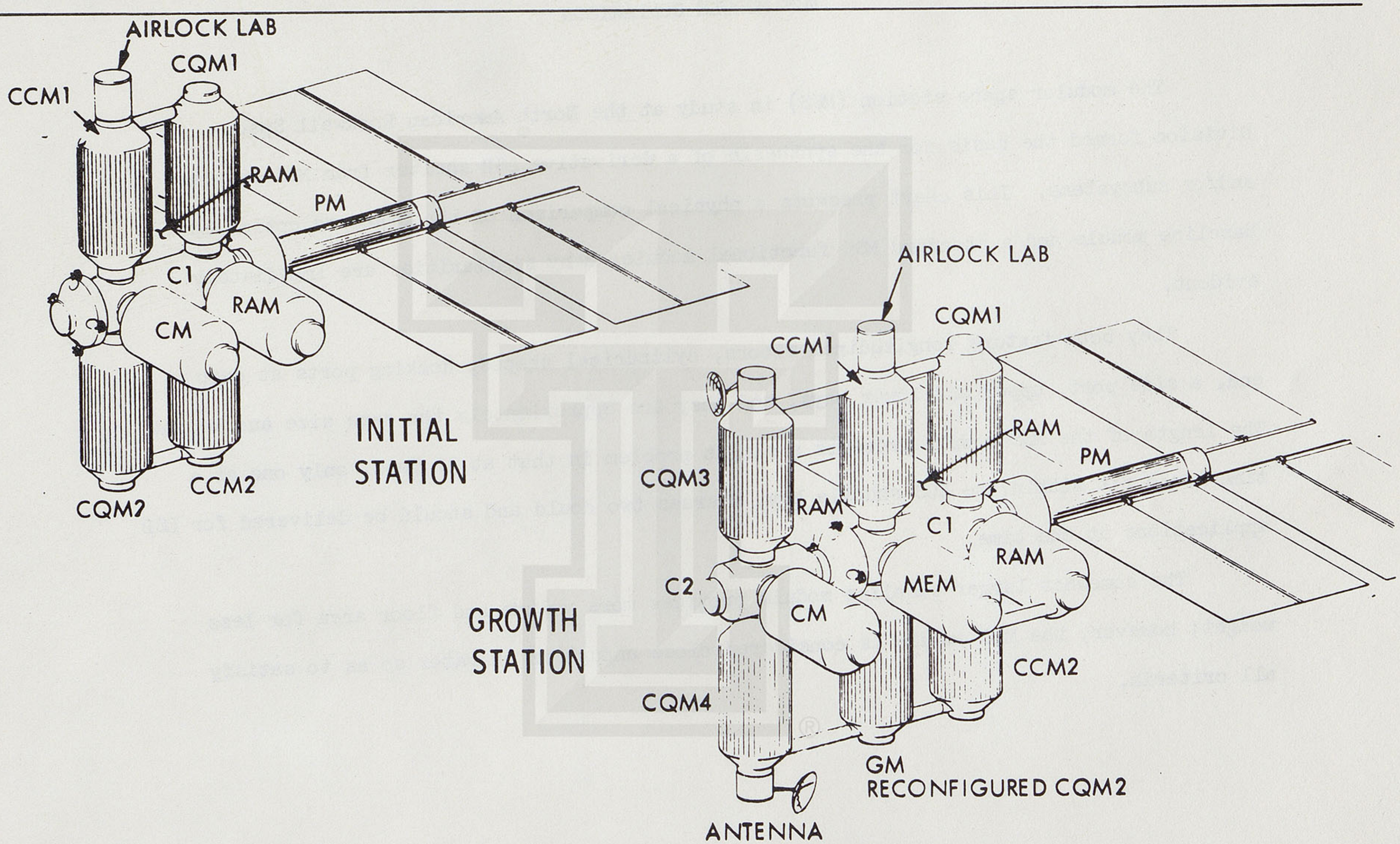
MSS BASELINE CONCEPT

The concept of the Modular Space Station which was selected as a baseline for the derivative shelter was that which was defined by the concurrent NR study under Contract NAS9-9953, for the Manned Spacecraft Center, and documented in NR report, SD 70-546-1, dated January 1971. The chart depicts the 6-man initial and 12-man growth versions of this concept. The derivative shelter utilizes modules primarily from the growth versions.

MSS BASELINE CONCEPT



MSS MODULE COMPARISON

The modular space station (MSS) in study at the North American Rockwell Space Division formed the basis for the synthesis of a derivative LSB shelter from MSS modules and/or subsystems. This chart presents a physical comparison of the standard optimized baseline module and a standard MSS functional module; many similarities are immediately evident.

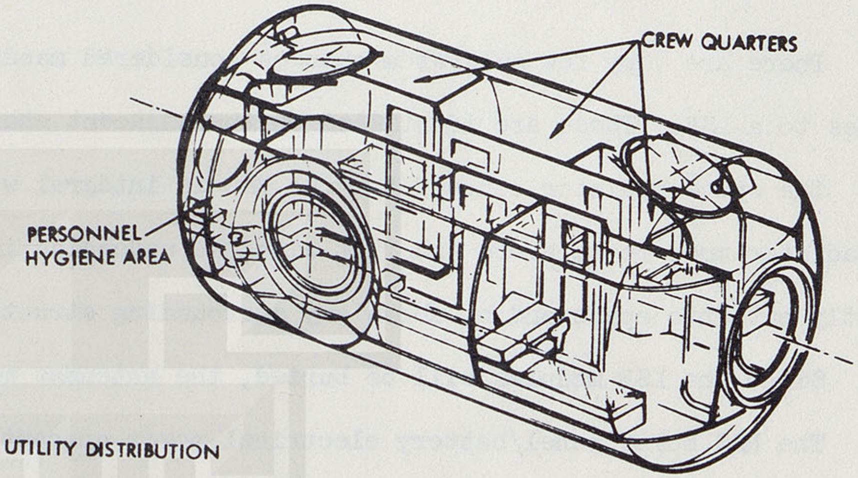
They both feature longitudinal floors, cylindrical shapes, docking ports at each end, a side port, upper and lower bays, and they are approximately the same size and weight. The length of the MSS module presents a slight problem in that at 31 feet, only one at a time could fit within the EOS shuttle bay, whereas two could and should be delivered for LSB applications at one time.

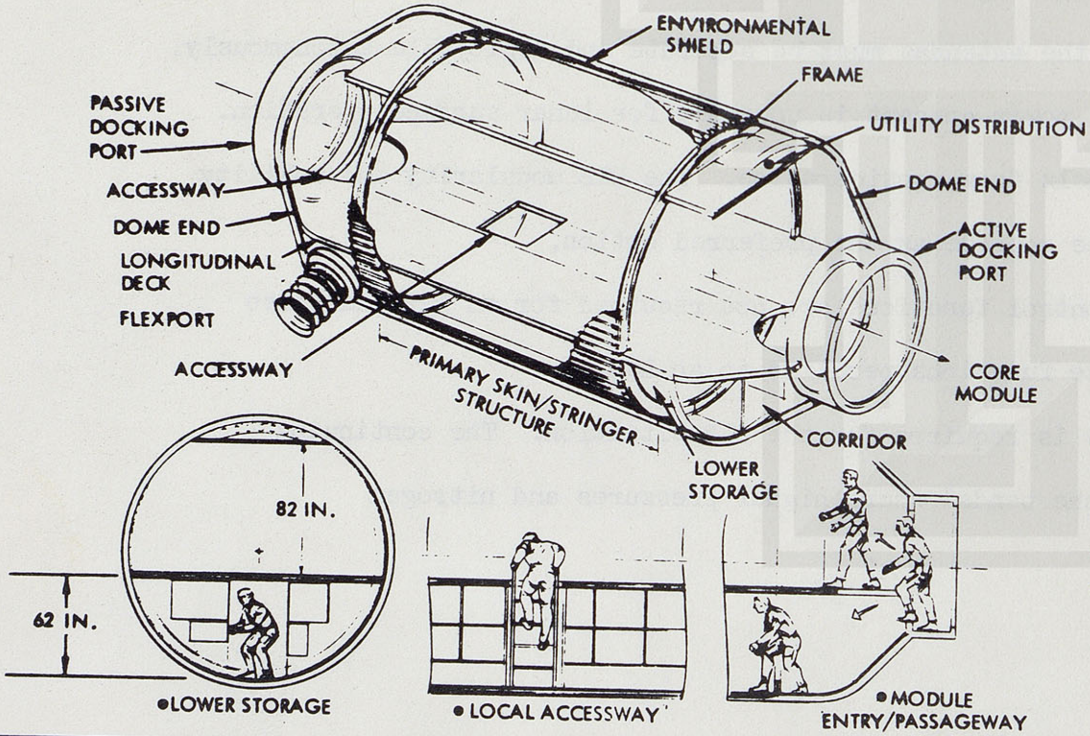
The somewhat larger baseline module provides more volume and floor area for less weight; however, the MSS module is considered close enough in charater so as to satisfy all criteria.

MSS MODULE COMPARISON

BASELINE

- SIZE = 15 FT DIAMETER
  30 FT LONG
- WEIGHT ~ 9.5K LB
- VOLUME ~ 5200 FT^3
- FLOOR AREA ~ 360 FT^2





MSS DERIVATIVE

- SIZE = 14 FT DIAMETER
  31.5 FT LONG
- WEIGHT = 11.1K LB*
- VOLUME = 4080 FT^3
- FLOOR AREA = 328 FT^2

*CONTAINS EXCESS FUNCTIONS FOR LSB APPLICATION

MANDATORY MSS SUBSYSTEM CHANGES

There are very few subsystem changes considered mandatory to permit the application of MSS modules to a LSB. These are identified on the adjacent chart.

The space radiator concept for the MSS is integral with the cylindrical surface, whereas the LSB radiator must be separate and flat with the underside insulated. It must be deployed to look directly out into space and be above any surrounding structure.

Since the LSB modules will be buried, the antennas must be separate and deployable autonomously.

The MSS solar panel/battery electrical power concept is unusable for lunar surface operation. The long day/night cycles eliminate solar panels from consideration. The LSB modularity and mobility requirements lead to the choice of the isotope sources as the preferred option.

Some of the MSS data processing and control functions are not required for an LSB and these peculiar functions must be replaced with those functions peculiar to an LSB.

A lower atmospheric pressure (10 psia) is required for the LSB situation. The continuing egress/ingress cycles could easily lead to "the bends" where higher pressures and nitrogen concentrations are used.

MANDATORY MSS SUBSYSTEM CHANGES

MSS CONFIGURATION	LSB REQUIREMENTS
• INTEGRATED WRAP-AROUND RADIATOR	• SEPARATE FLAT RADIATOR
• MODULE MOUNTED ANTENNA	• SEPARATE ANTENNA
• SOLAR CELL POWER	• ISOTOPE POWER
• MSS - PECULIAR CONTROLS	• LSB - PECULIAR CONTROLS
• MSS - PECULIAR SOFTWARE	• LSB - PECULIAR SOFTWARE
• 14.7 PSIA ATMOSPHERE CONTROL	• 10 PSIA ATMOSPHERE CONTROL

SUBSYSTEM WEIGHT OPTIMIZATION CHANGES

These are changes that are not required from a performance requirement apsect, but do eliminate superfluous functions or optimize the functional capability to better match the surface application and reduce weight.

The meteoroid bumper is not required since the LSB is buried below at least six inches of soil.

The docking approach radar, guidance and control as well as reaction control functions are not required since these functions are provided by the logistics vehicles in transit and are not required after arrival. Zero gravity aids are eliminated since there is a small but discrete gravity on the lunar surface.

The cryogenic storage concept is replaced with a hydrazine storage and a disassociator on the basis of a weight saving and ease of handling. Long term storage is possible with no losses through boiloff.

Waste processing is eliminated as an unnecessary function. Waste products may be buried in a crater or an empty cargo module.

Shower and lavatories could be modified to eliminate the zero-g features.

Docking ports may have to be modified for active neuter docking at both ends. However, if all logistics vehicles had active ports and the handling sequence were properly arranged, the present concept may be satisfactory.

