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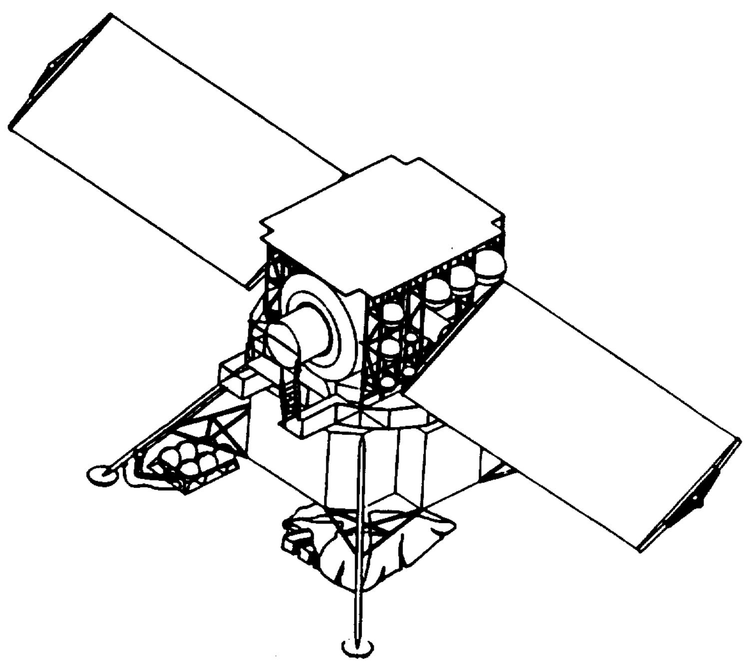
Final Report
Technical Directive 14
September 1993



Boeing Defense and Space Group
Advanced Civil Space Systems
Huntsville, Alabama

Contract NAS8-37857

Space Transfer Concepts and Analyses for Exploration Missions

Final Report
Technical Directive 14
September 1993

Gordon R. Woodcock
Program Manager

Boeing Defense and Space Group
Advanced Civil Space Systems
Huntsville, Alabama

Contract NAS8-37857

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PREPARED BY	STCAEM	2-1222	93-09-14
CHECKED BY	Irwin E. Vas	2-1222	93-09-14
SUPERVISED BY	Gordon R. Woodcock	2-1222	93-09-14
APPROVED BY	J. E. Kingsbury	2-1220	93-09-14

SIGNATURE	ORGN	DATE
J. E. Kingsbury	2-1220	9-15-93

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FOREW0RD

The study entitled "Space Transfer Concepts and Analyses for Exploration Missions" (STCAEM) was performed by Boeing Missiles and Space, Huntsville, for the George C. Marshall Space Flight Center (MSFC). The current activities were carried out under Technical Directive 14 during the period July 1992 through December 1992. The Boeing program manager was Gordon Woodcock, and the MSFC Contracting Officer's Technical Representative was Alan Adams. Support for the cost studies was provided by Rob Fowler and Theron Ruff. In addition, Hollis Black and Gene Albin from Parametric Estimating (Boeing) supported this costing activity.

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ABBREVIATIONS AND ACRONYMS

CER	Cost Estimating Relationship
ECLSS	Environmental Control Life Support System
FLO	First Lunar Outpost
GSE	Government Supplied Equipment
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
PCM	Parametric Cost Model
STCAEM	Space Transfer Concepts and Analyses for Exploration Missions
SSF	Space Station Freedom
STE	Special Test Equipment
WBS	Work Breakdown Structure

ABSTRACT

The current technical effort is part of the fourth phase of a broad-scoped and systematic study of space transfer concepts for human lunar and Mars missions. The study addresses the costs of the First Lunar Outpost habitat and alternatives to this habitat.

COST ANALYSES

Introduction

The goal of the FLO cost model analyses is to develop parametric models that reflect current SSF Hab - A cost estimates and will allow cost estimation of the FLO habitat and its subsystems as well as estimates of alternatives to the baseline FLO Hab. The Parametric Cost Model (PCM) is based on earlier FLO mass estimates and the SSF mass properties report dated July 15, 1992, Reference 1. Certain parts of the FLO were not costed, and these include medical equipment, science, EMUs, consumables, and spares. An assumption was made that the FLO could be manufactured using loaned tooling, Government Supplied Equipment (GSE) and STE from an established Space Station Freedom (SSF) production line, and these items were not costed. Other exclusions from the cost estimate include launch operations, training and support, NASA wraps and Government costs of facilities. The habitat cost is based on an assumption of a 1999 delivery, or the #3 Hab unit off the production line. An alternate cost estimate was developed for a delivery date of 2000.

Cost estimates have been developed for several alternatives to the baseline. These include three variations of structural material; aluminum-lithium, graphite-epoxy and metal matrix composites. Other alternatives to the configuration include an ellipsoidal habitat geometry, and a method of unloading the Hab from the baseline lander onto the lunar surface.

FLO Cost Analyses

The original concept for FLO baselined the Space Station Freedom Habitation Unit with a few minor modifications to compensate for the 1/6 gravity on the Moon; i.e., floor panels added, restraints and mobility aids removed. The major subsystems, structure, ECLSS, electronics, etc. would be changed only by re-routing wiring and plumbing. Details of the FLO habitat have been provided in Reference 2.

