Analysis Of Changes In Estimated Cost Of The Skylab Program B-172192

National Aeronautics and Space Administration

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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Contents

ABBREVIATIONS

GAO	General Accounting Office
NASA	National Aeronautics and Space Administration

COMPTROLLER GENERAL'S REPORT ON
ANALYSIS OF CHANGES IN ESTIMATED
COST OF THE SKYLAB PROGRAM
National Aeronautics and Space
Administration B-172192

D I G E S T

WHY THE REVIEW WAS MADE

The General Accounting Office (GAO) reviewed the system used by National Aeronautics and Space Administration (NASA) Office of Manned Space Flight in estimating the cost of the Skylab Program--its fourth manned space flight program. GAO also analyzed changes in the estimated cost and obtained NASA's reasons for those changes.

The goal of Skylab is to establish a workshop and solar observatory in earth orbit for the purpose of expanding scientific knowledge of the earth and the surrounding universe. Skylab will also build the foundation for future manned exploration beyond the moon, and it is the forerunner to a permanent space station. (See p. 6.)

Distribution of this report is being restricted because it contains NASA's estimates of contract cost for major hardware items. NASA believes that public disclosure of these estimates should not be made to

--avoid prejudicing the Government in future negotiations with contractors and

--avoid the disclosure of data which would permit contractors to base claims on NASA's estimates of projected costs. (See p. 92.)

FINDINGS AND CONCLUSIONS

Cost-estimating system

The Office of Manned Space Flight estimates the cost of Skylab through its program operating plan system. This system produces reports showing prior actual and future estimated cost and obligation data for manned space flight programs funded from NASA's research and development appropriation. These reports were designed to furnish basic financial data needed for budget planning and financial management and to meet the requirements of external review agencies. (See p. 12.)

NASA officials have stated that, during the preparation of a program operating plan, emphasis is placed upon estimating the financial requirements for the next budget submission. Estimates of the cost of the program may contain amounts which are not considered to be good estimates

but which remain in the totals because they are for future years. NASA officials have stated, however, that, at the time it is developed, the program operating plan's estimate is the best available estimate of the cost of the Skylab Program. (See p. 12.)

The estimated cost of the Skylab Program does not represent the program's total cost. Costs funded by either of NASA's two other appropriations--research and program management or construction of facilities--do not appear as part of the estimate. The additional costs charged to these appropriations cannot be measured completely because they are not always identified as being related specifically to a particular manned space flight program.

Also, the estimate did not include all research and development appropriation costs. For example, the Office of Manned Space Flight established a policy that, through the completion of the Apollo Program, the Skylab Program would fund its own support contracts, and the Apollo Program would fund the support contracts which benefited both programs (common support). NASA did not identify the value of common support which was applicable to the Skylab Program. (See p. 12.)

In addition, the estimate did not include the cost of hardware and equipment procured by the Apollo Program and transferred to the Skylab Program. (See p. 16.)

The Office of Manned Space Flight's guidelines for the preparation of program operating plans did not direct the centers to provide for inflation. GAO found that some elements of the Skylab estimate included a provision for inflation and others did not. Therefore the total increase in the estimated cost of the Skylab Program attributable to inflation could not be determined. (See p. 17.) GAO is making a Government-wide review of the policies and procedures for recognizing inflation in cost estimates. The report will be issued to the Congress at a later date.

Many cost estimates were based partially or entirely on experience and/or judgment for which sufficient documentation was not available to show what was considered in arriving at the estimate. (See chs. 3 and 4.) NASA indicated that it would continue its attempts to improve in the area of documentation.

Changes in cost estimates

The first program operating plan which provided an estimate of Skylab's cost was prepared in October 1968. GAO compared this estimate with one made in October 1970--the most current estimate available at the time of the review.

Projects	Estimated costs October 1968	Estimated costs October 1970	Increase or decrease (-) Amount	Increase or decrease (-) Percent
	(millions)			
Experiment definition	$ 23.8	$ 47.2	$ 23.4	98
Experiment development	110.8	218.8	108.0	97
Spacecraft modifications	604.4	624.7	20.3	3
Saturn workshop	274.0	680.2	406.2	148
Apollo telescope mount	195.8	113.2	-82.6	-42
Saturn IB vehicle	404.4	232.7	-171.7	-42
Saturn V vehicle	3.6	157.1	153.5	4264
Payload integration	163.0	148.6	-14.4	-9
Mission operations	281.1	54.7	-226.4	-81
Program support	164.7	74.3	-90.4	-55
Contract administration	11.7	15.6	3.9	33
Design and development	14.0	14.0	-	-
Lunar exploration	6.8	-	-6.8	-100
Space station definition	7.7	-	-7.7	-100
Total	$2,265.8	$2,381.2	$115.4	5

Note: Figures may not add due to rounding.

As shown above, the Office of Manned Space Flight's October 1970 estimate of cost of the Skylab Program was $2,381.2 million. Through fiscal year 1970, NASA has obligated $849.9 million of this amount from its research and development appropriation. Consequently an additional $1,531.3 million is needed for the program between fiscal years 1971 and 1974, the current estimated year of completion.

NASA attributed the increases primarily to

--change in the earth orbiting workshop configuration,

--better definition of experiments,

--additional hardware,

--contracting out for certain work which was to have been performed in-house,

--launch schedule slippages totaling 15 months, and

--inclusion of flight support costs in the October 1970 estimate

NASA attributed the decreases primarily to

--canceled production of two Saturn IB launch vehicles (except for the first stages),

--cancellation of lunar module modifications and simplified command and service module requirements resulting from the change in the workshop configuration,

--a reduction in the Office of Manned Space Flight's allowance for contingencies, and

--transfer of funding for certain support contracts from the Skylab Program to the Apollo Program.

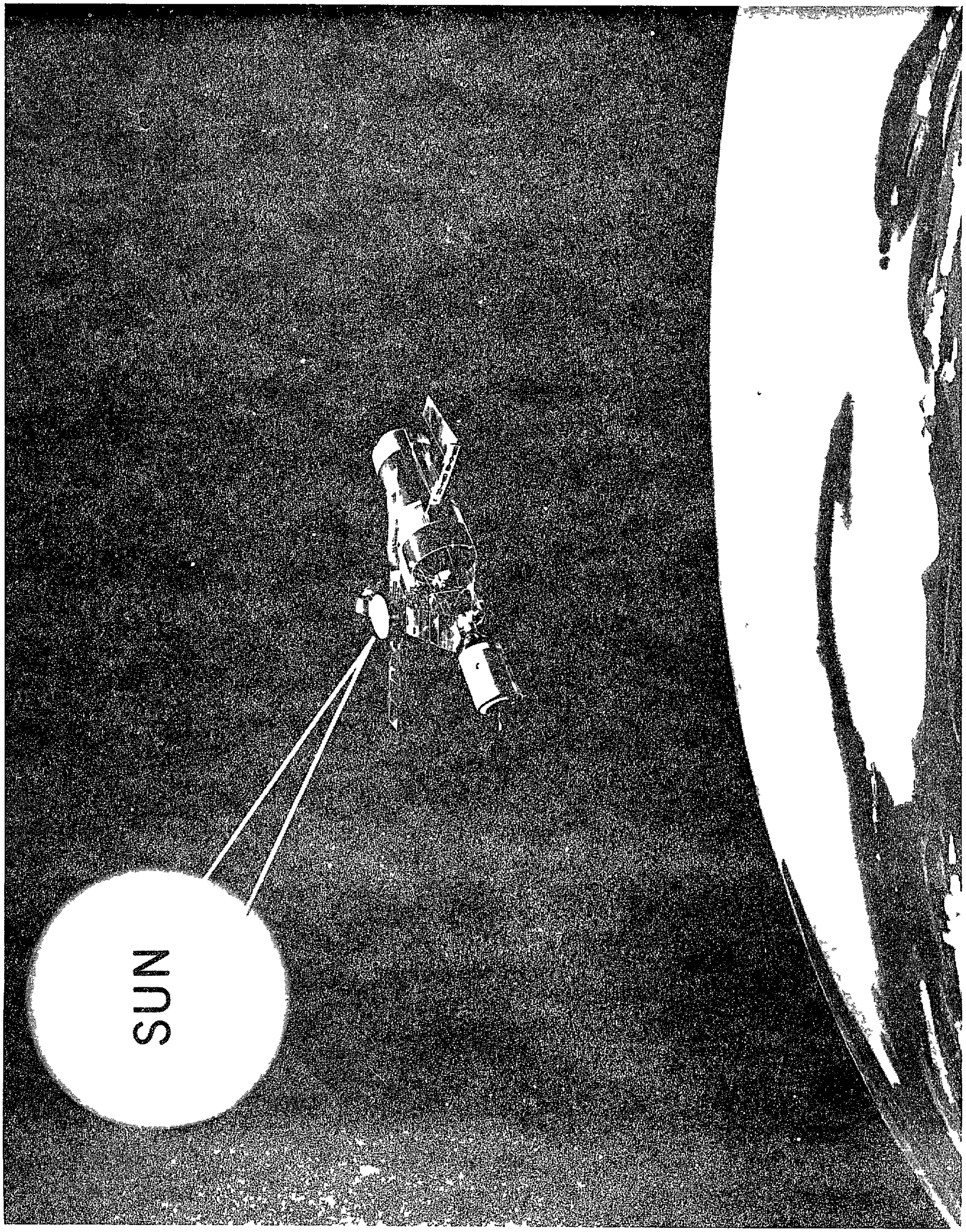
In addition, NASA stated that the transfer of program elements among projects explained many of the fluctuations in individual project cost estimates and that, from an overall point of view, these transfers did not constitute unwarranted cost growth. NASA stated, however, that it would be difficult to allocate the cost increases and decreases among projects involved in the transfers and that such an allocation could take as much as 3 months and might only result in a rough estimate. Accordingly, GAO was not able to price out the effect of the transfers. (See p. 85.)

RECOMMENDATIONS OR SUGGESTIONS

None.

AGENCY ACTIONS AND UNRESOLVED ISSUES

NASA agreed, in general, with the information in GAO's report. NASA's comments are included in appendixes I and II and are discussed in chapter 18.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CHAPTER 1

INTRODUCTION

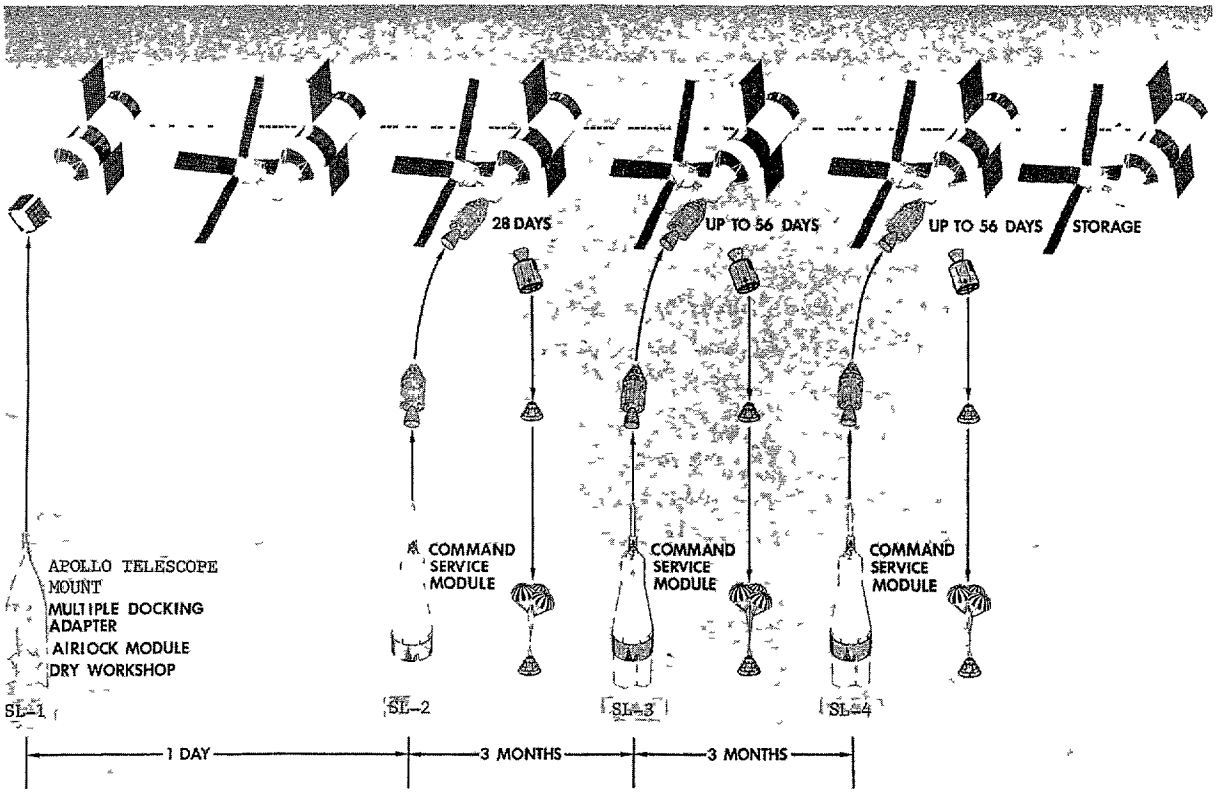
Responding to congressional interest in the cost of major research and development programs, we have reviewed the system used by the National Aeronautics and Space Administration's Office of Manned Space Flight for estimating the cost of the Skylab Program--its fourth manned space flight program. We analyzed changes in the cost estimates and obtained NASA's reasons for these changes.

Our review of the Office of Manned Space Flight's cost-estimating system is discussed in chapters 2, 3, 4, and 5. Chapters 6 through 17 present the changes in the cost estimates developed by NASA and NASA's reasons for these changes. Chapters 8 and 10 present also the results of our examination into the cost of selected hardware contracts. The illustrations included in this report were provided to us by NASA.

The goal of the Skylab Program is to establish a workshop and solar observatory in earth orbit for the purpose of expanding the scientific knowledge of the earth and the surrounding universe. The Skylab Program will also build the foundation for future major steps in manned exploration beyond the moon, and it is the forerunner to a permanent space station project.

MISSION PROFILE

The Skylab Program is structured around a solar observatory and a workshop containing laboratories, work areas, control stations, and crew living quarters. Following the launch of the workshop, three teams of astronauts, using modified Apollo command and service modules, will visit and use the workshop during an 8-month period currently planned to begin in November 1972. Following is a pictorial profile of the four Skylab Program missions which NASA identifies as SL-1, SL-2, SL-3, and SL-4.



A Saturn V launch vehicle, with its first two stages as propellant stages and its third stage completely outfitted as a workshop, will launch the hardware for the Skylab Program into an orbit approximately 235 nautical miles above the earth. This launch will be followed 1 day later by the launch of a Saturn IB carrying three astronauts to the workshop where they will remain for up to 28 days. Each of the two subsequent launches of Saturn IB's also will carry three astronauts to the workshop where each group will remain for up to 56 days.

The Office of Manned Space Flight at NASA Headquarters manages the Skylab Program. In carrying out this responsibility, the Office of Manned Space Flight has the following three field centers under its direction.

Center	Responsibility
George C. Marshall Space Flight Center, Huntsville, Alabama	Systems engineering, payload integration, launch vehicles, multiple docking adapter, airlock module, Apollo telescope mount development, orbital workshop systems, and payload enclosures.
Manned Spacecraft Center, Houston, Texas	Command module and service module modifications, medical research and operations, crew systems support and training, flight mission planning, operations, and recovery operations.
John F. Kennedy Space Center, Florida	Launch operations and mission support.

HISTORICAL PROFILE

The Skylab Program (formerly the Apollo Applications Program), as described above, is intended to capitalize on the capabilities and resources developed in the Apollo Program. As early as 1962 studies were being conducted to define future manned missions after the Mercury, Gemini, and Apollo Programs. These studies were aimed at determining the future use of Apollo flight hardware for extensive scientific and technological space exploration. The Apollo Applications Program, called the Apollo Extension Systems until 1966, was a result of these studies.

The objectives of the Apollo Applications Program, as delineated in 1966, included plans for both extended lunar exploration and earth orbit operations. In 1969, however, the extended lunar exploration portion was dropped from the Skylab Program and was assigned to the Apollo Program. The earth orbit operations portion remained with the Apollo Applications Program and has evolved into what now is referred to as the Skylab Program.

Until July 1969 the mission plan centered around converting the S-IVB stage of a Saturn IB launch vehicle into a workshop after its initial use as part of the propulsion system required to reach earth orbit. The spent S-IVB stage

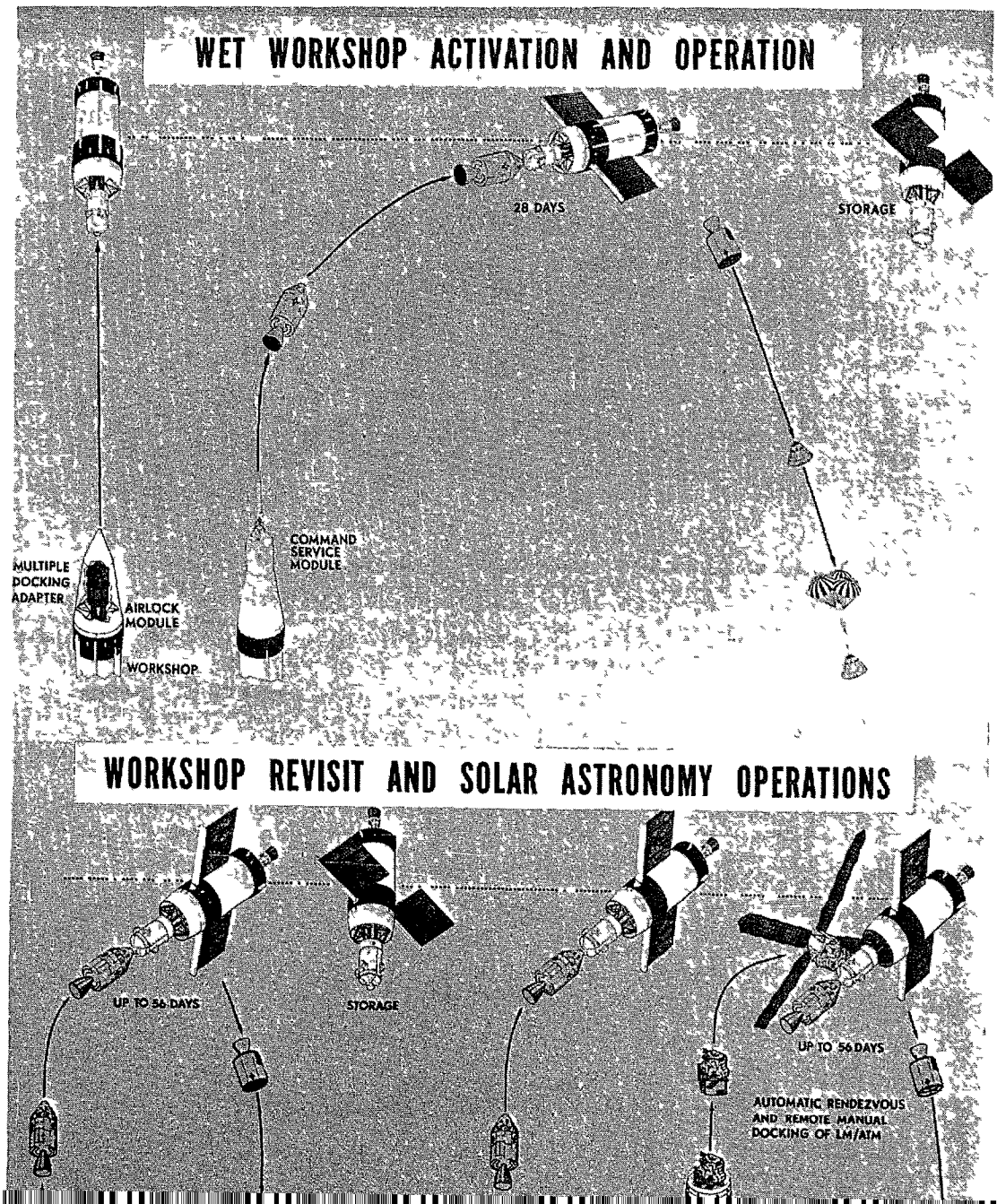
was to have been cleansed of fuel fumes and corrosive residue and used as a workshop for the conduct of scientific, technological, and applications experiments. NASA referred to this as the wet workshop concept.

A solar observatory--the Apollo telescope mount--carried in an unmanned modified lunar module ascent stage was to be launched by another Saturn IB, with automatic rendezvous and docking with the workshop occurring after its arrival in orbit. A pictorial profile of the Apollo Applications Program wet workshop concept is shown on page 10.

In July 1969 the mission plan was modified to use the launch capability of the larger Saturn V launch vehicle to launch simultaneously the orbital workshop, airlock module, multiple docking adapter, and the Apollo telescope mount. NASA refers to this as the dry workshop concept because the orbital workshop will be outfitted on the ground and will arrive in orbit equipped for immediate occupancy by the astronauts. The total payload package being outfitted and checked out on the ground eliminated the need for the astronauts to prepare the spent S-IVB stage for the conduct of scientific, technological, and applications experiments while in orbit. The dry workshop concept is being used in the Skylab Program today.

The decision to switch from the wet to the dry concept caused major program changes. The principal difference in the hardware configuration was the clustering of all payload modules into a single payload for the Saturn V launch vehicle--that is, the workshop, airlock module, multiple docking adapter, and Apollo telescope mount became integrated for the launch. This integration eliminated the need for the unmanned rendezvous and docking of the lunar module/Apollo telescope mount with the workshop after its arrival in orbit and thereby eliminated the need for the lunar module ascent stage.