SUBSYSTEM WEIGHT OPTIMIZATION CHANGES

SUPERFLUOUS FUNCTIONS

- ELIMINATE GUIDANCE AND CONTROL
- ELIMINATE REACTION CONTROL
- ELIMINATE DOCKING APPROACH RADAR
- ELIMINATE METEOROID BUMPER
- ELIMINATE ZERO-G AIDS

DESIRABLE CHANGES

- REPLACE CRYO STORAGE WITH HYDRAZINE
- ELIMINATE TRASH PROCESSING
- MODIFY ZERO-G SHOWER AND LAVATORIES
- MODIFY DOCKING PORT

SUBSYSTEM ADDITIONS REQUIRED

The additional subsystems required are those associated with the communications, EVA support, extended storage, and vehicle maintenance functions.

The S-band power amplifier and high gain antennas are required to compensate for the increase in communications distances to MSFN. An increase gain of about 40 db is required to provide the signal strength and bandwidth required.

The VHF transceiver system is required to provide the local and remote surface-to-surface links. Additionally, some form of relay system may be required to work in conjunction with the terminal units.

The VLF transceiver and antenna system provides a emergency surface-to-surface voice link.

A dust management function is required to permit cleaning off the lunar dust prior to entry into the shelter proper. It is integrated into an airlock and is composed of an air shower, a fast moving air column, and a series of traps and filters. This requirement does extend the size of the airlock.

The airlock laboratory identified for the MSS is inadequate to permit two to six-man crews to egress at the same time. Further, the need for moving equipment in and out and the dust management requirement all impose the requirement for multiple airlocks which are larger than the MSS airlock.

The warehousing facilities are required to permit constant shirtsleeve access to protected base supplies.

The garage facilities are required to facilitate shirtsleeve maintenance of the various base vehicles. The study indicated that at least 80 man-hours per month (shirtsleeve conditions) were required to maintain the base vehicles. EVA operations would extend this to at least 320 hours. The time saving and accuracy of work justifies the garage costs.

SUBSYSTEM ADDITIONS REQUIRED

EARTH-MOON COMMUNICATIONS

- S-BAND HIGH GAIN ANTENNA
- S-BAND POWER AMPLIFIERS

SURFACE-TO-SURFACE COMMUNICATIONS

- VHF TRANSCEIVERS AND ANTENNA
- VLF TRANSCEIVERS AND ANTENNA

INGRESS/EGRESS PROVISIONS

- DUST MANAGEMENT
- AIRLOCK FACILITIES (LARGE AND SMALL)

WAREHOUSE FACILITY

GARAGE FACILITY

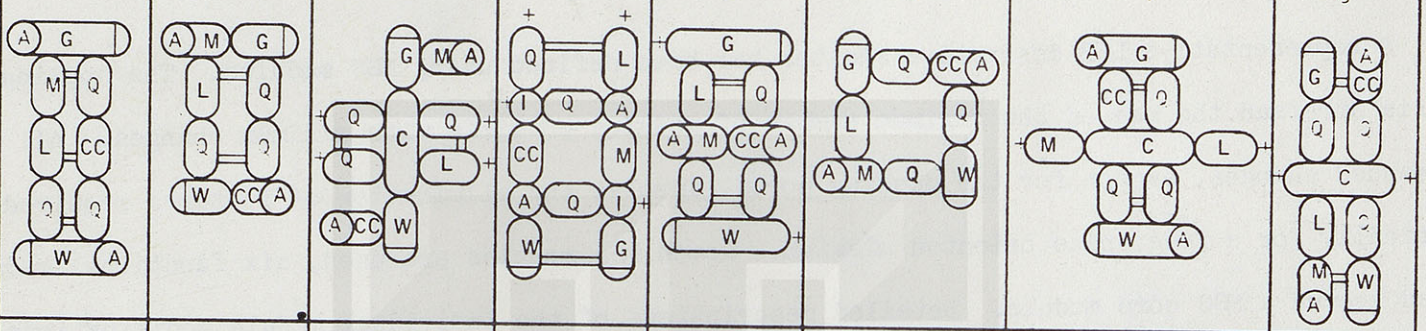
MSS DERIVATIVE SHELTER OPTIONS

The synthesis of configuration options for the derivative shelter is much like the same problem for the earth orbit application. There are a great number of combinations possible. The eight presented are representative of the potential configurations.

The selection criteria included: (1) the number of joints (the larger the number the greater the leak potential and the greater the workload); (2) the module alignment complexity created by the need to close loops increases the installation problem; (3) growth paths are desirable to facilitate base expansion; (4) dual escape paths are desirable from any module to provide adequate safety; (5) the number of MSS modules used out of the total number required should be high; (6) the number of special modules and/or major revisions to existing modules should be minimized (the minimum is two in order to provide the special functions required); (7) the total number of modules must be at least eight to provide the minimum functions, floor area, free volume and satisfy all the other criteria.

Concept 7 generally satisfies the criteria and provides the most flexible configuration. A significant portion of the shelter can be shut down (either as a result of a reduction in activity or an accident) and still maintain an operational configuration with good circulation. Its selection provides a representative baseline for the remaining effort.

MSS DERIVATIVE SHELTER OPTIONS



	1	2	3	4	5	6	7	8
Joints	8	8	8	12	9	8	10	8
Alignment	Complex	Complex	Simple	Complex	Modest	Complex	Modest	Simple
Growth Paths	0	0	4	4	2	0	2	2
Dual Paths	All	All	Part	All	All	All	Part	All
MSS Modules	6	4	5	6	4	4	7	5
Spec. Modules	2	4	4	6	4	4	2	4
Total Modules	8	8	9	12	8	8	9	9

MODULE LEGEND:

M	Maintenance
Q	Crew Quarters
L	Lab
CC	Command Center
G	Garage
W	Warehouse
A	Airlock
C	Core
I	Interconnect
+	Growth Points

MSS DERIVATIVE LSB SHELTER

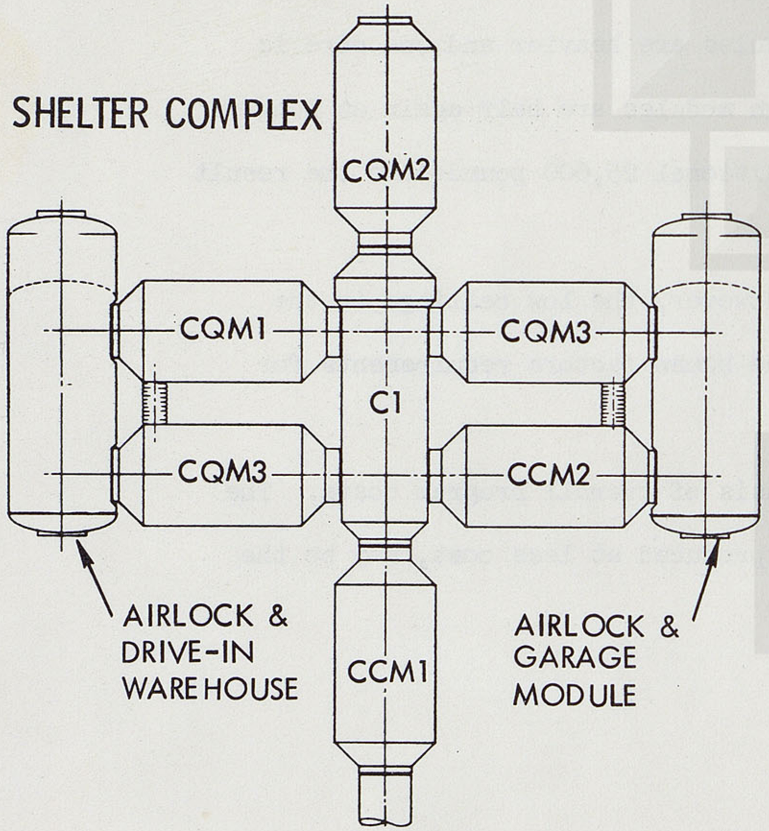
A representative LSB derivative shelter has been defined using MSS modules. The application criteria stressed the use of the maximum number of modules possible with minimum changes. All the recommended changes, except for the docking ports, involve the elimination of features required specifically for a free space oriented mission. Seven MSS modules are used, six functional modules grouped around a MSS core module. Detailed descriptions of the individual module modifications are contained in Volume III of the final report. The modules used include three 4-man crew modules, two laboratory modules, and one galley module.

In addition, two special modules were designed to provide the functions peculiar to an LSB. These modules are very similar in design and differ only in their application. One end contains a airlock for four to six men, the other end opens completely permitting a vehicle or cargo module to be driven inside for ready access and/or repair. The modules also function as shipping containers for the prime movers or other modularity elements. Two side ports are included for coupling into the main base, thereby providing ready access to the module and closing a double loop for each wing of the shelter complex.

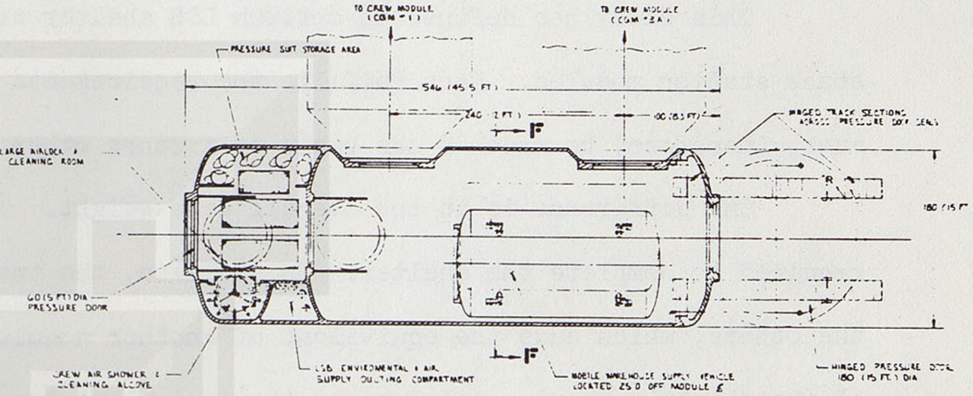
MSS DERIVATIVE LSB SHELTER

- DRY WEIGHT ~ 84.5K LB ~ 9.8K LB/MODULE
- CONTAINED VOLUME ~ 44.5K FT^3
- FLOOR AREA ~ 3.1K FT^2 + 540 FT^2 LOWER AISLE
- NINE MODULES

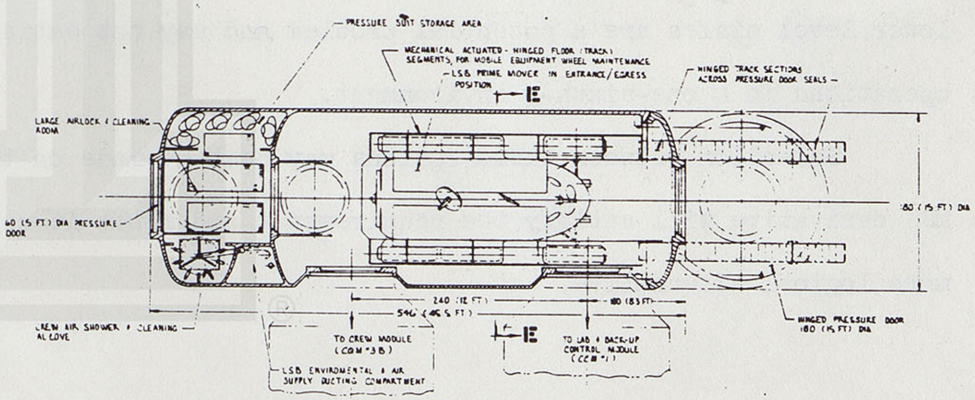
SHELTER COMPLEX



AIRLOCK & DRIVE-IN WAREHOUSE *(7.3K LB)



AIRLOCK & GARAGE MODULE *(6.9K LB)



* ALSO USED AS SHIPPING CONTAINERS FOR PRIME MOVERS

LSB SHELTER COMPARISONS

This study has defined an optimum LSB shelter and one derived from the modular (shuttle launched) space station modules. Each fulfills the requirements defined for the LSB. A comparative analysis must, therefore, be made on the basis of factors other than performance.

