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On

PRELIMINARY ESTIMATE OF DEVELOPMENT COSTS AND SCHEDULE FOR MOLAB

Prepared under contract No. NAS 8-11096 by
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J. A. Young

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Huntsville, Alabama

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Huntsville, Alabama

December 1964

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For

SYSTEMS CONCEPT PLANNING OFFICE
AERO-ASTRODYNAMICS LABORATORY

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ACKNOWLEDGEMENTS

The assistance of Mr. O. D. Myers in making the final tally and verifying all of the cost estimating sheets is gratefully acknowledged. Similarily appreciated is the effort extended by Mr. D. Drier in finalizing all of the figures and cost data sheets.

PREFACE

This report was prepared by Northrop Space Laboratories, Huntsville Department for George C. Marshall Space Flight Center, under authorization of Task Order N-27 extension, NAS8-11096. The NASA Technical Representative was Mr. Norman Levine of the Marshall Space Flight Center, Aero-Astrodynamics Laborator (R-AERO-S). The work was completed as a ten man-week effort from 10 August to 16 October 1964.

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SUMMARY

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The AES/MOLAB Development Project was estimated to cost $291,660,000 dollars based upon certain assumptions and a preliminary schedule. The confidence level in the total Development cost, if the assumptions are valid, is minus 15%, plus 30% of the quoted figure. For comparison, it was "guesstimated" that the operational phase of AES will cost at least 300 Million dollars additional.

Costs were estimated using a matrix type format of hardware end items against project functions. Costs were accrued starting at the major component level (5) and accumulated up through the manufacture and test of complete MOLAB prototypes (level 3). By performing the cost estimate in a matrix type fashion, it was the intent that any item or function could be readily revised (with new information, etc.) without the necessity of recalculating any of the other cost elements.

It was concluded that this cost estimate can and will be significantly improved when the AES/MOLAB project becomes better defined. It was also concluded that the accuracy of cost estimates in general for major projects can be greatly improved over the poor record to date. This can be done by a more systematic method of recording estimated and actual costs with subsequent analysis for discrepancy determinations and tabulating for computer analysis and recall.

author

1.0 INTRODUCTION

Task Order N-27 (Contract NAS8-11096) was initiated in May 1964, to prepare a preliminary cost estimate of the MOLAB Development Project. The initial three man-week effort was subsequently extended for three days to review and revise the original estimate.

This current report presents the results of an additional ten man-week extension to the original costing efforts. The objective of this second task extension was to prepare a more comprehensive estimate than was possible during the brief time allocated for the previous efforts. A much more comprehensive estimate was achieved in terms of identifying and assigning costs to individual project elements, and in the cost estimate organization and format. However, basic data utilized in preparation of estimates could not be refined due to limitations of time and project definition status. As in the original efforts, the principal categories of this cost estimate were also compared and weighed against other similar space project costs, such as LEM.

It should be noted that this cost estimate is limited to the Development Project portion only. Except as noted in the Exclusions (3.3), the Development Project includes all the effort up to the manufacture of the first operational hardware systems. This means that the total cost of the MOLAB Project will be approximately double the cost of the Development Project. Section 3.0, Cost Estimate Guidelines, briefly summarizes the project elements included in the Development Project Estimate.

As mentioned above, this current extension was intended as a ten man-week effort. Due to the comprehensive effort required, and the desire to obtain a creditable level of task performance, this report represents twenty-two man-weeks of work.

2.0 MOLAB DEVELOPMENT PROJECT

2.1 General

The MOLAB Project is one of the major subdivisions of the total Apollo Experiments Support (AES) Project, as illustrated in Figure 1. The MOLAB Project is being studied by NASA as the initial means of carrying out manned scientific exploration of the lunar surface. The Mobile Laboratory payload is currently projected to provide shelter and transportation for a two man crew for approximately a two week stay on the Moon. The basic hardware subsystems of the MOLAB, as presently identified, are shown at the bottom of Figure 1. For more detailed information on the various subsystems and their principal components, reference is made to Appendix A.

2.2 Cost Approach

The approach taken for costing the MOLAB Development Project was one of estimating the effort required for the various hardware end items against the basic operations or functions (e.g., Design, Manufacturing and Test). In brief, such estimates were performed for each level of hardware breakdown as identified in Figure 1. Level 3 identifies the total system (i.e., MOLAB); Level 4 identifies the various subsystems; and Level 5 identifies the major components of each subsystem. Additional levels of increasing detail also can be identified (at least through 7) as required. For this cost estimate, however, Level 5 was the basic level for accumulating costs. Thus in estimating Level 5 costs, all accrued costs up to and including the 5 level (i.e., from 6 and 7) were included and are shown as being incurred at Level 5. At levels 4 and 3 the additional costs (plus the accumulative totals) incurred for the work performed at each of these levels are estimated in turn. Total Project Management/Integration and Other Direct Cost (ODC) were added to the accumulated totals at level 3 to obtain the total development costs.

Figure 2 and Table 2.1, along with Appendix B Detail Cost Sheets illustrate and clarify the overall cost approach described above including the methodology, format and mechanics utilized to estimate and accrue costs.

In order to increase the level of confidence in the estimate for the MOLAB Development Project, the costs were compared with those of similar existing space programs (LEM in particular), and adjusted

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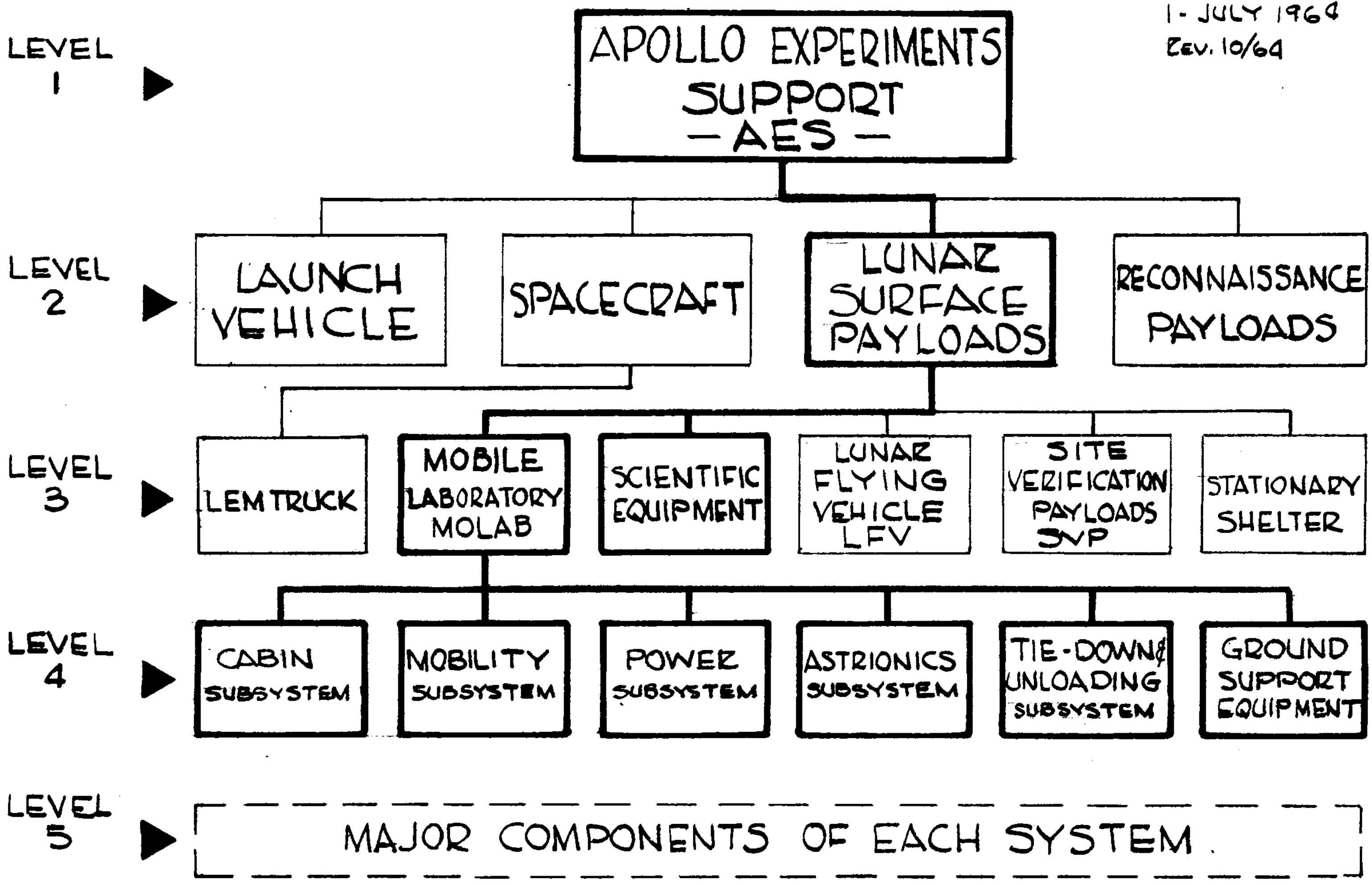