The change from the wet to the dry concept also reduced the interface requirements of the command and service module. While docked under the wet concept, the command and service module was the provider of the required atmosphere for the cluster--including the pressurization of the airlock module,


WET WORKSHOP ACTIVATION AND OPERATION
28 DAYS
STORAGE
COMMAND SERVICE MODULE
MULTIPLE DOCKING ADAPTER
AIRLOCK MODULE
WORKSHOP
WORKSHOP REVISIT AND SOLAR ASTRONOMY OPERATIONS
UP TO 56 DAYS
STORAGE
UP TO 56 DAYS
AUTOMATIC RENDEZVOUS AND REMOTE MANUAL DOCKING OF LM/ATM

multiple docking adapter, and workshop. In addition, the command and service module's propulsion system was to provide the attitude control for the cluster, whereas under the dry concept it is only a backup system.

During docked operations under the dry concept, the command and service module will be powered down to the lowest level possible to maintain operational readiness for return and will draw power from the workshop for housekeeping functions. NASA refers to this as a quiescent command and service module as compared to the command and service module under the wet concept.

CHAPTER 2

COST-ESTIMATING SYSTEM

The Office of Manned Space Flight estimates the cost of the Skylab Program through its program operating plan system. This system produces reports showing prior actual and future estimated cost and obligation data for manned space flight programs funded from NASA's research and development appropriation. These reports were designed to furnish basic financial data needed for budget planning and financial management and to meet the requirements of external review agencies.

In each estimate NASA includes allowances for contingencies in future years. According to NASA officials the basic reason for including such allowances is that there are many unknown variables in a research and development program, and these contingency allowances serve to absorb program changes that would otherwise cause changes in the estimated cost of the program.

NASA officials have stated that, during the preparation of a program operating plan, primary emphasis is placed upon estimating the financial requirements for the fiscal years to be included in the next budget submission. Each budget submission includes the preceding year, the current year, and the budget request for the next year. Because of this emphasis, differences which may arise between NASA Headquarters and the field centers concerning estimates for future years usually are not resolved until these years are included as part of a budget submission.

In this regard the officials have added that the estimates of the cost of the program may contain amounts which are not considered to be good estimates but which remain in the totals because they are for future years. Even so, these officials have said that the program operating plan's estimate of the cost of the Skylab Program is the best available estimate at the time it is developed.

PREPARATION OF THE PROGRAM OPERATING PLAN

The program operating plan is updated semiannually. The steps generally followed during each updating cycle are as follows:

1. On the basis of general guidelines from NASA Headquarters, the three manned space flight field centers, as well as NASA Headquarters, prepare estimates which are incorporated into a preliminary program operating plan.

2. Headquarters officials review the preliminary plan in view of anticipated funds availability and their knowledge of the program and prepare revised guidelines which provide estimate ceilings for each center and for NASA Headquarters.

3. On the basis of the revised guidelines, the preliminary plan is adjusted by the three field centers and NASA Headquarters and is consolidated into the final program operating plan.

As a part of our review, we examined into the preparation of the October 1970 program operating plan--the most recent estimate at the time of our review. The preparation of this estimate was initiated by guidelines dated July 31, 1970, issued by the Associate Administrator for the Office of Manned Space Flight to the Marshall Space Flight Center, the Manned Spacecraft Center, and the Kennedy Space Center. On the basis of these guidelines, preliminary estimates of the costs of manned space flight programs were prepared and submitted to NASA Headquarters.

The preliminary estimate for the Skylab Program was $2.1 billion as shown below.

	Millions
Marshall Space Flight Center	$1,160.0
Manned Spacecraft Center	757.2
Kennedy Space Center	86.5
NASA Headquarters and other centers	97.3
Total	$2,101.0

During our review we examined into the procedures followed by the Marshall Space Flight Center and the Manned Spacecraft Center in preparing their preliminary estimates. We examined also into the review process at NASA Headquarters. The results of these examinations are presented in chapters 3, 4, and 5.

COSTS NOT INCLUDED IN ESTIMATE

The program operating plan's estimate of the cost of the Skylab Program does not represent the total cost of the program. Costs which are related to the program but which are funded by either of NASA's two other appropriations--research and program management or construction of facilities--do not appear as part of the estimate. The additional costs charged to these appropriations cannot be measured completely because they are not always identified as being specifically related to a particular manned spaced flight program.

We found that the program operating plan's estimate of the cost of the Skylab Program had not included certain research and development appropriation costs related to that program. These costs are discussed below.

Common support

The coordination of the Skylab Program with the Apollo Program has resulted in the Office of Manned Space Flight's establishing a policy that, through the completion of the Apollo Program, the Skylab Program will fund its own support contracts, and the Apollo Program will fund the support contracts which benefit both programs (common support). We found that NASA did not identify the value of common support applicable to the Skylab Program.

As a result of this policy, changes in the scheduled completion date for the Apollo Program have had a direct effect upon the estimated cost of the Skylab Program. The following chart depicts the intended source of funding for common support at the dates of the program operating plans included in our review and demonstrates that the content of the estimate is different in each of the estimates.

Fiscal year	Programs funding common support		
	October 1968 (note a)	December 1969 (note b)	October 1970 (note c)
1971 and prior	Apollo	Apollo	Apollo
1972	Skylab	Apollo	Apollo
1973	Skylab	Apollo	Skylab
1974	-	Apollo	Skylab

[a]Apollo was scheduled for completion in fiscal year 1971, and Skylab in fiscal year 1973.

[b]Apollo was scheduled for completion in fiscal year 1975, and Skylab in fiscal year 1973.

[c]Apollo was scheduled for completion in fiscal year 1972, and Skylab in fiscal year 1974.

As shown above, the October 1968 program operating plan was prepared under the assumption that the Apollo Program would fund common support through fiscal year 1971 and that the Skylab Program would assume funding responsibility thereafter.

Prior to the preparation of the December 1969 program operating plan, the Apollo Program's scheduled completion date was extended past the completion date for the Skylab Program. This resulted in the December 1969 program operating plan's being prepared under the assumption that the Apollo Program would fund common support.

The scheduled completion date for the Apollo Program was changed from fiscal year 1975 to 1972 prior to the preparation of the October 1970 program operating plan. Therefore this plan was prepared under the assumption that the

Apollo Program would fund common support through fiscal year 1972 and that, after fiscal year 1972, common support would be divided into (1) flight support which would be funded by the Skylab Program during fiscal years 1973 and 1974 and (2) operating base which would be funded as a separate item--not as a part of any approved manned space flight research and development program.

Flight support costs consist of hardware contractor support for the Saturn IB vehicle, the Saturn V vehicle, and the command and service module. Contractor support includes checkout, launch, postflight data analysis, and sustaining engineering. The inclusion of flight support for fiscal years 1973 and 1974 in the October 1970 program operating plan increased the Skylab Program's estimated cost by about $290 million.

Operating base is the term used to describe contractor costs associated with center operational and support activities necessary to support approved and planned manned space flight programs. The estimate for operating base during fiscal years 1973 and 1974 in the October 1970 program operating plan was about $625.8 million. The portion of this amount applicable to the Skylab Program was not identified in the program operating plan.

Equipment

Our review showed that the following equipment was supplied to the Skylab Program by the Apollo Program and was not included in the estimated cost of the Skylab Program.

Description (note a)	Units
Command and service module and systems/components	4
Spacecraft guidance and navigation system	4
Spacecraft lunar module adapter	4
Launch escape system	4
Saturn IB	7[b]
Saturn IB electrical support equipment and ground support equipment	1
Saturn V (S-IVB stages will be outfitted as an orbital workshop)	2
Saturn V launch vehicle digital computers	2
Saturn V electrical support equipment and ground support equipment	1
Ground support equipment for the orbital workshop	1
Apollo telescope mount automatic checkout equipment stations at the Marshall Space Flight Center, the Manned Spacecraft Center, and the Kennedy Space Center	3

[a]The Skylab Program is to fund modifications.

[b]Current Skylab Program plans require the use of only four of these vehicles.

PROVISIONS FOR INFLATION

The cost-estimating system used by the Office of Manned Space Flight does not provide uniform treatment for inflation. Because the Office of Manned Space Flight's guidelines for the preparation of program operating plans had not directed the centers concerning provisions for inflation, we found that some elements of the Skylab Program estimate included a provision for inflation and others did not.

NASA officials stated that the amount of increase in the estimated cost for any element of the Skylab Program which was attributable to inflation was never shown in the program operating plan as a separate item and could not, in most instances, be identified. We were therefore unable to identify the amount of increase in the estimated cost of the Skylab Program that was attributable to inflation.

CHAPTER 3

COST-ESTIMATING PROCEDURES AND PRACTICES

AT THE MARSHALL SPACE FLIGHT CENTER

Upon receipt of the general guidelines from NASA Headquarters, the Marshall Space Flight Center issued amplifying instructions to each of its organizations for preparation of their cost estimates for the preliminary program operating plan. The offices responsible for the Skylab projects assigned to the Marshall Space Flight Center estimated that these projects would cost about $1.2 billion at completion. Of this amount, $432.3 million represented incurred cost through fiscal year 1970, and $727.7 million represented the estimated cost to complete the projects. The following schedule shows the estimated cost of the projects.

Project	Actual cost at June 30, 1970	Estimated cost to complete	Estimated cost at completion
	(millions)		
EXPERIMENT DEFINITION	$ 8 0	$ -	$ 8 0
EXPERIMENT DEVELOPMENT.	64 5	32 2	96 7
Apollo telescope mount experiments	61 8	29 4	91 2
Other	2.7	2.8	5 5
SATURN WORKSHOP	159 6	474 8	634 4
Airlock module	48 0	200 1	248 1
Multiple docking adapter	6 9	43 6	50.5
Orbital workshop	89 5	199 1	288.6
Support	15.2	32 0	47.2
APOLLO TELESCOPE MOUNT	73 2	31 9	105 1
Lunar module modifications	9 7	9	10 6
Systems	63 5	31 0	94 5
PAYLOAD INTEGRATION.	63 1	64 0	127 1
Definition	9 9	-	9 9
Implementation	53 2	64 0	117.2
PROGRAM SUPPORT	7 7	23 2	30 9
SATURN IB VEHICLE·	52 8	95 7	148 5
S-IB stage	28.7	32 7	61 4
S-IVB stage	5.8	27 3	33 1
Instrument unit	-	11.9	11 9
Ground support equipment	.3	7 9	8 2
Engines	14 4	2 2	16 6
Vehicle support	3 6	13 7	17 3
SATURN V VEHICLE	3 4	5 9	9 3
S-IC stage	2 3	5	2 8
S-II stage	-	-	-
S-IVB stage	-	-	-
Instrument unit	-	5	.5
Ground support equipment	-	-	-
Engines	1.1	.2	1 3
Vehicle support	-	4.7	4.7
Total	$432 3	$727.7	$1,160.0

HOW COST ESTIMATES WERE PREPARED

In preparing the project cost estimates, the estimators allocated the contract values to assign to each project its applicable share of the contract values. These adjustments were made because some of the Skylab Program contracts contained effort for more than one project, as well as effort for other NASA field centers. The estimators then added to the allocated contract values an estimate for changes to the contracts to complete the projects.

These changes are categorized as authorized changes--changes which the contractor has been directed to implement but the costs of which have not been negotiated; known and probable changes--changes which the contractor will probably be directed to implement at a future date; and anticipated changes--changes for which the extent and magnitude have not been defined. The amounts included in these categories were based on both in-house and contractor-furnished estimates.

Before the project cost estimates were furnished to NASA Headquarters, they had been subjected to reviews by the respective Skylab Project Managers, the Skylab Program Manager, the Center Program Management Director, and the Marshall Space Flight Center Director. During the review by the Skylab Program Manager, an allowance for contingencies was added to some of the project estimates to absorb possible future changes in the projects. No other changes had been made to the project estimates before they were submitted to NASA Headquarters.

The following schedule shows the increases made by the Skylab Program Manager to the Project Managers' estimates for anticipated changes.

Project	Project managers' estimate to complete	Increase by Skylab Program Manager	Revised estimated cost to complete
	(millions)		
Project estimates not increased	$165.7	$ -	$165.7
Project estimates increased:			
Saturn workshop:			
Airlock module	135.5	64.6	200.1
Multiple docking adapter	24.4	19.2	43.6
Orbital workshop	144.0	55.1	199.1
Support	27.2	4.8	32.0
Total	331.1	143.7	474.8
Payload integration	51.0	13.0	64.0
Program support	19.6	3.6	23.2
Total	401.7	160.3	562.0
Total	$567.4	$160.3	$727.7

As shown above, $160.3 million was added by the Skylab Program Manager to the estimates for the Saturn workshop, payload integration, and program support projects.

Our review of the cost estimating procedures at the Marshall Space Flight Center included a detailed examination into the preparation of the estimates for the airlock module project and for three of the experiments planned for the Apollo telescope mount. Of the $727.7 million estimated to complete the Skylab projects, we selected for review $210.2 million, or about 29 percent.

APOLLO TELESCOPE MOUNT EXPERIMENTS

Of the five major experiments planned for the Apollo telescope mount, we reviewed three for which the estimated cost to complete totaled $22.3 million. The composition of this amount and the results of our review are shown below.

	Estimated cost to complete	Amount not supported by documentation	Effect of errors made during preparation	
			Overstated	Understated
	(millions)			
Allocated contract value	$ 6.1	$ -	$ .3	$.1
Contract changes:				
Authorized	.3	-	.2	.1
Known and probable	16.0	2.5	.5	.2
Anticipated	-	-	-	-
Total	16 3	2.5	.7	.3
Total	$22.3	$2.5	$1.1	$.4

Note: Figures may not add due to rounding.

No supporting documentation

As shown above, documentation was not available to support $2.5 million, or 15 percent, of the $16.3 million estimated for contract changes. Although documentation was available for $13.8 million of the $16.3 million estimated for contract changes, we found that the in-house computations furnished for $9.4 million of this $13.8 million did not show the basis used to arrive at the elements (men multiplied by time multiplied by dollar rates) included in the computations. The estimator told us that the $2.5 million and the elements for the $9.4 million had been based on discussions with the contractors and that documentation was not available to show the content of the discussions.

Errors made during the estimating process

As shown in the table above, errors made during the estimating process caused overstatements of $1.1 million

and understatements of $0.4 million in the estimated cost to complete the three experiments.

Our review of the computation made in arriving at the allocated contract values of $6.1 million disclosed that this amount contained overstatements of $0.3 million, which was principally caused by the failure to delete from the contract values $0.3 million for effort applicable to other Skylab projects, and an understatement of $70,000, which resulted from use of the wrong contract value for one of the experiments.

Errors were also made during the preparation of the $16.3 million estimate for contract changes. These errors caused the estimate to contain overstatements of $0.7 million and understatements of $0.3 million. We found, for example, that part of the $0.7 million overstatement had been caused by using an estimate of $0.3 million for authorized contract changes although these changes had already been negotiated at a value of $0.2 million. The official who prepared the estimate told us that he did not know that the changes had been negotiated at the time he prepared the $0.3 million estimate.

The following are other examples of the errors that were made.

--Eight authorized changes were not considered in the preparation of the estimate because the estimator had not been aware of the changes at the time he had prepared the estimate.

--An amount for contractor effort was included in both the computations for the allocated contract value and the estimate for known and probable changes to the contract.

--A computation error resulted in an $80,000 understatement of an estimate.

AIRLOCK MODULE

The $474.8 million estimated to complete the Saturn workshop project included an amount of $200.1 million to

complete the airlock module. As a part of our review, we examined into the preparation of $187.9 million of this $200.1 million estimate. The results of our review are shown below.

	Estimated cost to complete	Amount reviewed by GAO	Amount not supported by documentation
	(millions)		
Allocated contract value	$ 60.3	$ 60.3	$ -
Contract changes:			
Authorized	42.9	39.8	22.1
Known and probable	21.2	12.1	11.4
Anticipated	75.8	75.8	75.8
Total	139.8	127.6	109.2
Total	$200.1	$187.9	$109.2

Note: Figures may not add due to rounding.

No supporting documentation

As shown above, documentation was not available to support $109.2 million, or about 86 percent, of the amount we reviewed for contract changes. The remaining $18.4 million was supported by contractor proposals or estimates. During our review we were told that the bases for the $109.2 million estimate were as follows:

Bases for the estimate	Amount (millions)
In-house discussions	$ 80.7
Verbal estimates obtained from the contractor	25.6
In-house adjustments to contractor proposals and estimates	3.0
Total	$109.2

Note: Figures may not add due to rounding.

$80.7 million

The $80.7 million estimated on the basis of in-house discussions included $4.9 million for known and probable changes and $75.8 million for anticipated changes--$64.6 million of which had been added by the Program Manager during his review for a contingency-type reserve to cover possible future changes.

We were advised that these estimates had been arrived at in various management meetings and that no documentation was available to show the bases for the judgments made or the rationale considered in arriving at the estimates.

$25.6 million

Concerning the $25.6 million which was based on verbal estimates received from the contractor, the estimator told us that he had maintained a file of informal notes for estimates obtained from the contractor but that he had thrown his notes away after the preliminary program operating plan had been prepared because he had no further use for the information.

We reviewed selected written cost estimates subsequently received from the contractor after the preliminary program operating plan based on the verbal estimates had been submitted to NASA Headquarters. In a number of instances, as shown by the following schedule, we noted significant differences between the written estimates and the verbal estimates. The estimator could not explain the differences.

Estimates based on verbal information from the contractor	Estimates later received from the contractor	Differences
	(millions)	
$1.8	$2.1	$.3
.2	.0	-.2
1.0	.4	-.7
.2	.2	-.1
1.7	2.5	.8
.4	.1	-.3
.1	.0	-.1

Note: Figures may not add due to rounding.

$3 million

For the $3 million which was a result of in-house adjustments to contractor proposals and estimates, we found that the contractor had furnished cost information showing that six contract changes had been estimated to cost less than $3.4 million. These estimates were adjusted to $3 million which included increasing three from $1.4 million to $1.6 million and decreasing three from $2 million to $1.4 million.

We were told that these adjustments had been made primarily because (1) the estimates had been considered to be either too high or too low for the proposed scope of work, (2) some of the proposed effort had not been needed or already had been provided for under the contract, and (3) certain effort known to be required had not been considered by the contractor. We were told, however, that there was no documentation available to support the revised estimates.

CHAPTER 4

COST-ESTIMATING PROCEDURES AND PRACTICES AT THE MANNED SPACECRAFT CENTER

Upon receipt of guidelines from NASA Headquarters for the preparation of the preliminary program operating plan estimate, the Manned Spacecraft Center issued amplifying instructions to its various organizational elements, including the Skylab Program Office and various directorate level organizations which supported Skylab Program activities. The Skylab Program Office then distributed supplemental guidelines to the directorates supporting Skylab Program activities.

After estimates had been prepared, they were subjected to review at three organization levels at the Manned Spacecraft Center before being transmitted to NASA Headquarters. First, the estimates were reviewed at the directorate level with the estimators generally participating in the review; second, the estimates were reviewed at the Skylab Program Office level; and third, the estimates were reviewed by the Director, Manned Spacecraft Center, or his designated representative.

We were told that any changes made to an estimate during the review process had been incorporated into all supporting documentation before the estimate had been sent to the next review level. This procedure precluded us from determining the degree of, and reasons for, changes which might have been made at any review level. In a number of instances, our discussions with individual estimators disclosed that changes had occurred, but generally there was no official documentation of the initial estimate or the changes.

The Manned Spacecraft Center's preliminary estimate for the Skylab projects assigned to that center was $757.2 million. As of June 30, 1970, $185.1 million was prior cost and $572.1 million was estimated cost to complete. These costs are listed below by project.

Project	Actual cost at June 30, 1970	Estimated cost to complete	Estimated cost at completion
	(millions)		
Design and development	$ 11.7	$ -	$ 11.7
Experiment definition	14.3	-	14.3
Experiment development	25.6	104.8	130.4
Spacecraft modifications	87.0	418.9	505.9
Saturn I workshop	19.5	-	19.5
Apollo telescope mount	7.6	-	7.6
Payload integration	10.3	16.6	26.9
Mission operations	9.1	31.8	40.9
Total	$185.1	$572.1	$757.2

HOW COST ESTIMATES WERE PREPARED

To determine how the above cost estimates were prepared, we reviewed the procedures and practices used by the estimators in preparing the estimates for the spacecraft modifications project. This project was selected because the estimated cost to complete accounted for $418.9 million, or about 73 percent, of the $572.1 million total cost to complete the projects assigned to the Manned Spacecraft Center. We were told by a center official that the practices and procedures used in preparing estimates for the spacecraft modifications project were basically the same as those used for the other estimates.

Our review showed that approximately 50 percent of the individual estimates for spacecraft modifications contained some provisions for inflation. For example, in computing some estimates, composite labor rates were used and were increased by 5 to 7 percent annually.

In addition to amounts provided for inflation or general price increases, the spacecraft modifications project

estimate contained a reserve totaling $52.2 million. Our review, however, disclosed additional amounts within individual estimates which were categorized as reserves, change allowances, and contingencies. These amounts totaled $52.6 million and were not supported by computations based on prior cost history, negotiated costs, or firm contractor proposals. The total of the above two amounts was $104.8 million, or about 25 percent of the $418.9 million estimated cost to complete the spacecraft modifications project.

Our review disclosed that the various individual estimates had been prepared by adding the actual costs through June 30, 1970, and the estimated costs to complete. We found that the methods of preparing the cost estimates varied significantly and ranged from computations using the latest manpower projections and cost data to estimates based entirely on the estimator's experience and judgment without any supporting computations. The following examples show how estimates were prepared for selected elements of the spacecraft modifications project.

North American Rockwell Corporation--
$291.3 million

The estimated cost of four command and service modules under contract with North American Rockwell Corporation was $291.3 million. This estimate consisted of prior actual costs as reported on the contractor's financial management report and estimated future costs. Costs of about $146 million funded by the Apollo Program were not included in the estimate. The future cost estimates were prepared by multiplying man-hour estimates by applicable labor rates and adding estimated costs for labor burden, major subcontracts, minor subcontracts, material procurement, other materials, general and administration items, major interdivision work authorizations, provisioning, fee, closeout, and other items.

We were told that the man-hour estimates were projected by the estimator for each month on the basis of prior production history and the approved production schedule.