One difference is in the overall base weight. The MSS modules are heavier and one more is required to complete the shelter. In addition, the two new design modules are half again as long as the others, which adds the equivalent of another module. The additional 25,000 pounds are the result of the slightly heavier modules and the equivalent two additional.

The MSS does provide more usable volume and floor area. However, the low ceilings in the lower level aisles are a potential problem and may not satisfy the human factors requirements for operations in a one-sixth-g environment.

Selection between these options may best be made on the basis of overall program costs. The MSS derivative will satisfy the requirements and since it can be produced at less cost, may be the more logical alternative.

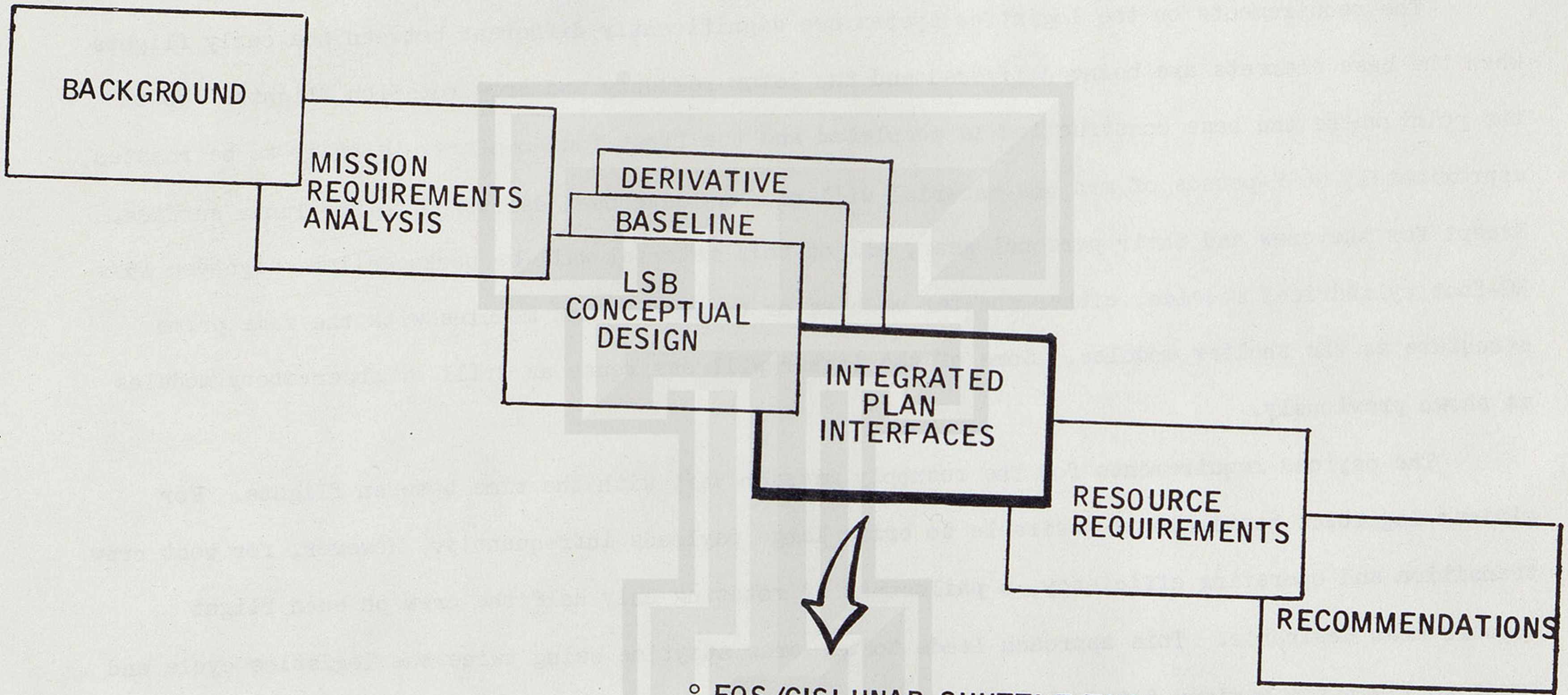
LSB SHELTER COMPARISON

	MSS	BASELINE
BASE WEIGHT (lb)	84.5 K	59.5 K
BASE VOLUME (ft^3)	44.5 K	41.6 K
FLOOR AREA (ft^2)	3.6 K	2.8 K
DEDICATED VOLUME (ft^3)	10.0 K	15.7 K
MODULE SIZE (ft)	14 DIAM. X 31.5	15 DIAM. X 30
NUMBER OF MODULES	9	8

PRESENTATION OUTLINE

The LSB interfaces with virtually all elements of an integrated space plan to some degree. This section describes the extent of some of these interfaces and presents a summary of the LSB operational program and logistics requirements.

PRESENTATION OUTLINE



- EOS/CISLUNAR SHUTTLE/TUG
- LSB OPERATIONAL PLAN
- OLS CONSIDERATIONS
- EOSS INFLUENCES

LOGISTICS SYSTEM REQUIREMENTS

The requirements on the logistics system are significantly different between the early flights when the base elements are being delivered and the later resupply and crew rotation flights. Up to the point where the base construction is completed and the first four-man crew is ready to be rotated, approximately 263K-pounds of men and material will need to have been delivered to the lunar surface. Except for the crew and their personal gear, all of this material will be packaged into eighteen 15 x 30-foot cylindrical modules, either shelter modules or transportation modules with the same prime structure as the shelter modules. Some of the latter will see reuse as drill or observatory modules as shown previously.

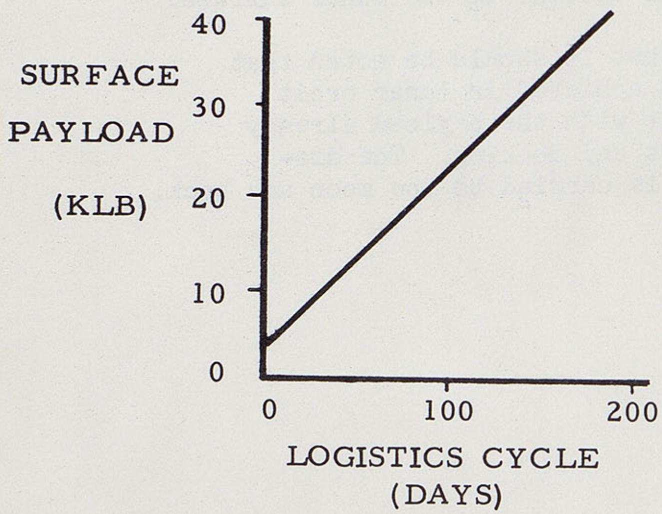
The payload requirements for the resupply mission vary with the time between flights. For minimum logistics costs, it is desirable to bring large payloads infrequently. However, for best crew transition and operating efficiency, a philosophy of rotating only half the crew on each flight appears most desirable. This approach leads to the crew staytime being twice the logistics cycle and tends to limit the maximum interval between flights.

LOGISTICS SYSTEM REQUIREMENTS

BUILD-UP PHASE (TO FIRST CREW ROTATION)

SHELTER	64.9 KLB	263-KLB 18 MODULES
POWER SOURCE	27.1	
MOBILITY	27.2	
SCIENCE	68.3	
CONSUMABLES AND SPARES	31.2	
CONTAINERS	40.6	
CREW	3.7	

CREW ROTATION AND RESUPPLY



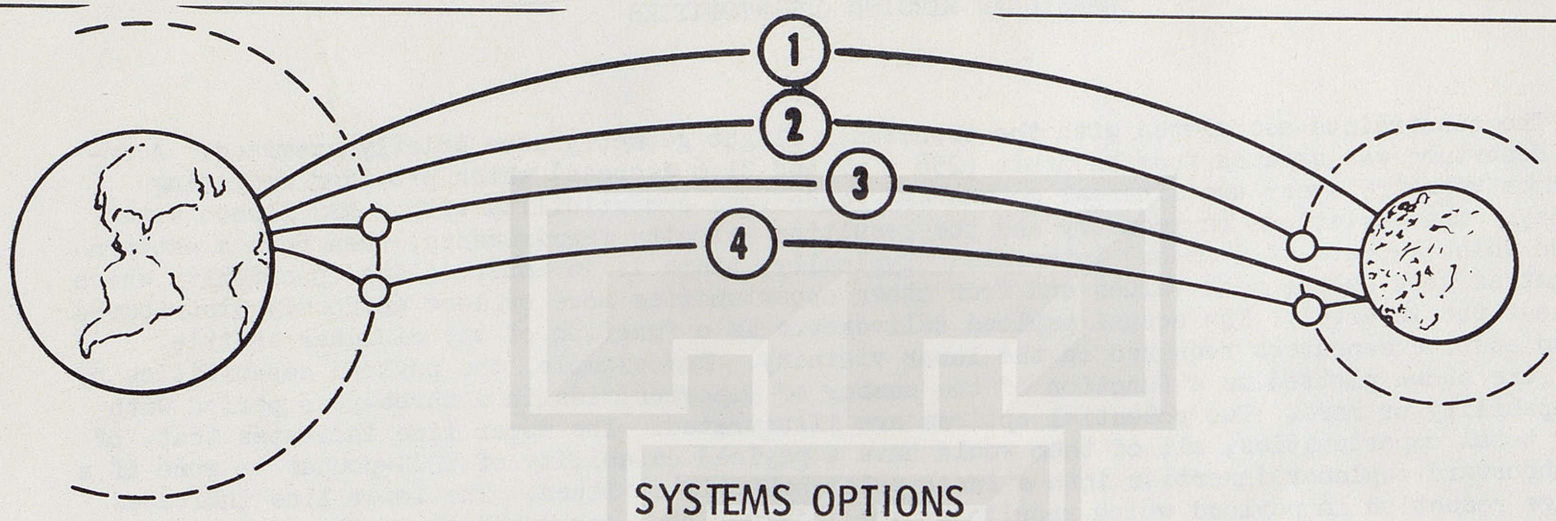
LSB LOGISTICS SUPPORT OPTIONS

A number of logistics systems options for support of the lunar surface operations can be identified using both existing hardware and the various vehicle design studies conducted and underway. One way of categorizing these systems is on the basis of the transfer points or nodes in the overall flow from the earth's surface to the lunar surface. The significance of these nodes lies in the complexities introduced by zero-g sorting and handling of crew and cargo to transfer from one vehicle to another. The Apollo system is typical of the minimum in that, although there are several staging points, the cargo is integrated into the lander prior to takeoff and only the crew is transferred. The introduction of various concepts for reusable elements of the logistics system will create a need for cargo and crew transfer at one or more points as indicated on the chart. In general, each nodal point introduced tends to increase the payload fraction of the system at the expense of zero-g transfer complexities.

One additional option, which is not shown explicitly on the chart, was recently suggested by R. W. Farquhar of NASA Goddard. His suggestion would involve two transfers in the lunar vicinity, one at or near the L_2 libration point and one at some lower circular orbit. The advantage of this mode is that the transfer at the libration area increases the payload capability of the cislunar shuttle sufficiently to more than offset the losses in the subsequent descent to the lunar surface.

All subsequent discussions assume a Mode 4 option selection, but it should be noted that Mode 3 has a potentially significant advantage in the simplification achieved in lunar orbit operations. If the tug is brought completely fueled from earth orbit with the payload already integrated, lunar orbit operations are reduced to a simple rendezvous and docking. The disadvantage is that approximately 10,000 pounds of extra tug hardware is carried to the moon and back.