FIGURE 1. APOLLO EXPERIMENTS SUPPORT - BLOCK DIAGRAM OF HARDWARE ITEMS VERSUS LEVELS

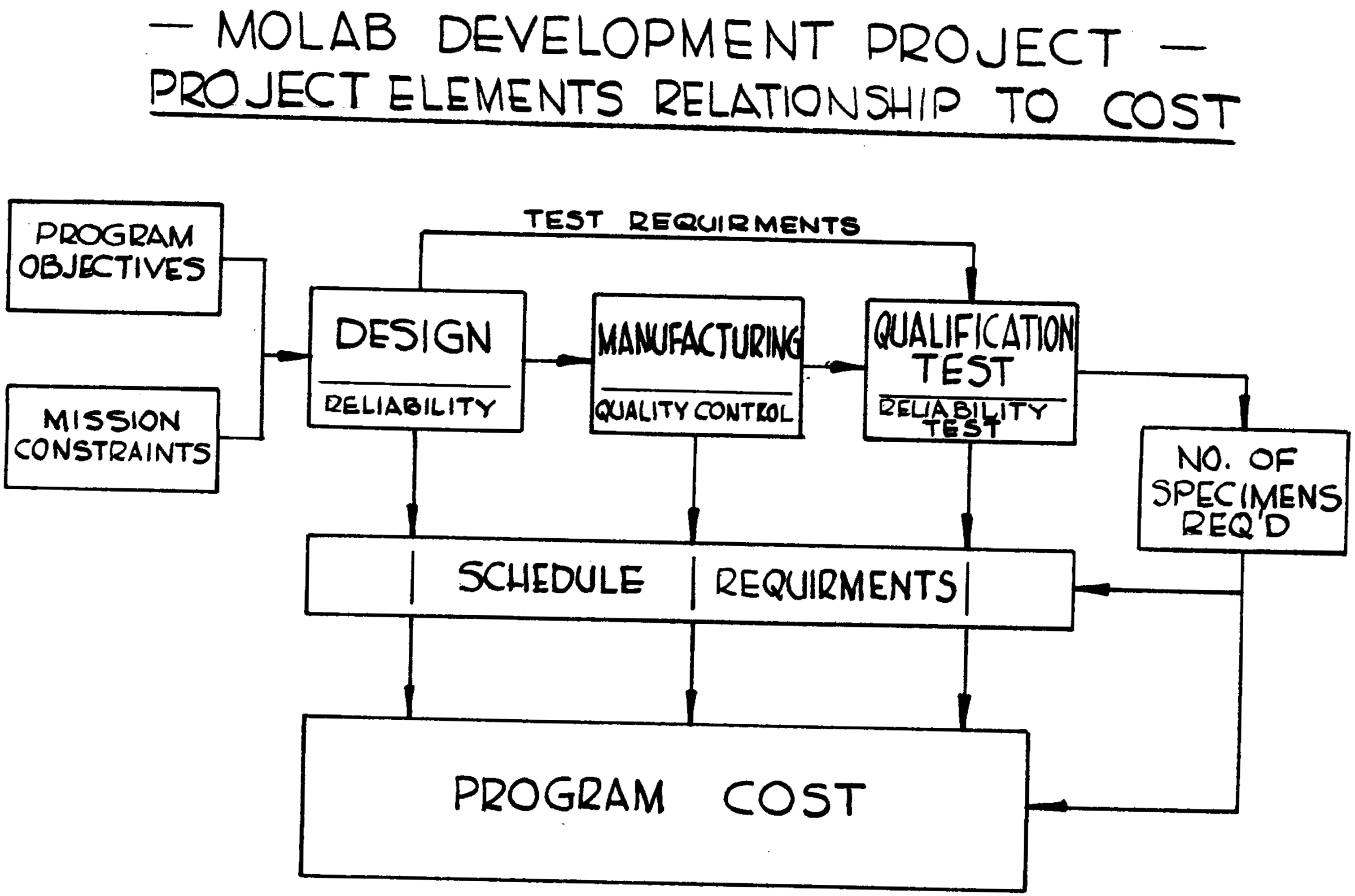

FIGURE 2. PROJECT ELEMENTS RELATIONSHIP TO COST

TABLE 2.1

METHODOLOGY OF COST ESTIMATES

LEVEL	END ITEM	FUNCTIONS				END ITEM SUBTOTALS
		DESIGN & ENGR.	MANUF.	TEST	PROJ. ADM.	
5	Major Components of MOLAB & GSE	Cost estimates (in Man-Weeks) of each end item at Level 5 (and below) for each appropriate function.				X X X X X X X X X X X X
	FUNCTION SUBTOTALS	X X X	X X X	X X X		Level 5 Subtotals
4	Each MOLAB System and GSE	Additional estimated costs (above level 5) to integrate components into major sub-assemblies; e. g., Cabin System, Mobility System, etc; plus accumulated subtotals of Level 4 + Level 5 costs.				X X X X X X X X X X X X
	FUNCTION SUBTOTALS	X X X	X X X	X X X		Level 4 subtotal; plus S/T of L 4 + 5
3	MOLAB Vehicle and GSE	Additional estimated costs incurred above all previous levels to integrate the various systems into complete MOLAB Vehicles (prototypes); plus accumulated subtotals for all levels of costs to give grand total.				X X X X X X
	FUNCTION SUBTOTALS	X X X	X X X	X X X	X X X	Level 3 Subtotals; plus Grand Total

See next page for applicable footnotes.

FOOTNOTES FOR TABLE 2. 1

(1) Costs for Project Administration are estimated only at Level 3 for the total program.

(2) Scientific Equipment is identified as a Level 3 item (ref. Fig. 2), same as MOLAB. Cost estimates were similarly developed (as shown above) for it, starting at Level 4, and combined with MOLAB costs in the summary tables.

(3) On actual Summary Cost Sheets, Level 3 totals are prorated and presented versus three different breakdowns: (1) Subsystem End Items; (2) Project Functions, and (3) Prototype Test Articles.

where appropriate. Another type of comparison was devised and utilized to provide a more direct check of specific elements of the MOLAB Project. This comparison involved establishing a relative rank-order cost rating factor for each MOLAB subsystem. This factor was obtained by assigning relative ratings (1 through 10) to each subsystem, and its major components, against three criteria that will significantly affect the subsystem costs. These ratings were obtained by independently enlisting the assistance of seven knowledgeable personnel by giving them a prepared rating sheet and a set of instructions. The results from all the individuals querried were combined and weighed according to a point system. The resultant averages then were used as a guiding index for the relative costs among the various subsystems. The derived rating factors were also particularly useful in making cost prorations, as was necessary to proportion the Project Administrations costs as in Table 4.2.

The cost sensitive criteria against which each subsystem were ranked, on a scale of one through ten, were:

- Relative system complexity
- Requirement for new development beyond contributions that can be anticipated from Apollo
- Relative criticality of system to crew safety; that is, the requirement for reliability as pertains to crew safety.

The rating factors that resulted from performing this general analysis, and which were later utilized to "balance" some of the previously estimated subsystem costs, were as follows:

Subsystem	Combined Relative Cost Factor
Cabin	10
Mobility	7
Astrionics	8
Power	6
Tiedown and Unloading	3
Scientific Equipment	5

From experience, GSE costs were compared as a percentage of total project costs (9 to 10%).

2.3 Test Specimen Estimates

In estimating the total Development Project cost, it was necessary to define a preliminary program and schedule and corresponding test specimen requirements. While it was possible to identify most of the major system tests for the "complete" MOLAB, and thus identify the number of test specimens required, it was not possible to evaluate such requirements at the subsystem, component and part levels. Therefore, these test specimen requirements were approximated on the basis of past experience with similar projects, knowing that the number of components and subsystems would exceed that required for the major system tests.

The actual number of components or subsystems to be manufactured for the Development Project are not detailed in the information shown in the cost estimates in Section 4.0. There are three principal reasons for this. First, time precluded definition of a detailed test program to the single component level. Second, the number of test specimens required will vary from component to component, and even among complete subsystems. This means that an "equivalent" subsystem or assembly (etc.) might have ten of item A, four of item B and seven of item C for an average number of 7 for that assembly (A + B + C). Third, reuse of some components (etc.) in the next level of testing is not only possible, but desirable from a cost standpoint. It was assumed that about 25% of the components could be so reused without compromise to project objectives and schedule.

Therefore, the actual number of component or subsystem test specimens to be produced (not including MOLAB prototypes) will vary as a function of individual components, and thus all test specimens for Level 4 and below are shown (of necessity) in equivalent MOLABs. The total spectrum of variation in the number of test specimens required, from the above mentioned factors, was estimated to vary from 25% more to twice that of the four equivalent MOLABs shown in Section 4.0, Table 4.3 for cost purposes.

For comments on test philosophy and approach, entries 3.0 through 3.7 in Appendix C should be consulted.

3.0 COST ESTIMATE GUIDELINES

The important considerations and assumptions upon which the accompanying cost estimate were based are summarized below. For emphasis and clarity, the items which were excluded from the estimate because they are not generally considered as part of a Development Program are also summarized.

3.1 General Notes

3.1.1 Level 5 cost figures include not only Level 5 cost, but all costs accured at the preceding lower levels, which were not specifically estimated.

3.1.2 The level of confidence in the results of this estimate is based upon all assumptions (3.2) being valid. Secondly, it must be recognized that the quoted confidence factors are approximations within themselves. Nevertheless, confidence factors do serve a useful purpose as an all inclusive accuracy guide to the reader.

The confidence factors (in percent of the referenced figure) for this estimate have been approximated to be:

(a)	Total Cost	-15%, +30%
(b)	Any subtotal cost (e.g., for a MOLAB subsystem or function)	-25%, +50%
(c)	Scientific Equipment	-50%, +100%

3.1.3 The costs were estimated in man-weeks. The conversion to dollars was made using the following rates, which includes allowances for burden and indirect costs.