The labor rates used were composite labor rates derived from individual labor rates in a North American Rockwell publication, and all but one were supported by several individual rates. The estimator derived the composite rates by weighting the contractor's individual rates according to the level of effort he anticipated for fiscal year 1971. Supporting computations, however, showing the weighting of the individual rate estimates and the composite cost rates subsequently derived were not prepared.

Percentages used in computing the labor burden, material procurement, and general and administrative costs were based on the estimator's past experience. There was no supporting documentation for these percentages.

Major subcontract, minor subcontract, other materials, major interdivision work authorizations, and provisioning costs were developed from the contractor's financial management report and from the estimated cost of anticipated changes not included in the report. Estimates for the costs of changes were based on the estimator's experience and were not supported by any computations or by any firm proposals by the contractor.

According to the estimator, other costs generally varied proportionately with direct labor costs; therefore, when the cost of direct labor was projected, the other costs were projected proportionately. There was no supporting documentation or computations for the other-costs estimate.

The estimated fee was calculated by using a factor of 7.5 percent which was the same as the maximum fee negotiated for the contract.

Estimated closeout costs were arbitrarily allocated between the Apollo and Skylab Programs, and there was no supporting documentation for the allocation. The estimate for closeout costs was based on discussions with individuals involved in the closeout of contracts under the Mercury and Gemini Programs.

Massachusetts Institute of Technology--
$11.4 million

Massachusetts Institute of Technology costs were for computer services and related support. Support costs were estimated by reducing the previous program operating plan estimate to account for a decrease in projected manpower requirements. The previous estimate was computed from (1) manpower estimates based on the estimator's experience and (2) cost rates determined from Massachusetts Institute of Technology reports increased at 7 percent compounded annually. Computer cost and travel and materials costs were allocated between the Skylab and Apollo Programs in the same ratio as software manpower projections for the two programs.

Astronaut life support assembly/
life support umbilical--$9.7 million

The estimated cost of $9.7 million for astronaut life support assembly/life support umbilical consisted of (1) the contractor's estimate at June 30, 1970, of $4.2 million, (2) estimated changes of $2.1 million, (3) potential overrun of $0.4 million, (4) additional field support of $1.1 million, (5) cost of living increase of $0.3 million, and (6) contingency reserve for production stretchout of $1.6 million.

The contractor's estimate of $4.2 million was the total contract potential reported in the contractor's summary of contract cost for the month ending June 30, 1970.

The estimated cost of changes of $2.1 million was computed by multiplying an estimated annual change cost rate by 2.5 years which included a 6-month production slippage provision. The annual change cost rate was based on approved and proposed changes which had occurred over a 5-month period ending June 30, 1970.

Potential overrun of $400,000 was based on the estimator's belief that the contractor would overrun an equivalent of about 3-months production costs on his analysis of the contractor's financial management report. There were no computations supporting his analysis.

Additional field support of $1.1 million was the same estimate used in the previous program operating plan. There was no documentation to support this estimate. The additional field support covered an 18-month period beyond that covered by the contract.

The contingency reserve of $1.6 million for an anticipated production stretchout consisted of about $1.3 million which was developed for the previous program operating plan and an increase of $0.3 million which was based on the estimator's judgment. He stated that he had no written support for this figure.

The cost of living allowance of $300,000 was computed by applying 6.5 percent a year to the estimated changes, potential overrun, additional field support, and contingency reserve costs. The estimator had no documented computations to support the estimate.

Space suits--$16 million

Estimated contract costs for space suits were allocated between the Apollo and Skylab Programs. Total costs were for production, management and engineering, field support, planned changes, and inflation at 7.5 percent. Costs were allocated between the programs under the assumption that (1) the Apollo Program would pay all field support costs in fiscal years 1971 and 1972, (2) each program would pay for production and change costs for the space suits it would receive, and (3) other costs for each fiscal year would be paid by the program which benefited most from the contract.

According to the estimator, costs used in preparing the total estimate were based on a contract modification; however, he could not reconcile the costs with the modification or reconstruct the basis for his allocation between the two programs.

CHAPTER 5

HEADQUARTERS REVIEW OF COST ESTIMATES

As stated in chapter 2, preliminary estimates of the cost of manned space flight programs for the October 1970 program operating plan were prepared on the basis of guidelines dated July 31, 1970, from NASA Headquarters.

The following table shows, by project, the breakdown of the $2.1 billion preliminary estimate and the final estimate as printed in the October 1970 program operating plan:

Project	Preliminary estimate	Final estimate	Increase or decrease(-)
	(millions)		
Experiment definition	$ 47.3	$ 47.2	$ -0.1
Experiment development	235.7	218.8	-16.9
Spacecraft modifications	508.7	624.7	116.0
Saturn workshop	684.5	680.2	-4.3
Apollo telescope mount	113.6	113.2	-0.4
Saturn IB vehicle	190.2	232.7	42.5
Saturn V vehicle	9.3	157.1	147.8
Payload integration	154.0	148.6	-5.4
Mission operations	52.3	54.7	2.4
Program support	75.7	74.3	-1.4
Contract administration	15.6	15.6	-
Design and development	14.0	14.0	-
Total	$2,100.9	$2,381.2	$280.3

Note: Figures may not add due to rounding.

The preliminary estimate of $2,100.9 million initially was reviewed by Skylab Program Office personnel at NASA Headquarters, and the total estimate was not changed. Only minor adjustments were made to projects within the estimate. After this review the Associate Administrator for Manned Space Flight decided that the Skylab Program's estimate

should be increased to include the cost of flight support during fiscal years 1973 and 1974. Prior to this decision the cost of flight support was to have been funded by the Apollo Program. When the scheduled completion date of the Apollo Program was changed from fiscal year 1975 to fiscal year 1972, however, funding for flight support during fiscal years 1973 and 1974 could no longer be through the Apollo Program.

Subsequent to this decision the Skylab Program Office at NASA Headquarters developed an estimate for flight support of about $224 million. According to agency officials this estimate was based on manpower and dollar levels for identical requirements in the Apollo Program. Revised guidelines reflecting this new funding requirement for the Skylab Program were issued and sent to the centers on September 18, 1970.

Upon receipt of these guidelines, officials at the NASA centers felt that the allowed increase over their initial submission was not sufficient to fund flight support requirements. NASA Headquarters allowed the centers to develop their own flight support estimates for fiscal years 1973 and 1974 and to include these amounts in the October 1970 program operating plan.

As developed by the centers and NASA Headquarters, the Skylab Program's estimate increased from $2,100.9 million to $2,381.2 million. This $280.3 million increase resulted from a $289.9 million increase for flight support and a net decrease of $9.6 million in other elements of the estimate. According to agency officials there were no significant changes, other than flight support, between the preliminary estimate and the final estimate printed in the October 1970 program operating plan.

As discussed in chapter 2, estimating the cost of the Skylab Program involves a great deal of uncertainty because the program is a research and development effort. Therefore provisions for contingencies in future years are incorporated into the estimated cost of the Skylab Program to absorb program changes that would otherwise cause changes in the estimated cost of the program.

Our review of the preparation of the October 1970 program operating plan showed that allowances for contingencies were added to the estimates at various levels within the cost estimating system. Although several different names were used by NASA to describe these contingency amounts--anticipated changes, management reserves, or manager's reserve--we were told that all of them represented allowances for unknown but expected increases in program costs.

During our review we identified the allowances for contingencies that were a part of the October 1970 estimate of the cost of the Skylab Program. The following schedule shows the amount of contingency allowances included in the estimated cost of the Skylab Program from July 1970 through completion.

	Estimated cost to complete	Allowances for contingencies	
		Amount	Percent
	(millions)		
Marshall Space Flight Center	$ 844.5	$163.9	19
Manned Spacecraft Center	641.6	103.6	16
Kennedy Space Center	175.4	-	-
NASA Headquarters and other centers	49.4	22.8	46
Total	$1,711.0	$290.3	17

Note: Figures may not add due to rounding.

Of the contingency amounts for the Marshall Space Flight Center and the Manned Spacecraft Center, $34 million and $30 million, respectively, were included at the direction of NASA Headquarters. The remaining contingency amounts--$129.9 million for the Marshall Space Flight Center and $73.6 million for the Manned Spacecraft Center--were included by the respective centers during preparation of their estimate of the cost to complete the Skylab Program.

CHAPTER 6

ESTIMATED COST OF THE SKYLAB PROGRAM

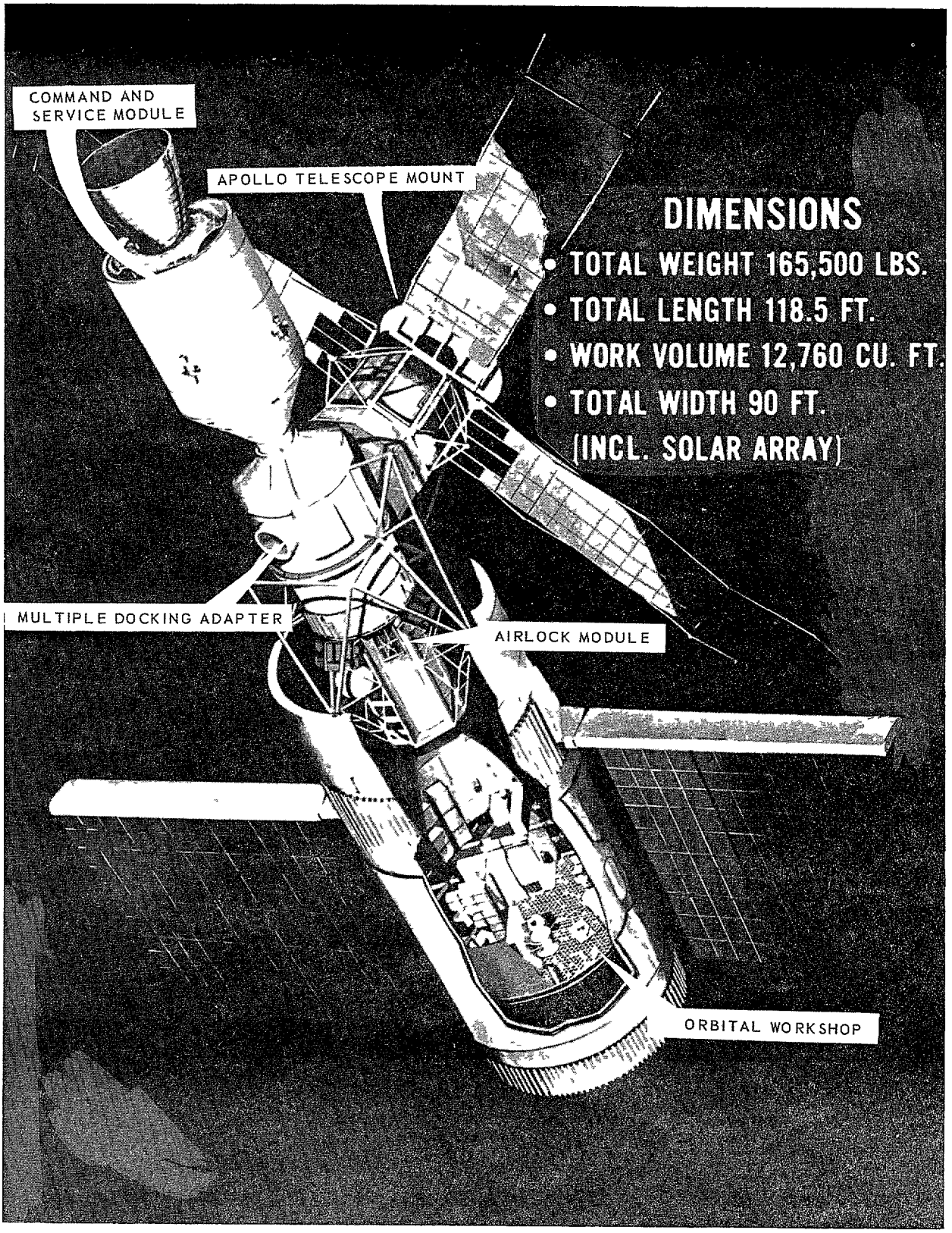
The first program operating plan which provided an estimate of the cost of the Skylab Program through completion was prepared in October 1968. Due to changing program definition, earlier program operating plans included only estimates of costs to be incurred during the next 2 years. Therefore we selected this estimate as the base for comparison with the current estimate.

The schedule on the following page compares the October 1968 estimate with the October 1970 estimate--the most recent estimate at the time of our review. As discussed in chapter 2, these estimates do not include costs associated with (1) NASA's other two appropriations--research and program management or construction of facilities, (2) hardware and equipment procured by the Apollo Program and transferred to the Skylab Program, and (3) support contracts which benefit both the Apollo and Skylab Programs.

Changes in Estimated Cost of Skylab Program

Projects and systems	Estimated costs October 1968	Estimated costs October 1970	Increase or decrease(-) Amount	Increase or decrease(-) Percent	Explanation of changes (page)
	(millions)				
EXPERIMENT DEFINITION	$ 23.8	$ 47.2	$ 23.4	98	41
EXPERIMENT DEVELOPMENT	110.8	218.8	108.0	97	43
Medical	10.1	17.7	7.6	75	
Technology	2.4	5.2	2.8	117	
Science	71.4	120.1	48.7	68	
Applications	16.4	0 7	-15.7	-96	
Engineering	10.4	75.1	64.7	622	
SPACECRAFT MODIFICATIONS	604.4	624.7	20.3	3	50
Command and service module	295.0	321 8	26.8	9	
Guidance and navigation	22.1	32 3	10.2	46	
Extended lunar module	2.6	2 6	-	-	
Subsystem development	123.2	102 7	-20.5	-17	
Spacecraft support	161.5	165.2	3.7	2	
SATURN WORKSHOP	274.0	680.2	406.2	148	57
Orbital workshop	115.4	289.0	173.6	150	
Airlock module	87.2	247.9	160.7	184	
Multiple docking adapter	9.4	45.8	36.4	387	
Support	62.0	97.5	35.5	57	
APOLLO TELESCOPE MOUNT	195.8	113.2	-82.6	-42	70
Lunar module modifications	104 8	17.3	-87.5	-83	
Apollo telescope mount systems	69 2	95.9	26.7	39	
Support	21.8	-	-21.8	-100	
SATURN IB VEHICLE	404.4	232.7	-171.7	-42	74
S-IB stage	68.2	64.9	-3.3	-5	
S-IVB stage	83.9	50.9	-33.0	-39	
Instrument unit	48 9	12.8	-36.1	-74	
Ground support equipment	23 8	7.7	-16.1	-68	
H-1 engine	20 4	32 0	11.6	57	
Vehicle support	159.1	64.4	-94.7	-60	
SATURN V VEHICLE	3.6	157.1	153.5	4,264	77
S-IC stage	2 3	31 1	28.8	1,252	
S-II stage	-	24.4	24.4	-	
S-IVB stage	-	27.3	27.3	-	
Instrument unit	-	41 9	41.9	-	
Ground support equipment	-	5 0	5.0	-	
F-1 engine	1 3	5.7	4 4	338	
Vehicle support	-	21 8	21.8	-	
PAYLOAD INTEGRATION	163.0	148.6	-14.4	-9	78
Definition	36 1	11 8	-24.3	-67	
Implementation	126.9	136.8	9.9	8	
MISSION OPERATIONS	281.1	54.7	-226 4	-81	80
Mission control	59 8	0.8	-59.0	-99	
Flight operations	60.4	19 3	-41.1	-68	
Flight crew operations	39 6	20 7	-18.9	-48	
Launch operations	108 8	12.8	-96.0	-88	
Launch instrumentation	12 5	1 1	-11.4	-91	
PROGRAM SUPPORT	164.7	74.3	-90.4	-55	82
CONTRACT ADMINISTRATION	11.7	15.6	3.9	33	83
DESIGN AND DEVELOPMENT	14.0	14.0	-	-	39
LUNAR EXPLORATION	6 8	-	-6.8	-100	39
SPACE STATION DEFINITION	7 7	-	-7.7	-100	39
Total	$2,265 8	$2,381 2	$115 4	5	

Note Figures may not add due to rounding


COMMAND AND SERVICE MODULE
APOLLO TELESCOPE MOUNT
DIMENSIONS
• TOTAL WEIGHT 165,500 LBS.
• TOTAL LENGTH 118.5 FT.
• WORK VOLUME 12,760 CU. FT.
• TOTAL WIDTH 90 FT. (INCL. SOLAR ARRAY)
MULTIPLE DOCKING ADAPTER
AIRLOCK MODULE
ORBITAL WORKSHOP

As shown above the Office of Manned Space Flight's October 1970 estimate of cost of the Skylab Program was $2,381.2 million. Through fiscal year 1970, NASA obligated $849.9 million of this amount from its research and development appropriation. Consequently an additional $1,531.3 million is needed for the program between fiscal years 1971 and 1974, the current estimated year of completion.

The above schedule also shows that, between October 1968 and October 1970, there was a $115 million, or 5-percent, increase in the estimated cost of the Skylab Program. The $115 million increase was the net result of increases at the system level, totaling about $800 million, and decreases at the system level, totaling about $685 million.

The workshop launch date on which each of the estimates was based is shown in the following table.

Date of program operating plan	Official launch date for workshop	Reason for schedule slip
Oct. 1968	Aug. 1971	(note a)
Dec. 1969	July 1972	Program reorientation due to change from wet to dry workshop configuration
Oct. 1970	Nov. 1972	Reduction in NASA's budget

[a]In May 1966 a launch schedule was approved for the launch of the first mission in April 1968. The April 1968 launch date was slipped to August 1971 because of NASA constraints on Skylab Program funding.

SUMMARY OF NASA REASONS FOR COST CHANGE

As a part of our review, we obtained explanations from NASA for the changes between the October 1968, December 1969, and October 1970 estimates of cost of the Skylab Program. From the information provided by NASA, we have

summarized below the primary factors which contributed to the overall change during the 2-year period.

NASA attributed the increases between October 1968 and October 1970 primarily to (1) change from the wet to the dry workshop configuration, (2) better definition of experiments, (3) additional hardware, (4) contracting out for certain work which was to have been performed in-house, (5) launch schedule slippages totaling 15 months, and (6) inclusion of flight support costs in the October 1970 estimate.

Contracting out for certain work which was to have been performed in-house increased the estimated cost because it required the Skylab Program to fund, through the research and development appropriation, costs for contractor labor, burden, and profit. These costs would otherwise have been funded through the research and program management appropriation if for civil service personnel salaries and/or by the Apollo Program if for support contractor costs.

The decreases between October 1968 and October 1970 were primarily attributed to (1) canceled production of two Saturn IB launch vehicles except for the first stages, (2) cancellation of lunar module modifications and simplified command and service module requirements resulting from the change to the dry workshop configuration, (3) a reduction in the Office of Manned Space Flight's allowance for contingencies, and (4) transfer of funding for certain support contracts from the Skylab Program to the Apollo Program.

The factors causing increases and decreases within the estimate during the 2-year period, along with our review of selected contracts, are discussed in more detail in chapters 7 through 17. A discussion of the design and development, lunar exploration, and space station definition projects was not included in the following chapters because (1) design and development included the nonrecurring costs for design and development of new and/or modification to hardware and services, all obligations for which were made prior to the October 1968 estimate, (2) lunar exploration funding was transferred to the Apollo Program when the

December 1969 estimate was prepared, and (3) space station definition was established as a funding category independent of the Skylab Program when the October 1970 estimate was prepared.

REVIEW OF SELECTED HARDWARE CONTRACTS

Although the October 1968 estimate was the first cost estimate for the program as a whole, we found that earlier estimates existed for certain hardware items. We examined into the cost history of the development effort for the orbital workshop, airlock module, and two of the five science experiments for the Apollo telescope mount to identify the amount of, and reasons for, changes in the estimated cost prior to the October 1968 estimate.

The starting points for our review were August 1966, when the contract was awarded for the development of the airlock module, and early in calendar year 1967, when the initial estimates were made for the development of the orbital workshop and the two Apollo telescope mount experiments. We limited our review to those costs to be incurred under hardware contracts.

NASA contended that the choice of these starting points produced highly questionable percentages of cost growth because at that time the overall program definition and the requirements on individual projects were still very much in the formative stage. NASA suggested that October 1968 be used as the base because it was the date of the first completed program operating plan showing cost through completion and because the program had stabilized reasonably well into its present program configuration and number of launches. In addition, NASA advised us that, as late as July 1969, changes as significant as the one from Saturn IB-launched wet workshop to Saturn V-launched dry workshop were still being made.

We believe, however, that the 1966 and 1967 bases are appropriate when viewed in the context that NASA sought and received congressional approval for the Skylab Program in calendar year 1967.

CHAPTER 7

EXPERIMENT DEFINITION PROJECT COSTS

Definition studies of experiments considered to be potential candidates for manned space flight missions are funded under the experiment definition project. The fields covered are science, applications, technology, engineering, biomedical, and human behavior.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of experiment definition cost.