The cost of the SSF Hab Unit from the PCP 400 model are divided, not only into non-recurring and recurring costs, but also into what is Hab unique and what is designed for the Space Station as a whole, part of which is located in the Hab. This includes items such as plumbing, thermal control. electronics, etc. The first costs mentioned are called "unique design costs" and the latter are referred to as "distributed systems cost."

For this task, the Hab part of the SSF systems cost was separated from SSF. In addition, the portion of the Hab associated with "unique" and "allocated" was added on to the Hab part of SSF. The SSF element weights, unique and distributed systems, break down into non-recurring and recurring cost and the total cost is shown in Figure 1. The mass and cost data shown in Column 1 was obtained from Space Station data.

The weight and cost results of the modifications made to SSF (in order to estimate the FLO hab module) is shown in Figure 2. The weight in the first column is adjusted to reflect the necessary changes; the recurring costs in Columns 3 and 7 are adjusted accordingly by the same percentage. Columns 5 and 9 represent the percentage change in the system relating to the non-recurring cost. This value for the unique design and distributed systems was estimated by the design team for each WBS in SSF. This percentage was used as a multiplier against the same number (Column 2 and 5) in Figure 1 to produce the values in Columns 2 and 6 in Figure 2. For example, Design Integration, WBS 3.X.2 in Figure 1 is $11.986M. This would be a complete redesign for the FLO, and in Figure 2, WBS 3.X.2, Column 5, we find 100% change or redesign. Column 2 reflects this with a 100% change in cost. The support equipment shown in WBS 3.X.3, needs only a 5 per-cent change (Figure 2, Column 5). The resulting number goes from 1, 422 (Figure 1, Column 2) to 71 (Figure 2, Column 2). This FLO estimate, for unique and distributed, non-recurring and recurring costs, based on SSF PCP400 now becomes the baseline. A series of trade studies on alternative FLO habitats were run using this baseline as reference including an elliptical Hab, an aluminum-lithium hab, and an alternative airlock design known as the "Crewlock".

Trade Studies

To perform a series of trade studies, it is necessary to have a cost model based on history to accurately reflect cost changes brought about by design or material changes, and to have the model calibrated to a known cost, in this case, the FLO baseline (Figure 2). The model chosen was the Parametric Cost Model and the curves developed by the CER's as a weight changed were accurate and needed only to have the model calibrated to the baseline FLO cost. This was accomplished by taking the cost of the FLO hardware such as structures, ECLSS, etc., and running them through the PCM. No integration or support cost was included. Each WBS or line item in the PCM then had a multiplier added to it, in order to force it to equal the cost of the FLO baseline. These numbers were based on the FLO system weights, average complexities of each system and an aluminum structure. Weights were then adjusted, along with the complexity and/or material of each line item according to what was required for the trade. The result was a new cost, based on the PCM CERs, and calibrated to the FLO.

The line items that run through the PCM include WBS in 3.X.7 to 3.X.15.1.9. The integration and support costs 3.X.1 to 3.X.6 and 3.X.15.1.10 to 3.X.33 were found by calculating the cost of each as a percentage of the cost of the sum of the hardware WBSs of the FLO baseline of Figure 2. In other words, the sum total of WBS 3.X.7 to 3.X.15.1.9 (Figure 3, Column 1) equals $8.428M. WBS 3.X.6 FLT.ART. Assy & Test equals 114 or 1.35263% of the total, (Figure 2). This percentage was then used on each trade study, on everything that wasn't hardware or WBS 3.X.1 to 3.X.6 and 3.X.15.1.10 to 3.X.33.

With these percentages in place, as design, weight or material changes cause the cost of the hardware to change, so the support and integration costs will change by the same percentage. The effect of this method of comparing the FLO with an aluminum structure, and a FLO with an aluminum-lithium structure is shown in Figure 3. The structures WBS 3.X.7 is increased from 558 (Column 1) to 604 (Column 2) and from 5720 (Column 3) to 6788 (Column 4). No other hardware (WBS 3.X.7 to 3.X.15.1.9) is affected. The result can be seen to have raised the non-hardware item (integration, support, etc.) by the same percentage. The result in 1992 dollars is for non-recurring costs of $39.35 M for aluminum and $39.569 M for aluminum-lithium. The recurring costs are $62.911 M and $63.948 M for aluminum and aluminum-lithium respectively.

The cost effect of a major redesign from the original FLO based on the SSF design with minor modifications and PCP 400 costs is shown in Figure 4. The FLO based on the SSF configuration is shown in Figure 5. The ellipsoidal configuration for the FLO is shown in Figure 6.

The benefits associated with the ellipsoidal configuration are that it better utilizes interior space on the lunar surface,and therefore in a gravity environment, than would the FLO based on SSF, which is designed for a micro-gravity environment. The drawback, however, is the cost of the redesign and the loss of benefits from design work already completed in distributed systems. In Figure 2, Column 5 and 9, many of the 5 and 10 percent changes relative to SSF will go to 100 percent. The benefit of producing one more SSF Hab, assembled on an operational assembly line, would then be lost. The cost effect of the redesign, and the additional cost of redesigning existing distributed systems is shown in Figure 4.

Many of the FLO subsystems can be used in the ellipsoidal design without modification, or with only minor modification and this was taken into consideration. The results can be seen in the totals - 1992 dollars line, Figure 4. FLO non-recurring cost has gone from $39.351M to $94.976M for the ellipsoid, and recurring has increased from $62.911M for FLO to $80.120 for totals of $102.3M for FLO and $175.1 for the ellipsoidal alternative habitat.