LSB LOGISTICS SUPPORT OPTIONS



SYSTEMS OPTIONS

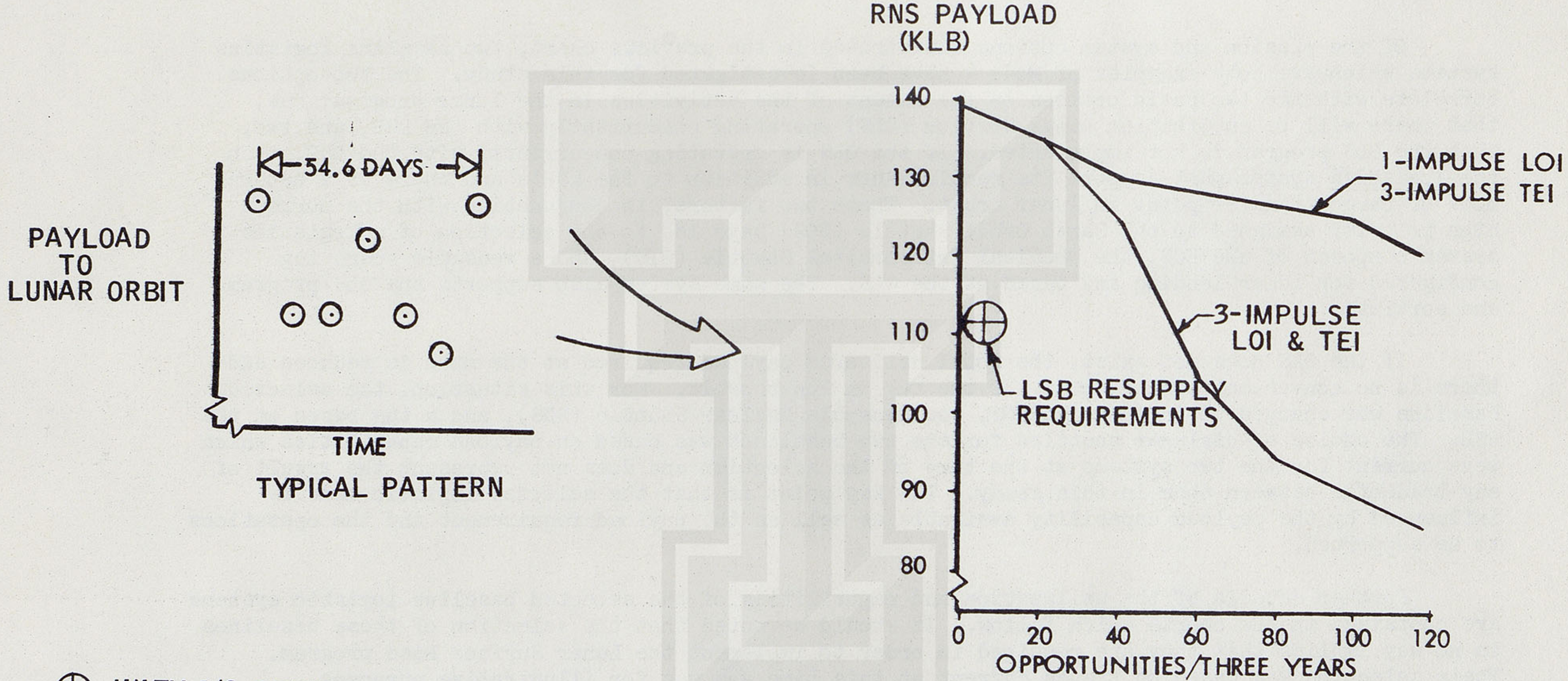
CARGO TRANSFER POINTS	FIRST LEG	SECOND LEG	THIRD LEG
(1) NONE	SAT V W/LANDER		
(2) LUNAR ORBIT	SAT V OR DERIV.	LUNAR BASED LANDER	
(3) EARTH ORBIT	EOS, SAT V DERIV., SAT IB, OIS, OR ?	CISLUNAR SHUTTLE (RNS, CIS) W/LANDER	
(4) LUNAR ORBIT & EARTH ORBIT	SAME AS ABOVE	CISLUNAR SHUTTLE	LUNAR BASED LANDER

TRANSLUNAR MISSION OPPORTUNITIES

The constraints associated with the translunar flight geometry were briefly examined. A co-planar departure was assumed from an orbit (258 n mi and 31.6 degrees) which provided repeating earth-moon geometry every two sidereal months and rendezvous compatibility with a KSC launch site every day. The variations in geometry and the resulting velocity requirements, then form a pattern as shown which repeats at 54.6-day intervals. Typically, there is an intermediate opportunity which is almost as good as the peak values and four other opportunities more or less uniformly distributed throughout the interval. The actual payload deliverable is a function of the cislunar shuttle selected and the maneuvers required in the lunar vicinity. For example, the payload capabilities of the RNS are shown plotted as a function of the number of opportunities in a three-year period with that capability or more. Two potential options are illustrated. The upper line indicates that, of the 120 total opportunities, all of them would have a payload capability of 120K-pounds or more if a straightforward coplanar insertion into a lunar polar orbit is utilized. The lower line indicates the large reduction in payload which results at the intermediate opportunities if the cislunar shuttle is required to rendezvous with a particular lunar polar orbit which has varying orientations to the earth-moon line. This latter case is typical of the resupply flight to the OLS.

The requirements imposed by the LSB resupply are indicated based on the approach discussed on the previous chart; i.e., one-half of the crew rotated each time and limiting the crew staytime to one sidereal year. As can be seen, considerable payload margin is available for either growth in requirements or decreases in logistics system performances. Also, multiple backup opportunities are available in the event a particular flight window is missed.

TRANSLUNAR MISSION OPPORTUNITIES



⊕ WITH 1/2 CREW ROTATED EVERY 18th OPPORTUNITY

- CREW STAYTIME ≈ 328 DAYS
- PAYLOAD MARGIN AVAILABLE FOR GROWTH AND/OR PERFORMANCE LOSSES
- MULTIPLE BACK-UP OPPORTUNITIES AVAILABLE

BASELINE LOGISTICS SYSTEM

Of the mission and system options illustrated in the previous chart, two baseline logistics systems which are both examples of Mode 4 have been investigated for this study. The two options correlate with the two basic options on the extent of the activities in the lunar program; one, that there will be an Orbiting Lunar Station (OLS) operating concurrently with the LSB, and two, that the OLS program is not implemented. If the OLS is operating concurrently with the LSB, then the logistics system must support its requirements in addition to the LSB's and there is a natural node or cargo transfer point in lunar orbit. These two factors, in conjunction with the current high priority assigned to the Earth Orbit Shuttle (EOS) have led to the selection of a logistics system composed of the EOS, the Chemical Interorbital Shuttle (CIS), and a reusable space tug configured for lunar landing and based at the OLS. The same system also supports the OLS program and sorties.

If the OLS does not exist, the total delivered payload required at the moon is reduced and there is no convenient basing point for the tug in lunar orbit. For this situation, the selected baseline was changed to include the EOS, the Reusable Nuclear Shuttle (RNS), and a tug based at the LSB. The choice of cislunar shuttles for the two baselines was based on payload capabilities which were current for the two systems at the time of the selection and does not represent the result of any tradeoffs between them in this study. The key point is that the selected logistic mode is influenced by the payload capability available as well as the payload requirement and the operations to be supported.

Further details of the utilization and capabilities of the selected baseline logistic systems are contained in the charts which follow. It should be noted that the selection of these baselines in no way implies that they are required in order to implement the Lunar Surface Base program. Their selection was based on trends current at this time and was for illustrative purposes.

BASELINE LOGISTICS SYSTEM

NO CONCURRENT ORBITING LUNAR STATION (OLS)

- EOS
- RNS
- MANNED TUG AT LSB

CONCURRENT ORBITING LUNAR STATION (OLS)

- EOS
- CIS
- MANNED TUG AT OLS

BUILD-UP PHASE

- SAME BASIC SYSTEM - SOME UNMANNED FLIGHTS

BASELINE STAGE-AND-A-HALF TUG CONCEPT

The LSB logistics support can be a very strong driver in the design of a tug for the integrated plan. The requirements for landing on the lunar surface with a reusable system, manned and unmanned, and carrying large modules present unique conditions to the tug designer. In addition, if the tug is based on the surface, it will be presented a very stringent environment.

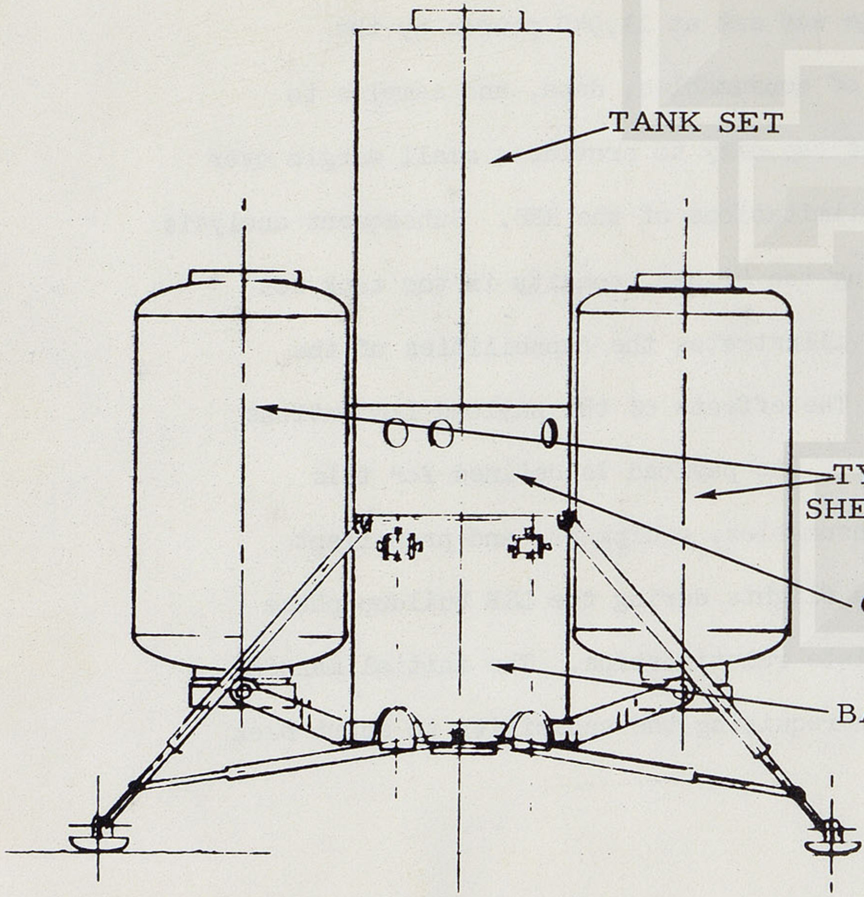
One of the concepts which was derived in the concurrent NR study of the Reusable Space Tug (Contract NAS9-10925) involved a small reusable tug which could utilize the propellants from a larger, expendable tank set until they were exhausted, then stage the tank set and complete the mission utilizing the basic stage propellants. This concept arose in the examination of the synchronous earth orbit missions and was sized in the tug study to do that mission. However, this concept appears to offer some significant advantages for the Lunar Surface Base mission also. In particular, in addition to the performance advantage of staging the tank set, it would appear feasible to design the connection between the basic stage and the tank set such that they could be mated by a docking maneuver in lunar orbit. This arrangement would be basically the same as the connections to be made for orbital propellant transfer, but would eliminate the need for zero-g propellant transfer, propellant modules or farms, and the losses associated therewith. The basic mode would be for the tug to dispose of the tank set on the lunar surface and, upon return to lunar orbit, to dock with another tank set brought by the cislunar shuttle. It should be noted that the tanks in the basic stage will essentially be empty when it returns to lunar orbit and the plumbing and tank set sizing has to consider refilling these tanks prior to disposal of the tank set so that the sequence can be continued.

The LSB will provide a semi-prepared landing site and a capability for monitoring the status while on the surface. In addition, if the tug is based on the surface, reliquefaction of boil-off may be required. The surface based tug also provides the added safety of another habitable module and ready escape to orbit.