October 1968	Increase 1968-69	December 1969	Decrease(—) 1969-70	October 1970	Increase 1968-70 Amount	Increase 1968-70 Percent
(millions)						
$23.8	$23.5	$47.3	—$0.1	$47.2	$23.4	98

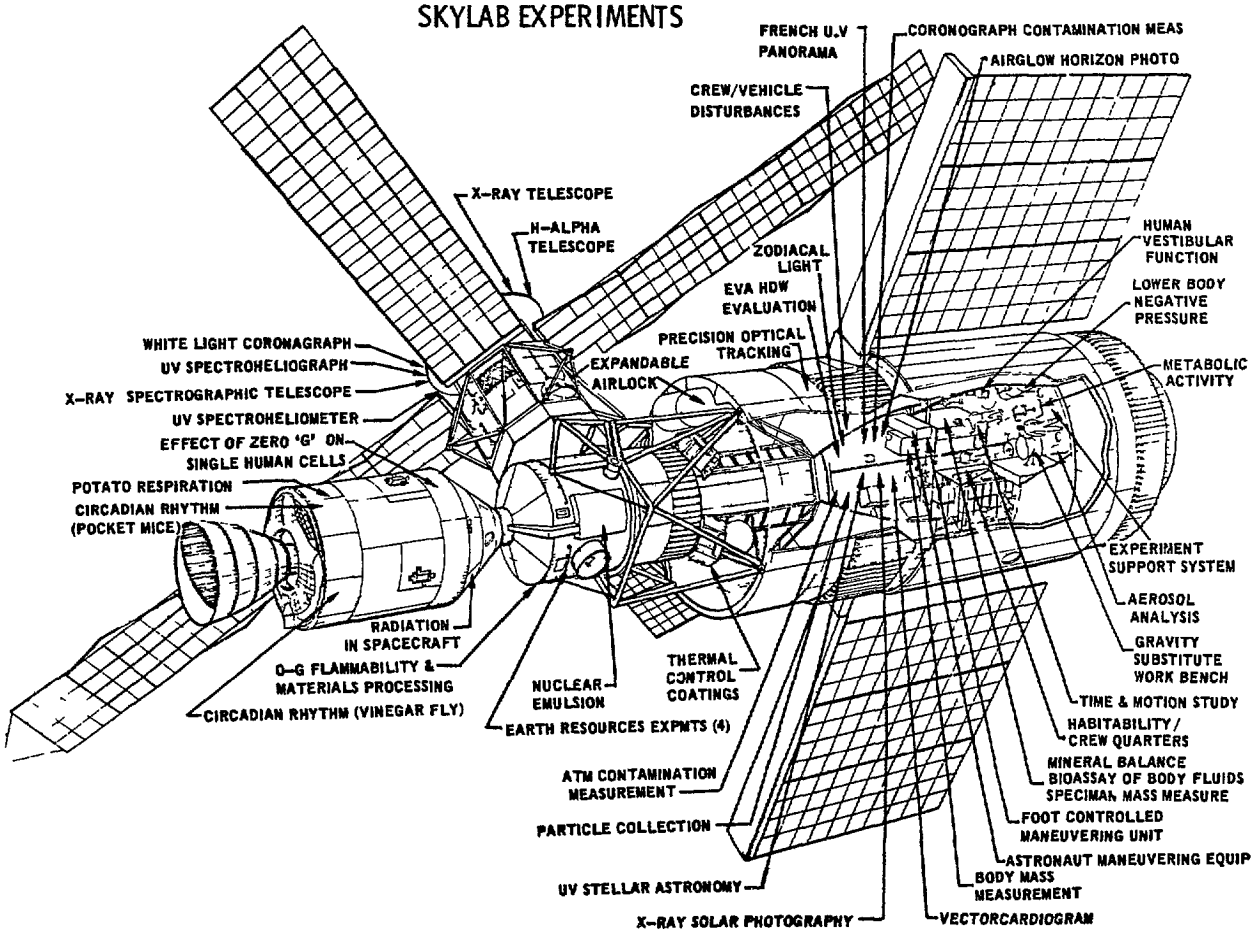
NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

We were advised by NASA that the net increase of $23.4 million between October 1968 and October 1970 was primarily due to (1) inclusion of $33.5 million applicable to definition of Skylab Program experiments sponsored by the Office of Space Science and Applications and the Office of Advanced Research and Technology and (2) deletion of a $10 million management reserve.

CHAPTER 8

EXPERIMENT DEVELOPMENT PROJECT COSTS

The locations of experiments to be performed in the Skylab Program are shown in the following pictorial profile.



The development, integration, and operation of Skylab Program experiments and the translation of experiment data into a usable form are funded under experiment development. The four categories of experiments currently being funded and their objectives are listed below.

1. Medical--to accumulate information required to understand man's capability for long-duration space flight.

2. Technology--to improve and apply scientific knowledge, methods, and research to industrial arts.

3. Science--to learn more about the universe, space environment, and phenomena in the solar system which affect the environment of man on earth and to learn more about the earth by gathering data for use by experts studying oceanography, water management, agriculture, forestry, geology, geography, and ecology.

4. Engineering--to evaluate and demonstrate engineering principles or techniques in a space environment.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for each category of experiments, including applications experiments which were reclassified as science experiments in the October 1970 estimate.

	October 1968	Increase or decrease(-) 1968-69	December 1969	Increase or decrease(-) 1969-70	October 1970	Increase or decrease(-) 1968-70 Amount	Percent
	(millions)						
EXPERIMENT DEVELOPMENT	$110 8	$70 3	$181 1	$37 7	$218 8	$108 0	97
Medical	10 1	6 8	16 9	0 8	17 7	7 6	75
Technology	2 4	2 3	4 7	0 5	5 2	2 8	117
Science	71 4	25 9	97 3	22 8	120 1	48.7	68
Applications	16 4	-6.7	9 7	-9 0	0 7	-15 7	-96
Engineering	10 4	42.2	52 6	22 5	75 1	64 7	622

Note. Figures may not add due to rounding

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

NASA attributed the increase of $70.3 million in the December 1969 estimate to (1) a more refined estimate as compared with the preliminary estimates in October 1968, (2) an 11-month launch schedule slippage from August 1971 to July 1972, (3) incorporation of additional experiments, (4) the change to the dry workshop configuration, (5) the award of contracts for work which was to have been performed in-house, and (6) cost overruns.

NASA attributed the additional increase of $37.7 million in the October 1970 estimate to (1) additional experiment changes related to the dry workshop configuration, (2) a 4-month launch schedule slippage from July to November 1972, (3) incorporation of additional experiments, (4) revised estimates based on contract negotiations and better definition of some of the experiments, and (5) cost overruns.

The $6.7 million decrease shown under the applications category between October 1968 and December 1969 was due to the cancellation of experiments which had an estimated cost of $9.3 million and increases of $2.6 million in the estimated cost of the remaining experiments.

Between December 1969 and October 1970, the remaining applications experiments were reclassified as science experiments. Of the $9.7 million included in the December 1969 estimate, $9 million was deleted from the applications category in the October 1970 estimate; the remaining $0.7 million in costs had already been incurred. When these experiments were reclassified as science experiments in the October 1970 estimate, however, they were estimated to cost $12.7 million.

REVIEW OF SELECTED SCIENCE EXPERIMENTS

We reviewed the Marshall Space Flight Center's contracts and the initial cost estimates for the X-ray spectrographic telescope (S054) and the ultraviolet scanning polychromator spectroheliometer (S055A) to identify the amount of, and reasons for, changes in cost since the initial estimates were prepared. The initial estimates were included in an experiment implementation plan dated April 3, 1967. These experiments are two of the five science experiments scheduled to be flown on the Apollo telescope mount.

As of October 31, 1970, the contracts for experiments S055A and S054 had experienced a cost increase of $27.9 million over the initial estimated cost of $8.3 million in April 1967. NASA estimated that a further cost increase of $11 million will be experienced through completion of the contracts. At completion, therefore, the total cost of the contracts is estimated to be $47.2 million.

The explanations provided by NASA for the changes between the October 1968 and October 1970 cost estimates were generally consistent with the reasons identified during our review.

Cost increase through October 31, 1970

The reasons and related dollar amounts established for the $27.9 million cost increase include

--$11.3 million for unrealistic initial estimates,

--$6.7 million for contractor cost overruns,

--$5.3 million for redesign effort and hardware modifications,

--$2 7 million for development of an alternate experiment, and

--$1.9 million for contract schedule slippage.

The results of our review of this cost increase is discussed in the next two sections.

Comparison of initial estimates with initial contract values

The initial estimates for the two experiments totaled $8.3 million and were contained in an April 1967 experiment implementation plan which provided for a three-phase procurement Phase 1 was to cover definition of the experiments; phase 2 was to cover fabrication of flight hardware; and phase 3 was to cover field support and data acquisition, retrieval, and analysis. The contract files for the two experiments showed that the initial contract value for these three phases was $19.6 million, or $11.3 million higher than the initial estimates.

The Chief of the Experiments Branch told us that, because there had been very little experience to rely upon, the initial estimate for experiment S054 had been prepared by doubling the cost of an orbiting solar observatory

experiment which had a basic concept similar to the S054 experiment. He stated that the estimate for experiment S055A also had been developed using experience gained from the orbiting solar observatory program. He advised us that the estimates later proved to be unrealistic because (1) experiments of this type had never been built, (2) experiment definition had not been completed at the time the estimates were prepared, and (3) the configuration of the Apollo telescope mount and the flight configuration of the hardware to which it was to be attached were unknown.

We found that the reasons cited for the estimates being unrealistic generally were supported by documentation contained in the files.

Cost increases over the initial contract values

As of October 31, 1970, the contract values for the two experiments totaled $36.2 million, or $16.6 million higher than the initial values of $19.6 million

The contract files showed that:

--A $6 7 million increase for contractor cost overruns was attributed to a number of reasons, including technical problems, failure of subcontractors to deliver flight quality components and subassemblies, late delivery of parts, replacement of defective parts, difficulties in obtaining power supplies, and an unrealistic estimate by one of the contractors for the phase 1 work.

--There was a $5.3 million increase for redesign effort and hardware modifications, $3.6 million of which was attributed to the need for additional experiment definition effort to correct incompatibilities between the experiments and Apollo telescope mount canister designs. The Chief of the Experiments Branch told us that these incompatibilities were the result of oversights during the concurrent design of the experiments and the canister. The remaining $1.7 million cost increase was attributed to a number of reasons including (1) incorporation of a

mirror launch lock, (2) addition of pressure gauges, alternate power supply modules, and control and display components, and (3) minor hardware modifications and additions.

--A $2.7 million increase was attributed to the development of an alternate experiment which was later canceled. When it became apparent that the contractor could not deliver experiment S055A in time to meet the launch date for the first Apollo telescope mount, the contractor was directed to initiate preliminary design and development of a less complicated instrument to be flown in place of the more complex S055A experiment. At the same time, however, the contractor was to continue the development of experiment S055A at a rate to meet the launch date for the second Apollo telescope mount. All contract effort on the alternate experiment was terminated, however, when a 31-month slip in the scheduled launch date for the first Apollo telescope mount allowed the contractor sufficient time to develop the more complex S055A experiment.

--A $1.9 million increase resulted from a decision to extend the delivery dates of the S054 experiment prototype and flight units by 9 and 16 months, respectively. A Skylab official told us that the delivery dates had been extended because of a restriction placed on funds during fiscal year 1968.

Estimate of additional cost increase through contract completion

In addition to the value of the contracts at October 31, 1970, NASA estimated that $11 million will be required to complete the contracts. The estimated increase of $11 million consists of (1) $5.5 million for additional field support and real-time data analysis, (2) $2.7 million for hardware changes, (3) $2.4 million for additional postflight data analysis, and (4) $0.4 million for changes in delivery schedules.

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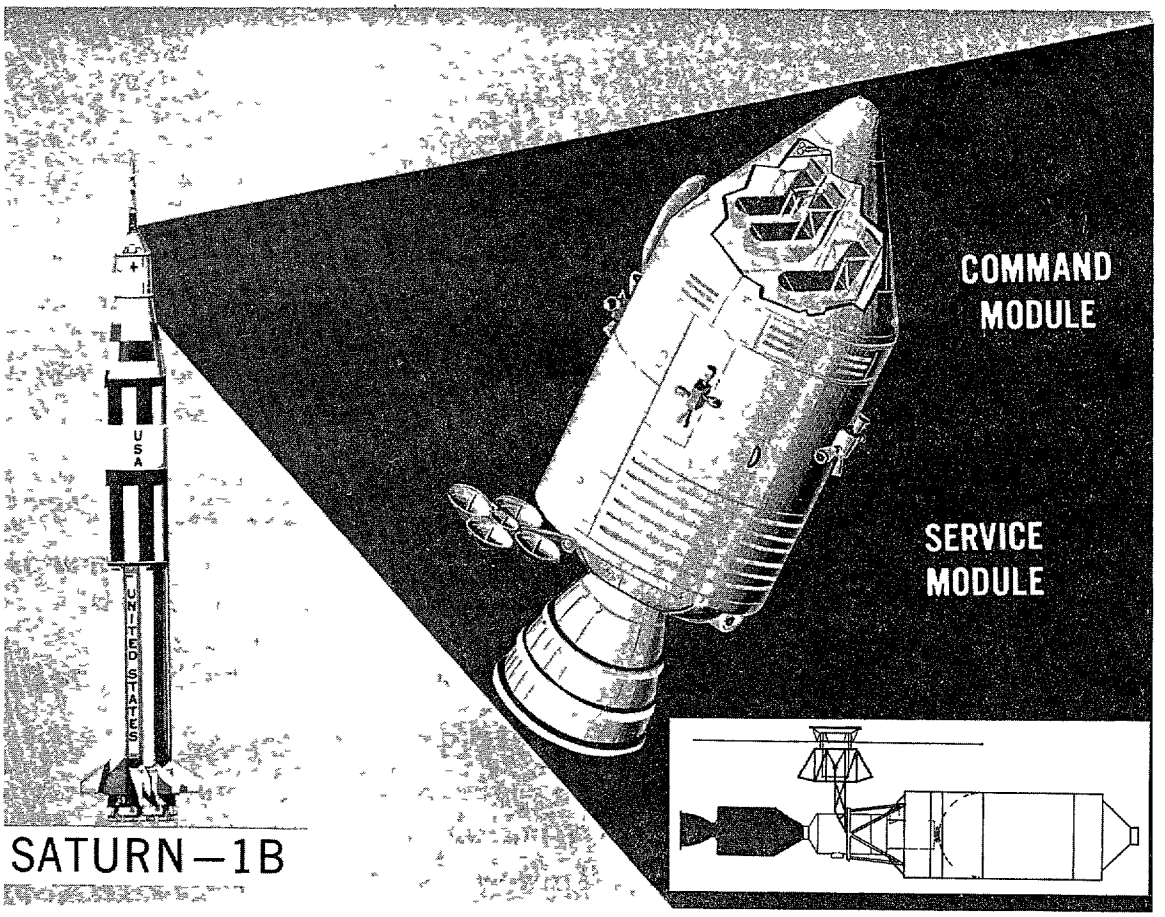
Included in appendix II of this report are the Marshall Space Flight Center's comments concerning programmatic and other influences contributing to the cost increases during the development of these experiments.

CHAPTER 9

SPACECRAFT MODIFICATIONS PROJECT COSTS

The Skylab Program requires a spacecraft to transport each crew of three men into earth orbit, dock with a workshop, and return for a normal splashdown. During orbital operations the spacecraft will be powered down to the lowest level possible to maintain operational readiness for return.



Spacecraft to be used in the Skylab Program are four Apollo command and service modules which have been transferred to the Skylab Program and will be modified to meet Skylab Program objectives. The Apollo Program is funding completion of the spacecraft structures and the Skylab Program is funding development, production, and integration of modified subsystems and the checkout of these modified spacecraft.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for each funding element of spacecraft modifications.

	October 1968	Increase or decrease(-) 1968-69	December 1969	Increase or decrease(-) 1969-70	October 1970	Increase or decrease(-) 1968-70 Amount	Percent
	(millions)						
SPACECRAFT MODIFICATIONS	$604 4	-$97 1	$507 3	$117 4	$624 7	$20 3	3
Command and service module	295 0	36 9	331 9	-10 1	321 8	26 8	9
Guidance and navigation	22 1	-5 4	16 7	15 6	32 3	10 2	46
Extended lunar module	2 6	-	2 6	-	2 6	-	-
Subsystem development	123 2	-33 9	89 3	13 4	102 7	-20.5	-17
Spacecraft support	161.5	-94.7	66.8	98.4	165.2	3.7	2

Note Figures may not add due to rounding

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The explanations provided by NASA stated that the primary reason for the decrease in the December 1969 estimate was that the Skylab Program no longer had responsibility for funding common support. The Apollo Program funded all common support in the December 1969 estimate. (See pp. 14 through 16.)

NASA attributed the $117.4 million increase in the October 1970 estimate primarily to the addition of a management reserve and to the Skylab Program's newly acquired funding responsibility for flight support costs during fiscal years 1973 and 1974 which were formerly to have been funded by the Apollo Program.

The following sections present NASA's explanations for the changes shown in the above schedule of estimated cost for each funding element of spacecraft modifications.

Command and service module

The October 1968 estimate of $295 million was based on preliminary estimates of the command and service module modification costs required under the wet workshop concept. A proposal had not been received from the contractor.

The December 1969 estimate of $331.9 million, an increase of $36.9 million, was based on preliminary estimates for simplified quiescent command and service modules under the dry workshop concept. The contract for the modifications to the command and service modules was not yet finalized. Also contributing to the increase was the 11-month launch schedule slippage from August 1971 to July 1972.

The October 1970 estimate of $321.8 million represented a decrease of $10.1 million from the December 1969 estimate. This $10.1 million decrease was the net result of an increase of $11.6 million due to the addition of flight support costs for fiscal years 1973 and 1974 and a decrease of $21.7 million due to the June 1970 finalization of the contract for modifications to the command and service modules.

Guidance and navigation

The decrease in the estimate from $22.1 million in October 1968 to $16.7 million in December 1969 was attributed to a reduced level of guidance and navigation contractor support.

The increase of $15.6 million in the October 1970 estimate was attributed to the funding by the Skylab Program during fiscal years 1973 and 1974 of flight support costs which were previously to have been funded by the Apollo Program.

Subsystem development

The October 1968 estimate included funding for common support amounting to $45.5 million. This funding responsibility was not included under the Skylab Program in the December 1969 estimate. The December 1969 estimate, however, included additional space suit funding amounting to $11.6 million which resulted in a net decrease of $33.9 million.

The increase of $13.4 million reflected in the October 1970 estimate was attributed to the funding by the Skylab Program of flight support costs during fiscal years 1973 and 1974.

Spacecraft support

The decrease of $94.7 million in the December 1969 estimate was attributed to

--deletion of Skylab funding responsibility for common support;

--reduced estimates for automatic checkout equipment, support contractors, and logistics;

--elimination of assembly and test of the lunar module for the Apollo telescope mount; and

--more support from the Apollo Program, due to less checkout overlap time on command and service modules.

The increase of $98.4 million in the October 1970 estimate was due to the addition of Skylab funding responsibility for flight support costs during fiscal years 1973 and 1974 and the inclusion of a management reserve during fiscal years 1972 and 1973.

CHAPTER 10

SATURN WORKSHOP PROJECT COSTS

The Saturn workshop project includes the estimated costs of the payload shroud, orbital workshop, airlock module, and multiple docking adapter.

A payload shroud provides an environmental shield and an aerodynamic fairing for the workshop and protects the multiple docking adapter, airlock module, and Apollo telescope mount during launch. Certain consumables will be carried on the lower fixed portion of the shroud whereas the upper portion will be jettisoned on attaining orbit.

The orbital workshop is a modified S-IVB stage of the Saturn V launch vehicle that is outfitted on the ground for manned habitation. Modifications will be made prior to launch to remove systems required for a propulsive stage. Integration of the orbital workshop provides for a

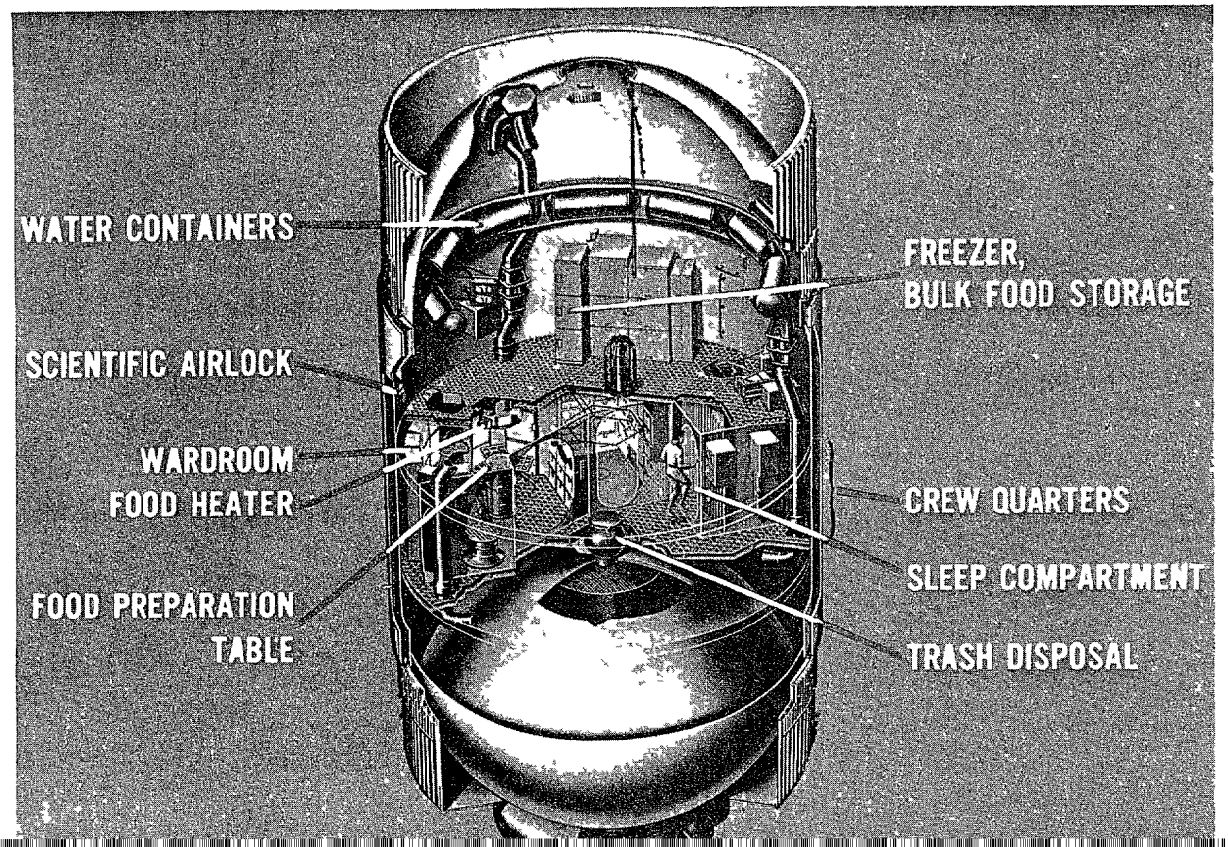
--habitable environment with storage for crew provisions, consumables, and waste material;