The final trade study was conducted on an alternative airlock, designed to reduce the overall weight of the FLO by reducing the airlock size, and by reducing the weight of airlock support systems, (Figure 7). This element was also run through the PCM, and was calibrated to the FLO cost from the PCP 400, (Figure 8). These costs were then put in the second format where support and integration costs were based on a percentage of the sum of the cost of the hardware subsystems as covered earlier.

Again, looking at the total 1992 cost line, it can be seen that the baseline FLO airlock and alternative "crewlock" non-recurring costs are reasonably close together, although the crew lock is less complex and requires fewer subsystems. This is a result of costing the benefits of previous design work.

COLUMN		1	2	3	4	5	6	7	8
ALT A THEN YEAR $		SPACE STATION HAB-A UNIQUE DESIGN				SPACE STATION HAB-A - ALLOCATED DISTRIBUTED SYSTEMS			SPACE STATION TOTAL
WBS		WEIGHT (LBS)	NON/REC $K	RECUR $K	TOTAL $K	NON-RECUR $K	REC $K	TOTAL $K	$K
3.X.1	ELEMENT INTEGRATION		4,128		4,128	1,061		1,061	5,189
3.X.2	DESIGN INTEGRATION	2239	11,986	79	12,065	15,845	383	16,228	28,293
3.X.3	SUPPORT EQUIPMENT		1,422	3,135	4,557	4,637	1,840	6,477	11,034
3.X.4	SOFTWARE		1,303	43	1,346	13,374	188	13,562	14,908
3.X.5	ELEM TEST ART ASS & TEST		5,498	3,078	8,576				8,576
3.X.6	FLIGHT ARTICLE ASS & TEST		2,275	2,735	5,010				5,010
3.X.7	STRUCTURES	9143	1,227	5,371	6,598	4,348	582	4,930	11,528
3.X.8	MECHANISMS	978	780	1,604	2,384	2,867	329	3,196	5,580
3.X.9	PACKAGES	5138		2,089	2,089	1,164	533	1,697	3,786
3.X.10	ELECTRICAL POWER	772	832	1,394	2,226	3,333	323	3,656	5,882
3.X.11	DATA MANAGEMENT	509	1,494	1,003	2,497	1,913	654	2,567	5,064
3.X.12	INTERNAL AUDIO/VIDEO	291	1,072	2,786	3,858	12,041	54	12,095	15,953
3.X.13	THERMAL CONTROL	2040	250	3,051	3,301	2,357	90	2,447	5,748
3.X.14	ECLSS								
3.X.14.1	TEMP & HUMIDITY CONTROL	1988	447	5,738	6,185	2,354	164	2,518	8,703
3.X.14.2	ATMOS CONT & SUPPLY	308	1,545	6,606	8,151	1,066	88	1,154	9,305
3.X.14.3	ATMOS REVITALIZATION	852	340	8,760	9,100	5,451	208	5,659	14,759
3.X.14.4	FIRE DETEC & SUPPRESS	429	81	931	1,012	964	116	1,080	2,092
3.X.14.5	WATER RECOVERY & MANAG	2377	255	9,153	9,408	3,638	164	3,802	13,210
3.X.14.6	WASTE MANAGEMENT	268	47	1,829	1,876	549	29	578	2,454
3.X.14.7	EXPANDED ECLSS TEST & INTEG					852		852	852
3.X.14.8	EXPANDED ECLSS (POST)					2,559		2,559	2,559
3.X.14.9	EXPANDED ECLSS (ER/T)					843		843	843
3.X.14.10	EXPANDED ECLSS (BOST)					2,652		2,652	2,652
3.X.14.11	EXPANDED ECLSS (MOST)					1,048		1,048	1,048
3.X.15.1	MAN SYSTEMS								
3.X.15.1.1	RESTRAINTS & MOBILITY AIDS	157	699	348	1,047	906	16	922	1,969
3.X.15.1.2	WORKSTATIONS	1348	25	106	131	23		23	154
3.X.15.1.4	INTERFACING PARTS/STRUCTURES	287	61	555	616	175		175	791
3.X.15.1.5	STOWAGE	1727	175	1,146	1,321	133		133	1,454
3.X.15.1.6	HOUSEKEEPING/TRASH MANAGMENT	296	351	720	1,071	196		196	1,267
3.X.15.1.7	CREW QUARTERS		1,263	7,339	8,602	2,417	118	2,535	11,137
3.X.15.1.8	GALLEY & FOOD MANAGMENT	1438	2,191	6,938	9,129				9,129
3.X.15.1.9	PERSONAL HYGIENE SYSTEM (PHS)	711	1,103	5,337	6,440	2,229		2,229	8,669
3.X.15.1.10	WARDROOM		1,392	1,954	3,346				3,346
3.X.15.1.11	CREW HEALTH CARE		106	36	142				142
3.X.15.1.12	PORTABLE EMERGENCY PROVISIONS	4725		34	34	14		14	48
3.X.15.2	MAN SYS EQUIPMENT INTEGRTION		592	3,750	4,342				4,342
3.X.15.3	HUMAN ENGINEERING					1,545		1,545	1,545
3.X.17	LAB SUPPORT EQUIP (GLOVEBOX)								
3.X.18	SYS CERT TEST/MANU & ASSY					100		100	100
3.X.19	CERT TEST ARTICLE SYSTEMS					1,645		1,645	1,645
3.X.30	MANUFACTURING & ASSEMBLY					7,657	1,590	9,247	9,247
3.X.31	TECHNOLOGY DEMO HARDWARE					5,157		5,157	5,157
3.X.32	FLUID MANAGEMENT SYSTEM (FMS)					45	7	52	52
3.X.33	TEST BED SUPPORT					8,950	15	8,965	8,965
	DRY WEIGHT	38,021							
	TOTALS - THEN YEAR DOLLARS		42,940	87,648	130,588	116,108	7,491	123,599	254,187
	TOTALS - 1992 DOLLARS		39,209	69,798	109,007	106,019	5,965	111,984	220,991