(a) Design/Engineering, and Testing Functions $680/M-W ($17.00/M-Hr.).

(b) Manufacturing Functions, $480/M-W ($12.00/M-Hr.).

(c) Project Administration, $800/M-W ($20.00/M-Hr.).

3.1.4 The cost estimate for the Scientific Equipment is more of an approximation than that estimated for the MOLAB subsystem. This results from the fact that the scientific objectives, and thus the equipment, are not well defined at this time. For these reasons the estimates for the Scientific Equipment were started at Level 4 instead of Level 5.

3.1.5 The estimates for GSE (7 sets) includes the cost of three sets that will actually end up as flight hardware support systems: two at the launch site, and one at the contractor's plant for flight acceptance tests.

3.1.6 One of the MOLAB prototypes costed as part of the Development Project costs, will be used primarily for crew training (not part of the Development Project costs).

3.2 Assumptions

3.2.1 That the MOLAB will be equivalent in complexity, etc., to the MSFC MOLAB VII concept; See Figure 3.

3.2.2 There will be considerable direct benefit in cost savings of of hardware and operational development resulting from the Apollo Project.

3.2.3 The reliability goals and requirements will be as stringent as those stipulated for Apollo.

3.2.4 There will be no major sterilization requirements for the MOLAB; only a few specialized instruments or equipment items will be sterilized.

3.2.5 That the MOLAB Development Project will be initiated no later than December 1965, and will not exceed five years duration; nor will it be greatly accelerated to meet a compressed schedule.

3.2.6 The necessary detailed information on the lunar environment and lunar surface will be available when needed and there will be no major changes to this basic data after the development project is ititiated.

3.2.7 The objective and scope of the AES/MOLAB project will not significantly change from its current conception. Changes in project scope or objectives can result in extensive changes to the estimated costs.

3.2.8 All facilities required for the Development Project will be available when required (but also see 3.3.6 under Exclusions).

3.2.9 The modified LEM-T will be sufficiently complete and available for tests with the MOLAB when required.

3.2.10 Although it does not apply directly to the Development Project estimate, it was assumed that five operational MOLAB's would be built.

GROSS WEIGHT : 6500-7000 LBS.
OVERALL LENGTH : 185"
OVERALL WIDTH : 150"
OVERALL HEIGHT : 106.5"
WHEEL BASE : 94"
WHEEL DIA. : 60"

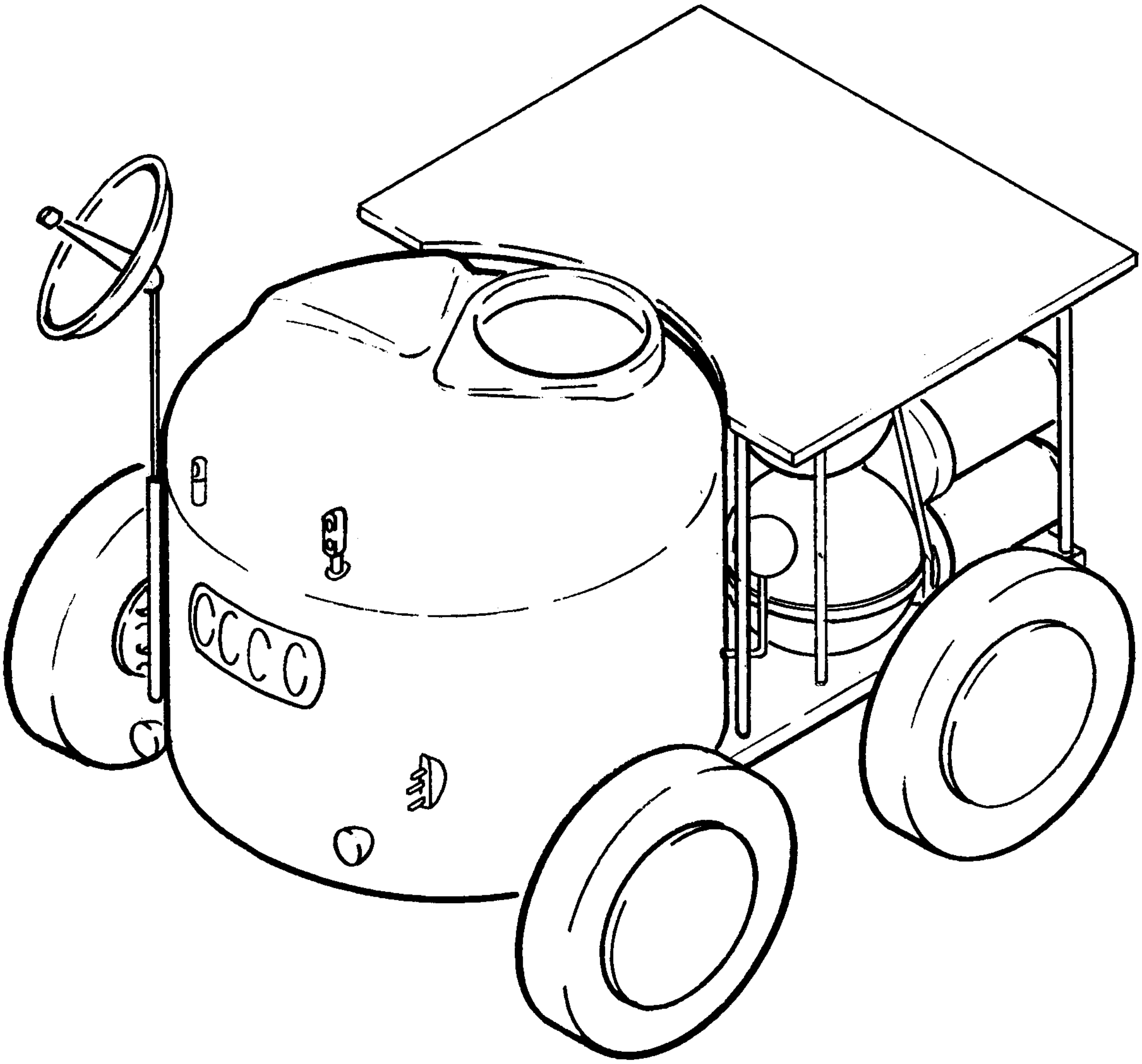

FIGURE 3. MOLAB - CONCEPT VII

3.3 Exclusions

The Development Program estimate does not include the costs of:

3.3.1 Operational or flight hardware costs of manufacture, acceptance tests, procurement, supporting design or project management, etc.

3.3.2 Launch and operations costs of operational hardware.

3.3.3 Crew training.

3.3.4 Mission simulations or practice missions.

3.3.5 LEM-Truck modifications to accommodate the MOLAB mission.

3.3.6 The acquisition of major new, or special purpose facilities (such as a Lunar Environmental Chamber).

3.3.7 Development of basic human factors equipment such as space suits.

4.0 COST ESTIMATE

The basis, approach and format utilized in performing the cost estimate have been described in Sections 2.0 and 3.0. This Section Summarizes the results obtained in performing the MOLAB Development Project Cost Estimate.

The results are presented in the following Tables and Figures:

- Table 4.1 Summary of Level 3 Costs by Function
- Table 4.2 Summary of Level 3 Costs by Subsystem
- Table 4.3 Summary of Level 3 Costs by Test Specimen End Items
- Figure 4 Preliminary Milestone Schedule
- Figure 5 Preliminary Development Schedule

The additional Tables presented in this Section (4.4 thru 4.7) contain pertinent supporting information that clarify the basis and assist in the interpretation of the data contained in the above listed summary Tables and Figures. The Appendices should be consulted for the more detailed supporting data.

TABLE 4.1

DEVELOPMENT PROJECT ESTIMATE IN MILLIONS OF DOLLARS

SUMMARY OF LEVEL 3 COSTS BY FUNCTIONS:

FUNCTION	MOLAB, w/GSE* & Special Test Equipment	SCIENTIFIC EQP w/GSE & Special Test Equipment	SUBTOTALS
DESIGN & ENGR.	$63.42	$ 8.69	$ 72.11
MANUFACTURING	91.36	13.06	104.42
TEST	53.55	5.58	59.13
PROJ. ADM (w/ODC)	27.80	4.10	31.90
PROCUREMENT	21.10	3.00	24.10
	$257.23	$34.43	

DEVELOPMENT PROJECT TOTAL $291.66 Million

APPROXIMATION OF COSTS FOR OPERATIONAL AES/MOLAB PROJECT:
(REF. ONLY)

5 MOLAB @ $27M	$135M
Launch & Operations (5)	50M
LEM-T Modification	65M
Crew Training	10M
Major Facilites	40M
Other Requirements (e.g. Simulated Missions)	10M
OPERATIONAL PROJECT	≈ $310M
DEVELOPMENT PROJECT	$291.66M
AES/MOLAB - GRAND TOTAL	> $600M

* w/GSE - with GSE

TABLE 4.2

DEVELOPMENT PROJECT ESTIMATE IN MILLIONS OF DOLLARS

SUMMARY OF LEVEL 3 COSTS BY SUBSYSTEMS:

SYSTEM	LABOR	PROCUREMENT	PROJ. ADM.		SUBTOTALS
			P.MGT	ODC	
CABIN	$53.80	$5.39	$3.33	$4.44	$66.96
MOBILITY	38.01	3.77	2.33	3.10	47.21
ASTRIONICS	43.28	4.30	2.67	3.55	53.80
POWER	32.08	3.23	2.00	2.66	39.97
TIE DOWN & UNLOADING	16.83	1.61	1.00	1.33	20.77
SCIENTIFIC EQP.	25.40	2.70	1.67	2.22	31.99
GSE	22.65	2.20	1.00	.60	26.45
SPEC. TEST & HANDLING	3.61	.90			4.51
	$235.66	$24.10	$14.00	$17.90	

DEVELOPMENT PROJECT TOTAL $291.66 Million

APPROXIMATION OF OPERATIONAL PHASE (Ref. Only) ≈ $310M

(For overall breakdown see bottom of Table 4.1)

APPROXIMATION OF TOTAL AES/MOLAB PROJECT > $600M

TABLE 4.3

DEVELOPMENT PROJECT ESTIMATE IN MILLIONS OF DOLLARS

SUMMARY OF LEVEL 3 COSTS BY TEST SPECIMEN END ITEMS:

TEST SPECIMEN	REF. TABLE	NO. REQ'D	EST. AVE. COST/ITEM	SUB-TOTAL
MOLAB PROTOTYPES *	4.4	4	$28.0M	$112.00
TEST ARTICLES	4.5	5	15.1M	75.50
EQUIVALENT MOLABS in Parts, Components, & Subsys. For (non-sys.) Qualification Tests	—	4	19.0M	76.00
HARD MOCK-UPS	4.6	6	0.26M	1.56
SOFT MOCK-UPS	4.6	2	0.07+	0.15
GSE**	4.7	7	3.78M	26.45

DEVELOPMENT PROJECT TOTAL $291.66 Million

APPROXIMATION OF OPERATIONAL PHASE (Ref. Only) ≈ $310M
(For overall breakdown see bottom of Table 4.1)

APPROXIMATION OF TOTAL AES/MOLAB PROJECT > $600M

** Includes 3 GSE sets that will also be used for the operational phase.

* All prototypes do not necessarily include complete Scientific Equipment installations.

TABLE 4.4

MOLAB PROTOTYPE

ACCOUNTIBILITY AND IDENTIFICATION

FOR SYSTEM TESTS

PROTO. NO.	IDENTIFICATION OF MOLAB SYSTEM TESTS
1	System Integration Functional Check-out. System Calibrations. Integrated System Overall Performance (ambient) Test. Mass Properties Determinations - MOLAB, and MOLAB plus LEM-T. MOLAB, and MOLAB plus LEM-T Dynamic Tests.
2	MOLAB Lunar Thermal Balance; also with LEM/T. Locomotion Performance in Simulated Lunar Environment. Dormant and Reactivation Performance Tests. Reliability Demonstration Test.
3.	Remote Control, Telecommunciations & Naviagation Field Tests. Integrated MOLAB Locomotion Field Tests. Landing and Unloading Tests. Pyrotechnics and Deployment Tests.
4	Overstress and Emergency Conditions Tests. Human Factors and Man/Machine Compatibility Tests (as req'd to qualify prototype, but not for crew training (per se).

No. 4 MOLAB will be subsequently used for Crew Training (cost of vehicle is part of Development Project cost).

TABLE 4.6

MOCK-UP ACCOUNTIBILITY AND JUSTIFICATION IN EQUIVALENT MOLABS

NO. REQ'D	TYPE	REQUIREMENT
2	SOFT	One mock-up of each subsystem for configuration, fit and size determinations; one "complete" MOLAB for integration and arrangement trade-offs.
2	HARD	Equivalent of one total MOLAB in sets of subsystems at two different stages of development for engineering and design development, and system analysis and integration: for prime contractor use.
2	HARD	For subcontractors; requirement similar to above for Prime contractor.
1	HARD	Mock-up required for Human Factor studies.
1	HARD	Mock-up complete MOLAB delivered to NASA for system evaluations.

Equivalent of 6 hard and 2 soft complete MOLAB Mock-ups required.

TABLE 4.5

MOLAB TEST ARTICLES *

ACCOUNTIBILITY AND IDENTIFICATION FOR MULTISUBSYSTEM AND SYSTEM TESTS

TEST ARTICLE	IDENTIFICATION AND USE
1	MOLAB Systems Matecheck and Compatibility Tests, including interfaces with GSE, LEM-T, CSM, and fairing.
2	Vehicle Mobility Tests. Locomotion Dynamics Response For Simulated Lunar Gravity.
3	Locomotion Performance in Lunar Environment. Seal Integrity and Endurance Tests under Environmental and Operational Conditions.
4	Lunar Descent: Attitude Control and Retro-Firing Test with Lem-T (Includes thermal and condensation effects on critical surfaces).
5.	Shipping and Handling Tests. Initial Human Factors and Man/Machine Tests.

---

* Incomplete MOLAB Prototype

TABLE 4.7

GSE SYSTEMS ACCOUNTIBILITY AND REQUIREMENTS

GSE SETS	REQUIREMENTS
1	For GSE vendors' development and check out of their respective portions of GSE hardware.
1	MOLAB subsystem subcontractors for functional checkout and qualification testing.
2	Prime contractor for qualification and inspection testing (later for acceptance tests).
1	Prime contractor for compatibility and system integration testing.
2	NASA for Launch operations and check-out (one for primary use, one for backup especially during count down).
7	TOTAL