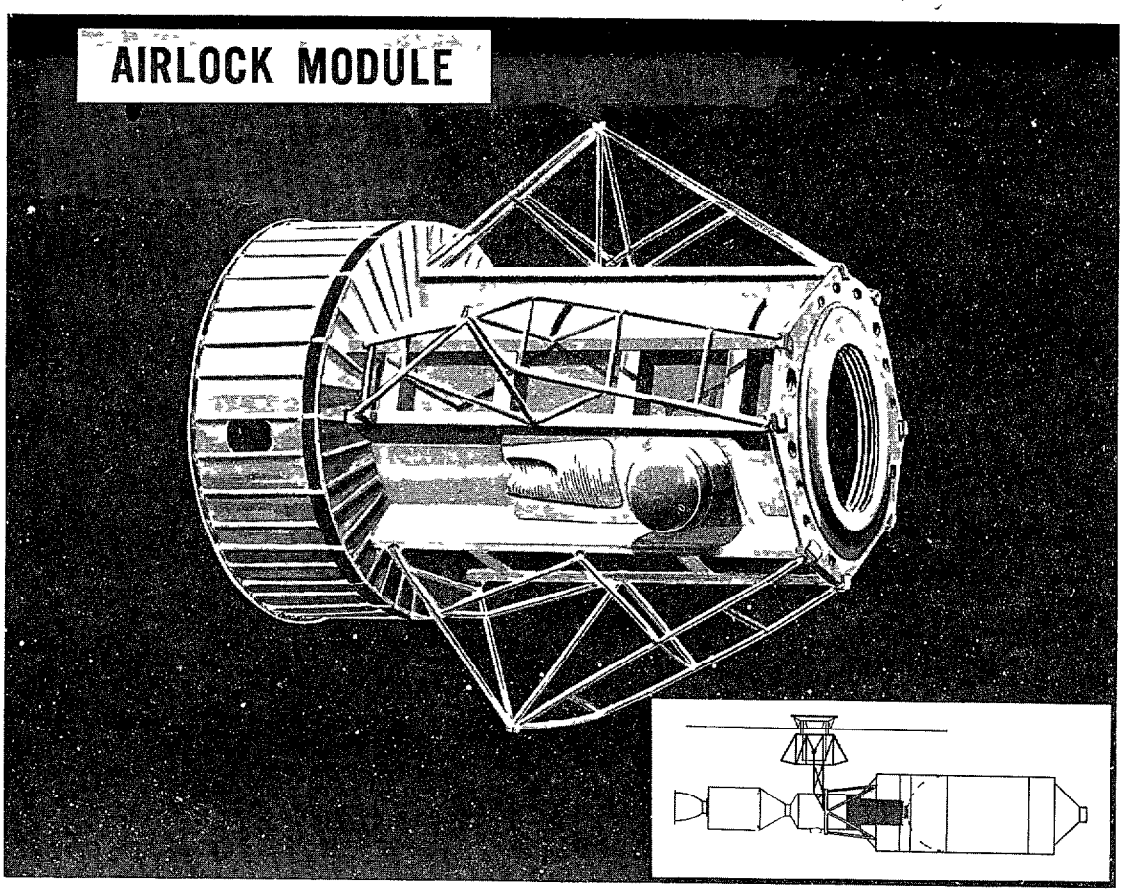
--capability for installation, storage, and operation of experiments;

--propulsive capability for maneuvering the cluster; and

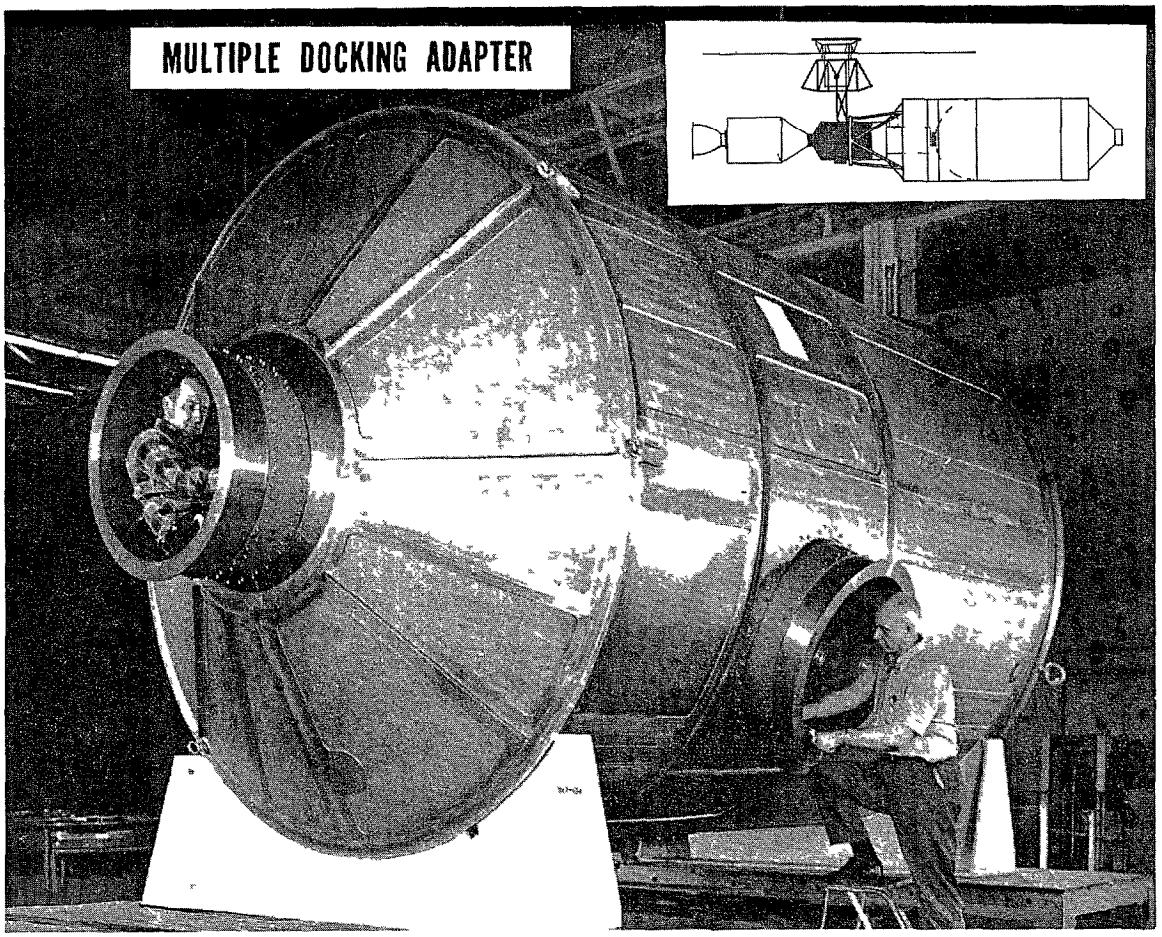
--solar array electrical power source.

ORBITAL WORKSHOP





The multiple docking adapter provides docking accomodations in space for the command and service module and permits the transfer of personnel, equipment, power, and electrical signals between the command and service module, airlock module, and orbital workshop. Contained in the multiple docking adapter is the control station for operation of the Apollo telescope mount, earth resources and other experiments, as well as the thruster attitude control system which will orient the workshop to a solar-inertial attitude. Also housed inside the multiple docking adapter is the control and display equipment to operate the solar telescope system. An optical quality window for viewing the earth is also provided.



The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for the Saturn workshop project.

	October 1968	Increase or decrease(–) 1968-69	December 1969	Increase 1969-70	October 1970	Increase 1968-70 Amount	Increase 1968-70 Percent
	(millions)						
SATURN WORKSHOP	$274 0	$221 2	$495 2	$185 0	$680 2	$406 2	148
Orbital workshop	115 4	112 3	227 7	61 3	289 0	173 6	150
Airlock module	87 2	104 6	191 8	56 1	247 9	160 7	184
Multiple docking adapter	9 4	4 8	14 2	31 6	45 8	36 4	387
Support	62 0	–0 5	61 5	36 0	97 5	35 5	57

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The following sections present the explanations provided by NASA for the changes in the estimated cost for each funding element shown in the above schedule.

Orbital workshop

The increase of $112.3 million in the December 1969 estimate was a result of the change from the wet to dry workshop configuration and the 11-month launch schedule slippage from August 1971 to July 1972. Additional hardware included in the December 1969 estimate was the habitability support system, upgraded solar array system, and thruster attitude control system.

The increase of $61.3 million in the October 1970 estimate was attributed to the negotiation of the contract for the dry workshop configuration and changes that had been made due to better definition of the dry workshop design. Also contributing to the increase was the 4-month launch schedule slippage from July to November 1972.

We examined into the cost of the contracts for the development of the orbital workshop. The results of our review are discussed on pages 60 through 64 of this report.

Airlock module

The increase of $104.6 million in the December 1969 estimate was a result of the change to the dry workshop configuration and the 11-month schedule slippage from August 1971 to July 1972. Under the dry workshop configuration, the airlock module became the control center for the workshop. Additional hardware included in the December 1969 estimate was a fixed airlock shroud and an Apollo telescope mount deployment assembly.

The increase of $56.1 million in the October 1970 estimate was primarily due to further definitization of the dry workshop configuration and completion of contract negotiations. Also contributing to the increase was the 4-month launch

schedule slippage from July to November 1972 and the addition of a jettisonable payload shroud.

We examined into the cost of the contract for the development of the airlock module. The results of our review are discussed on pages 65 through 68 of this report.

Multiple docking adapter

The October 1968 estimate of $9.4 million was based on the complete multiple docking adapter being built in-house at the Marshall Space Flight Center. In the conversion to the dry workshop configuration, the need for the lunar module was eliminated and some of the lunar module systems were transferred to the multiple docking adapter. A contract was awarded for the integration of the multiple docking adapter internal systems. This integration effort and the 11-month launch schedule slippage from August 1971 to July 1972 were primarily responsible for the $4.8 million increase in the December 1969 estimate.

The October 1970 estimate of $45.8 million, an increase of $31.6 million, was based on a definitized contract for the final assembly and integration of the multiple docking adapter. Also contributing to the increase were the addition of effort for the integration of the earth resources experiments package into the multiple docking adapter and the 4-month launch schedule slippage from July to November 1972.

Support

The decrease of $0.5 million in the December 1969 estimate was the net result of (1) increased requirements for the attitude pointing control system, the 11-month launch schedule slippage from August 1971 to July 1972, and the inclusion of an estimate for a jettisonable payload shroud and (2) decreased requirements due to a revised major contractor estimate and cancellation of the workshop attitude control and solar array systems. The workshop attitude control and solar array systems were replaced by the thruster attitude control and upgraded solar array systems which were included in the December 1969 estimate for the orbital workshop.

The increase of $36 million in the October 1970 estimate was attributed to (1) an $18.8 million increase resulting from the 4-month launch schedule slippage from July to November 1972 and increases in the allowance for program changes and (2) a $17.2 million increase resulting from revised major contractor estimates and the reassignment of contractor manpower formerly charged to the Saturn IB launch vehicle project.

REVIEW OF SELECTED SATURN WORKSHOP PROJECT CONTRACTS

We reviewed the contracts for the orbital workshop and the airlock module administered by the Marshall Space Flight Center to identify the amount of, and reasons for, changes in cost as of October 1970.

The explanations provided by NASA for the changes between the October 1968 and October 1970 estimates of cost are generally consistent with the reasons identified during our review.

Extent of cost increase in the orbital workshop contracts

As of September 29, 1970, the contracts for the orbital workshop had experienced a cost increase of $165.4 million over the initial estimate of $2.3 million in January 1967. In addition, NASA estimated that a further cost increase of $119.4 million will be experienced through contract completion. The total cost of the contracts through completion therefore is estimated to be $287.1 million.

The reasons and related dollar amounts established for the $165.4 million cost increase include

--$32.4 million for placing work under contract previously planned to be accomplished in-house and an increase in the complexity of the work;

--$64 million for the addition of a second orbital workshop, incorporation of a habitability support system, schedule slippages, and additional requirements for testing and ground support equipment;

--$64 million primarily for the change from the wet to the dry workshop configuration; and

--$5 million for orbital workshop effort included in the S-IVB stage production contract.

The results of our review of these cost increases are discussed below.

Cost increase between the initial estimate and approved procurement plan

On the basis of an early concept of the orbital workshop, the Marshall Space Flight Center prepared a statement of work dated January 31, 1966, which, in essence, provided for the incorporation of a passivation system into the basic S-IVB stage and for special studies to ensure the acceptability of the stage for manned occupancy. The passivation function includes dumping and venting of unused propellant and other residuals, deactivation of hazardous systems, and preparation for a pressurized atmosphere.

On February 10, 1966, the contractor furnished a rough estimate of $848,000 for the effort but pointed out that the estimate did not cover all the work which would be required. In March 1966 the contractor was authorized to proceed with certain modifications to the S-IVB stage under the S-IVB stage production contract.

As the Apollo Applications Program continued to be refined during the first part of 1966, increased emphasis was placed on establishing a basis for long-duration manned missions. As a result, NASA Headquarters decided in December 1966 that the orbital workshop would be made habitable and that experiment modules would be docked to the workshop while in orbit to form a cluster. In addition, the orbital workshop was to be capable of reactivation and reuse for subsequent missions occurring up to a year later.

On the basis of these new mission requirements, the Marshall Space Flight Center prepared a procurement plan dated February 20, 1967, for the study, design, test, and manufacturing effort required to attain a shirt-sleeve environment in the S-IVB stage for its use as an orbital workshop. The procurement plan provided for the modification of four S-IVB stages on a time-phased basis at an estimated cost of $2.4 million.

Skylab Program officials informed us, however, that the estimate contained in the procurement plan did not include total development effort. They provided us instead with an estimate prepared in developing the January 1967 preliminary program operating plan which included $11 million for in-house effort and $17.3 million for contractor effort required for development of three wet and two dry workshops.

We were also told that the records showing a breakdown of the estimated contract cost could not be located but that about 40 percent of the $17.3 million, or $6.9 million would have been applicable to the three wet workshops. On this basis, we estimated that the contract cost for one wet workshop would have been about $2.3 million.

On October 18, 1967, a revised procurement plan was issued by the Marshall Space Flight Center which provided for the adaption of two S-IVB stages for use as orbital workshops

at an estimated cost of $34.7 million for the first one and $34.9 million for the second. On January 8, 1968, after making several changes to the procurement plan, including the deletion of the second workshop, NASA Headquarters approved the procurement of one orbital workshop at an estimated cost of $34.7 million.

Skylab Program officials told us that one of the reasons for the increase was their decision to have work accomplished by the contractor which was previously planned to be accomplished in-house. The other reason was that the complexity of the work required to develop the orbital workshop had increased considerably during the period between the two estimates.

Cost increase between the approved procurement plan and contract definitization

On the basis of the procurement plan approved by NASA Headquarters on January 8, 1968, the S-IVB stage production contract was modified by a letter amendment issued in February 1968 which contained a complete statement of work for the modification and adaption of one S-IVB stage for use as an orbital workshop. The letter amendment established a contract delivery date of July 31, 1969, and a contract completion date of June 15, 1970. Before the issuance of the letter amendment, modifications to the S-IVB stage production contract had been issued on a time-phased basis for only certain segments of the work.

In November 1968 a revised procurement plan to definitize the letter amendment was issued which proposed to combine the contractor's effort on the airlock module and the orbital workshop under the same contract except for certain S-IVB stage modifications which were to remain under the basic S-IVB stage production contract. These modifications consisted of changes to the S-IVB stage which permitted the installation of various hardware items. The procurement plan also provided for a second orbital workshop and a habitability support system which were major additions to the scope of work previously planned. NASA Headquarters approved the revised procurement plan in February 1969.

Negotiations were completed in May 1969 to definitize the letter amendment for the orbital workshop portion of the contract at $98.7 million, or $64 million higher than the $34.7 million estimate approved by NASA Headquarters in the January 1968 procurement plan. A supplemental agreement, effective August 8, 1969, was issued incorporating the definitized value for the orbital workshop effort into the airlock module contract. The supplemental agreement also changed the contract delivery date of the first orbital workshop from July 31, 1969, to March 1, 1971, and the contract completion date for the orbital workshop from June 15, 1970, to July 31, 1972. A delivery date of August 31, 1971, was established for the second orbital workshop.

In addition to the second orbital workshop, the habitability support system, and the schedule slippage discussed above, Skylab Program officials told us that an additional requirement for ground support equipment and testing was another major area of cost impact causing the $64 million increase. Although the records did not contain a breakdown of the cost increase applicable to each of these four areas, Skylab Program officials estimated that the cost impact was about $16 million for each area.

Cost increase between contract definitization and September 1970 contract value

In July 1969 the Skylab Program mission plan was modified to use the launch capability of the larger Saturn V launch vehicle which permitted the complete outfitting of the workshop on the ground. As a result of this decision, a number of redesign and structural modifications to the orbital workshop were required. The scope of work under the contract was also substantially increased by adding new tasks such as the solar array system, thruster attitude control system, and changes in water storage and food management facilities.

Negotiations were completed in May 1970 to definitize the wet to dry workshop configuration changes at $62.1 million. The contract delivery dates for the flight and backup unit were changed from March and August 1971 to July 1971 and January 1972, respectively, and the contract completion date was changed from July 1972 to February 1973. These definitized changes were incorporated into the contract on

August 27, 1970. Since definitization of these changes, several minor modifications totaling $1.9 million have been negotiated which increased the contract value to $162.7 million as of September 29, 1970.

Cost increase in the S-IVB stage production contract

As discussed above, certain modifications to the S-IVB stage were accomplished under the S-IVB stage production contract. We noted that the negotiations for the wet to dry configuration changes included a part of the costs incurred under the S-IVB stage production contract which were applicable to the orbital workshop. As of September 1970, however, the S-IVB stage production contract still contained costs of $5 million applicable to the orbital workshop.

Estimate of additional cost increase through contract completion

In addition to the September 1970 contract values totaling $167.7 million, NASA estimated that a $119.4 million cost increase will be experienced through contract completion. This amount includes $112.7 million for redesign effort, hardware changes, and increased testing requirements and $6.7 million for schedule slippage.

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Included in appendix II of this report are the Marshall Space Flight Center's comments concerning programmatic and other influences contributing to the cost increases during the development of the orbital workshop.

Extent of cost increase in the airlock module contracts

As of October 19, 1970, the airlock module contract had experienced a cost increase of $117.4 million since the initial contract was awarded in August 1966 for $10.5 million NASA estimated that a further cost increase of $121.4 million will be experienced; the total cost of the contract through completion therefore is estimated to be $249.3 million.

The reasons and related dollar amounts for the $117.4 million cost increase between August 1966 and October 1970 include

--$25.9 million for a major redefinition of the airlock module;

--$52.3 million for the addition of a second (backup) airlock module, schedule slippages, addition of supporting engineering and integration effort, redesign effort and hardware modifications, and preparation of an updated test program; and

--$39.2 million for the change from the wet to the dry workshop configuration.

The results of our review of these cost increases are discussed below.

Cost increase between initial contract and proposed definitization of contract conversion

In August 1966 the Manned Spacecraft Center awarded a fixed-price contract in the amount of $10.5 million for the design and development of the airlock module and related hardware. The contemplated design of this early unit was essentially a pressurized tunnel with one end providing a sealed connection to a hatch in the orbital workshop and the other end providing a docking adapter for the command and service module. The performance requirements for this early unit were limited to a single mission of 14 to 28 days' duration.

In December 1966, NASA Headquarters issued a new set of mission requirements which established a more complex program. As a result, a major redefinition of the airlock module hardware, supporting effort, testing requirements, and interface requirements with other modules was required. Changes to be made to the airlock module included the incorporation of a power and distribution system, environmental conditioning, a communications system, storage for certain experiments, provisions for ground control, and a means for astronaut extravehicular and intravehicular activity.

Because of the significant changes to be made to the airlock module, the Manned Spacecraft Center directed the contractor to stop work on the early version and issued a new scope of work for the more complex unit. The fixed-price contract was then converted to a cost-type letter contract to be definitized at a later date.

In early 1968, negotiations were completed to definitize the letter contract for the redesigned airlock module at $36.4 million, or $25.9 million higher than the value of the fixed-price contract. The NASA Administrator decided not to approve the definitization action and directed that the performance period of the letter contract be extended to December 1968. A NASA Headquarters official told us that documentation was not available which showed the Administrator's reasons for not approving the definitization action and that he could only speculate on what the reasons were.

Cost increase between proposed definitization of contract conversion and definitized contract

In September 1968 the NASA Administrator approved the realignment of management responsibilities for developing certain flight hardware, including the airlock module for which responsibility was transferred to the Marshall Space Flight Center. Because of the many changes to the unit that resulted from the revised mission requirements issued in December 1966, a new procurement plan was prepared and submitted to NASA Headquarters for approval.

In addition to incorporating the revised mission requirements, the plan provided for a backup airlock module

and for systems engineering and integration effort. After preparation of the procurement plan, the contractor was requested to submit a proposal for the definitization of the letter contract. To allow time for this action, the letter contract period of performance was extended several times with the last extension being to August 31, 1969.

Negotiations were concluded in May 1969 to definitize the letter contract at $88.7 million which was approved by NASA Headquarters on August 8, 1969. The definitized contract was $52.3 million higher than the amount negotiated by the Manned Spacecraft Center in early 1968, and it established a contract completion date of August 31, 1972. The airlock module flight unit and backup unit were scheduled for delivery on March 1 and August 1, 1971, respectively.

We obtained an internal NASA working paper dated February 11, 1969, which summarized the various contract changes and related contractor proposals that had been submitted after the $36.4 million was negotiated with the contractor by the Manned Spacecraft Center in early 1968. On the basis of discussions with Skylab Program officials and the proposed dollar amounts shown on the working paper, we estimated that $41.9 million of the $52.3 million increase included about $17.4 million for the addition of the backup airlock module, $13.2 million for schedule slippages, $9.2 million for redesign effort and hardware modifications, and $2.1 million for the preparation of an updated test program. The contract files showed that the remaining $10.4 million increase was for the addition of supporting engineering and integration effort.