Figure 1 Space Station Mass and Cost Elements

COLUMN		1	2	3	4	5	6	7	8	9	10
THEN YEAR $		LUNAR OUTPOST HAB-A UNIQUE DESIGN				UNIQUE NON/REC	LUNAR OUTPOST HAB-A - ALLOCATED DISTRIBUTED SYSTEMS			DIST SYS NON/REC	LUNAR OUTPOST
WBS		WEIGHT (LBS)	NON/REC $K	RECUR $K	TOTAL $K	% CHANGE %	NON-RECUR $K	REC $K	TOTAL $K	% CHANGE %	TOTAL $K
3.X.2	DESIGN INTEGRATION	1760	11,986	62	12,048	100	15,845	383	16,228	100	28,276
3.X.3	SUPPORT EQUIPMENT		71	3,135	3,206	5	232	1,840	2,072	5	5,278
3.X.4	SOFTWARE		326	43	369	25	3,344	188	3,532	25	3,900
3.X.5	ELEM TEST ART ASSY & TEST										
3.X.6	FLIGHT ARTICLE ASSY & TEST		114	2,735	2,849	5					2,849
3.X.7	STRUCTURES	8747	123	5,138	5,261	10	435	582	1,017	10	6,278
3.X.8	MECHANISMS	453	78	743	821	10	287	329	616	10	1,437
3.X.9	PACKAGES	3353		1,363	1,363	5	58	533	591	5	1,954
3.X.10	ELECTRICAL POWER	1442	83	2,604	2,687	10	333	323	656	10	3,343
3.X.11	DATA MANAGEMENT	1514	75	2,983	3,058	5	96	654	750	5	3,808
3.X.12	INTERNAL AUDIO/VIDEO	216	54	2,068	2,122	5	602	54	656	5	2,778
3.X.13	THERMAL CONTROL	2506	63	3,748	3,810	25	589	90	679	25	4,490
3.X.14	ECLSS										
3.X.14.1	TEMP & HUMIDITY CONTROL	1260	45	3,637	3,681	10	235	164	399	10	4,081
3.X.14.2	ATMOS CONT & SUPPLY	265	77	5,684	5,761	5	53	88	141	5	5,902
3.X.14.3	ATMOS REVITALIZATION	1431	17	14,713	14,730	5	273	208	481	5	15,211
3.X.14.4	FIRE DETEC & SUPPRESS	265	8	575	583	10	96	116	212	10	796
3.X.14.5	WATER RECOVERY & MANAG	1869	51	7,197	7,248	20	728	164	892	20	8,139
3.X.14.6	WASTE MANAGEMENT	267	9	1,822	1,832	20	110	29	139	20	1,970
3.X.14.7	EXPANDED ECLSS TEST & INTEG										
3.X.14.8	EXPANDED ECLSS (POST)										
3.X.14.9	EXPANDED ECLSS (ER/T)										
3.X.14.10	EXPANDED ECLSS (BOST)										
3.X.14.11	EXPANDED ECLSS (MOST)										
3.X.15.1	MAN SYSTEMS										
3.X.15.1.1	RESTRAINTS & MOBILITY AIDS	113	699	250	949	100	906	16	922	100	1,871
3.X.15.1.2	WORKSTATIONS	102	13	8	21	50	12		12	50	32
3.X.15.1.4	INTERFACING PARTS/STRUCTURES	312	15	603	619	25	44		44	25	662
3.X.15.1.5	STOWAGE	790	70	524	594	40	53		53	40	647
3.X.15.1.6	HOUSEKEEPING/TRASH MANAGMENT	294	105	715	820	30	59		59	30	879
3.X.15.1.7	CREW QUARTERS										
3.X.15.1.8	GALLEY & FOOD MANAGMENT	611	876	2,948	3,824	40					3,824
3.X.15.1.9	PERSONAL HYGIENE SYSTEM (PHS)	211	331	1,584	1,915	30	669		669	30	2,583
3.X.15.1.10	FURNITURE/ACCOMODATIONS										
3.X.15.1.11	CREW HEALTH CARE										
3.X.15.1.12	PORTABLE EMERGENCY PROVISIONS										
3.X.15.2	MAN SYS EQUIPMENT INTEGRTION		30	3,750	3,780	5					3,780
3.X.15.3	HUMAN L..GINEERING						1,545		1,545	100	1,545
3.X.17	LAB SUPPORT EQUIP (GLOVEBOX)	478		3000	3,000						3,000
3.X.18	SYS CERT TEST/MANU & ASSY						5		5	5	5
3.X.19	CERT TEST ARTICLE SYSTEMS						82		82	5	82
3.X.30	MANUFACTURING & ASSEMBLY						383	1,590	1,973	5	1,973
3.X.31	TECHNOLOGY DEMO HARDWARE						258		258	5	258
3.X.32	FLUID MANAGEMENT SYSTEM (FMS)										
3.X.33	TEST BED SUPPORT						448	15	463	5	463
	DRY WEIGHT	28,259									
	TOTALS - THEN YEAR DOLLARS		15,318	71,633	86,951		27,778	7,366	35,144		122,095
	TOTALS - 1992 DOLLARS		13,987	57,045	71,032		25,364	5,866	31,230		102,261
	TOTALS - UNIT 3		13,987	54,307	68,293		25,364	5,584	30,948		99,242
	TOTALS - UNIT 5		13,987	51,112	65,099		25,364	5,256	30,620		95,719