BASELINE STAGE-AND-A-HALF TUG CONCEPT

LSB INFERENCES ON TUG

- MULTIPLE ROUNDTRIPS - LUNAR ORBIT / LUNAR SURFACE
- UNMANNED VERSIONS DURING BUILD-UP
- LUNAR SURFACE BASING (NO-OLS CASE)
- MULT. LOW DENSITY (~3 LB/FT^3) MODULAR PAYLOADS



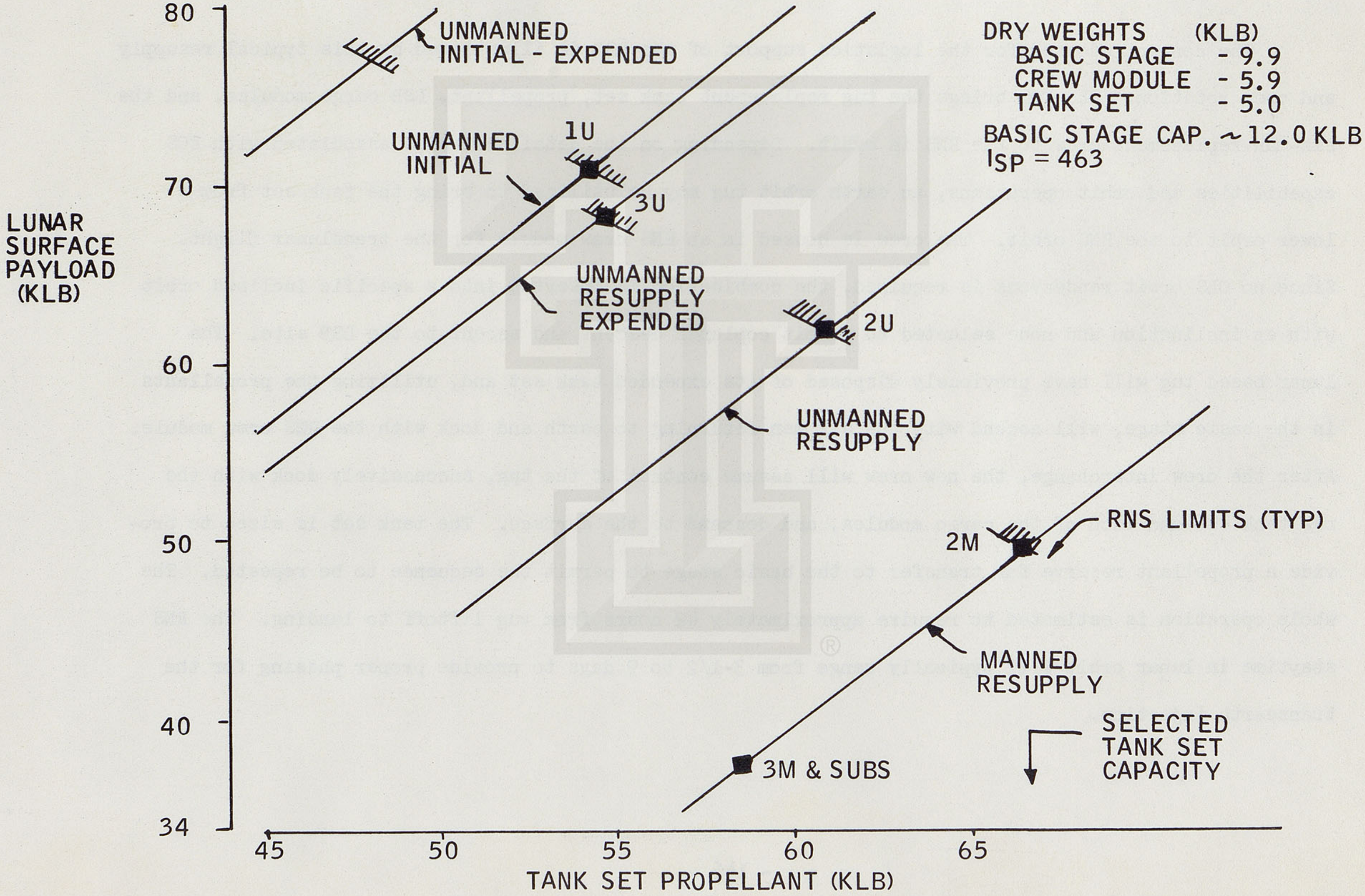
TUG INFERENCES ON LSB

- LANDING SITE FACILITIES
- RE-LIQUEFACTION (?)
- STATUS MONITORING
- SAFETY - HABITABLE MODULE
  - ESCAPE TO ORBIT

BASELINE TUG CAPABILITIES

The tug configuration utilized for the LSB logistics analysis was one which was derived during the Reusable Space Tug Study (Contract NAS9-10925) for performing a geosynchronous mission. For the LSB study, the propellant tank sizing was adjusted slightly to better match requirements of the LSB buildup and resupply. The usable propellant in the basic stage was set at 11,940 pounds by the requirement to be able to return a 6-man crew and 2000 pounds of consumables, data, and samples to lunar orbit. The tank set was originally sized at 66.7K pounds capacity to provide a small margin over the estimated resupply payload requirement within the payload limitations of the RNS. Subsequent analysis of the buildup process indicated the desirability of maintaining the higher capacity in the tank set even though the resupply requirements were reduced. The chart illustrates the capabilities of the selected tug configuration for the various types of missions. The effects of the payload limitations of the assumed RNS model are shown as upper bound for each case. The payload is defined for this figure to include all useful delivered weight such as crew, consumables, equipment, and propellant boiloff allowances. The points selected for the three unmanned flights during the LSB buildup phase and the regular manned resupply are indicated in their appropriate relationships. The initial manning flight is not shown because of the assumed special mission rule requiring the capability to abort back to lunar orbit without any unloading.

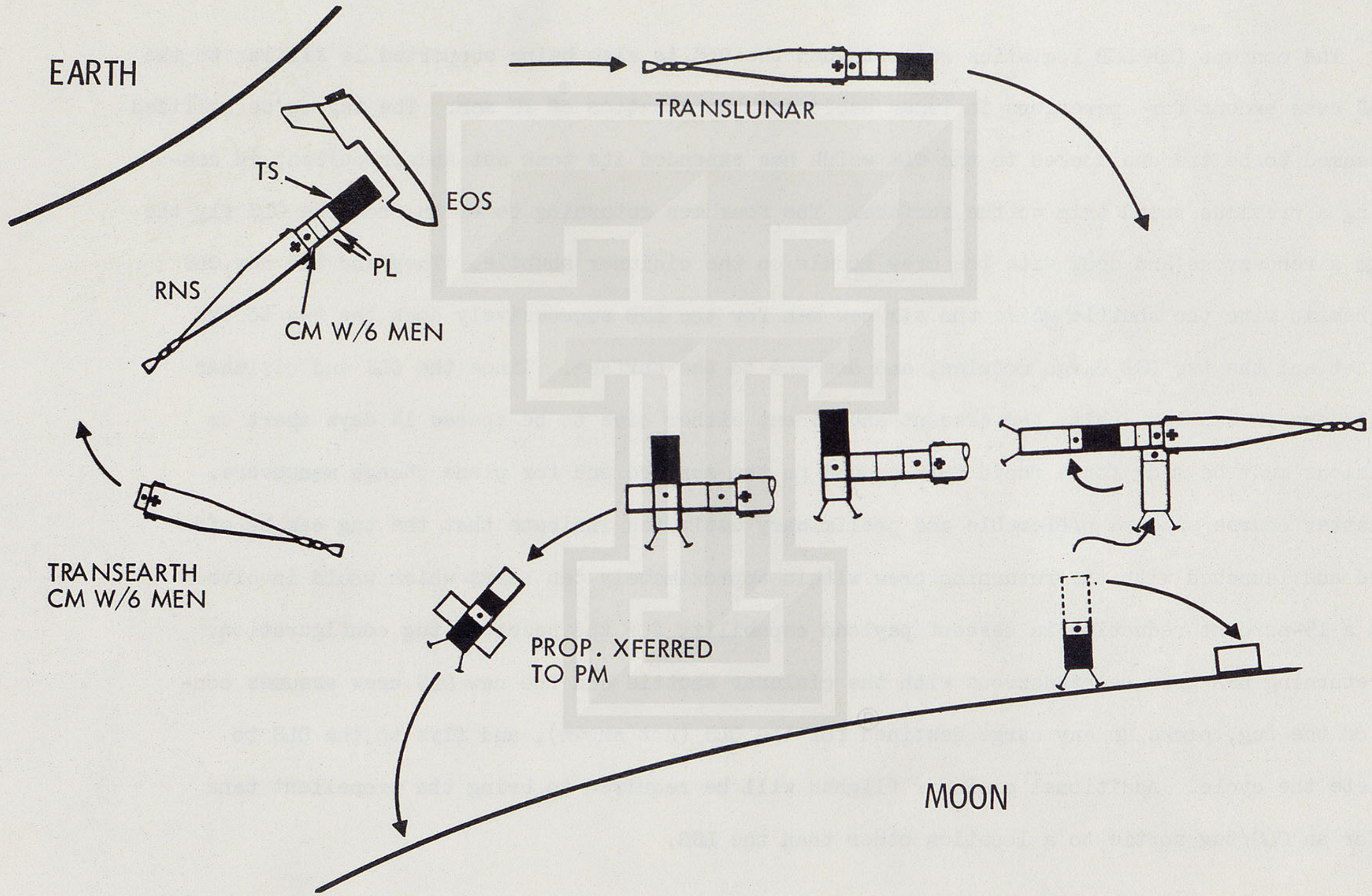
BASELINE TUG CAPABILITIES



LSB LOGISTICS CONCEPT
(WITHOUT OLS)

The concept adopted for the logistics support of the LSB is illustrated by this typical resupply and crew rotation. The EOS brings the tug replacement tank set, propellant, LSB cargo modules, and the six-man replacement crew to the RNS in orbit. Depending on the detailed trades associated with EOS capabilities and orbit operations, an earth orbit tug may be utilized to bring the tank set from a lower orbit to the RNS orbit. The crew is housed in an RNS crew module for the translunar flight. Since no OLS orbit rendezvous is required, the combination is inserted into a specific inclined orbit with an inclination and node selected to permit coplanar descent and ascent to the LSB site. The lunar based tug will have previously disposed of its expended tank set and, utilizing the propellants in the basic stage, will ascend with the six men returning to earth and dock with the RNS crew module. After the crew interchange, the new crew will assume control of the tug, successively dock with the new tank set and each of the cargo modules, and descend to the surface. The tank set is sized to provide a propellant reserve for transfer to the basic stage to permit the sequence to be repeated. The whole operation is estimated to require approximately 42 hours from tug liftoff to landing. The RNS staytime in lunar orbit will typically range from 3-1/2 to 9 days to provide proper phasing for the transearth injection.

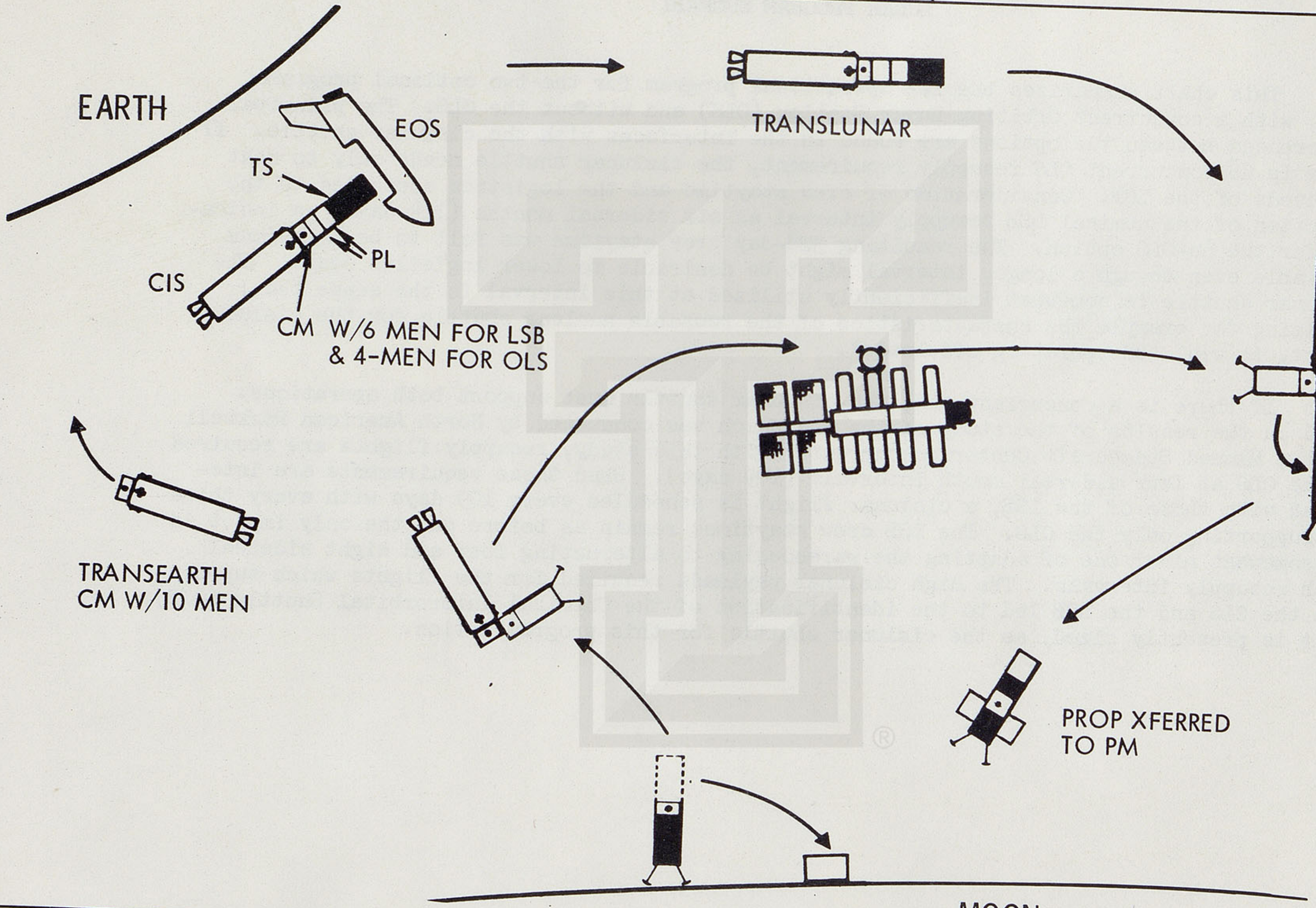
LSB LOGISTICS CONCEPT
(WITHOUT OLS)