Cost increase between definitized contract and contract value at October 1970

In July 1969 the Skylab Program mission plan was modified to use the launch capability of the larger Saturn V launch vehicle which permitted the complete outfitting of the workshop on the ground. As a result, major modifications to the airlock module were required; and a payload shroud and deployment assembly for the Apollo telescope mount were added to the airlock module contract. The contract completion date was extended from August 31, 1972, to February 28, 1973, and the delivery dates for the airlock

module flight and backup units were changed from March 1 and August 1, 1971, respectively, to July 1, 1971, for both units. These changes were incorporated into the contract on July 23, 1970, at a value of $39.7 million.

On the basis of our review of the contractor proposals and contract files, we estimated that the $39.7 million increase consisted of $21.1 million for hardware modifications, $15.8 million for hardware additions, and $2.8 million for schedule slippage. Since July 23, 1970, several minor contract modifications have been made which reduced the value of the contract by $0.5 million for a total net increase of $39.2 million between definitization of the letter contract on August 8, 1969, and its value of $127.9 million as of October 19, 1970.

Estimate of additional cost increase through contract completion

In addition to the October 1970 contract value of $127.9 million, NASA estimated that an additional $121.4 million cost increase will be experienced through contract completion. The estimated increase of $121.4 million consists of $108.1 million for redesign effort, hardware modifications, and testing and $13.3 million for schedule slippage.

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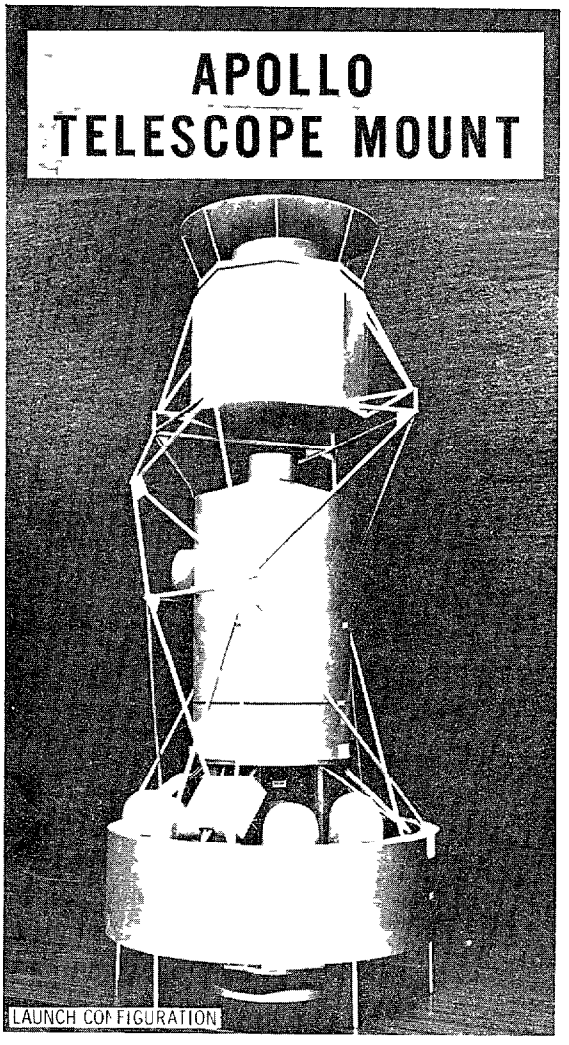
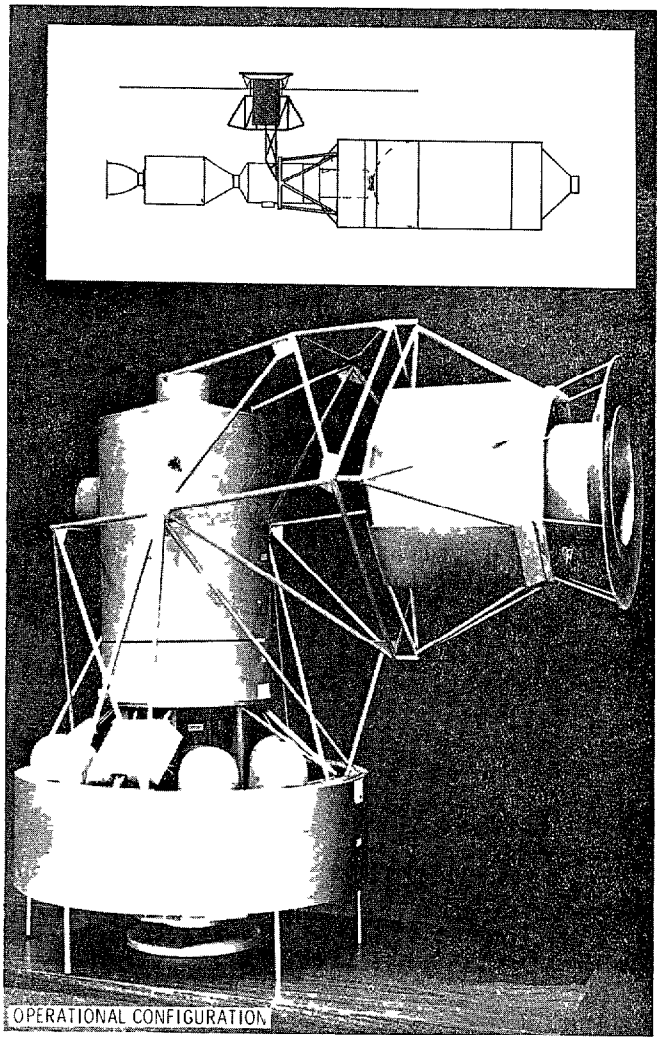
Included in appendix II of this report are the Marshall Space Flight Center's comments concerning programmatic and other influences contributing to the cost increases during the development of the airlock module.

CHAPTER 11

APOLLO TELESCOPE MOUNT PROJECT COSTS

The Apollo telescope mount is to be designed and developed to permit man to observe, monitor, and record solar phenomena outside the distorting atmosphere of the earth and to demonstrate and evaluate man's ability to perform scientific experiments with high resolution astronomical telescopes while in space. Funding for the cost of experiments that are to be flown on the Apollo telescope mount is provided under the experiment development project. (See ch. 4.)





The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for the Apollo telescope mount project.

	October 1968	Increase or decrease(-) 1968-69	December 1969	Increase or decrease(-) 1969-70	October 1970	Increase or decrease(-) 1968-70 Amount	Increase or decrease(-) 1968-70 Percent
	(millions)						
APOLLO TELESCOPE MOUNT	$195 8	-$82 1	$113 7	-$0 5	$113 2	-$82 6	-42
Lunar module modifications	104 8	-85 3	19 5	-2 2	17 3	-87.5	-83
Apollo telescope mount systems	69 2	21.4	90 6	5 3	95 9	26.7	39
Support	21.8	-18 2	3.6	-3 6	-	-21.8	-100

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The major cause for the decrease in the estimated cost of the Apollo telescope mount was attributed to the cancellation of the modifications to the lunar module that would have been required under the wet workshop configuration.

NASA's explanations for the changes in estimated cost for each funding element of the Apollo telescope mount project are presented in the following sections.

Lunar module modifications

The decrease of $85.3 million in the December 1969 estimate resulted from the cancellation of the lunar module modifications that were no longer required after the change to the dry workshop configuration.

The contract termination and closeout costs for the lunar module modifications were less than anticipated and resulted in an additional decrease of $2.2 million which was reflected in the October 1970 estimate.

Apollo telescope mount systems

The change to the dry workshop configuration and the 11-month launch schedule slippage from August 1971 to July 1972 resulted in the increase of $21.4 million in the December 1969 estimate.

A further launch schedule slippage to November 1972 and the addition of a backup mission capability resulted in the increase of $5.3 million in the October 1970 estimate.

Support

The decrease of $18.2 million in the December 1969 estimate was caused by the elimination of contractor checkout effort for the Apollo telescope mount at the Kennedy Space Center.

Retained in the December 1969 support cost estimate was a contingency fund amounting to $3.6 million for possible experiment installation costs. This fund was subsequently eliminated and a decrease of $3.6 million in the October 1970 estimate resulted.

CHAPTER 12

SATURN IB VEHICLE PROJECT COSTS

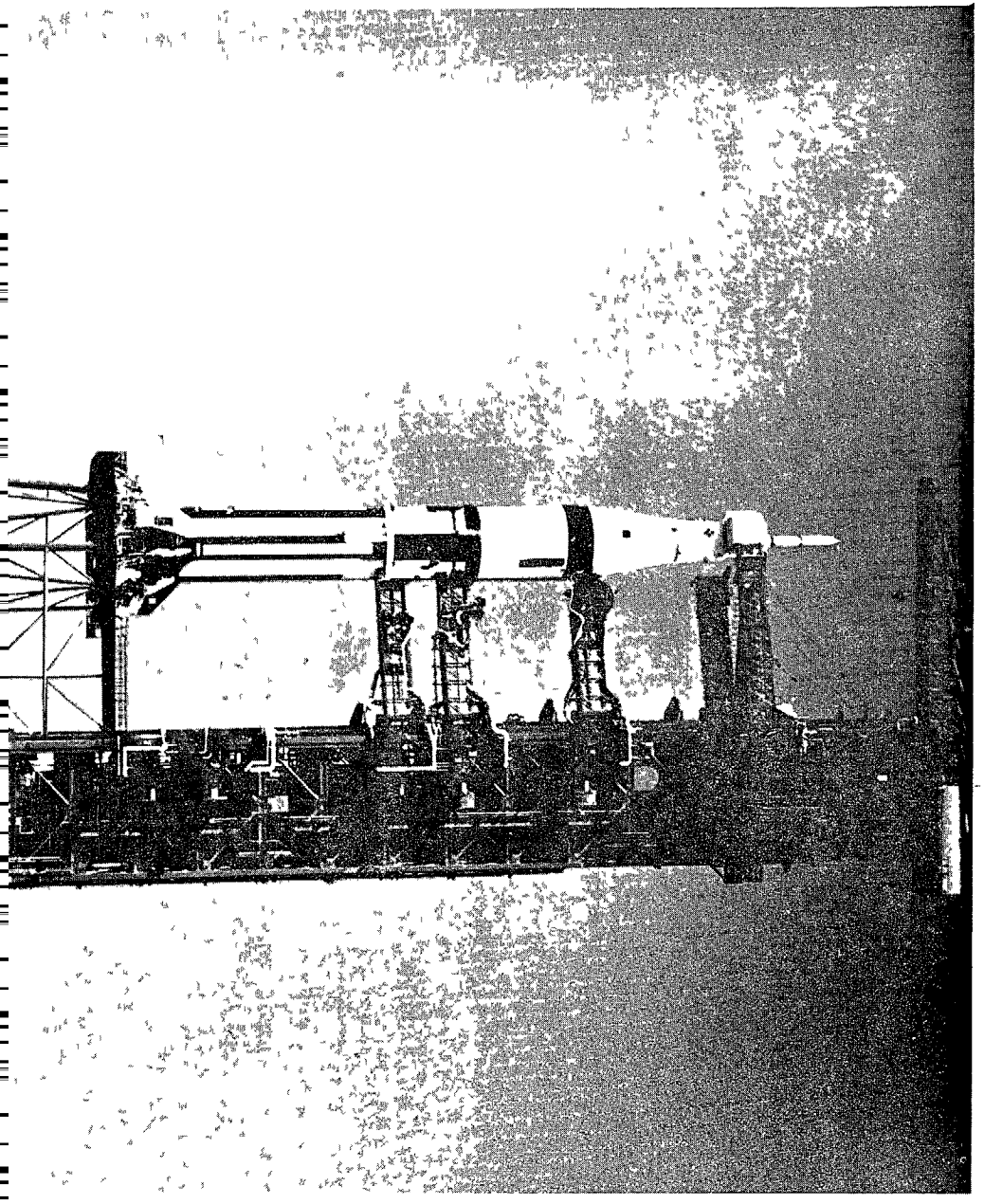
The two-stage Saturn IB launch vehicle will be used to launch three astronauts in a modified command and service module for the initial visit and two subsequent visits to the workshop. A picture of the Saturn IB on a modified Saturn V mobile launch structure is shown on the following page.

Seven unused Apollo Saturn IB launch vehicles procured by the Apollo Program have been transferred to the Skylab Program. In addition to the seven vehicles procured by the Apollo Program, the Skylab Program was funding the production of two additional Saturn IB vehicles. In calendar year 1969, production was suspended except for the two first stages which were already near completion. Of the seven vehicles transferred, three are to be used for the initial and two subsequent workshop visits, one is a backup, and three will remain unassembled in storage.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for each funding element of the Saturn IB vehicle project. The production costs of the seven vehicles transferred to the Skylab Program are not reflected in the estimates shown below.

	October 1968	Increase or decrease(-) 1968-69	December 1969	Increase or decrease(-) 1969-70	October 1970	Increase or decrease(-) 1968-70 Amount	Increase or decrease(-) 1968-70 Percent
	(millions)						
SATURN IB VEHICLE	$404 4	-$205 1	$199 3	$33 4	$232 7	-$171 7	-42
S-IB stage	68.2	-24 4	43.8	21.1	64.9	-3 3	-5
S-IVB stage	83.9	-45.2	38.7	12 2	50.9	-33 0	-39
Instrument unit	48.9	-26.2	22.7	-9.9	12.8	-36.1	-74
Ground support equipment	23.8	-11.0	12 8	-5.1	7.7	-16.1	-68
H-1 engine	20.4	2.7	23.1	8.9	32.0	11.6	57
Vehicle support	159.1	-101.0	58.1	6 3	64 4	-94.7	-60

Note Figures may not add due to rounding.



NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The primary reasons for the $205.1 million decrease in the estimate as of December 1969 were the cancellation of production of the second stage and instrument unit for two Saturn IB vehicles and the elimination of the Skylab Program funding responsiblity for common support. (See pp. 14 through 16.) Also contributing to the decrease were the elimination of a Saturn IB dual launch capability, a lower negotiated level of Saturn IB vehicle support, and a cost-reduction study which resulted in cost savings and planning changes.

The increase of $33.4 million in the October 1970 estimate was primarily a result of including closeout costs for the completed S-IB stage contract and the Skylab Program's newly acquired funding responsibility for flight support costs during fiscal years 1973 and 1974 as a result of the Apollo Program phasing out. Funding for the assembly of two instrument units was added, and the 4-month launch schedule slippage from July to November 1972 contributed to the increase. These increases were partially offset, however, by the elimination of the Skylab Program's need for launch complex 34 and the accompanying realignment of contractor manpower at launch complex 39.

CHAPTER 13

SATURN V VEHICLE PROJECT COSTS

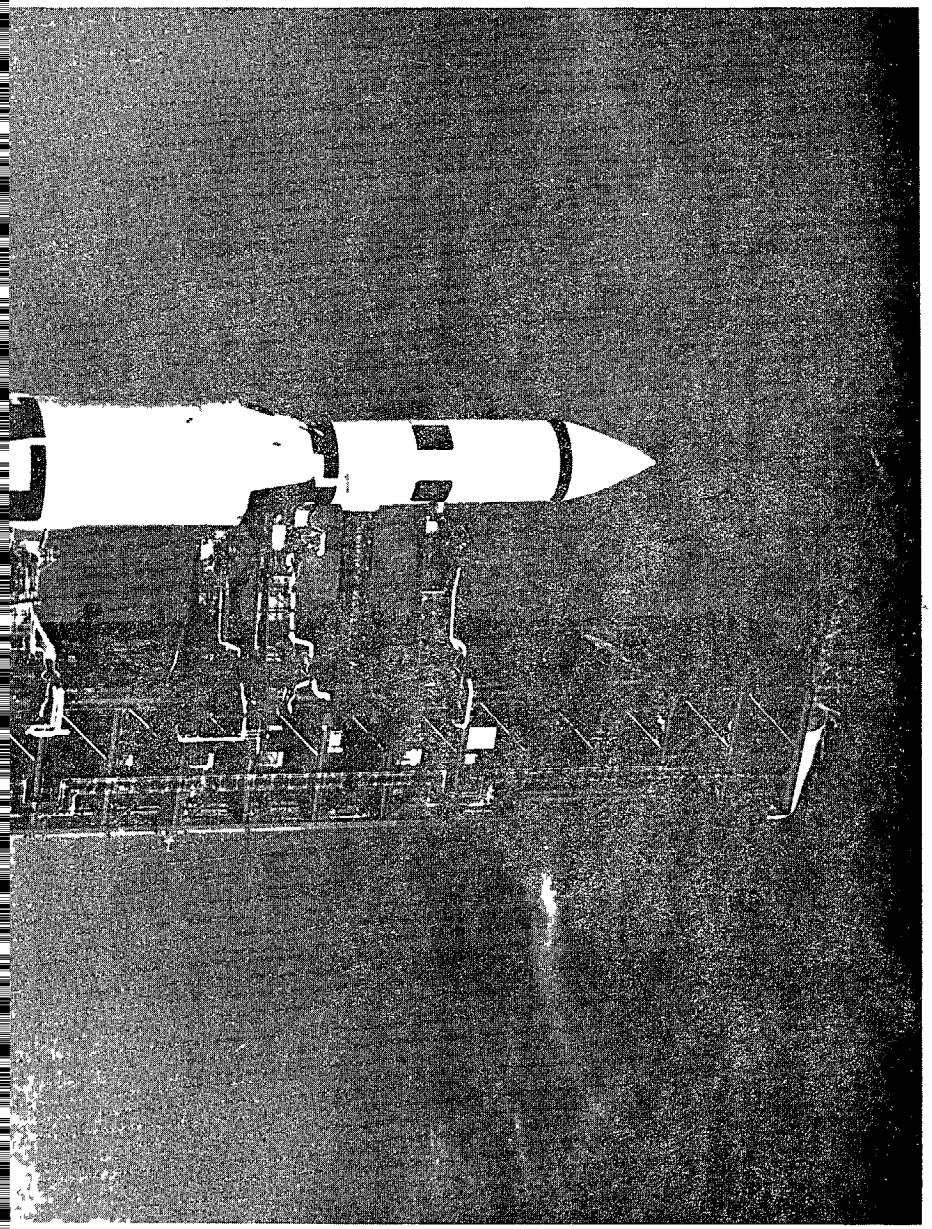
The availability of a Saturn V launch vehicle procured by the Apollo Program enabled the Skylab Program to change to the dry workshop configuration. Only the first two stages (S-IC and S-II) of the Saturn V will be used to simultaneously launch the orbital workshop, airlock module, multiple docking adapter, and Apollo telescope mount. During the launch, the orbital workshop, airlock module, multiple docking adapter, and Apollo telescope mount will occupy the area that is normally occupied by the S-IVB stage, lunar module, and command and service module during Apollo missions. Skylab has funding responsibility for modifications to the Saturn V vehicle configuration which are unique to the Skylab Program.

A picture of the Saturn V vehicle launch configuration for the Skylab Program is shown on the following page.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for the Saturn V vehicle project.

	October 1968	Increase 1968-69	December 1969	Increase 1969-70	October 1970	Increase 1968-70 Amount	Increase 1968-70 Percent
	(millions)						
SATURN V VEHICLE	$3.6	$5.5	$9 1	$148 0	$157 1	$153 5	4,264
S-IC stage	2 3	-	2.3	28.8	31 1	28 8	1,252
S-II stage	-	-	-	24.4	24 4	24 4	-
S-IVB stage	-	-	-	27.3	27 3	27.3	-
Instrument unit	-	-	-	41.9	41.9	41.9	-
Ground support equipment	-	-	-	5.0	5.0	5.0	-
F-1 engine	1.3	-	1.3	4.4	5.7	4.4	338
Vehicle support	-	5.5	5.5	16.3	21 8	21.8	-

Note Figures may not add due to rounding.



NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The October 1968 estimate of $3.6 million was for long-lead procurements for Saturn V launch vehicles. Early Skylab Program planning included several missions which required Saturn V vehicles. At that time all Apollo Saturn V's were still assigned to Apollo lunar missions which made it necessary for the Skylab Program to purchase additional Saturn V vehicles. The procurement was canceled, however, when all requirements for follow-on Saturn V's were removed from the Skylab Program. Long-lead items already purchased were placed in storage for use as spares.

The $5.5 million increase for vehicle support in the December 1969 estimate was attributed to effort for launch umbilical tower modifications required by and unique to the Skylab Program. These modifications were required as a result of the change to the dry workshop configuration.

The additional increase of $148 million in the October 1970 estimate consisted of (1) $142.3 million for flight support costs in fiscal years 1973 and 1974 due to the planned completion of the Apollo Program in fiscal year 1972 and (2) $5.7 million for Saturn V modifications required for the dry workshop configuration.

CHAPTER 14

PAYLOAD INTEGRATION PROJECT COSTS

Payload integration is the activity necessary to complement and integrate the work that is being performed under other Skylab projects. This activity includes

--mission analysis for experiment operations,
--system analysis,
--system integration and requirements analysis,
--experiment analysis, and
--program management requirements and controls.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for these activities.

	October 1968	Increase or decrease(-) 1968-69	December 1969	Decrease(-) 1969-70	October 1970	Increase or decrease(-) 1968-70 Amount	Percent
	(millions)						
PAYLOAD INTEGRATION.	$163 0	-$11 5	$151 5	-$2 9	$148 6	-$14.4	-9
Definition	36.1	-24.3	11.8	-	11.8	-24.3	-67
Implementation	126.9	12.8	139.7	-2.9	136.8	9.9	8

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The October 1968 estimate of $163 million was based on preliminary estimates made prior to negotiation of the contract for the payload integration effort.

