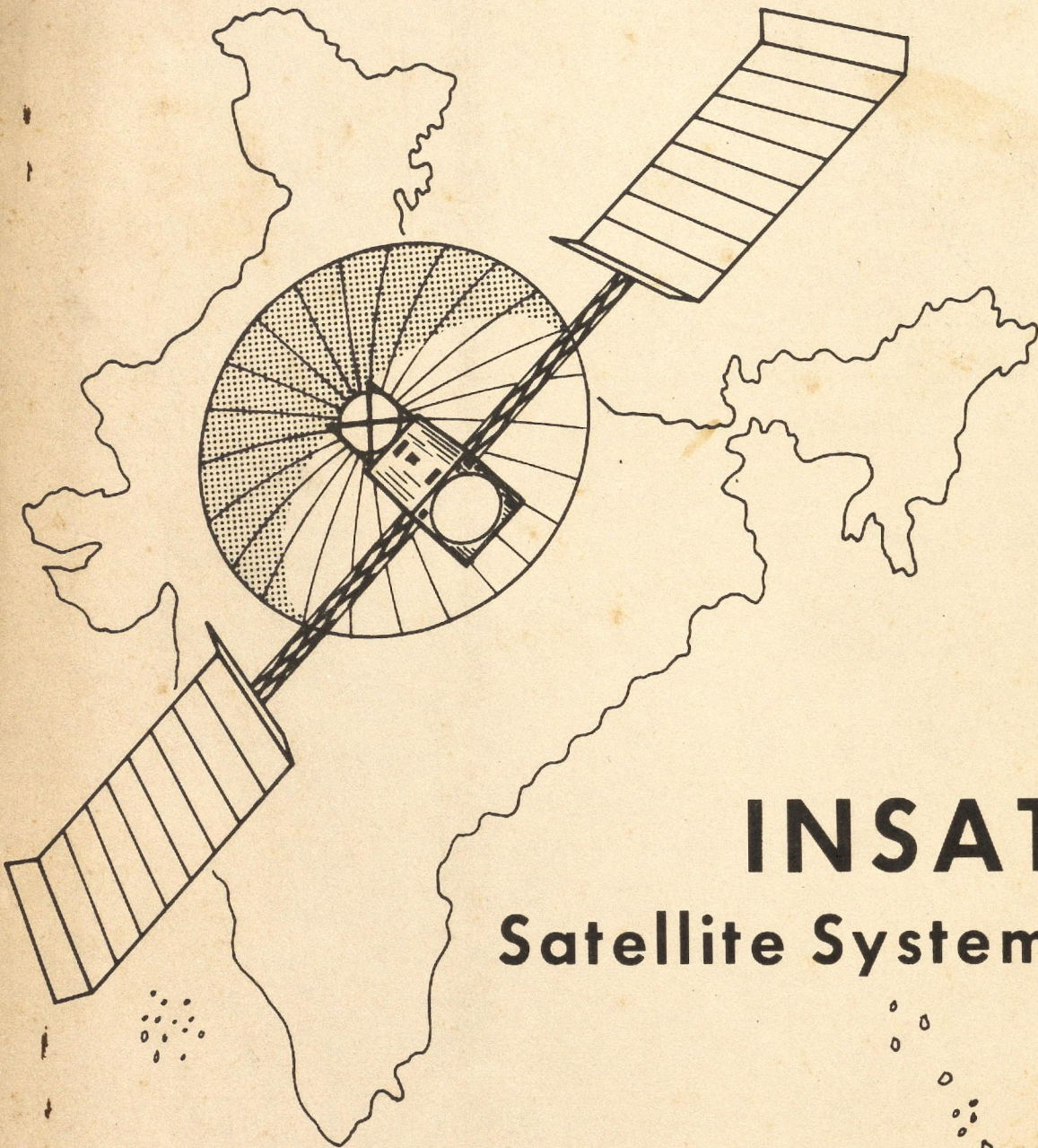


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INSAT

Satellite Systems Study

VOLUME III

INSAT Program Cost Analysis

INSAT
Satellite Systems Study

Indian Space Research Organization

MIT
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Massachusetts Institute of Technology