LSB LOGISTICS CONCEPT
(WITH OLS)

The concept for LSB logistics support when the OLS is also being supported is similar to the no-OLS case except for operations in lunar orbit and the rotation of 10 men. The tug to be utilized is assumed to be the one docked to the OLS which has expended its tank set and propellant in conducting a previous round trip to the surface. The four men returning to earth from the OLS fly the tug to a rendezvous and dock with the crew module on the cislunar shuttle. They and the new OLS crew remain with the shuttle while the six new men for the LSB successively dock the tug to the tank set and the two LSB cargo modules, and descend to the surface. Since the OLS and cislunar shuttle are in a polar orbit, the descent and ascent either have to be spaced 14 days apart or provisions must be made for a rapid turn around on the surface and for plane change maneuvers. The latter course appears preferable and preliminary estimates indicate that the tug can be off-loaded and launched with the returning crew within approximately ten hours which would involved about a 15-percent reduction in descent payload capability for the baseline tug configuration. The returning LSB crew re-rendezvous with the cislunar shuttle and the new OLS crew assumes control of the tug, picks up any cargo destined for the OLS (not shown), and flys to the OLS to complete the cycle. Additional cislunar flights will be required to bring the propellant tank set for an OLS/tug sortie to a location other than the LSB.

LSB LOGISTICS CONCEPT
(WITH OLS)

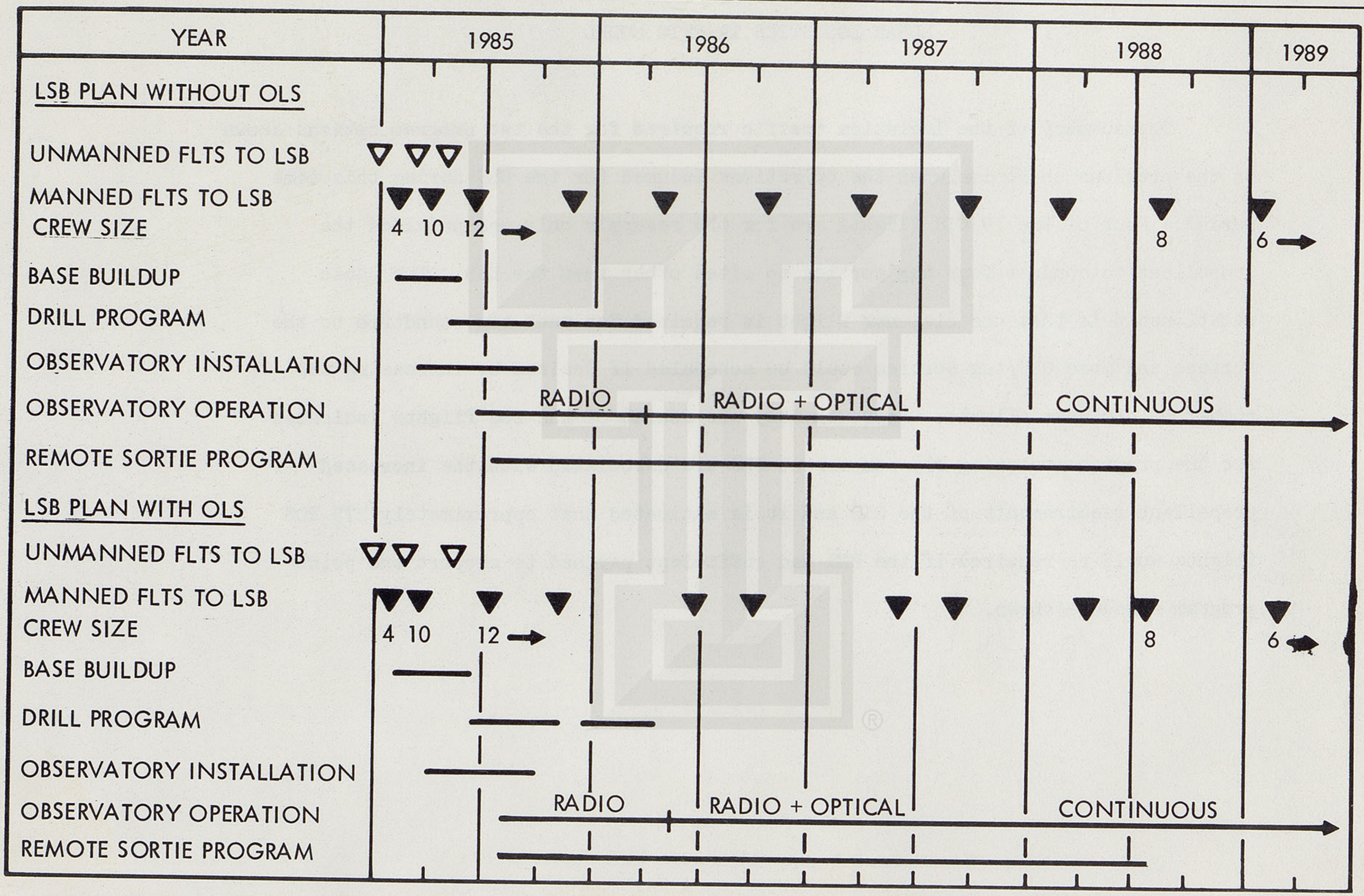


LUNAR PROGRAM SUMMARY

This chart summarizes the LSB operational program for the two optional programs, i.e., with a concurrent Orbiting Lunar Station (OLS) and without the OLS. The principal differences between the options are found in the interfaces with the cislunar shuttle. If there is no concurrent OLS resupply requirement, the cislunar shuttle needs only to meet the needs of the LSB. Consideration of crew staytime and the logistics costs led to the selection of the nominal LSB resupply interval as six sidereal months (164 days) as indicated for the no-OLS option. The resulting 328-day crew staytime was felt to be a maximum allowable even though a longer interval might be desirable to lower logistics costs. The cislunar shuttle is somewhat inefficiently utilized at this interval in the sense that, utilizing for example the characteristics of the reusable nuclear shuttle for the cislunar flight, it would be operating off-loaded.

If there is a concurrent OLS, the cislunar shuttle must support both operations. Based on the results of the study of the OLS which was conducted by North American Rockwell for the Manned Spacecraft Center concurrently with this study, resupply flights are required to the OLS at four sidereal month intervals (109 days). When these requirements are integrated with those of the LSB, a cislunar flight is scheduled every 109 days with every third one supporting only the OLS. The LSB crew staytimes remain as before and the only impact is the somewhat minor one of adapting the warehousing to alternating four and eight sidereal month resupply intervals. The high cislunar payloads required for the flights which support both the OLS and the LSB led to the identification of the Chemical Interorbital Shuttle (CIS), as it is presently sized, as the cislunar shuttle for this program option.

LUNAR PROGRAM SUMMARY



LUNAR LOGISTICS TRAFFIC MODEL

The summary of the logistics traffic required for the two program options shown on the previous chart includes the operations assumed for the OLS during this time period. Four of the 19 CIS flights are for OLS resupply only and provided the propellant to conduct four tug sorties to sites other than the LSB. The basic relationship is that one cislunar flight is required for each tug roundtrip to the surface and more OLS/tug sorties could be scheduled if desired by increasing the number of cislunar flights. Approximately one-fourth of the EOS flights indicated for the program including the concurrent OLS are associated with the increased propellant requirements of the CIS and it is estimated that approximately 275 EOS flights would be required if the RNS had sufficient payload to support the joint program schedule shown.

LUNAR LOGISTICS TRAFFIC MODEL

LSB PROGRAM YEAR	WITHOUT OLS				INCLUDING OLS			
	EOS	EOT	RNS	TUG	EOS	EOT	CIS	TUG
1	98	7	7	7	137	9	7	7
2	28	2	2	2	59	5	3	3
3	28	2	2	2	78	6	4	4
4	28	2	2	2	59	5	3	3
5*	14	1	1	1	20	2	1	1
TOTALS	196	14	14	14	353	27	18	18

*TO COMPLETION OF PHASE-DOWN TO OBSERVATORY OPERATIONS ONLY

OLS CONSIDERATIONS

The LSB program of surface missions and logistics missions was separately defined under two program models. One included an OLS in a 60-nautical mile polar orbit and the other was based on an LSB alone for lunar exploration.

Based on the results of the seven LSB sites analyzed and the capability of the LSB concept, three potential operational interfaces were defined but the considerations listed revealed no primary role for the OLS. These considerations assumed that the experiment site requirements justified the use of an LSB initially and the OLS concept was examined for any functions, primary or secondary, which it could perform for the LSB.

A different type of interface results when the overall lunar exploration program accomplishment is considered. The distribution of experiment sites over the lunar surface and the duration of science time at each site are the governing factors in the utilization of a single fixed site shelter (LSB) or the use of manned tugs operating from an orbital base (OLS) as the most feasible model. The LSB is best suited to many closely spaced sites within the radius of action of the mobility systems with each requiring staytimes in excess of the manned tug capability for a single mission. The opposite is true for the OLS tugs.

OLS CONSIDERATIONS

POTENTIAL INTERFACES	CONSIDERATIONS
LOGISTICS WAY STATION	• MORE COMFORTABLE QUARTERS FOR ORBIT PHASING CREW LAYOVERS
	• POTENTIAL CISLUNAR PAYLOAD REDUCTION FOR OLS RENDEZVOUS
	• POLAR ORBIT CONSTRAINS CREW AND CARGO TRANSFER OPERATIONS
EMERGENCY OR RESCUE	• LSB AS SAFE FOR EMERGENCY WAIT - MULTIPLE REDUNDANCY
COMMUNICATIONS SUPPORT	• LOW ORBIT INEFFECTIVE DUE TO SHORT VIEWING TIMES
LUNAR EXPLORATION	• EXPLORATION SORTIES TO SITES UNFEASIBLE FROM LSB

EARTH ORBIT SPACE STATION INFLUENCES

While no direct operational interface with the EOSS is visualized at this time because of the differences in earth orbits utilized, significant cost savings to the LSB program are anticipated from utilizing the subsystems and technological know-how developed for the EOSS.