Figure 2 FLO Baseline Mass and Cost Elements

COLUMN		1	2	3	4	5	6
		LUNAR OUTPOST HAB-A				LUNAR OUTPOST HAB-A	
THEN YEAR $ WBS		OCT FLO NON/REC $K	ALUM-LI NON/REC $K	OCT FLO RECUR $K	ALUM-LI RECUR $K	OCT FLO TOTAL $K	ALUM-LI TOTAL $K
3.x.1	ELEMENT INTEGRATION						
3.X.2	DESIGN INTEGRATION	27,831	27,985	445	453	28,276	28,438
3.X.3	SUPPORT EQUIPMENT	303	305	4,975	5,060	5,278	5,365
3.X.4	SOFTWARE	3,669	3,689	231	235	3,900	3,924
3.X.5	ELEM TEST ART ASSY & TEST						
3.X.6	FLIGHT ARTICLE ASSY & TEST	114	115	2,735	2,782	2,849	2,897
3.X.7	STRUCTURES	558	604	5,720	6,788	6,278	7,392
3.X.8	MECHANISMS	365	365	1,072	1,072	1,437	1,437
3.X.9	PACKAGES	58	58	1,896	1,896	1,954	1,954
3.X.10	ELECTRICAL POWER	417	417	2,927	2,927	3,343	3,344
3.X.11	DATA MANAGEMENT	170	170	3,637	3,637	3,808	3,807
3.X.12	INTERNAL AUDIO/VIDEO	656	656	2,122	2,122	2,778	2,778
3.X.13	THERMAL CONTROL	652	652	3,838	3,838	4,490	4,490
3.X.14	ECLSS						
3.X.14.1	TEMP & HUMIDITY CONTROL	280	280	3,801	3,801	4,081	4,081
3.X.14.2	ATMOS CONT & SUPPLY	131	131	5,772	5,772	5,902	5,903
3.X.14.3	ATMOS REVITALIZATION	290	290	14,921	14,921	15,211	15,211
3.X.14.4	FIRE DETEC & SUPPRESS	105	105	691	691	796	796
3.X.14.5	WATER RECOVERY & MANAG	779	779	7,361	7,361	8,139	8,140
3.X.14.6	WASTE MANAGEMENT	119	119	1,851	1,851	1,970	1,970
3.X.15.1	MAN SYSTEMS						
3.X.15.1.1	RESTRAINTS & MOBILITY AIDS	1,605	1,605	266	266	1,871	1,871
3.X.15.1.2	WORKSTATIONS	24	24	8	8	32	32
3.X.15.1.4	INTRFC PRTS/STRCS & FLRS	59	59	603	603	662	662
3.X.15.1.5	STOWAGE	123	123	524	524	647	647
3.X.15.1.6	HOUSEKEEPING/TRASH MANAGMENT	164	164	715	715	879	879
3.X.15.1.7	CREW QUARTERS						
3.X.15.1.8	GALLEY & FOOD MANAGMENT	876	876	2,948	2,948	3,824	3,824
3.X.15.1.9	PERSONAL HYGIENE SYSTEM (PHS)	1,000	1,000	1,584	1,584	2,583	2,584
3.X.15.1.10	FURNITURE/ACCOMODATIONS						
3.X.15.1.11	CREW HEALTH CARE						
3.X.15.1.12	PORTABLE EMERGENCY PROVISIONS						
3.X.15.2	MAN SYS EQUIPMENT INTEGRTION	30	30	3,750	3,814	3,780	3,844
3.X.15.3	HUMAN ENGINEERING	1,545	1,545			1,545	1,545
3.X.17	LAB SUPPORT EQUIP (GLOVEBOX)			3,000	3,000	3,000	3,000
3.X.18	SYS CERT TEST/MANU & ASSY	5	5			5	5
3.X.19	CERT TEST ARTICLE SYSTEMS	82	82			82	82
3.X.30	MANUFACTURING & ASSEMBLY	383	385	1,590	1,617	1,973	2,002
3.X.31	TECHNOLOGY DEMO HARDWARE	258	259			258	259
3.X.32	FLUID MANAGEMENT SYSTEM (FMS)						
3.X.33	TEST BED SUPPORT	448	450	15	15	463	465
	TOTALS - THEN YEAR DOLLARS	43,095	43,334	78,999	80,303	122,095	123,637
	TOTALS - 1992 DOLLARS	39,351	39,569	62,911	63,948	102,261	103,517
	UNIT 2, 95% LEARNING CURVE			59,765	60,751	59,765	60,751