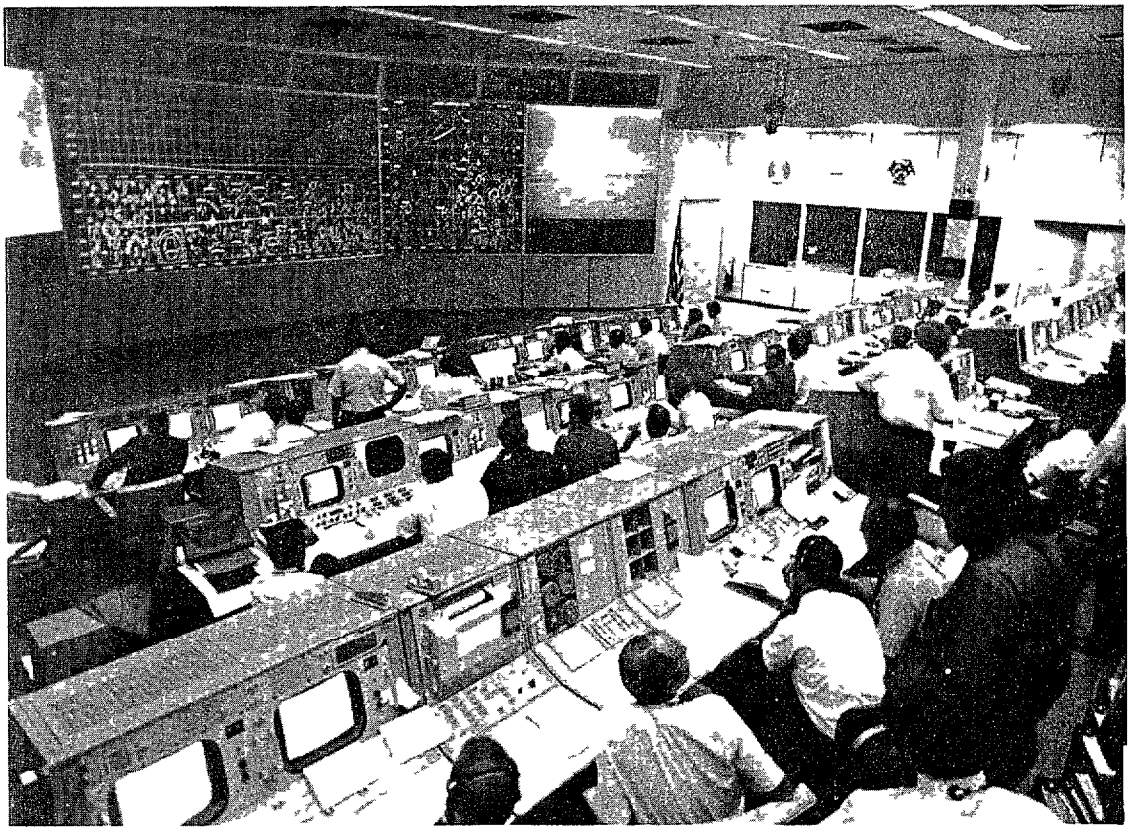
The December 1969 estimate of $151.5 million, a decrease of $11.5 million, was primarily attributed to (a) a decrease of $13.1 million which resulted from the negotiated contract being less than the October 1968 preliminary estimate and (b) a partially offsetting increase of $1.6 million which was caused by the 11-month launch schedule slippage from August 1971 to July 1972.

The decrease of $2.9 million from December 1969 to October 1970 was primarily attributed to a reduction in the allowance for program changes.

CHAPTER 15

MISSION OPERATIONS PROJECT COSTS

Mission operations provides for the overall operational capability of the Skylab Program. Mission operations funding includes all mission control; preflight, flight and recovery operations; crew training; crew systems; crew operations; launch support operations; launch instrumentation support; and liaison activity for the NASA offices participating in each Skylab Program mission.



The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for mission operations.

	October 1968	Decrease(-) 1968-69	December 1969	Decrease(-) 1969-70	October 1970	Decrease(-) 1968-70 Amount	Decrease(-) 1968-70 Percent
	(millions)						
MISSION OPERATIONS	$281 1	-$214 2	$66 9	-$12 2	$54 7	-$226 4	-81
Mission control	59 8	-59.0	0 8	-	0.8	-59 0	-99
Flight operations	60.4	-37.5	22.9	-3.6	19 3	-41.1	-68
Flight crew operations	39 6	-16.7	22.9	-2.2	20 7	-18.9	-48
Launch operations	108.8	-89.8	19.0	-6.2	12 8	-96 0	-88
Launch instrumentation	12.5	-11.1	1.4	-0.3	1.1	-11.4	-91

Note: Figures may not add due to rounding

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The following sections present NASA's explanations as they relate to each element of cost shown in the above schedule.

Mission control

The decrease of $59 million in the December 1969 estimate was attributed to the elimination of the Skylab Program's funding responsibility for common support. (See pp. 14 through 16.)

Flight operations

The decreases of $37.5 million and $3.6 million in the December 1969 and October 1970 estimates, respectively, were attributed to a reduced level of support contractor effort.

Flight crew operations

The decrease of $16.7 million in the December 1969 estimate was primarily attributed to the deletion of the lunar module/Apollo telescope mount simulator when the workshop configuration was changed from wet to dry.

The $2.2 million decrease in the October 1970 estimate resulted from reduced camera requirements and the transfer of funding responsibility for modifications and maintenance of simulators from the Skylab Program to the operating base.

Launch operations

The decrease of $89.8 million in the December 1969 estimate was attributed to (1) elimination of the Skylab Program's funding responsibility for common support, (2) conversion of contractor tasks to in-house at the Kennedy Space Center, and (3) cost reductions at the Air Force Eastern Test Range where Saturn IB launches were scheduled to take place.

The decrease of $6.2 million in the October 1970 estimate was primarily a result of the consolidation of manned launch operations at launch complex 39 which eliminated the Skylab Program's need for launch complex 34.

Launch instrumentation

The decrease of $11.1 million in the December 1969 estimate was primarily attributed to the elimination of the Skylab Program's funding responsibility for common support.

The decrease of $0.3 million in the October 1970 estimate was primarily attributed to better manpower utilization through the consolidation of manned launch operations at launch complex 39.

CHAPTER 16

PROGRAM SUPPORT PROJECT COSTS

The program support project provides activities to assist the Skylab Program Office in the establishment of program requirements and the review of program implementation activities. Program support includes funding for systems engineering, technical and management services, and related support services, including some electrical support equipment.

The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for program support.

October 1968	Decrease(–) 1968-69	December 1969	Decrease(–) 1969-70	October 1970	Decrease(–) 1968-70 Amount	Decrease(–) 1968-70 Percent
(millions)						
$164.7	–$5.1	$159.6	–$85.3	$74.3	–$90.4	–55

NASA EXPLANATIONS FOR CHANGES IN ESTIMATED COST

The decrease of $5.1 million in the December 1969 estimate was the net result of (1) a decrease of $33.5 million due to the transfer of funding responsibility to the Apollo Program for common support costs applicable to laboratory support contractors at the Marshall Space Flight Center and (2) an increase of $28.4 million in the management reserve when the workshop configuration was changed from wet to dry.

The decrease of $85.3 million in the October 1970 estimate was the net result of (1) an increase of $3 5 million due to the 4-month launch schedule slippage from July to November 1972 and (2) an $88 8 million decrease resulting from a reduction in the management reserve and reduced contractor effort for the test program, the reliability-quality-safety program, and configuration management.

CHAPTER 17

CONTRACT ADMINISTRATION COSTS

Contract administration funding consists of the Skylab Program's allocated portion of costs associated with audits of NASA contractors which are performed primarily by Department of Defense audit agencies. The following schedule compares the October 1968, December 1969, and October 1970 estimates of cost for contract administration.

October 1968	Increase 1968-69	December 1969	Decrease(-) 1969-70	October 1970	Increase 1968-70 Amount	Increase 1968-70 Percent
(millions)						
$11.7	$4.1	$15.8	-$0.2	$15.6	$3.9	33

NASA EXPLANATION FOR CHANGES IN ESTIMATED COST

NASA attributed the net increase of $3.9 million between the October 1968 and October 1970 estimates to extended Department of Defense audit activities resulting from launch schedule slippages.

CHAPTER 18

AGENCY COMMENTS AND OUR EVALUATION

In a letter dated March 2, 1971, the Associate Administrator for Organization and Management commented upon the rationale behind NASA's request that we restrict the distribution of our report and transmitted the Office of Manned Space Flight's comments on the report. This letter is included as appendix I. Comments were also obtained from the Director of the Marshall Space Flight Center and these are included as appendix II. Following is a summary of NASA's comments and our evaluation thereof.

NASA commented that the general facts showing only a small cost growth since mid-1968 were sound and that the general narrative of the program in chapter 1 reasonably portrayed the situation. NASA felt, however, that the report became very confusing in later chapters on individual projects because we had shifted the reference base for costs from the October 1968 program operating plan to various earlier bases.

NASA stated that the October 1968 program operating plan had been well chosen as the base for the general section of the report because this represented the first completed program operating plan containing the estimated cost of the program through completion and because the program had stabilized reasonably well into its present program configuration and number of launches. NASA stated also that the use of reference bases as early as 1966 in the report for several individual projects--a time when the overall program definition and the requirements on individual projects were still very much in the formative stage--had made it extremely difficult to follow a train of logic through the report. NASA felt that it also produced highly questionable percentages of cost growth and strongly suggested that the project sections of the report be rewritten around the same base as the more general parts of the report.

Initially, we had planned to use as our base the earliest possible estimate of the cost of the program as a whole. Since the October 1968 estimate, however, was the first estimate of the cost of the program through completion,

we decided to trace the cost of selected hardware items from the initial estimate to the most recent estimate to obtain a more complete understanding of the changes in the program. We believe that the bases used, 1966 and 1967, in this part of our review are appropriate when viewed in the context that NASA sought and received congressional approval for the program in calendar year 1967.

TRANSFER OF EFFORT

NASA commented that the transfer of program elements between projects had explained many of the fluctuations in individual project cost estimates. As an example, NASA commented that major functions of the lunar module had been transferred to the airlock module which increased its cost; however, because of this transfer, it was possible to cancel the lunar module project and decrease its cost. NASA believes that identification of such transfers is essential since they do not, from the overall point of view, constitute unwarranted cost growth.

We met with officials of the Marshall Space Flight Center on March 19, 1971, to discuss the effect of transfers between projects. During this meeting, the officials stated that the transfers pertained only to the period between July 1969 and October 1970--the time when transfers between projects were being made as a result of the decision to change from the wet to the dry workshop configuration. They stated also that it would be a difficult task to allocate the applicable cost increases and decreases among the projects involved in the transfers. They estimated that such an allocation could take as much as 3 months and even then might result in only a rough estimate. Therefore we were not able to price out the effect of the transfers.

ACCOUNTING EFFECTS

NASA commented that the effect of changes in accounting had perhaps been overemphasized by our comments regarding common support costs. In this regard, the information provided in our report concerning the common support was provided by NASA as part of its explanation for cost decreases in the program. We reported and explained common support as it was presented to us.

METHODS OF ESTIMATING

The agency also stated that within our report there were numerous references to the fact that estimates were often based on judgment and experience and that documents in the file did not preserve the rationale and calculations on which the estimates were based. NASA felt that the reporting of the use of judgment and experience should not be construed as critical in a program of this nature.

In this regard, emphasis in our report was placed on NASA's lack of documentation. We were not suggesting that judgment and experience should not be used but that sufficient documentation was not available to show what was considered in arriving at the estimate. NASA indicated that it would continue its attempts to improve in the area of documentation.

PROVISION FOR INFLATION

NASA commented that a GAO summary of facts concerning our review at the Marshall Space Flight Center had erroneously indicated that conflicting statements had been made by center officials concerning the provision for inflation. NASA stated that provision for inflation had been made in the cost estimates but that inflation had not been separately identified as a percentage factor.

We do not feel that conflicting statements were presented. During our review, one official told us that an estimate being discussed did not include a specific provision for inflation but that the estimate included contractor-proposed costs which did. Other officials told us that estimates would provide for inflation but that they could not identify the amounts provided.

In contrast to our summary of facts, our final report does not deal with the provision for inflation solely at the Marshall Space Flight Center. Rather, we state that program operating plan guidelines do not direct the centers concerning the provision for inflation and that, as a result, some estimates do not include a provision for inflation.

CHAPTER 19

SCOPE OF REVIEW

We examined the policies, procedures, and practices followed by the Marshall Space Flight Center, Huntsville, Alabama; the Manned Spacecraft Center, Houston, Texas; and NASA Headquarters, Washington, D.C., in estimating the cost of the Skylab Program. We discussed with agency officials the procedures followed in preparing the most recent estimate of the cost of the program--the October 1970 estimate.

At NASA Headquarters we also examined into the cost history of the program between October 1968 and October 1970. We selected as our base the estimate of program cost in the October 1968 program operating plan because it provided the first estimate of the cost of the Skylab Program through completion. Due to changing program definition, earlier program operating plans included only estimates of costs to be incurred during the next 2 years of the program. We identified the changes that occurred between the October 1968, December 1969, and October 1970 program operating plan estimates and obtained NASA's reasons for these changes.

We examined the cost history of selected Marshall Space Flight Center hardware contracts. We reviewed the records and documents related to these contracts and held discussions with cognizant NASA officials. The contracts selected and the related hardware being developed are shown below.

Item	Contractor
Orbital workshop	McDonnell Douglas Astronautics Company
Airlock module	McDonnell Douglas Astronautics Company
X-ray spectrographic telescope	American Science and Engineering, Inc.
Ultraviolet scanning polychromator spectroheliometer	Harvard College Observatory

APPENDIXES

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

MAR 2 1971

REPLY TO
ATTN OF D-2

Mr. Klein Spencer
Assistant Director, Civil Division
U.S. General Accounting Office

Dear Mr. Spencer:

In response to your letter, dated February 24, 1971, there are enclosed the comments of the Office of Manned Space Flight relating to GAO's draft report on the review of estimated cost of the Skylab Program.

The following information is furnished pursuant to your request for a reiteration of the rationale behind NASA's limitations on the use and release of certain types of information made available to the GAO auditors assigned to the review of the Skylab Program. Such rationale was stated in the several GAO/NASA meetings that were held on the need for documents and data. These meeting resulted in mutually accepted "groundrules" for the performance of this survey and, also, for the other recently announced "cost-growth" reviews of certain OSSA and OART Programs.

Specifically, GAO auditors agreed not to use or disclose to others, without prior approval of NASA, any of the following data if it should come to the auditors' attention while other information is being made available for GAO review:

(a) Budget estimates until such time as they are made public by the President.

(b) Obsolete budget requests of the Administrator.

(c) Agency estimates of the run-out costs of individual contracts.

There was no restriction on NASA's latest estimate of total program run-out costs for the Skylab Program, including a breakdown of the elements (line items) comprising such total, Provided: budget estimates or program projections, by fiscal years, were not used or disclosed. Also, there was no restriction on the use or disclosure of agency estimates of total run-out costs of all Skylab contracts in the aggregate.

The rationale supporting the above limitations (a) and (b) is set forth in NMI-7440.1 and BOB Circular A-10 which are designed to implement the instructions of the Executive Office of the President. The rationale behind limitation (c) above is to prevent public disclosure of in-house determinations on existing contracts in order to:

1. Avoid prejudicing the Government in future negotiations with the contractors, and
2. Avoid the disclosure of data which would permit contractors to predicate their claims on NASA's estimates of projected costs.

In brief, these limitations are designed to protect the interests of the United States.

To our knowledge, the above groundrules have created no significant problems in the conduct of the review of the Skylab Program. In fact, the GAO auditors themselves recognized that care would have to be exercised in the presentation of some schedules and financial data, as well as narrative, in the GAO report to preclude a meaningful interpretation by contractors' representatives even though identification of NASA projections of run-out costs on individual contracts might not be readily apparent to some readers of the report. For example, report financial data or narrative on a program line item (or sub-item) might be extrapolated to information on individual contracts by knowledgeable contractors even though contract or contractor identification is not shown.

The draft report provided with your letter of February 24, 1971, does include several NASA estimates (specific or interpretable) of run-out costs on individual contracts. As a matter of preference, NASA continues to urge you to delete from your report the agency's estimates of run-out costs of individual contracts. If, however, such information is in GAO's view essential to the report then as a minimum we request that you make the survey report "restricted", in compliance with the limitations agreed upon, and accompany it with a suitable explanation regarding the sensitive nature of the specified information.

Bernard Martin
for Richard C. McCurdy
Associate Administrator for
Organization and Management

Enclosure:
As stated

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D C 20546

REPLY TO ATTN OF MLB

MAR 2 1971

MEMORANDUM

TO: D/Associate Administrator
for Organization and Management

FROM: M/Deputy Associate Administrator
for Manned Space Flight

SUBJECT: Comments on the GAO February 24 Draft Report on the Skylab Program

Attached are OMSF comments in response to the GAO draft report on Skylab, received February 24.

Per our conversation this morning, these are intended to be attached to your letter to GAO.

Charles W. Mathews

Attachment

APPENDIX I

NASA COMMENTS ON GENERAL ACCOUNTING OFFICE DRAFT REPORT ON THE SKYLAB PROGRAM

General

The general facts showing only a small cost growth since mid 1968 are sound, and the general narrative of the program in Chapter 1 reasonably portrays the situation. However, the report becomes very confusing in later chapters on individual projects because it shifts the reference base from POP 68-2 to various earlier bases. This makes it very difficult to follow through the thread of development and also leads to erroneous conclusions at the project level.

Base

The POP 68-2 was well choosen as the base for the general section of the report because this represented the first completed POP going to runout and because the program had stablized reasonably well into its present program configuration and number of launches. Even after that time, as late as July 1969, changes as significant as the one from Saturn IB-launched wet to Saturn V-launched dry workshop were still being made.

Earlier reference bases are used in the report for several individual projects extending back into periods as early as 1966, a time when the overall program definition and the requirements on individual projects were still very much in the formative stage. Structuring these individual project analyses to a different base in time and in degree of definition makes it extremely difficult to follow a train of logic through the report. It also produces highly questionable percentages of cost growth. For instance, the Airlock Module is reported to have experienced a very large percentage cost growth. This was calculated from a very early base related to early tasks and a concept of a simple Airlock which later grew into a sophisticated nerve center of the Cluster, taking over numerous functions originally assigned elsewhere. This is typical of numerous instances where growth in one project represented transfers of effort from another project without increase to overall program.

It is strongly suggested that the project sections of the report be rewritten around the same POP 68-2 base as the more general parts of the report.

Transfer of Effort

Both the general section of the report and the detailed project analysis could be greatly improved by stressing and presenting more clearly the transfer of program elements from project to project. Such transfers explain many fluctuations in individual projects which, without accompanying explanation, would appear quite unusual. For instance, using the example cited before, major functions of the LM were transfered into the Airlock Module creating a substantial growth in cost of the Airlock Module project; but because of this and similar changes it was possible to cancel the LM project altogether with a consequent decrease in cost of the LM project. Identification of such transfers is essential since they do not, from the overall point of view, constitute unwarranted growth. As written, individual project chapters could be construed to imply unwarranted growth.

Accounting Effects

The effect of changes in NASA accounting has perhaps been over-emphasized by implication in Chapter 1's comments regarding the operating base. While there have been some changes into and out of the program, we believe that the overall success in holding cost growth to 4% reflects the legitimate management process at work. [See GAO note p. 96.]

Methods of Estimating

There are numerous references to the fact that estimates were often based upon judgment and experience and that documents in the file do not preserve the rationale and calculations upon which the estimates are based. In advanced R&D projects we must and should rely heavily upon experienced development engineers and estimators. We choose that kind of people for the work. We will continue to attempt to improve our documentation; but reporting the use of judgment and experience should not be construed as a critical comment in a program of this nature, and it would be helpful if the report made this clear.

Other Specifics

There are other specific details of fact or emphasis which are being dealt with routinely by comments from the Skylab Program Office and the Centers directly to GAO. MSFC is making a written response dealing in greater detail with the specific cost history or MSFC's projects.

GAO note: The cost growth percentage was revised from 4 percent to 5 percent in the final report.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER ALABAMA 35812

MAR 1 1971

REPLY TO
ATTN OF DIR

Mr. J. J. Bevis
Audit Manager
General Accounting Office
Building 4202, Room B-18
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Dear Mr. Bevis:

Although we have not heretofore provided written comments to the GAO fact sheets on cost growth and cost estimating procedures of selected MSFC Skylab contracts, our concern has been expressed to your people in meetings with what we consider improper context and other shortcomings of the fact sheets.

We have now received copies of the GAO draft report transmitted to Mr. McCurdy of NASA by letter, dated February 24, 1971, from Mr. Spencer of GAO. Although overall response to this report will be forthcoming from NASA Headquarters, our concern continues with the individual fact sheets, which are contained in toto in the body of the report.

In reviewing your report, we note that after describing the history of the program, October 1968 was selected as the baseline for R&D costs through completion for each project and system contained in the Skylab Program. In the selected MSFC contracts, however, the baseline established was 1966, two years earlier. Not only is this entirely inconsistent with the project and systems cost examination in the report, but these individual fact sheets alone are misleading in several respects

First, they do not address the major external influences, programmatic or broader, caused by the concept evolution described in the historical profile. The period selected was one when the Workshop and ATM were the relatively simple first mission of an extensive program, as compared to their constituting the hub of the total program today.

Next, no recognition is made that many additions to the individual contracts were not additions to the program, but rather requirement shifts from another part of the program. For instance, many of the functions added to the Airlock requirements had formerly been provided by the CSM.

Another shortcoming of the fact sheets is a skipping back and forth among procurement plan estimates, contract value, and POP estimates. Although the amounts cited in the fact sheets for contract values and contract changes are generally correct, coherency is lost because there is no connection made between these contract estimates and the POP estimates, rather they have been lumped as a total differential to the current contract value.

For the foregoing reasons, we recommend that the MSFC cost growth fact sheets be stricken from the report. If GAO feels that individual contract cost growth examinations must be made, we recommend the following·

a. Use October 1968 as the baseline, consistent with the system level cost review,

b. Recognize that each addition to a contract is not necessarily an addition to the program, but may be a requirement shift from another part of the program,

c. Use consistent method of describing projected increases, from POP to POP.

In line with the above, we are enclosing logical descriptions of each of the selected contracts.

We have also reviewed your individual fact sheets on cost estimating procedures and your general observations, and are enclosing our comments to them.