EARTH ORBIT SPACE STATION INFLUENCES

- NO DIRECT OPERATIONAL INTERFACE - DIFFERENT ORBITS

- PRINCIPAL SOURCE OF SUBSYSTEMS AND TECHNOLOGY

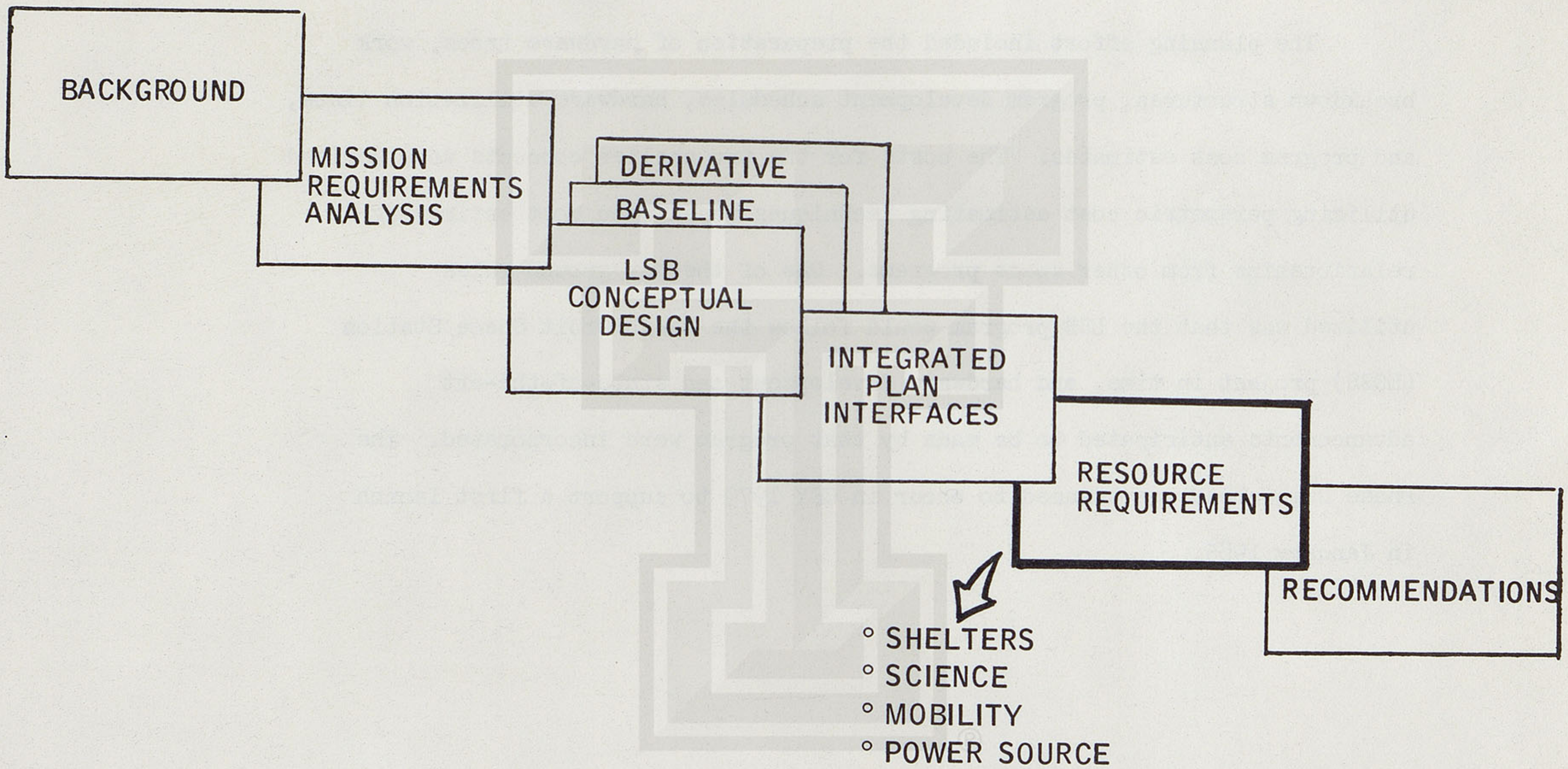
  ATMOSPHERIC MANAGEMENT
  CREW SYSTEMS
  COMMUNICATIONS
  DATA MANAGEMENT
  STRUCTURAL TECHNOLOGY

- MAJOR COST SAVINGS RESULTING FROM ADVANCED STATE OF DEVELOPMENT

PRESENTATION OUTLINE

The next section of the presentation presents the summary of the development planning and cost estimation efforts for the various elements of the Lunar Surface Base Program.

PRESENTATION OUTLINE



LSB SHELTER DEVELOPMENT PLANNING

The planning effort included the preparation of hardware trees, work breakdown structures, program development schedules, hardware utilization lists, and program cost estimates. The costs for the two shelter concepts were derived utilizing parametric cost estimating techniques based upon cost estimating relationships from other space programs. One of the key ground rules utilized was that the LSB program would follow the Earth Orbit Space Station (EOSS) project in time, and hardware development and state-of-the-art advancements anticipated to be made by that program were incorporated. The Phase D go-ahead was assumed to occur in GFY 1979 to support a first launch in January 1985.

LSB SHELTER DEVELOPMENT PLANNING

PLANNING DATA PREPARED

- HARDWARE TREES
- WORK BREAKDOWN STRUCTURES
- PROGRAM DEVELOPMENT SCHEDULES
- HARDWARE UTILIZATION LISTS
- PROGRAM COST ESTIMATES

APPROACH FOR OPTIMIZED BASELINE AND MSS DERIVATIVE

- PARAMETRIC COST ESTIMATING METHODS
- CONTRACTOR COSTS ONLY - PHASES C AND D UP TO FIRST LAUNCH
- BASICALLY SINGLE PRODUCTION LINE
- LSB PROGRAM FOLLOWS EOSS IN TIME

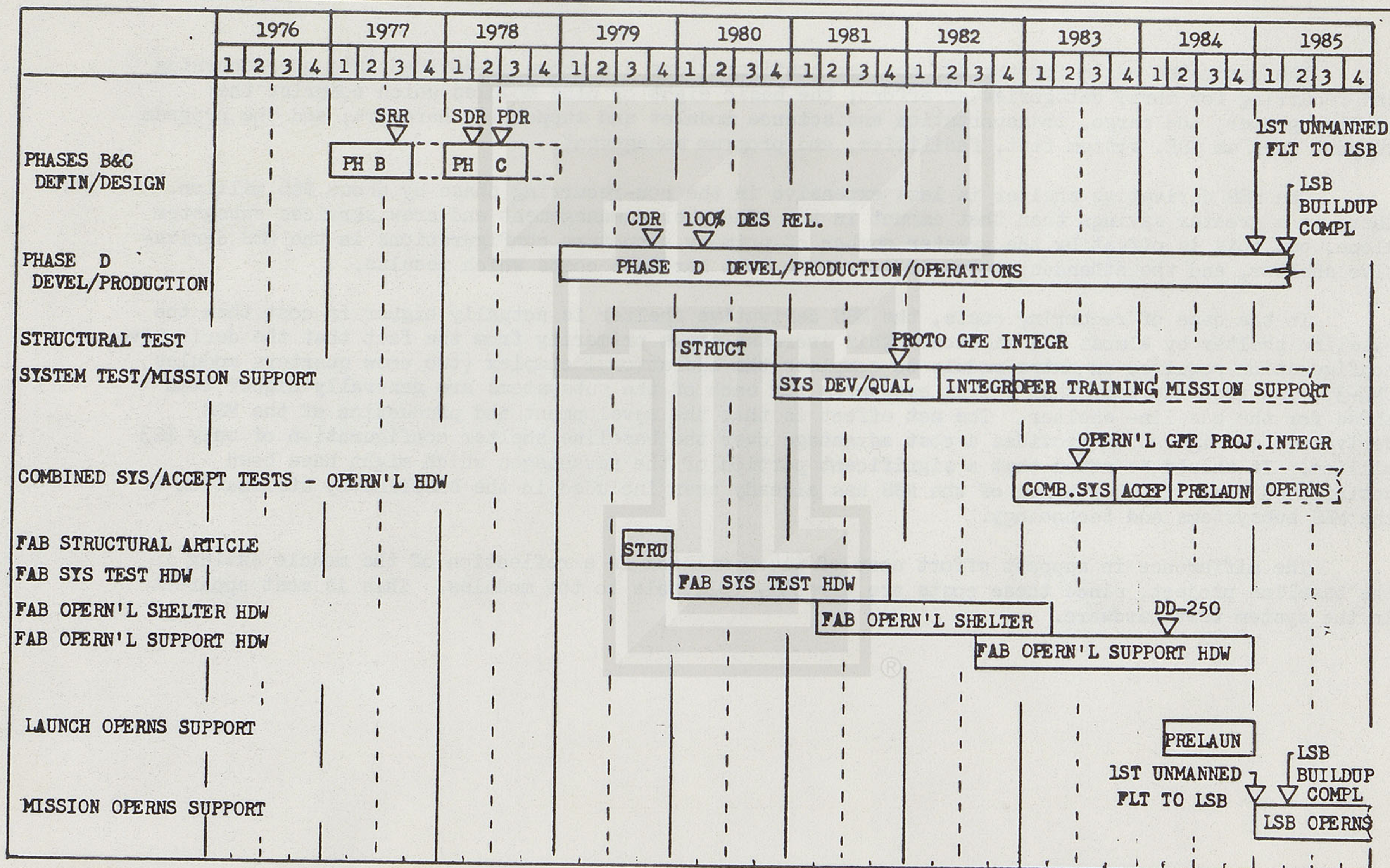
BASELINE SHELTER CONFIGURATION SUMMARY PROGRAM SCHEDULE

The program schedule covers an integrated set of activities and major program milestones for the definition, design, development and production of the baseline LSB. The schedule is based on an analysis of the technical configuration and subsystems described in the technical portion of the final report and shows an orderly evolution of events leading to the LSB buildup on the lunar surface.

The schedule is based on the fabrication of one structural test article of a typical module (Crew and Medical Module), one dynamic test article of a typical module (Crew and Medical Module), and one full-up system test hardware of each of seven shelter modules (Crew and Medical, Crew and Operations, Sortie and Transient Crew, Lab and Backup Command Post, Assembly and Recreation, Base Maintenance, and Drive-In Garage). Included in the system test hardware will be one typical support module (Mobile Cargo Module) with prototype kits of specialized furnishings of the other support modules. The fabrication time spans for the test hardware and the operational hardware are based on the use of one set of structural fabrication tooling and one manufacturing checkout and test station.

A similar schedule was prepared for the MSS derivative shelter LSB which was six-months longer because of the additional module and structural configurations.

BASELINE SHELTER CONFIGURATION SUMMARY PROGRAM SCHEDULE



SHELTER COST ESTIMATES

The estimated costs for the two shelter configurations are shown subdivided into non-recurring and recurring for three categories of effort; the basic eight or nine modules which comprise the shelter proper; the cargo, transportation and science modules and supporting hardware; and the program support such as GSE, system test, facilities, and program management.

The MSS derivative shelter is less expensive in the non-recurring phase by about $66 million. There is a greater savings than that amount in the atmospheric management and crew services subsystem alone, but this is offset by the greater number of primary structure configurations in the MSS derivative shelter, and the attendant increase in system test hardware costs which results.

In the case of recurring costs, the MSS derivative shelter is actually higher in cost than the baseline shelter by almost $33 million. This increase stems primarily from the fact that the derivative configuration requires an extra module to complete the operational complex (two crew quarters modules CMQ-3), and from the fact that weight estimates for each of the subsystems are generally higher than those for the baseline shelter. The net effect is that the development and production of the MSS derivative configuration provides a cost advantage over the baseline shelter configuration of only $23 million. It should be noted that a significant portion of the advantages which might have been anticipated from the adaptation of the MSS has already been included in the baseline by utilization of the MSS subsystems and technology.

The difference in support effort cost of $14.9 million is a reflection of the module saving in the baseline project, since these costs are directly relatable to the modules. This is most apparent in the system test hardware.