Figure 3 Comparison of FLO Baseline With Aluminum-Lithium Structure

WBS	COLUMN	1	2	3	4	5	6
THEN YEAR $		LUNAR OUTPOST HAB-A				LUNAR OUTPOST HAB-A	
		OCT FLO NON/REC $K	ELLIP NON/REC $K	OCT FLO RECUR $K	ELLIP RECUR $K	OCT FLO TOTAL $K	ELLIP TOTAL $K
3.x.1	ELEMENT INTEGRATION		5,189				5,189
3.X.2	DESIGN INTEGRATION	27,831	27,831	445	542	28,276	28,373
3.X.3	SUPPORT EQUIPMENT	303	303	4,975	6,057	5,278	6,360
3.X.4	SOFTWARE	3,669	3,669	231	281	3,900	3,950
3.X.5	ELEM TEST ART ASSY & TEST		10,531		6,021		16,552
3.X.6	FLIGHT ARTICLE ASSY & TEST	114	2,275	2,735	2,735	2,849	5,010
3.X.7	STRUCTURES	558	23,555	5,720	10,870	6,278	34,425
3.X.8	MECHANISMS	365	1,094	1,072	1,276	1,437	2,370
3.X.9	PACKAGES	58	11,355	1,896	1,962	1,954	13,317
3.X.10	ELECTRICAL POWER	417	417	2,927	3,690	3,343	4,107
3.X.11	DATA MANAGEMENT	170	170	3,637	3,638	3,808	3,808
3.X.12	INTERNAL AUDIO/VIDEO	656	656	2,122	2,122	2,778	2,778
3.X.13	THERMAL CONTROL	652	652	3,838	3,838	4,490	4,490
3.X.14	ECLSS						
3.X.14.1	TEMP & HUMIDITY CONTROL	280	280	3,801	4,525	4,081	4,805
3.X.14.2	ATMOS CONT & SUPPLY	131	131	5,772	7,036	5,902	7,167
3.X.14.3	ATMOS REVITALIZATION	290	290	14,921	18,198	15,211	18,488
3.X.14.4	FIRE DETEC & SUPPRESS	105	105	691	823	796	928
3.X.14.5	WATER RECOVERY & MANAG	779	779	7,361	8,366	8,139	9,145
3.X.14.6	WASTE MANAGEMENT	119	119	1,851	2,204	1,970	2,323
3.X.15.1	MAN SYSTEMS						
3.X.15.1.1	RESTRAINTS & MOBILITY AIDS	1,605	1,605	266	266	1,871	1,871
3.X.15.1.2	WORKSTATIONS	24	24	8	8	32	32
3.X.15.1.4	INTRFC PRTS/STRCS & FLRS	59	236	603	860	662	1,096
3.X.15.1.5	STOWAGE	123	123	524	656	647	779
3.X.15.1.6	HOUSEKEEPING/TRASH MANAGMENT	164	164	715	715	879	879
3.X.15.1.7	CREW QUARTERS						
3.X.15.1.8	GALLEY & FOOD MANAGMENT	876	876	2,948	4,018	3,824	4,894
3.X.15.1.9	PERSONAL HYGIENE SYSTEM (PHS)	1,000	1,000	1,584	729	2,583	1,729
3.X.15.1.10	FURNITURE/ACCOMODATIONS						
3.X.15.1.11	CREW HEALTH CARE						
3.X.15.1.12	PORTABLE EMERGENCY PROVISIONS						
3.X.15.2	MAN SYS EQUIPMENT INTEGRTION	30	592	3,750	4,566	3,780	5,158
3.X.15.3	HUMAN ENGINEERING	1,545	1,545			1,545	1,545
3.X.17	LAB SUPPORT EQUIP (GLOVEBOX)			3,000	3,000	3,000	3,000
3.X.18	SYS CERT TEST/MANU & ASSY	5	5			5	5
3.X.19	CERT TEST ARTICLE SYSTEMS	82	82			82	82
3.X.30	MANUFACTURING & ASSEMBLY	383	7,657	1,590	1,590	1,973	9,247
3.X.31	TECHNOLOGY DEMO HARDWARE	258	258			258	258
3.X.32	FLUID MANAGEMENT SYSTEM (FMS)						
3.X.33	TEST BED SUPPORT	448	448	15	18	463	466
	TOTALS - THEN YEAR DOLLARS	43,095	104,014	78,999	100,610	122,095	204,624
	TOTALS - 1992 DOLLARS	39,351	94,976	62,911	80,120	102,261	175,096
	UNIT 2, 95% LEARNING CURVE			59,765	76,114	59,765	76,114