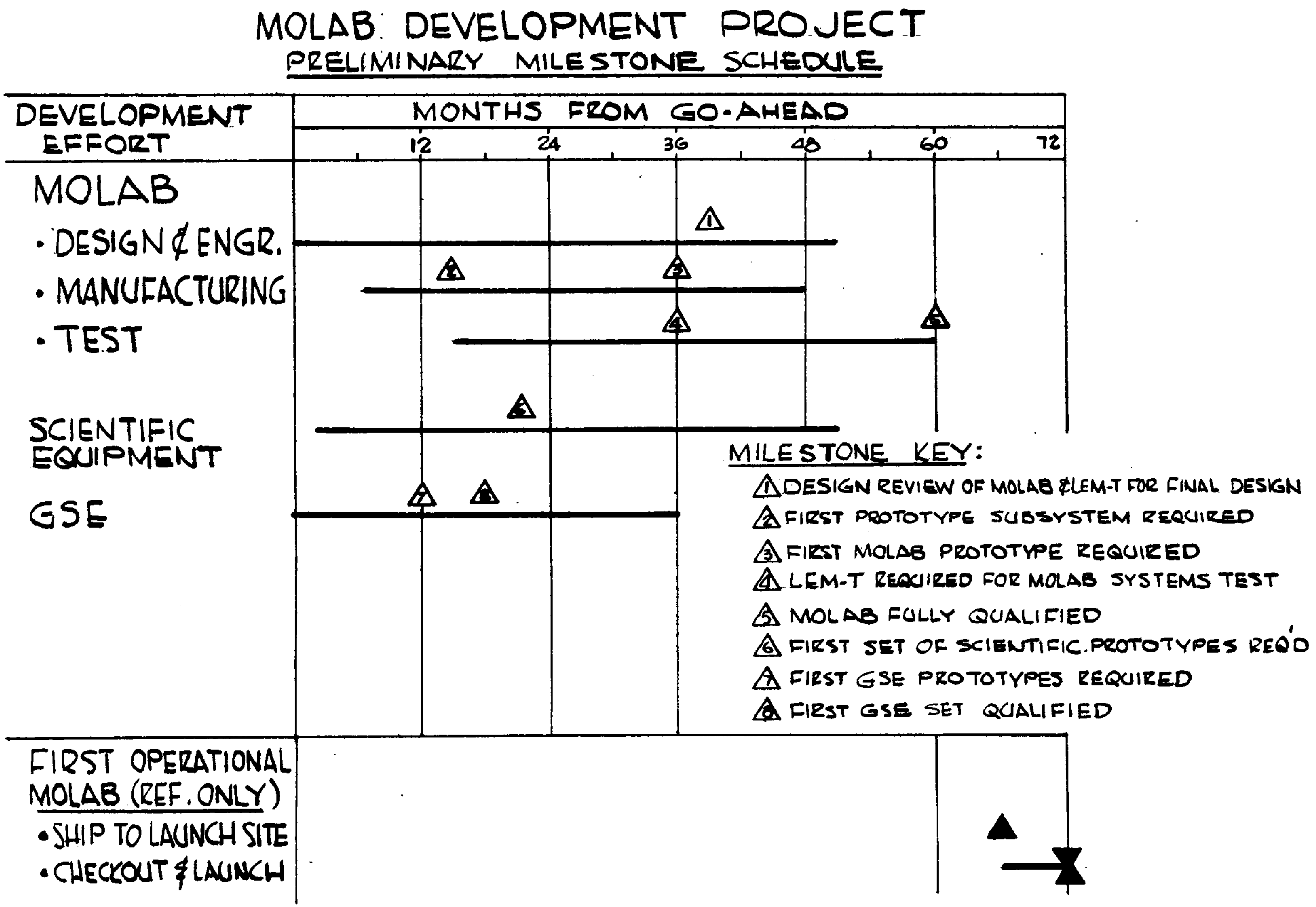

FIGURE 4. PRELIMINARY MILESTONE SCHEDULE

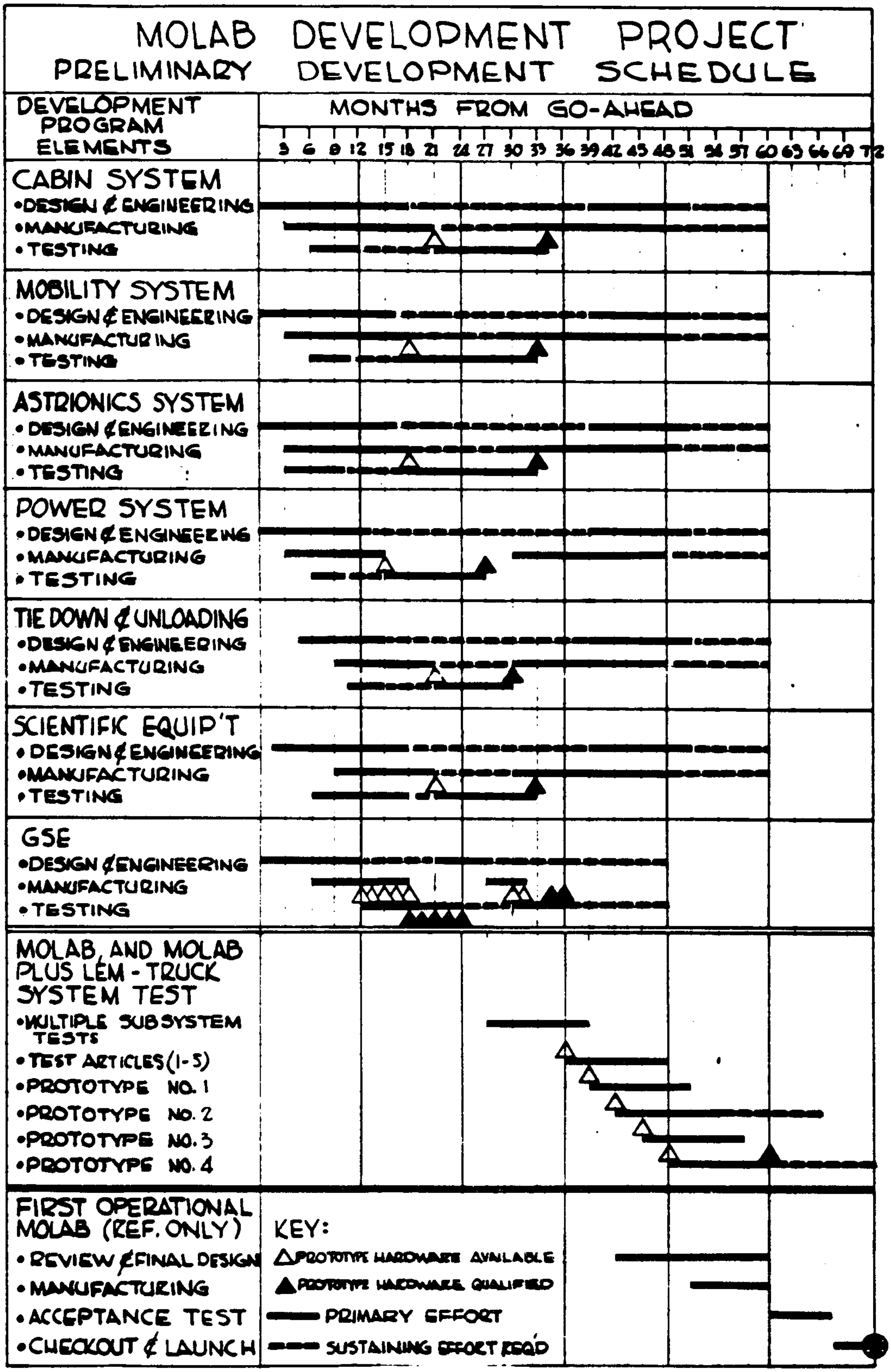

FIGURE 5. PRELIMINARY MOLAB DEVELOPMENT SCHEDULE

5.0 CONCLUSIONS AND COMMENTS

5.1 The total cost estimated for the Development Project appears valid based on the preliminary information currently available. The estimate also generally compares well with recent similar space projects, such as LEM.

5.2 A refined and more valid cost estimate for AES/MOLAB can be made when the project becomes better defined, which would allow a detail comprehensive cost analysis to be undertaken.

5.3 It is further concluded that cost estimating accuracy for national major projects can be, and should be, greatly improved over the current state-of-the-art. In general, this can be accomplished by establishing and maintaining a centralized cost recording and analysis effort for all major projects. With the proper system for computer handling and control, keeping of detail cost records, conducting comparisons, and analyses more accurate estimates could be readily accomplished. Even more important perhaps, the reasons for low estimates, overruns, delays, etc., could be easily traced (and probably predicted) and thus taken into account and/or remedied for any current project.

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APPENDIX A

MOLAB HARDWARE BREAKDOWN

1.0 CABIN SYSTEM

2.0 MOBILITY SYSTEM

3.0 ASTRIONICS SYSTEM

4.0 POWER SYSTEM

5.0 TIEDOWN AND UNLOADING SYSTEM

6.0 SCIENTIFIC EQUIPMENT

APPENDIX A

This appendix itemizes the MOLAB and Scientific Equipment hardware against which the estimated costs were identified. It is recognized that the list is not complete, or consistent as to levels of detail. However, with the limitation of current knowledge the list represents the best information that was readily available.

1.0 CABIN SYSTEMS

1.1 STRUCTURE

1.1.1. Crew cabin structure

1.1.2 Secondary structure for interconnecting all systems, partitions, decks, cabinets.

1.1.3 Shielding; meteoroid and radiation

1.1.4 Insulation

1.1.5 Door installations

1.1.6 Exterior coating; thermal and vacuum

1.2 AIRLOCKS

1.2.1 Door installations

1.3 DOCKING ADAPTER

1.3.1 Engaging and release mechanism

1.3.2 Hatch installation

1.4 VIEWING PORTS

1.4.1 Window installations

1.4.2 Shields

1.4.3 Viewports

1.4.4 Periscopes

1.5 CONTROLS AND DISPLAYS

1.5.1 Interior controls, ECS, Mobility.

1.5.2 Interior instruments and displays.

1.5.3 MOLAB checkout and monitoring systems

1.5.4 System status displays

1.5.5 Crew status monitoring panel

1.5.6 Navigation display

1.6 CREW SYSTEMS

1.6.1 Food storage and preparation facilities

1.6.2 Water storage

1.6.3 Sanitary provisions

1.6.4 Emergency medical supplies

1.6.5 Lighting (fixed and portable)

1.6.6 Crew chairs

1.6.7 Sleeping cots

1.6.8 Work tables

1.6.9 Backpack and spares

1.6.10 Space suits and maintenance kits

1.6.11 Waste water storage

1.6.12 Drinking water valve

1.7 ENVIRONMENTAL CONTROL SYSTEM (ECS)

1.7.1 Coolant pump
1.7.2 Coolant pump power supply
1.7.3 Water evaporator
1.7.4 Radiator
1.7.5 Equipment cold plates
1.7.6 Radiator by-pass temperature control valve
1.7.7 Coolant loop piping
1.7.8 Primary ECS O_2 heat exchanger
1.7.9 Secondary ECS O_2 heat exchanger
1.7.10 Temperature sensitivity and control instrumentation.
1.7.11 Cabin fans
1.7.12 Cabin heat exchanger
1.7.13 Suit compressors
1.7.14 Suit heat exchangers
1.7.15 CO_2 control
1.7.16 Odor control
1.7.17 Debris trap
1.7.18 Cabin pressure regulator
1.7.19 Cabin pressure relief
1.7.20 Primary O_2 supply
1.7.21 Secondary O_2 supply

1.7.22 Suit compressor power supplies

1.7.23 Cabin Fans power supplies

1.7.24 Cabin repressurization valve

1.7.25 Airlock pump and motor

1.7.26 Airlock pump motor power supply

1.7.27 Demand regulator and suit relief valve

1.7.28 Oxygen pressure regulators.

1.7.29 Suit and cabin temperature control valves

2.0 MOBILITY SYSTEMS

2.1 CHASSIS

2.2 DRIVE MECHANISM

2.2.1 Drive motors

2.2.2 Drive train

2.2.3 Winch Assembly

2.2.4 Leveling and stabilization jacks

2.3 WHEEL ASSEMBLIES

2.3.1 Wheels

2.3.2 Hubs

2.3.3 Brake mechanisms, actuators and locks

2.4 SUSPENSION ASSEMBLY

2.4.1 Springs and torsion bars

2.4.2 Dampers

Cabin mounts

2.5 STEERING MECHANISMS

2.5.1 Steering motors

2.5.2 Steering actuators

2.5.3 Linkage assembly

2.5.4 Feedback sensors

2.6 CRYOGENIC STORAGE

2.6.1 Oxygen storage container including fill, relief, and supply.

2.6.2 Hydrogen storage container including fill, relief and supply.

2.6.3 Reactant demand regulator and control.

3.0 ASTRIONICS

3.1 NAVIGATION & GUIDANCE

3.1.1 Optical transit

3.1.2 Sextant

3.1.3 IMU

3.1.4 Odometer

3.1.5 Tachometer

3.1.6 Vehicle Attitude Sensor

3.1.7 Navigation computer

3.1.8 Azimuth gyro

3.1.9 Navigation accessory equipment

3.2 COMMUNICATIONS

3.2.1 RTG

3.2.2 Batteries

3.3 COMMAND AND CONTROL

3.3.1 Vehicle controller

3.4 ELECTRONICS

4.0 POWER SYSTEMS

4.1 FUEL CELLS

4.2 AUXILIARY

4.2.1 RTG

4.2.2 Batteries

4.3 POWER DISTRIBUTION

4.3.1 Power regulator

4.3.2 Power conversion

4.3.3 Distribution, including relays, controller and wiring.

4.4 TEMPERATURE CONTROL

4.4.1 Coolant pump

4.4.2 Pump power supply

4.4.3 Radiator

4.4.4 O_2 heat exchanger

4.4.5 H_2 heat exchanger

4.4.6 Fuel Cell temperature control valve

4.4.7 Regenerative heat exchanger

4.4.8 Regenerative heat exchanger temperature control valve.

5.0 TIEDOWN AND UNLOADING

5.1 SUPPORT AND TIEDOWN

5.1.1 Chassis support struts

5.1.2 Axle supports

5.1.3 Release mechanisms

5.2 VARIABLE AZIMUTH DRIVE

5.2.1 Turntable

5.2.2 Turntable bearing

5.2.3 Bearing Platform

5.2.4 Turntable motor and gear motor assembly

5.3 DEPLOYMENT MECHANISM

5.3.1 Unloading tracks

5.3.2 Track extension motor and actuator assembly

5.4 ELECTRONICS

5.4.1 Unloading programmer

5.4.2 Batteries and electronic equipment

5.4.3 Wiring installation

6.0 SCIENTIFIC EQUIPMENT

The cost estimate for the Scientific Equipment was based upon about 700 pounds of instrumentation comprised of such items, and as extensive, as listed below:

6.1 Emplaced Scientific Station (ESS)

Atmosphere Mass Spectrometer
Charged Dust Spectrometer
Charged Particle Spectrometer
Electric Field Meter
Gamma Ray Detector
Lunar Ejecta Spectrometer
Lyman Alpha Detector
Magnatometer
Neutron Phoswitch Detector
Power Supply
Quake Seismometer
Star Tracker
Solar Plasma Spectrometer
Tape Recorder
Telemetry System
Thermal Probe (permanent)
Tidal Gravimeter
Total Radiation Dosimeter
Vacuum-Pressure Gauge

6.2 Mobile Laboratory (MOLAB)

Acoustic Ejecta Detector
Acoustic Velocity Instrument
Active Seismology Instrumentation
Alpha Particle Mass Spectrometer
Cameras
Drills (one large, one small)
Gravimeter
Gamma Ray Densitometer
Interferometer Spectrometer
Magnatometer
Mass Spectrometer (Solids)
Neutron Gamma Ray Detector
Radioactivity Probe

Reflection Grating Spectrometer
Sample Containers
Television Camera
Theodolite
Total Radiation Dosimeter
X-Ray Diffractometer

6.3 Portable

Electrical Measuring Instruments
Disffusitivity Instruments
Gamma Ray Densitometer
Temperature Profile Instruments
Theodolite
Thermal Conductivity Instruments
Television Cameras

APPENDIX B

DETAIL COST SHEETS

MOLAB VEHICLE SYSTEM

DEVELOPMENT PROJECT ESTIMATE

LEVEL 3 SUMMARY WITH PROJECT ADMINISTRATION COSTS

END ITEM	PROC.	FUNCTIONS					END ITEM SUBTOTALS
		D & E	MFG	TEST	PROJ. MGT.	ODC	
MOLAB w/GSE, Spec. Test & Handl.	$21.10	63.42	91.36	53.55	12.20	15.60	$257.23
SCIENTIFIC EQUIP. w/GSE & Sp. Test.	3.00	8.69	13.06	5.58	1.80	2.30	$34.43
FUNCTION SUBTOTALS	$24.10	72.11	104.42	59.13	14.00	17.90	

GRAND TOTAL $291.66 Million

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

OPTION 1 OF 2
(Detail Cost Forms)

LEVEL 3

MAN-WEEKS

		DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
		1	2	3	4	5	6	7	8	9			
END ITEMS		Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat'n	THIS LEVEL	FROM LEVEL 4	ACCUMUL. TOTALS
MOLAB VEHICLE GSE & Sp. Test Equipment													
(GSE)													
(Special Test & Handling Equip.)													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL 4												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 3

MAN-WEEKS

		MANUFACTURING & QUALITY CONTROL											
		13	14	15	16	17	18	19	20	21	END ITEM SUB TOTALS		
END ITEMS		Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport		THIS LEVEL	FROM LEVEL 4	ACCUMUL TOTALS
MOLAB VEHICLE GSE & Sp Test Equipment													
(GSE)													
(Special Test & Handling Equip.)													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL 4												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 3

MAN-WEEKS

	TESTING									END ITEM SUB TOTALS		
	25	26	27	28	29	30	31	32	33			
END ITEMS	Design/ Development	Preliminary Qual. Check-Out	Parts & Components Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Subsystem & Integr. Qual/En	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio	THIS LEVEL	FROM LEVEL 4	ACCUM. TOTALS
MOLAB VEHICLE, GSE & Sp. Test Equipment												
(GSE)												
(Special Test & Handling Equip.)												
FUNCTION SUBTOTALS THIS LEVEL												
FROM LEVEL 4												
ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 4

MAN-WEEKS

MOLAB SYSTEMS		DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
END ITEMS		1 Preliminary Design	2 Systems Analysis	3 Primary Engr. & Design	4 Specifications	5 Reliability	6 Data Review & Analyses	7 Design Rev. & Final Des.	8 Engr. Plan. & Liaison	9 Documentat'n	THIS LEVEL	FROM LEVEL 5	ACCUMUL. TOTALS
CABIN													
MOBILITY													
ASTRIONICS													
POWER													
TIEDOWN													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL 5												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 4

MAN-WEEKS

		MANUFACTURING & QUALITY CONTROL											
		13	14	15	16	17	18	19	20	21	END ITEM SUB TOTALS		
MOLAB SYSTEMS	END ITEMS	Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport		THIS LEVEL	FROM LEVEL 5	ACCUMUL TOTALS
CABIN													
MOBILITY													
ASTRIONICS													
POWER													
TIEDOWN													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL 5												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL **4**

MAN-WEEKS

		TESTING											
		25	26	27	28	29	30	31	32	33	END ITEM SUB TOTALS		
	MOLAB SYSTEMS END ITEMS	Design/ Development	Preliminary Qual. Check-Out	Parts & Components Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Sub-system & In-tegr. Qual/E	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio	THIS LEVEL	FROM LEVEL 5	ACCUM. TOTALS
	CABIN												
	MOBILITY												
	ASTRIONICS												
	POWER												
	TIEDOWN												
	SUBTOTALS												
	GSE												
	SPECIAL TEST & HANDL. EQUIP												
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL 5												
	ACCUMUL. ATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

CABIN SYSTEMS	DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
	1	2	3	4	5	6	7	8	9			
END ITEMS	Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat'n	THIS LEVEL	FROM LEVEL___	ACCUMUL. TOTALS
STRUCTURE												
AIRLOCK												
DOCKING ADAPTER												
VIEWING PORTS												
CONTROLS AND DISPLAYS												
CREW SYSTEMS												
ECS												
SUBTOTALS												
GSE												
SPECIAL TEST & HANDLING EQUIP.												
FUNCTION SUBTOTALS THIS LEVEL												
FROM LEVEL___												
ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

		MANUFACTURING & QUALITY CONTROL									END ITEM SUB TOTALS		
		13	14	15	16	17	18	19	20	21			
CABIN SYSTEMS	END ITEMS	Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport		THIS LEVEL	FROM LEVEL___	ACCUMUL TOTALS
STRUCTURE													
AIRLOCK													
DOCKING ADAPTER													
VIEWING PORTS													
CONTROLS & DISPLAYS													
CREW SYSTEMS													
ECS													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

		TESTING									END ITEM SUB TOTALS		
CABIN SYSTEMS END ITEMS		25	26	27	28	29	30	31	32	33			
		Design/ Development	Preliminary Qual. Check-Out	Parts & Com-ponents Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Sub-system & In-tegr. Qual/En	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio	THIS LEVEL	FROM LEVEL ___	ACCUM. TOTALS
STRUCTURE													
AIRLOCK													
DOCKING ADAPTER													
VIEWING PORTS													
CONTROLS & DISPLAYS													
CREW SYSTEMS													
ECS													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

		DESIGN AND ENGINEERING											
MOBILITY SYSTEMS		1	2	3	4	5	6	7	8	9	END ITEM SUB TOTALS		
END ITEMS		Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat'n	THIS LEVEL	FROM LEVEL ___	ACCUMUL. TOTALS
CHASSIS													
DRIVE MECHANISM													
WHEEL ASSEMBLY													
SUSPENSION ASSEMBLY													
STEERING MECHANISM													
CRYOGENIC STORAGE													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL__												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

MOBILITY SYSTEMS		MANUFACTURING & QUALITY CONTROL									END ITEM SUB TOTALS		
END ITEMS		13	14	15	16	17	18	19	20	21	THIS LEVEL	FROM LEVEL ___	ACCUMUL TOTALS
		Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport				
CHASSIS													
DRIVE MECHANISM													
WHEEL ASSEMBLY													
SUSPENSION ASSEMBLY													
STEERING MECHANISM													
CRYOGENIC STORAGE													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

MOBILITY SYSTEMS	TESTING									END ITEM SUB TOTALS		
	25	26	27	28	29	30	31	32	33			
END ITEMS	Design/ Development	Preliminary Qual. Check-Out	Parts & Components Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Sub-system & In-tegr. Qual/En	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio	THIS LEVEL	FROM LEVEL ___	ACCUM. TOTALS
CHASSIS												
DRIVE MECHANISM												
WHEEL ASSEMBLY												
SUSPENSION ASSEMBLY												
STEERING MECHANISM												
CRYOGENIC STORAGE												
SUBTOTALS												
GSE												
SPECIAL TEST & HANDL. EQUIP.												
FUNCTION SUBTOTALS THIS LEVEL												
FROM LEVEL ___												
ACCUMUL. ATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

		DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
ASTRIONICS SYSTEMS		1	2	3	4	5	6	7	8	9			
END ITEMS		Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat!n	THIS LEVEL	FROM LEVEL ___	ACCUMUL. TOTALS
NAVIGATION & GUIDANCE													
COMMUNICATIONS													
COMMAND & CONTROL													
ELECTRONICS													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL__												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

	ASTRIONICS SYSTEMS END ITEMS	MANUFACTURING & QUALITY CONTROL									END ITEM SUB TOTALS		
		13 Procurement (Matls & Part	14 Manuf. Engr	15 Material Handl. & Cont	16 Tooling	17 Fabrication & Processing	18 Assembly Operations	19 Q. C. & Inspections	20 Handl., Pack & Transport	21	THIS LEVEL	FROM LEVEL___	ACCUMUL TOTALS
	NAVIGATION & GUIDANCE												
	COMMUNICATIONS												
	COMMAND & CONTROL												
	ELECTRONICS												
	SUBTOTALS												
	GSE												
	SPECIAL TEST & HANDL. EQUIP.												
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

ASTRIONICS SYSTEMS		TESTING									END ITEM SUB TOTALS		
END ITEMS		25	26	27	28	29	30	31	32	33			
		Design/ Development	Preliminary Qual. Check-Out	Parts & Components Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Sub-system & In-tegr. Qual/En	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio	THIS LEVEL	FROM LEVEL ___	ACCUM. TOTALS
NAVIGATION & GUIDANCE													
COMMUNICATIONS													
COMMAND & CONTROL													
ELECTRONICS													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

		DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
		1	2	3	4	5	6	7	8	9			
POWER SYSTEMS	END ITEMS	Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat;n	THIS LEVEL	FROM LEVEL___	ACCUMUL. TOTALS
	FUEL CELLS												
	AUXILIARY (RTG)												
	POWER DISTRIBUTION												
	TEMPERATURE CONTROL												
	SUBTOTALS												
	GSE												
	SPECIAL TEST & HANDL. EQUIP.												
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL__												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS		MANUFACTURING & QUALITY CONTROL									END ITEM SUB TOTALS		
POWER SYSTEMS		13	14	15	16	17	18	19	20	21			
END ITEMS		Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont.	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport.		THIS LEVEL	FROM LEVEL ___	ACCUMUL TOTALS
FUEL CELLS													
AUXILIARY (RTG)													
POWER DISTRIBUTION													
TEMPERATURE CONTROL													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

POWER SYSTEMS		TESTING									END ITEM SUB TOTALS		
END ITEMS		25 Design/Development	26 Preliminary Qual. Check-Out	27 Parts & Components Qual/Environ	28 Subsystem & Integ. Qual/Environ.	29 Multiple Subsystem & Integr. Qual/E	30 Sys. & Integ. Qual/Environ	31 Reliability	32 Data Handling & Reduction	33 Documentatio	THIS LEVEL	FROM LEVEL ___	ACCUM. TOTALS
FUEL CELLS													
AUXILIARY (RTG)													
POWER DISTRIBUTION													
TEMPERATURE CONTROL													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

TIEDOWN & UNLOAD SYSTEM		DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
END ITEMS		1 Preliminary Design	2 Systems Analysis	3 Primary Engr. & Design	4 Specifications	5 Reliability	6 Data Review & Analyses	7 Design Rev. & Final Des.	8 Engr. Plan. & Liaison	9 Documentation	THIS LEVEL	FROM LEVEL___	ACCUMUL. TOTALS
SUPPORT & TIEDOWN													
VARIABLE AZIMUTH DRIVE													
DEPLOYMENT MECHANISM													
ELECTRONIC EQUIPMENT													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL__												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

	MANUFACTURING & QUALITY CONTROL											
	13	14	15	16	17	18	19	20	21	END ITEM SUB TOTALS		
MAN-WEEKS TIEDOWN & UNLOAD SYSTEM END ITEMS	Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport		THIS LEVEL	FROM LEVEL ___	ACCUMUL TOTALS
SUPPORT & TIEDOWN												
VARIABLE AZIMUTH DRIVE												
DEPLOYMENT MECHANISM												
ELECTRONIC EQUIPMENT												
SUBTOTALS												
GSE												
SPECIAL TEST & HANDL. EQUIP.												
FUNCTION SUBTOTALS THIS LEVEL												
FROM LEVEL ___												
ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 5

MAN-WEEKS

TIEDOWN & ~~UNLOAD SYSTEM~~		TESTING									END ITEM SUB TOTALS		
		25	26	27	28	29	30	31	32	33			
END ITEMS		Design/ Development	Preliminary Qual. Check-Out	Parts & Components Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Sub-system & In-tegr. Qual/En	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio	THIS LEVEL	FROM LEVEL ___	ACCUM. TOTALS
SUPPORT & TIEDOWN													
VARIABLE AZIMUTH DRIVE													
DEPLOYMENT MECHANISM													
ELECTRONIC EQUIPMENT													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMUL. ATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 3

MAN-WEEKS

	DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
	1	2	3	4	5	6	7	8	9			
END ITEMS	Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat'n	THIS LEVEL	FROM LEVEL 4	ACCUMUL. TOTALS
SCIENTIFIC EQUIPMENT												
TOTAL SCIENTIFIC EQUIP. (w/GSE & SP. TEST EQUIP) DESIGN & ENGR. LABOR:												
FUNCTION SUBTOTALS: THIS LEVEL												
FUNCTION SUBTOTALS: FROM LEVEL 4												
FUNCTION SUBTOTALS: ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 3

MAN-WEEKS

	MANUFACTURING & QUALITY CONTROL									END ITEM SUB TOTALS		
	13	14	15	16	17	18	19	20	21			
END ITEMS	Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont.	Tooling	Fabrication & Processing	Assembly Operations	Q.C. & Inspections	Handl., Pack & Transport		THIS LEVEL	FROM LEVEL 4	ACCUMUL TOTALS
SCIENTIFIC EQUIPMENT												
TOTAL SCIENTIFIC EQUIP. (W/GSE & SP. TEST EQUIP) MANUFACTURING LABOR:												
FUNCTION SUBTOTALS THIS LEVEL												
FROM LEVEL 4												
ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 3

		TESTING									END ITEM SUB TOTALS		
MAN-WEEKS		25	26	27	28	29	30	31	32	33	THIS LEVEL	FROM LEVEL 4	ACCUM. TOTALS
END ITEMS		Design/ Development	Preliminary Qual. Check-Out	Parts & Components Qual/Environ	Subsystem & Integ. Qual/ Environ.	Multiple Sub-system & In-tegr. Qual/En	Sys. & Integ. Qual/Environ	Reliability	Data Handling & Reduction	Documentatio			
SCIENTIFIC EQUIPMENT													
TOTAL SCIENTIFIC EQUIP. (W/GSE & SP. TEST EQUIP) TESTING LABOR:													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL 4												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 4

MAN-WEEKS

SCIENTIFIC EQUIPMENT		DESIGN AND ENGINEERING									END ITEM SUB TOTALS		
END ITEMS		1	2	3	4	5	6	7	8	9			
		Preliminary Design	Systems Analysis	Primary Engr. & Design	Specifications	Reliability	Data Review & Analyses	Design Rev. & Final Des.	Engr. Plan. & Liaison	Documentat!;n	THIS LEVEL	FROM LEVEL___	ACCUMUL. TOTALS
FIXED INSTR. (VEHICLE)													
PORTABLE INSTR.													
ESS													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL__												
	ACCUMUL. TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 4

MAN-WEEKS

		MANUFACTURING & QUALITY CONTROL											
		13	14	15	16	17	18	19	20	21	END ITEM SUB TOTALS		
SCIENTIFIC EQUIPMENT END ITEMS		Procurement (Matls & Part	Manuf. Engr	Material Handl. & Cont	Tooling	Fabrication & Processing	Assembly Operations	Q. C. & Inspections	Handl., Pack & Transport		THIS LEVEL	FROM LEVEL ___	ACCUMUL TOTALS
FIXED INSTR. (VEHICLE)													
PORTABLE INSTR.													
ESS													
SUBTOTALS													
GSE													
SPECIAL TEST & HANDL. EQUIP.													
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMULATED TOTALS												

MOLAB VEHICLE SYSTEM
DEVELOPMENT PROGRAM ESTIMATE

LEVEL 4

MAN-WEEKS

	SCIENTIFIC EQUIPMENT END ITEMS	TESTING 25 Design/ Development	 26 Preliminary Qual. Check-Out	 27 Parts & Components Qual/Environ	 28 Subsystem & Integ. Qual/ Environ.	 29 Multiple Sub-system & In-tegr. Qual/En	 30 Sys. & Integ. Qual/Environ	 31 Reliability	 32 Data Handling & Reduction	 33 Documentatio	END ITEM SUB TOTALS THIS LEVEL	 FROM LEVEL ___	 ACCUM. TOTALS
	FIXED INSTR. (VEHICLE)												
	PORTABLE INSTR.												
	ESS												
	SUBTOTALS												
	GSE												
	SPECIAL TEST & HANDL. EQUIP.												
FUNCTION SUBTOTALS	THIS LEVEL												
	FROM LEVEL ___												
	ACCUMUL. ATED TOTALS												

APPENDIX C

DEFINITIONS OF FUNCTION COLUMN HEADINGS-COST ESTIMATING SHEETS

APPENDIX C

This appendix defines the cost sheet "Function" column headings in order to clarify, the items that were considered in the cost estimate under the respective headings. All estimates are in man-weeks, except Procurement (Col. 13) which is in thousands of dollars.

