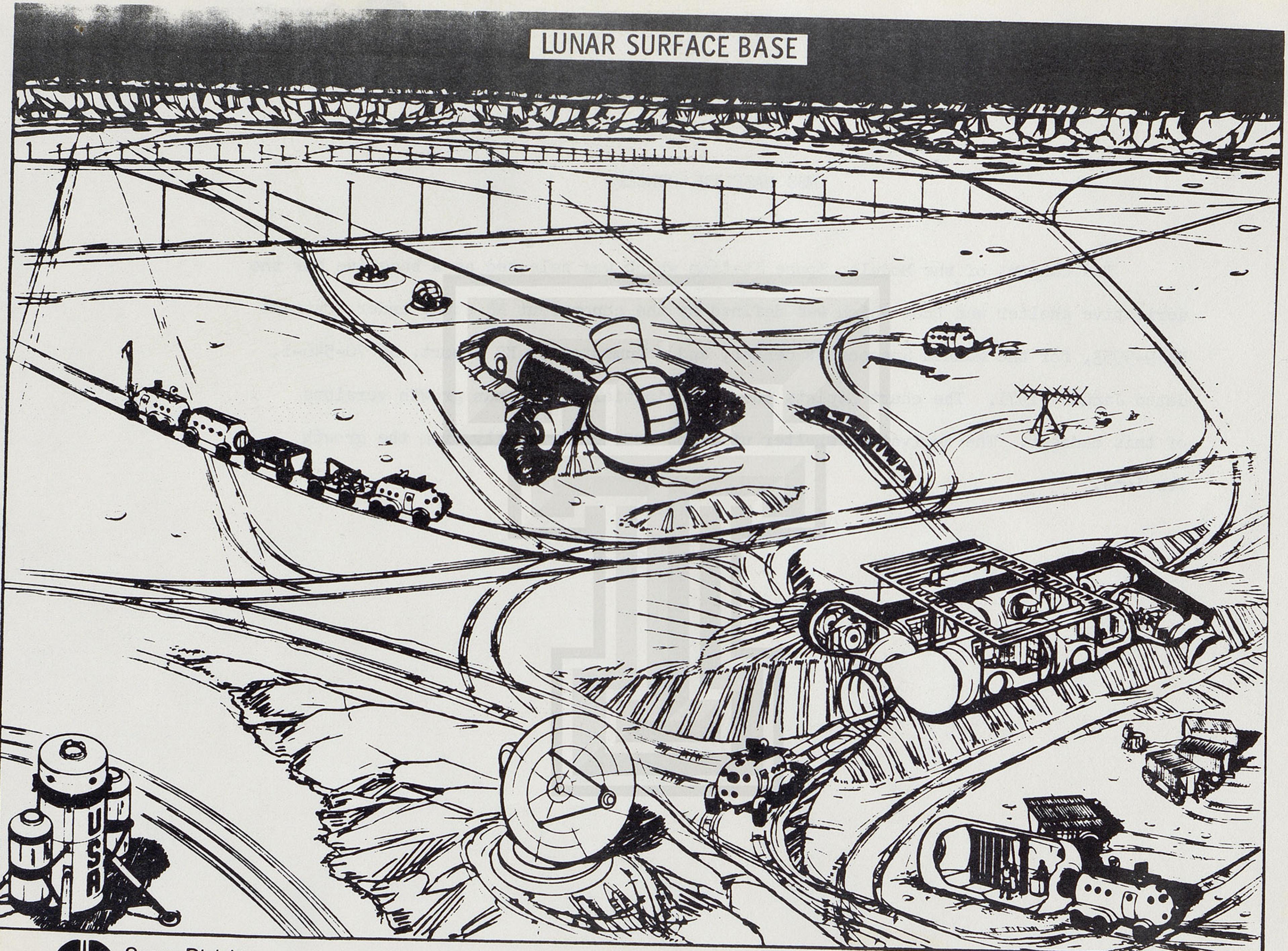
OPTIONS BASICALLY AFFECT SUPPORT EQUIPMENT - LSB EQUIPMENT SIMILAR FOR ALL OPTIONS

LUNAR SURFACE BASE

This chart presents a representative layout of an LSB complex. It should be noted that the configuration is sensitive to the selected site topography and the ideal site may never be achievable since both location and topography are selection factors. The combined astronomy criteria call for a 60-mile diameter crater, with walls one half mile high, located just south of the equator on the back side or the limb.

This representative complex embodies most of the site selection and preparation criteria. The main base is covered with soil for environmental protection. It and other elements are separated by over a mile from the vehicle landing sites and protected against potential sand blasting by the intervening mounds. One deep drilling site is close by and yet isolated enough to minimize interference with base systems. The base complex can cover an area of up to 12 square miles, depending on the radio astronomy and deep drilling locations. The antenna farm illustrated involves the largest area coverage and is sensitive to location, orientation, and installation errors.

A large paraboloid antenna has been included for the MSFN link. A small phased array may be required if a relay link and/or orbiting vehicles require that service.



Space Division
North American Rockwell