Figure 4 Comparison of FLO Baseline With Ellipsoidal Structure

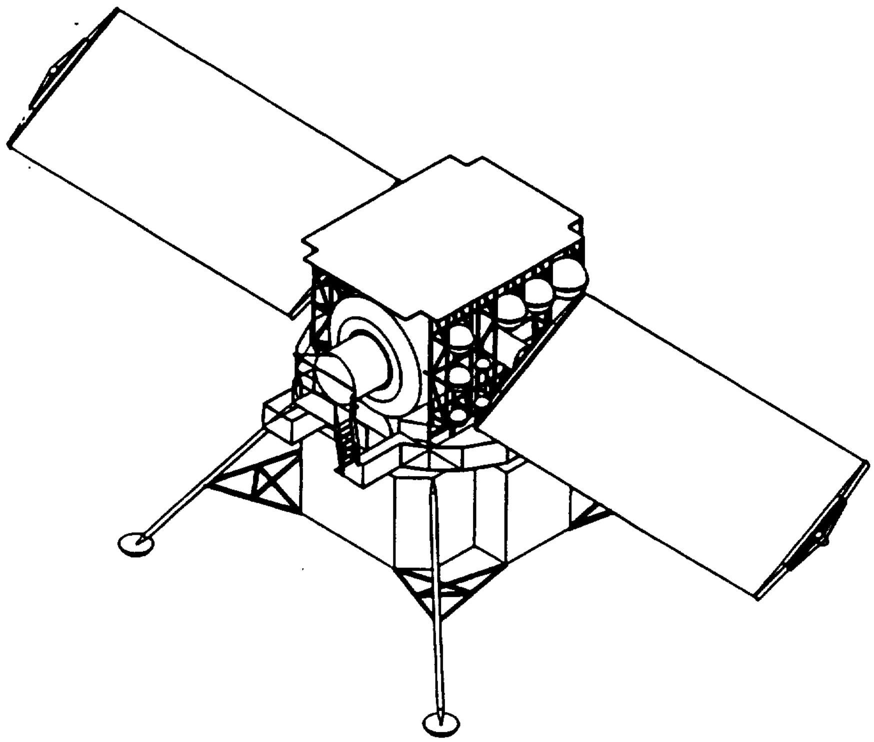


Figure 5 First Lunar Outpost (View)

Habitable Volume	42 m3	(FLO Baseline - 32 m3)
Usable Floor Area	21 m2	(FLO Baseline - 14 m2)

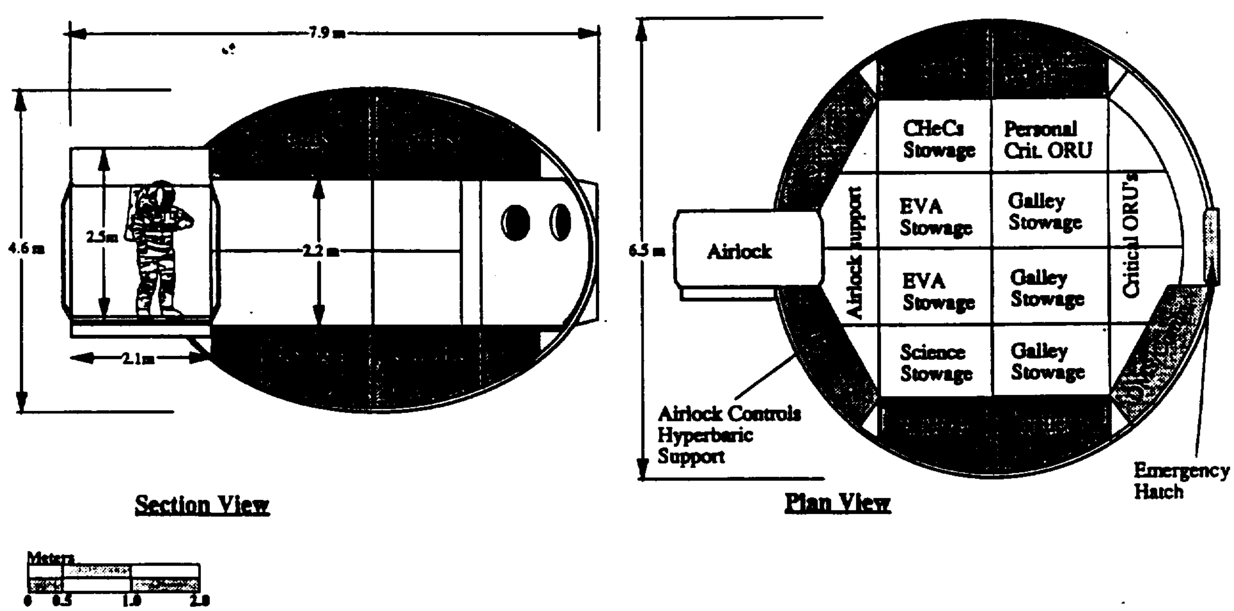
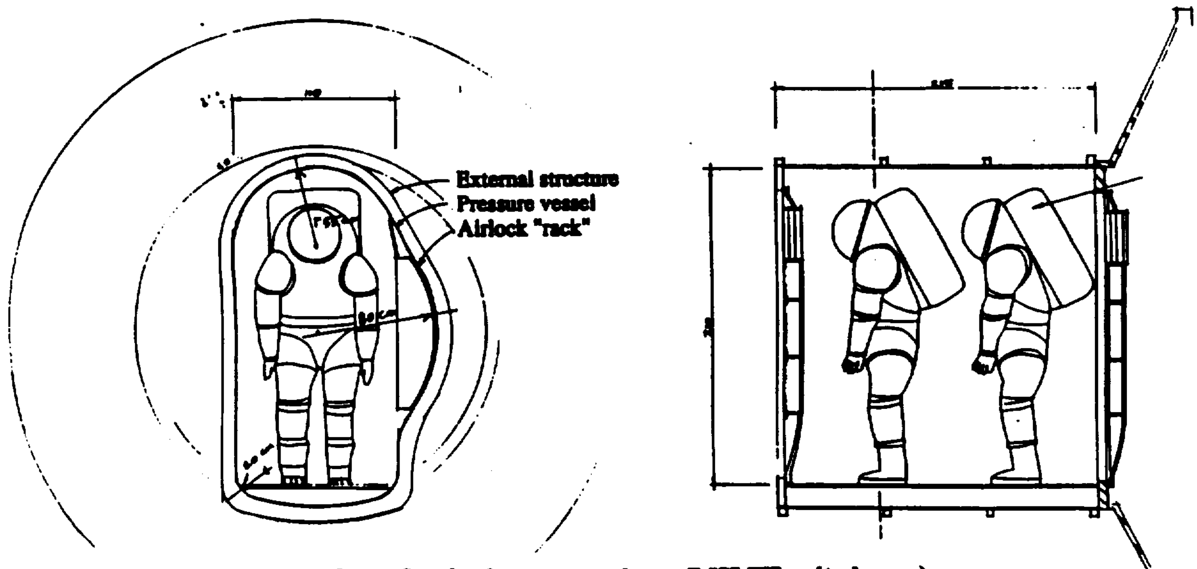