1.0 DESIGN AND ENGINEERING

Design and Engineering is the total engineering effort that eventually results in the final design set of drawings to produce the particular item to be manufactured. This effort includes all analyses, engineering, drafting, development, technical investigation and coordination, direct engineering support services, and engineering and design changes and design maintenance activities.

1.1 Preliminary Design - Col. 1

Preliminary design is the initial and exploratory analysis and design effort to determine and evaluate the various feasible design alternatives. This includes selecting the basic approach, configuration, arrangement, weight allocation, etc. which will best satisfy the performance and operational requirements. The use of mock-ups and design development tests greatly assist in evaluating and selecting the best alternatives.

1.2 System Analysis - Col. 2

System analysis encompasses all the engineering, design, performance, operational, and cost factors for the total spacecraft system and the total mission. All such factors are considered, analyzed, evaluated and trade-offs made from a total system standpoint. The purpose is to integrate all factors so as to achieve an overall design which adequately, reliably and safely achieves the mission operation performance objectives at a reasonable cost.

1.3 Primary Engineering and Design - Col. 3

Primary engineering is the term employed to denote the effort required to engineer the actual payload design. This engineering results from the determinations of preliminary design and system analyses.

The primary engineering includes all the detail effort of selecting materials, parts and components, up through the complete design process of drafting the final engineering drawings which defines the design.

1.4 Specifications - Col. 4

Specifications include all the effort from the engineering through the actual writing required to produce the whole spectrum of specifications (e.g., performance, design, procurement, component, test, etc.).

1.5 Reliability - Col. 5

Under "Design and Engineering" (also see Test Col. 31), reliability includes the set up and conduct of the reliability program; as well as establishing the basic reliability related criteria, the selection of parts and components, requirements for redundancy, acquisition and analysis of all pertinent data, inputs to qualification test requirements, etc.

1.6 Data Review and Analyses - Col. 6

Data review and analysis includes the acquisition, assimilation and summary of all design and engineering data from that existing on specific hardware, to analysis of all development and qualification test data.

1.7 Design Review and Final Design - Col. 7

Design review is the process used for determining what design changes be instituted to correct deficiencies exposed by data analysis results; especially, those from tests. Final Design encompasses the total effort required to up-date the prototype design (and drawings) to result in the required flight hardware configuration--as concluded from the design review process.

1.8 Engineering Planning and Liaison - Col. 8

This column includes the indirect engineering effort required to plan and conduct the total engineering and design function; and particularly all the interdepartmental, intercompany and NASA coordination effort.

1.9 Documentation - Col. 9

Documentation encompasses all the effort required for producing engineering reports status reports, technical brochures, written communications, and substantiation of decisions, data, specifications, reproduction of documents, etc.

2.0 MANUFACTURING AND QUALITY CONTROL

Manufacturing and quality control encompasses the effort required to produce the hardware end items. For the Development Project this is limited to the manufacture of mock-ups, test articles, prototypes, and other support and test equipment.

2.1 Procurement - Col. 13

Procurement cost estimates (in 1,000's of dollars) are limited to materials, parts and basic components. Subcontract work has been excluded as direct procurement; instead it has been broken down into all the basic functions and estimated as though the prime contractor performed all the operations.

2.2 Manufacturing Engineering - Col. 14

Manufacturing engineering encompasses the planning, coordination and incorporation of additional information required to convert engineering design drawings to shop working drawings and instructions. This includes such items as production and process planning, sequence of operations, fabrication methods, etc.

2.3 Material Handling and Control - Col. 15

This column includes the direct changes required for in-plant handling and control of all material and parts stock; such as the keeping of records, stock cribs, storage, etc.

2.4 Tooling - Col. 16

Tooling is the effort necessary to engineer, design, manufacture, delivery, installation and checkout of all jigs, tools, fixtures, check and control tools, and other special items required in the manufacture and assembly of the spacecraft hardware.

2.5 Fabrication and Processing - Col. 17

Fabrication and processing includes all the primary fabrication-type operations required to manufacture the hardware end items not covered under other headings. The functions include: cutting, bending, shaping, machining, welding, plating, finishing, coating, etc.

2.6 Assembly Operations - Col. 18

Assembly is the process of successively integrating and assembling the hardware parts, components, subassemblies and so forth into the next higher level of end item completion.

2.7 Quality Control and Inspection - Col. 19

Quality control is the overall system and conduct of controlling the quality of all manufactured items, and of verifying that they were fabricated and assembled within the engineering specifications. The various inspections, from receiving through inspection tests of the final product, are the principal methods of performing the verifications.

2.8 Handling, Packaging and Transport - Col. 20

This column includes the general support effort required in the overall handling and care of the items being produced, including the packaging, protection and transporting of the hardware.

3.0 TESTING

Two general categories of tests are included. Design/Development tests, and Qualification test. The first is conducted during the design phase to assist in developing the desired design. Qualification tests are conducted to verify the performance of the selected design. Qualification testing encompasses several sub-categories of test using "test articles" and/or prototype (i.e., flight configuration) hardware; and are conducted at various levels as defined by the following column headings.

3.1 Design/Development - Col. 25

Design/development along with mock-ups, are part of the engineering effort required to make design evaluations and determine the most practical design; and/or to determine the best concept or design of two or more alternatives.

3.2 Preliminary Qualification Checkout - Col. 26

This column, and all subsequent columns on test activities, refer to some phase of qualification testing. Preliminary checkout is the initial effort to functionally check a new item of hardware before it undergoes the various environmental tests. Checkout is required at all hardware levels, from parts and components through complete systems. The functional checks made during the normal course of environmental tests, or for trouble-shooting during a test, are not included in the estimates under this column. They are included in the specific types of tests under the respective columns.

3.3 Parts and Components - Environmental Qualification - Col. 27

This phase is the qualification testing of prototype parts and components (and small subassemblies) to verify the design and to demonstrate that the items will perform as specified under the predicted environmental and operational conditions.

3.4 Subsystem and Integration - Environmental Qualification Col. 28

Qualification testing of prototype assemblies through complete subsystems verify the adequacy of the design to the subsystems level and demonstrate that the equipment will perform as specified under the predicted environmental and operational conditions. These tests also verify that the level of stress or exposure of any component as integrated into the assembly/subsystem has not significantly changed from the values tested to at the component level, and verify that the component has not exceeded its design range of exposure or stress.

3.5 Multiple Subsystem and Integration-Environmental Qualification - Col. 29

The integration, or marriage, of certain subsystems below the complete system level is necessary to isolate or test specific performances and operations without the complexity (or expense) of the total system. The general test objectives are the same as in 3.4 and 3.6.

3.6 System and Integration - Environmental Qualification - Col. 30

The integration of all subsystems (e.g., of the MOLAB, LEM-T and GSE) for system tests are required to verify the design to the systems level and to demonstrate that the equipment will perform as specified under the predicted environmental and operational conditions. These tests further verify that the level of stress, or exposure of any component, assembly or subsystem as integrated within the system has not significantly changed from the values demonstrated by tests at previous levels and also verify that the item(s) have not exceeded their design range of exposure or stress.

3.7 Reliability - Col. 31

Under "Testing" (also see Col. 5), reliability includes conduct of tests which are performed primarily for demonstrating or obtaining reliability data. For the MOLAB, it has been assumed that the principal reliability test effort will be performed at the parts and component level, with an overall demonstration at the systems level. Reliability requirements are primary considerations in the parts certification tests, which are of two basic types:

3.7.1 Identification and selection of previously certified processes, materials, parts or components that are applicable to the MOLAB design.

3.7.2 Space Certification of existing parts (etc.) that appear to be applicable but that have not been previously certified (i.e., qualified); or recertification of previously certified parts but which have been altered or modified for the present application.

3.8 Data Handling and Reduction - Col. 32

This function includes all the effort required to obtain, reduce, transpose, and record all test data for presentation to the cognizant design engineers in the desired form. Basic instrumentation set-up is not included herein.

3.9 Documentation - Col. 33

Documentation encompasses the effort required to produce test reports, progress and status reports, formal transmittal of data, etc.

4.0 PROJECT ADMINISTRATION AND CONTROL

This broad category encompasses all the project management functions, plus other project costs not directly associated with any one function, or end item.

4.1 Project Management and Integration - Col. 37

Project management includes the staff of personnel responsible for the conduct and control (e.g., PERT, costs, schedules, reports) of the whole (MOLAB) project. It includes the administration and technical direction of the project, and the performance of the management functions necessary to control the project. Project Integration as used here, is that portion of the overall management function that relates more to the actual coordination and liaison activities with NASA, and within the prime contractors plants and among his subcontractors.

4.2 Other Direct Costs (ODC) - Col. 38

ODC includes the many miscellaneous charges that are necessary in the conduct of any project, but that cannot be directly attributed to any particular end item or function. These charges include such items as:

Computer services
Travel Cost
Per Diem
Rentals
Consultant fees

Plant Rearrangements
Technical Presentations
Project Documentation
Project Reports
Purchase of special items (not included under special test equipment and tooling)

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