SHELTER COST ESTIMATES

	OPTIMIZED BASELINE SHELTER		MSS DERIVATIVE SHELTER	
	NR	R	NR	R
• BASIC SHELTER MODULES	230.6	108.2	164.7	141.7
• SUPPORT MODULES AND EQUIPMENT	114.3	92.2	117.0	93.0
• SUPPORT EFFORT	299.2	31.5	310.3	35.1
SUB-TOTALS	644.1	231.9	592.0	269.2
TOTALS	876.0		861.2	

(ALL COSTS IN MILLIONS OF DOLLARS)

SCIENCE, MOBILITY, AND POWER COST ESTIMATES

The basic approach followed in preparing the cost estimates for the LSB mobility elements and scientific equipment was to depend heavily on prior studies of candidate concepts. Sources utilized included the following:

- Scientific Mission Support for Extended Lunar Exploration (ELE)
- Mission Modes and Systems Analysis (MIMOSA)
- Lunar Surface Mobility System Comparison and Evolution Study
- Space Probes and Planetary Exploration
- Research Program on Radio Astronomy and Plasma for AAP Lunar Surface Missions
- Study of One-Man Lunar Flying Vehicle
- Candidate Experiments Program for Manned Space Station
- Garrett, Sundstrand, Aerojet (Nuclear Power Systems)
- International Latex Corporation (Expandable Shelter)

Applicable cost data was correlated and updated to 1970 dollars. In some instances, potential suppliers were contacted as indicated.

SCIENCE, MOBILITY AND POWER COST ESTIMATES

APPROACH

- REVIEW PRIOR STUDIES FOR APPLICABLE COST DATA, CORRELATE, UPDATE, AND SUPPLEMENT AS APPROPRIATE
- SCIENCE EQUIPMENT AS DEFINED IN MISSION ANALYSIS
- MOBILITY ELEMENTS AS DEFINED IN CONCEPT DESIGN

  MULTI-PURPOSE PRIME MOVER W/ATTACHMENTS

  MOBILE SHELTER

  UTILITY POWERED TRAILERS

  FLYER
- MODULAR ELECTRICAL POWER SOURCE SYSTEMS
- ISOTOPE FUEL COSTS NOT INCLUDED

Space Division
North American Rockwell

SCIENTIFIC EQUIPMENT COST ESTIMATES

The chart indicates the cost by discipline for both non-recurring and first unit recurring. Approximately 83 percent of the scientific equipment costs are in one discipline, Astronomy and, as a further example of the disparity, just ten elements of equipment compromise almost 87 percent of the total. This is further illustrated on the following chart.

SCIENTIFIC EQUIPMENT COST ESTIMATES

	NON-RECURRING (MILLIONS)	RECURRING (MILLIONS)
1. ASTRONOMY	$ 630.0	$ 60.6
2. GEOLOGY/GEOCHEMISTRY	81.9	12.9
3. BIOMEDICAL	16.1	4.7
4. GEODESY AND GEOPHYSICS	10.2	2.3
5. LUNAR ATMOSPHERE	7.1	2.1
6. ENGINEERING TECHNOLOGY	4.3	.8
TOTAL	$ 749.6	$ 83.4

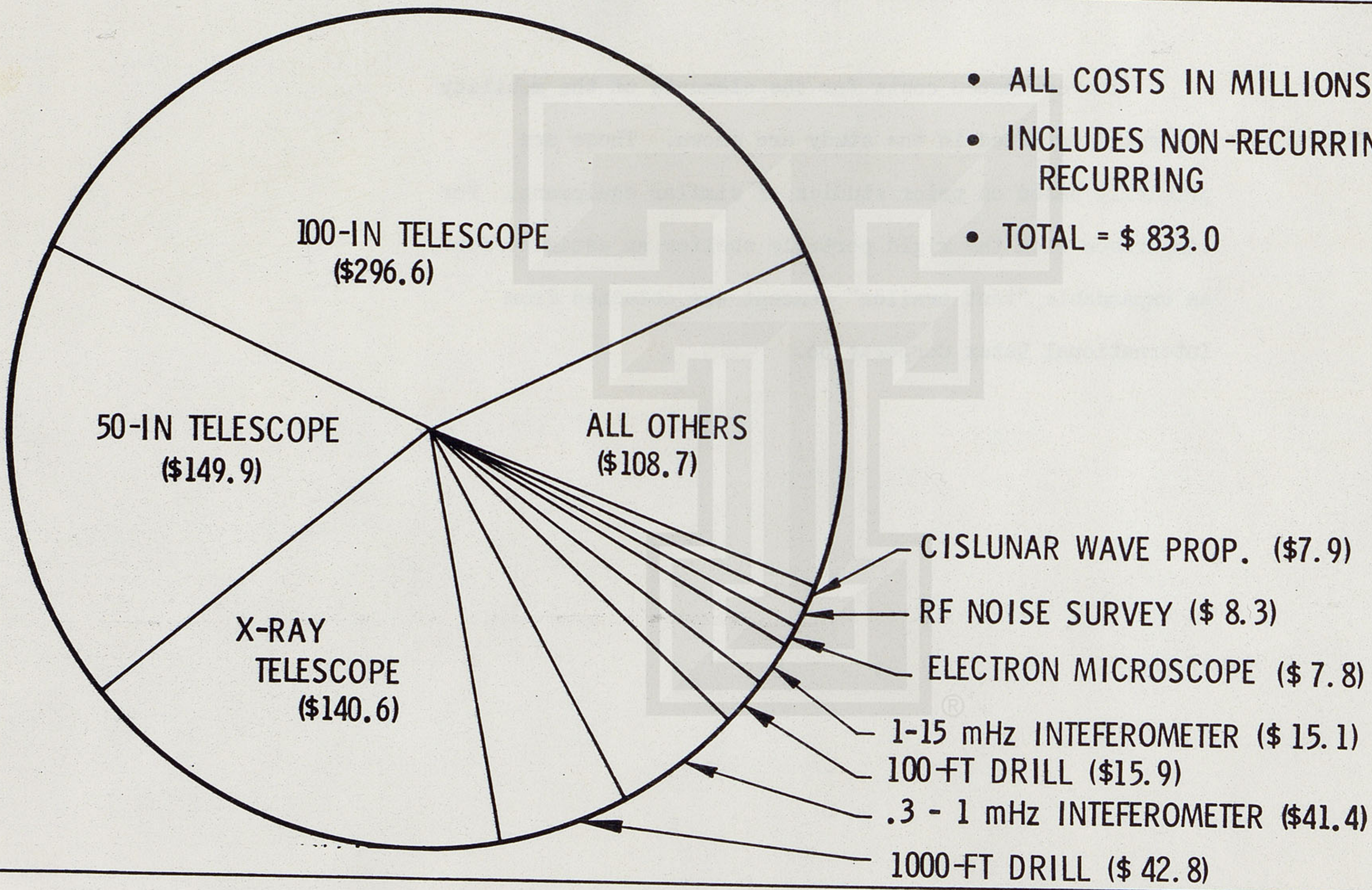
10 ELEMENTS OF SCIENTIFIC EQUIPMENT ARE MAJOR COST DRIVERS

- 7 ASTRONOMY
- 2 GEOLOGY/GEOCHEMISTRY
- 1 BIOSCIENCE

SCIENTIFIC EQUIPMENT COSTS DISTRIBUTION

After researching the applicable reference data and updating the costs for each piece of equipment, the equipment lists were examined for major cost drivers. The criteria for the major cost drivers was that the development cost would exceed five million dollars. This criteria separated a majority of the smaller supporting items and allowed concentration on the major equipments. These major cost drivers are shown in relationship to the total equipment costs. The costs shown include the non-recurring and recurring costs. The "All Others" category includes approximately 120 items.

SCIENTIFIC EQUIPMENT COSTS DISTRIBUTION



- ALL COSTS IN MILLIONS
- INCLUDES NON-RECURRING AND RECURRING
- TOTAL = $ 833.0

Space Division
North American Rockwell

MOBILITY EQUIPMENT COST ESTIMATES

The estimated costs for the elements of the mobility concept identified in the study are shown. These are primarily based on prior studies of similar equipment. For comparison with the rigid portable shelter an estimate for an expandable "tent trailer" concept was obtained from International Latex Corporation.

MOBILITY EQUIPMENT COST ESTIMATES

	NON-RECURRING (MILLIONS)	1ST UNIT RECURRING (MILLIONS)	NUMBER REQ'D	TOTAL RECURRING (MILLIONS)
• PRIME MOVER	$ 221.4	18.6	4	$ 71.7
• POWERED TRAILERS	-	4.6	10	41.7
• APPENDAGES				
SKIPLOADER/BACKHOE	5.2	.9	1	.9
CRANE	2.2	.4	1	.4
• PORTABLE SHELTER				
RIGID	215.6	24.4	2	52.8
EXPANDABLE (REF)	(178.6)	(21.4)	2	(44.8)
• LUNAR FLYING VEHICLE	29.8	1.9	2	3.8
TOTALS	$ 474.2			$ 171.3

PROGRAM TOTAL $ 645.5

LSB POWER SYSTEM COST ESTIMATES
MODULAR 3.5 KWE NUCLEAR

The electrical power system concept for the LSB which was evolved during the study involves use of a number of mobile modular power units which can be utilized at the widely dispersed activities when required and grouped at the main shelter when the crews are all localized. The estimated costs for this power system are indicated assuming selection of the Organic Rankine conversion cycle and a Polonium 210 heat source. For reference Brayton cycle and Plutonium 238 fuel system costs are shown but not included in the totals. The Pu 238 system would offer significant cost savings even though the isotope itself is considerably more expensive. Availability of sufficient quantities to meet the LSB requirements is considered marginal at this time.

LSB POWER SYSTEM COST ESTIMATES
MODULAR 3.5 KWE NUCLEAR

	NON-RECURRING (MILLIONS)	1ST UNIT RECURRING (MILLIONS)	NUMBER REQ'D	TOTAL RECURRING (MILLIONS)
ORGANIC RANKINE	$ 54.7	$ 8.9	6	$ 52.1
BRAYTON CYCLE (REF)	(62.6)	(10.3)	(6)	(60.4)
FUEL SUBSYSTEM (W/O ISOTOPE)				
PO 210	42.0	2.0	54	42.4
PU 238 (REF)	(44.8)	(2.4)	(6)	(9.5)
TOTALS	$ 96.7			$ 94.5

PROGRAM TOTAL $ 191.2

PROGRAM COSTS

The summary cost estimates for the two shelter options and the science, mobility, and power source equipments are shown. The cost savings from utilizing the MSS modules is a small percentage of the total cost and the two program options can be considered essentially equivalent in cost. This result stems basically from two factors: (1) the baseline shelter estimates assumed utilization of space station technology and subsystems and incorporated the cost savings resulting from the advanced state of development, and (2) the shelter configuration utilizing the MSS modules involves more structural configurations and one more module than the baseline configuration which was able to standardize on one basic structure. It should also be noted that the shelter costs represent only about one-third of the total. Another third is attributable to the science equipment cost, about one-fourth to the mobility, and the remainder to the power source.

When the costs are accumulated at the WBS level 5, the elements shown represent items over $100 million. Most of these elements are associated with the science, mobility, and power sources.

PROGRAM COSTS

	OPTIMIZED BASELINE	MSS DERIVATIVE
SHELTER PROJECT	$ 876.0 M	$ 861.2 M
LSB SCIENCE EQUIPMENT	833.0	833.0
MOBILITY EQUIPMENT	645.5	645.5
POWER SOURCE	191.2	191.2
TOTAL	$2545.7 M	$2530.9 M

MAIN ELEMENTS

100-INCH TELESCOPE	$ 296.6 M
PRIME MOVERS	293.1
MOBILE SHELTERS	268.4
MODULAR POWER SOURCES	191.2
DERIVATIVE SYSTEM TEST	162.3
50-INCH TELESCOPE	149.9
X-RAY TELESCOPE	140.6
BASELINE SYSTEM TEST	140.4
BASELINE A&CS	136.8
DERIVATIVE STRUCTURE	123.3
BASELINE STRUCTURE	104.0

PRESENTATION OUTLINE

The last section of the briefing summarizes the recommendations which were derived during the study in several categories; i.e., recommendations relative to the overall lunar exploration program, the course of the integrated plan, and potential supporting studies.