Figure 6 FLO Ellipsoidal Habitat Option (View)



- Accommodates 2 suited crewmembers (MK III suit shown)
- Accommodates hyperbaric treatment activities
- Minimum volume to conserve gas and power
- Accommodates resupply operations as well as SSF crewlock

Figure 7 Alternative FLO Airlock (View)

COLUMN		1	2	3	4	5	6
		LUNAR OUTPOST HAB-A				LUNAR OUTPOST HAB-A	
THEN YEAR $ WBS		OCT FLO NON/REC $K	FLOLOK NON/REC $K	OCT FLO RECUR $K	FLOLOK RECUR $K	OCT FLO TOTAL $K	FLOLOK TOTAL $K
3.x.1	ELEMENT INTEGRATION		1,912				1,912
3.X.2	DESIGN INTEGRATION	27,831	21,777	445	66	28,276	21,843
3.X.3	SUPPORT EQUIPMENT	303	237	4,975	740	5,278	977
3.X.4	SOFTWARE	3,669	2,871	231	34	3,900	2,905
3.X.5	ELEM TEST ART ASSY & TEST						
3.X.6	FLIGHT ARTICLE ASSY & TEST	114	89	2,735	407	2,849	496
3.X.7	STRUCTURES	558	3,541	5,720	3,268	6,278	6,809
3.X.8	MECHANISMS	365	665	1,072	1,204	1,437	1,869
3.X.9	PACKAGES	58	20	1,896	110	1,954	130
3.X.10	ELECTRICAL POWER	417	0	2,927	0	3,343	0
3.X.11	DATA MANAGEMENT	170	0	3,637	0	3,808	0
3.X.12	INTERNAL AUDIO/VIDEO	656	0	2,122	0	2,778	0
3.X.13	THERMAL CONTROL	652	2,282	3,838	4,103	4,490	6,385
3.X.14	ECLSS						
3.X.14.1	TEMP & HUMIDITY CONTROL	280	0	3,801	0	4,081	0
3.X.14.2	ATMOS CONT & SUPPLY	131	0	5,772	0	5,902	0
3.X.14.3	ATMOS REVITALIZATION	290	0	14,921	0	15,211	0
3.X.14.4	FIRE DETEC & SUPPRESS	105	0	691	0	796	0
3.X.14.5	WATER RECOVERY & MANAG	779	0	7,361	0	8,139	0
3.X.14.6	WASTE MANAGEMENT	119	0	1,851	0	1,970	0
3.X.15.1	MAN SYSTEMS						
3.X.15.1.1	RESTRAINTS & MOBILITY AIDS	1,605	0	266	0	1,871	0
3.X.15.1.2	WORKSTATIONS	24	0	8	0	32	0
3.X.15.1.4	INTRFC PRTS/STRCS & FLRS	59	87	603	573	662	660
3.X.15.1.5	STOWAGE	123	0	524	0	647	0
3.X.15.1.6	HOUSEKEEPING/TRASH MANAGMENT	164	0	715	0	879	0
3.X.15.1.7	CREW QUARTERS						
3.X.15.1.8	GALLEY & FOOD MANAGMENT	876	0	2,948	0	3,824	0
3.X.15.1.9	PERSONAL HYGIENE SYSTEM (PHS)	1,000	0	1,584	0	2,583	0
3.X.15.1.10	FURNITURE/ACCOMODATIONS						
3.X.15.1.11	CREW HEALTH CARE						
3.X.15.1.12	PORTABLE EMERGENCY PROVISIONS						
3.X.15.2	MAN SYS EQUIPMENT INTEGRTION	30	23	3,750	558	3,780	581
3.X.15.3	HUMAN ENGINEERING	1,545	1,209			1,545	1,209
3.X.17	LAB SUPPORT EQUIP (GLOVEBOX)			3,000		3,000	0
3.X.18	SYS CERT TEST/MANU & ASSY	5	4			5	4
3.X.19	CERT TEST ARTICLE SYSTEMS	82	64			82	64
3.X.30	MANUFACTURING & ASSEMBLY	383	300	1,590	236	1,973	536
3.X.31	TECHNOLOGY DEMO HARDWARE	258	202			258	202
3.X.32	FLUID MANAGEMENT SYSTEM (FMS)						
3.X.33	TEST BED SUPPORT	448	351	15	2	463	353
	TOTALS - THEN YEAR DOLLARS	43,095	35,634	78,999	11,301	122,095	46,935
	TOTALS - 1992 DOLLARS	39,351	32,537	62,911	9,000	102,261	41,537
	UNIT 2, 95% LEARNING CURVE			59,765	8,550	59,765	8,550

Figure 8 FLO Baseline and FLOlock

REFERENCES

1. "Space Station Freedom WP01 Mass Properties Report", Boeing Document D683-10275-22., July 15, 1992

2. "Space Transfer Concepts and Analyses for Exploration Missions", Phase 3, Final Report, Boeing Defense and Space Group, Huntsville, D615-10062-2, June 1993