We will be happy to meet with you at any time to provide further amplification or clarification.

Sincerely,

Eberhard Rees
Director

Enclosures

COMMENTS ON GAO COST GROWTH FACT SHEET
AIRLOCK MODULE
MDAC-EASTERN DIVISION
CONTRACT NAS9-6555

The logical starting point for examining the Airlock Project cost growth is early CY 1969, at the time of submission of POP 69-1C. This was the first budget submission containing MSFC estimate of requirements for a "wet" workshop mission and hardware that is reasonably comparable to today's "dry" workshop. Prior to that time, the major additional requirements to the original pressurized tunnel had not been firmly defined nor completely budgeted The original pressurized tunnel concept was based on the CSM supplying power, oxygen and nitrogen, and environmental control Because of the major changes involved in revising this concept, work on Airlock flight hardware was suspended for approximately a year during 1967-68

The POP 69-1C was the first POP which provided MSFC estimates and included $89 5 M The Airlock Module was to be delivered in March 1971 to support an August 1971 launch date The primary Airlock Module function at this time was to support the "wet" workshop mission. Briefly, this mission was to launch an orbital workshop as the propulsive Saturn IB S-IVB to be converted in orbit by the crew for habitation and for the conduct of scientific and engineering experiments. The mission of the Airlock Module was to support the orbital operations during the planned 14-days operations using previously qualified hardware from the Gemini and Apollo programs and to support an "open-ended" mission beyond the first 14 days up to 28 and 56-day durations. The Airlock Module at this point was to provide access hatches to the Multiple Docking Adapter and Workshop and an external hatch for EVA purposes The instrumentation and communication systems would provide engineering and operational data and some limited experimental data The command or ground control system would only provide for those functions necessary for safety and to prepare the AM-OWS-MDA for docking by the CSM with the crew The electrical power and distribution system would utilize stored and distributed electrical power from the OWS solar arrays and the CSM The environmental conditioning system provided only for proper mixing and purefication of the breathing atmosphere In summary, the Airlock Module was a semi-passive module with limited capability for distributing electrical power, transmitting telemetry data, providing means for EVA and stowage of some experiments and equipment and providing equipment to maintain proper pressure and atmosphere

The next major cost growth and corresponding hardware changes was the "wet" to "dry" conversion configuration as reflected in POP 69-2C at $132 6M. The Airlock Module was to be delivered in July 1971 to support a March 1972 launch date As a result of the new "wet" to "dry" configuration and added hardware requirements to the AM, more emphasis was being placed on the function of the AM to support the full 8-month mission duration. It was to be determined by analysis and additional

testing on hardware that from a design standpoint all systems should be capable of operating for the 8-month mission duration The mission requirements of this change reflected in the Airlock Module were· (a) addition of the Fixed Airlock Shroud (FAS) for stowage of O_2 and N_2 consumables, formerly provided by the CSM, to support the entire mission without orbital resupply, (b) added the temperature or thermal control provisions to the environmental control system for the AM-MDA-OWS and CSM; (c) additional power storage, conditioning and distribution system since the CSM would now be quiescent during operation of the OWS by the crew; (d) expanded communication system to accomodate additional operations, housekeeping, engineering and experiment data; (e) expanded ground control system since the crew would not be utilizing the CSM; (f) added the two-gas control system to the AM; (g) added additional cooling loop requirements to support ATM, and (h) provided emergency and warning system for the safety of the crew Many of these additional requirements, including cooling for the ATM Controls and Displays and additional instrumentation, were added to replace functions formerly provided by the LM which had been deleted from the program for an overall savings to the program Deletion of the LM also required changes to the Airlock attendant to its becoming the primary EVA mode

The next major Airlock cost growth corresponded to the addition of the Payload Shroud and the ATM Deployment Assembly as reflected in POP 69-2 estimate of $181 8 M. These two items were added to the program as a result of converting to the "dry" workshop concept, but it was not until POP 69-2 that they were included as Airlock components The Payload Shroud is used to protect the AM-MDA-ATM during launch and also supports the weight of the ATM until earth orbit is attained. It replaces the SLA which was provided for in another contract during the "wet" workshop program The ATM weight is then transferred to the Deployment Assembly for positioning the ATM for in-orbit operation The Deployment Assembly is a tubular structure not only for supporting the ATM but various experiments and equipment

Since the POP 69-2, additional mission requirements and corresponding hardware changes have been added to the Airlock Module. A new launch date of November 1972 with flight hardware delivery of February 1972 was reflected in POP 70-2 A complete listing of changes will not be enumerated, but some examples are cited to convey the rationale for increased cost of the Airlock Module Recently the AM trainer to be delivered to MSC for crew training underwent a complete review and update of requirements and specification to reflect the latest MSC crew training hardware requirements The Earth Resources Experiments are becoming more mature in design and reflect requirements for additional AM power, communication, and cooling. Additional hardware has been required to support testing requirements that were not in earlier program requirements The reviews of hardware design for the crew have resulted in many changes that add cost to the program A significant

increase in complexity of the Caution and Warning system to improve crew safety has caused considerable cost increase in the program The changes imposed on the AM from external interfacing equipment at this point in the program add to cost, especially when hardware has to be refabricated or changed late in fabrication

APPENDIX II

COMMENTS ON GAO COST GROWTH FACT SHEET
WORKSHOP PROJECT
McDONNELL-DOUGLAS ASTRONAUTICS COMPANY - WESTERN DIVISION
CONTRACT NAS9-6555

The program identified by POP 68-2C, fourth quarter CY 1968, funding represents a common baseline in terms of making a direct program comparison with the program hardware and missions of today (POP 70-2C) In the formative period prior to this time the major effort was spent in trying to define programs and missions that would make use of the basic Apollo hardware. Today's program has matured from the original intent of allowing an EVA astronaut to open the hatch of a Saturn S-IVB spent stage, enter for a short experimental period and return to the CSM That rudimentary concept has evolved into a spacecraft that is capable of fully sustaining the crew of three astronauts, 24 hours a day continuously for the full 28 and 56 day missions.

The $104.5M in POP 68-2C is funding for a "wet" Workshop program scheduled to be completed in January 1972. KSC delivery was March 1971. The basic program consisted of-

1. One propulsive Saturn IB (S-IVB 212) flight stage,

2. One propulsive Saturn IB (S-IVB 210) backup stage

a. Scar modifications to the basic propulsive S-IVB stage to permit kit installation of Workshop life support equipment after the propellants are evacuated, including pre-installed open grid walls and floor, quick-opening hatch, thermal curtains, fire retardative liner, micrometeoroid bumper and passivation capability.

b. Hardware in the form of kits that could be installed in the spent propulsive stage after passivation,

c. One one-g trainer for use by the crew;

d Thirty-one (31) items of zero-g and neutral buoyancy test, plus one complete set of neutral buoyancy trainer hardware,

e. Habitability Support System to be provided as GFE by NASA/MSC,

f. 123 qualification and development tests;

g. Production acceptance testing of a "scarred" S-IVB to be the same as Saturn,

h. Launch support operations to be covered by Saturn/Apollo,

i. The hot gas Attitude Control System and Solar Array System was to be provided as GFE by MSFC,

j. Twenty-seven (27) new models of GSE and thirty-five (35) modified models,

k. Program completion scheduled for January 1972,

l. Launch date scheduled for August 1971.

The $121.7M in POP 69-1C, first quarter CY 1969, is funding for a "wet" Workshop program. The major program differences from the previous POP 68-2C are

1. Flight configured manufacturing development fixture,

2. One one-g trainer utilizing the flight configured manufacturing development fixture from MDAC-WD,

3. Active Environmental Control System,

4. Habitability Support System to be provided by the MSFC contractor,

5. Production acceptance testing of the scarred stage, plus compatibility testing of hardware kits,

6. Launch support and mission operations to be funded by the Orbital Workshop Project;

7. Four (4) additional new models of GSE, four (4) fewer modified S-IVB models of GSE,

8. Eighteen (18) new development and qualification tests on the Habitability Support System. Other development and qualification tests were reduced from 123 to 63,

9. Program completion extended six months, from January to July 1972, to provide full coverage of launch operations with the later launch date of August 1971,

10. Food freezers were added

The $199.3M in POP 69-2C, third quarter CY 1969, is funding for a "dry" Workshop program. The major program differences from the previous POP 69-1C are·

1. One "dry" Saturn V (S-IVB 513) flight stage in lieu of a Saturn IB stage,

2. One "dry" Saturn V (S-IVB 515) backup stage in lieu of a Saturn IB stage

a Hardware to be completely installed during manufacturing since the stage would be a living/working environment and be launched "dry." Beefed-up crew quarters floor. A tank access door was added,

b. One Dynamic Test Article using the basic S-IVB facilities stage;

c. One set of zero-g and neutral buoyancy hardware,

d. One engineering mockup with later conversion to a one-g trainer;

e. Accommodations for twenty-two (22) GFE experiments, including responsibility for Interface Control Documents. Two scientific Airlocks were added,

f. Habitability Support System for food, water, waste and personal hygiene management, including a closed loop refrigerator system. Added Z-local vertical orbit capability.

g. Cold gas Attitude Control System (TACS);

h. Solar Array System to be furnished by MSFC contractor;

i. Consolidated GSE into fewer models but with more systems capability. Number of new models reduced from 31 to 21, and number of modified models changed from 31 to 7,

j. Environmental Control System, Caution and Warning, plus all electrical lighting and provisions for a 28-day and two 56-day orbital missions,

k. Extended program completion seven months, from July 1972 to February 1973, due to change in the launch date,

l. Slipped KSC delivery four months, from March to July 1971, due to change in the launch date,

m. Slipped launch date seven months, from August 1971 to March 1972, due to FY 70 budget restrictions, plus the use of the larger, more complex "dry" Workshop,

n. Total update of the development and qualification testing requirements to be compatible with the Saturn V stage, loads, vibration and new environments in the "dry" Workshop. The number of development and qualification tests was changed from 63 to 82;

o. Production acceptance testing peculiar only to the Workshop.

The $225.3M in POP 69-2, fourth quarter CY 1969, is funding for a "dry" Workshop program. The major program differences from the previous POP 69-2C are.

1. Reorientation of floor and ceiling;

2. Addition of a viewing window in the wardroom,

3. Crew compartment rearrangement,

4. Additional general illumination lighting,

5. Crew system evaluation lab at MDAC-WD,

6. Addition of a trash disposal Airlock,

7. Additional sleep accommodations caused by the deletion of a DOD experiment.

APPENDIX II

The $239.4M in POP 70-1C, first quarter CY 1970, is funding for a "dry" Workshop program The major program differences from the previous POP 69-2 are·

1. Four months slip in launch date, from March to July 1972, due to a total budget reduction,

2. Changed the flight inclination trajectory from 35° to 50°,

3. Noise suppressors for fans,

4. Habitability Support System (HSS) refrigeration subsystem repackaging for system safety improvement in use of coolanol,

5. Added film vaults;

6. Orbital Workshop proof pressure testing,

7. Added Experiment S183,

8. High Fidelity Mockup

The $286.8M in POP 70-2C, third quarter CY 1970, is funding for a "dry" Workshop program. The major program differences from the previous POP 70-1C are

1. Four months adjustment in KSC delivery date, from July to November 1971, for better compatibility with the KSC need and July 1972 launch date, plus an anticipated three months additional delay in delivery.

2. Major changes in Habitability Support System (HSS) (food, water, waste, sleep, off-duty equipment).

3. Numerous GSE changes for compatibility with the flight hardware changes,

4. Redesign of the Thruster Attitude Control System,

5. Additional measurements for in-flight monitoring,

6. Orbital Workshop film vault changes,

7. Caution and Warning System changes,

8. Experiment accommodation changes,

9. Optical viewing window,

10. Additional subsystem assessment and testing for flight environments with increased criteria,

11. Increased Z-local vertical orbit capability,

12. Added Experiment S063,

13. Fidelity improvement of engineering mockup,

14. Increased stowage capability.

The $287.2M in POP 70-2, fourth quarter CY 1970, is funding for a "dry" Workshop program The major program differences from the previous POP 70-2C are·

1. Deleted the cost for a potential three month delay in delivery to KSC reported in POP 70-2C,

2. Added Critical Design Review (CDR) and Crew Station Review (CSR) Review Item Discrepancies (RID's);

3. Four months slip in launch date, from July to November 1972, due to changes in Apollo launch scheduling. SL-1 to be launched five months after Apollo 17,

4. Extended program completion date from February 1973 to November 1973 to provide coverage of later launch operations caused by a change in launch dates.

SATURN WORKSHOP PROGRAM

	POP 68-2C $104.5M	POP 69-1C $121.7M	POP 69-2C $199.3M	POP 69-2 $225.3M	POP 70-1C $239.4M	POP 70-2C $286.8M	POP 70-2 $287.2M
Program Completion Date	Jan. 1972	July 1972	Feb. 1973	Feb. 1973	Feb. 1973	Feb. 1973	Nov 1973
KSC Delivery OWS-1	Mar. 1971	Mar. 1971	July 1971	July 1971	July 1971	Nov. 1971	Nov. 1971
KSC Delivery OWS Backup	AUG. 1971	Aug. 1971	Jan. 1972	Jan. 1972	Jan. 1972	Apr. 1972	Apr. 1972
Launch Date (OWS-1)	Aug. 1971	Aug. 1971	No sys tst Mar. 1972	No sys tst Mar. 1972	No sys tst Jul. 1972	No sys tst Jul. 1972	No sys tst Nov. 1972
OWS-1 (Launch Vehicle)	SAT. IB (212)	SAT. IB (212)	SAT. V (513)	SAT. V (513)	SAT. V (513)	SAT. V (513)	SAT. V (513)
OWS Backup (Launch Vehicle)	SAT. IB (210)	SAT. IB (210)	SAT. V (515)	SAT. V (515)	SAT. V (515)	SAT. V (515)	SAT V (515)
Habitability Support System	GFE (MSC)	CFE	CFE	CFE	CFE	CFE	CFE
Solar Array System	GFE (MSFC)	GFE	CFE	CFE	CFE	CFE	CFE
Attitude Control System	GFE (MSFC)	GFE	CFE	CFE	CFE	CFE	CFE
One-G Trainer	yes	Use D.F.	Convert EMU	Convert EMU	Convert EMU	Convert EMU	Convert EMU
Development Fixture (D.F.)	No	yes	yes	yes	yes	yes	yes
Engineering Mockup (EMU)	yes	yes	yes	yes	yes	yes	yes
O-G & Neutral Bouyancy Hardware	limited	limited	yes	yes	yes	yes	yes
High Fidelity Mockup	NO	NO	NO	NO	yes	yes	yes
Crew System Evaluation Laboratory	NO	NO	NO	yes	yes	yes	yes
Dynamic Test Article	NO	NO	yes	yes	yes	yes	yes

COMMENTS ON GAO COST GROWTH FACT SHEET
ATM EXPERIMENT S-054
AMERICAN SCIENCE AND ENGINEERING
CONTRACT NAS5-9041

In context with the general Skylab Program preamble, the S-054 experiment with American Science and Engineering went through a formative phase during the period from late 1966 to late 1968. The design concept of the experiment was finalized during the period from completion of the Preliminary Design Review in December 1967 until completion of the Critical Design Review in June 1968, at which time POP 68-2 was prepared. The resulting hardware definition was essentially the same as existed on November 1970.

The total cost as registered in POP 68-2 was $14.4 M. In POP 70-2 we registered a total cost of $20.2 M, for a cost growth of $5.8 M. This cost growth from POP 68-2 through POP 70-2 is explained as follows:

Overrun (technical problems *	$3.4 M
Additional scope **	.8 M
Nine month launch slip	1.0 M
Wet to dry conversion resulting in increased mission support	$ .6 M

* Hycon camera problem
Late delivery of Fairchild integrated circuits
Power supply problems
Difficulties in manufacturing which necessitated alternate sources
Quality failure in main electronic assembly

** .3 C&D components
.2 Rocket shot
.1 Main electronic assembly problem
.1 Filter
.1 Camera

COMMENTS ON GAO COST GROWTH FACT SHEET
ATM EXPERIMENT S-055
HARVARD COLLEGE
CONTRACT NAS5-3949

In context with the general Skylab Program preamble, the S-055 experiment with Harvard College went through a formative phase during the period from late 1966 to late 1968. The design concept of the experiment was finalized during this period. The resulting hardware definition was initially the same as existed in November 1970.

The total cost registered in POP 68-2 was $14.7 M. In POP 70-2 we registered a total cost of $22 M, for a cost growth of $7.3 M. This cost growth from POP 68-2 through POP 70-2 is explained as follows:

Under estimate of phase two in November 1968	$1.6 M
Overrun (technical problems) *	1.9 M
Added scope **	1.4 M
Increase in field support - 9 month extension in duration	1.6 M
Wet to dry configuration with increased mission duration	.8 M

*Detecter unit problems - Bendix qualification of primary mirror assembly

**Power supplies and pressure relief valve	.3
Mirror launch lock	.2
Alternate launch lock	.4
Additional UV testing	.2
Pressure gauge	.3
	1.4

GENERAL COMMENTS ON GAO COST ESTIMATING FACT SHEETS

Throughout the fact sheets dealing with cost estimating, there are repeated references to the lack of available documentation to support change estimates. We feel that an amplification of the change projection process is in order to provide proper perspective to the references.

In preparation of a POP, the projects are asked to state their requirements in order of their maturity of definition. Naturally, therefore, the contract value is stated first. Next come the changes which have been authorized but not definitized. Normally, these changes will have complete detailed documentation of costs in the form of firm proposals within sixty days of authorization. Prior to that time, documentation may consist of ECP estimates, contractor ROM's, or MSFC ROM's. As cited in the fact sheets, a small portion (2+% cited in the Airlock fact sheet) of these changes do not have written documentation describing the breakdown of the cost estimate. In a development program of this magnitude, and with the interface complexity, there are necessarily some instances when changes must be authorized on relatively short notice in order to minimize program impact. In these instances, an estimate obtained by means of meetings or telephone conversations among the principals affected may satisfy the immediate requirement.

The next category of requirements, known and probable changes, consists of potential requirements that have been defined to some degree of detail but which have not been authorized. A considerably larger percentage of the changes cited in the fact sheet as not having supporting documentation of cost estimate detail are in this category. It should be noted, however, that there is usually a large amount of documentation describing the technical aspects of the problem or requirement. This information provides the basis for project ROM cost estimates of the change, and conversation or meetings with the contractor provide contractor ROM's.

The definitions of these known and probable changes mature as they proceed through the ECP cycle, preparation, evaluation, decision. There is a concurrent maturation of the cost estimate from ROM to ECP estimate to firm proposal. Detailed documentation of cost estimate at beginning of cycle is not warranted because the definition process results in changes. As was pointed out in the Airlock Cost Estimating Fact Sheets, later estimates may be 50% or more different from the original ROM's, although the sum of these estimates agrees within 4% of the ROM's.

The last category, anticipated changes, covers potential problem areas, many of which have been identified, but whose extent has not been defined. The estimates made for these changes, from the wide range of possible costs, are based on the Project Manager's knowledge and prior experience with similar changes. The contingency reserve added in the Program Manager's review is a further range of anticipated change based on Program Manager's knowledge and experience in overall program aspects, and may include allowance for out-of-plan assessment and Headquarters directed contingency reserve.

It should be apparent from the foregoing description that the amount of detail for cost estimates should be proportional to the maturity of the change definition, and that record documentation of cost estimates, other than the POP record, is warranted generally only when the change reaches the ECP stage of definition. Therefore, the percentages of available documentation cited in the fact sheets are considered reasonable when examined in the proper context.

In the General Observation Fact Sheet, there is an erroneous indication that conflicting statements were made about inclusion of provisions for inflation in cost estimates. To set the record straight, provision for inflation is made in the cost estimates, but is not separately identified as a percentage factor. The labor rates used in making government cost estimates are comparable to rates negotiated with the contractor. Those negotiated rates are mid-point rates, which allow for cost of living increases, projected overhead changes, and other factors usually referred to as inflation. Higher rates are used for estimates for changes beyond the current contract life.

We have further comments on details such as arithmetic errors which we will be happy to discuss in a meeting with you.

PRINCIPAL OFFICIALS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION RESPONSIBLE FOR THE ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
ADMINISTRATOR:		
James C. Fletcher	Apr. 1971	Present
George M. Low (acting)	Sept. 1970	Apr. 1971
Thomas O. Paine	Oct. 1968	Sept. 1970
James E. Webb	Feb. 1961	Oct. 1968
DEPUTY ADMINISTRATOR:		
George M. Low	Dec. 1969	Present
Thomas O. Paine	Mar. 1968	Oct. 1968
Robert C. Seamans, Jr.	Dec. 1965	Jan. 1968
Hugh L. Dryden	Oct. 1958	Dec. 1965
ASSOCIATE ADMINISTRATOR:		
Homer E. Newell	Oct. 1967	Present
Robert C. Seamans, Jr.	Sept. 1960	Sept. 1967
ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT:		
Dale D. Myers	Jan. 1970	Present
Charles W. Mathews (acting)	Dec. 1969	Jan. 1970
George E. Mueller	Sept. 1963	Dec. 1969
D. Brainerd Holmes	Nov. 1961	Sept. 1963
DIRECTOR, KENNEDY SPACE CENTER:		
Kurt H. Debus	July 1962	Present
DIRECTOR, MANNED SPACECRAFT CENTER:		
Robert R. Gilruth	Nov. 1961	Present

	Tenure of office	
	From	To
DIRECTOR, MARSHALL SPACE FLIGHT CENTER:		
Eberhard F. M. Rees	Mar. 1970	Present
Wernher von Braun	July 1960	Mar. 1970
DIRECTOR, SKYLAB PROGRAM:		
William C. Schneider	Jan. 1969	Present
John H. Disher (acting)	Nov. 1968	Jan. 1969
Harold T. Luskin	May 1968	Nov. 1968
Charles W. Mathews	Jan. 1967	Apr. 1968
Major General David M. Jones, USAF (acting)	Aug. 1965	Jan. 1967

U S GAO Wash , D C