7 December 1970

VOLUME III
INSAT PROGRAM COST ANALYSIS

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VOLUME III
INSAT STUDY COST ANALYSIS

1.1 COSTING CONSIDERATIONS (no facilities considered)

Cost analyses presented in this volume represent a first-order estimate to construct INSAT I, II and launch them into synchronous equatorial orbits. Areas considered in this costing:

- a. Prime contract
- b. Preliminary development, analysis and breadboard (PDAB) contract
- c. Contract Management Office (CMO)
- d. First-choice launch vehicle.

These estimates are summarized to indicate total cost for in-orbit realizations for two satellites. Estimated Indian Satellite Development facilities costs are covered in Vol. II.

The panel makes no pretense that the data in these cost analyses are 100 percent correct. Neither the MIT nor the ISRO panel members had much prior experience in industrial costing. Panel estimate of the prime contract cost is based on discussions with personnel from three sources:

- a. Segments of the U. S. aerospace industry regarding specific subsystem costs
- b. NASA ATS Project Office that has had considerable experience in managing and costing large satellite contracts
- c. Industrial recommendations for in-house administration of satellite contracts.

Although individuals may take issue with specific costs represented in the prime contract analysis, the panel believes the overall estimate should be within 10 percent of the actual cost.

The PDAB contract was not broken down into specific sections, but is based on a percentage analysis.

The CMO estimate, based on estimated manpower requirements only, includes no hardware costs.

Launch vehicle costs are fairly well known.

All estimates have been made in terms of 1970 dollars and do not account for inflation. All costs are based on U. S. sources and do not take into account cost differentials that might result from non-U. S. procurements. No additional costs have been included that might arise from Indian personnel participation in this program.

2.1 PRIME CONTRACT COST ANALYSIS

Prime contract costs (Fig. 2.1-1) are based primarily on personnel estimates for: program management and systems engineering administration, hardware for engineering studies, prototype satellite construction, in-flight satellite construction, reliability and quality assurance, ground support equipment, and refurbishing the prototype to flight quality level. All manpower cost estimates were arrived at by considering representative salaries for required individuals for the period their services are needed, and increasing this by 120 percent overhead and 15 percent G&A costs. Hardware costs were derived from discussions with personnel in industry, and estimated costs for the ATS-F/G program which has a number of similarities to the INSAT program.

Specific aspects of the prime contract breakdown (Fig. 2.1-1) are estimated as follows:

2.1.1 Program Management Office

Personnel within the prime contracting organization that oversees the total in-house management of the satellite program. Assumedly this office will be active for the estimated 27 months of INSAT I construction and launch, as well as six months after launch.

a. Program Managers

Program manager at salary of \$30,000 annually, and two assistant program managers at \$25,000 annually have prime responsibility for overall in-house management of the program.

b. Documentation

Writing and art work, including overhead and G&A costs, will each require approximately \$200,000 annually.

c. Fiscal Control

Three people at approximately \$13,000 each annually to keep track of fiscal control. Additional personnel can be included in overhead costs.

d. Schedule Control

Three people at approximately \$13,000 annually for schedule control. Additional personnel can be included in overhead costs.

e. Subcontract Management

Subcontract managers require an engineering background. Phasing out six months prior to launch, an average of six men are required over a 25-month period at an average salary of \$17,000 annually.

f. Operation and Maintenance Manual Generation

Manual describing satellite operation, its ground interactions, and maintenance in orbit should be produced as part of the program. Editorial coordinator to gather information from technical personnel and assemble in functional format costs \$12,000 annually; more depending on the coordinator's writing and technical backgrounds.

g. Configuration Management

Three people at \$18,000 annually to coordinate overall mechanical and electrical satellite configuration require substantial technical background and are required in the program up to launch time.

h. Project Engineers

Three senior engineers at \$21,000 annually to troubleshoot the entire project require a broad technical background and must be capable of solving a wide range of problems. Required until launch time.

2.1.2 Systems Engineering Office

Systems engineering office, remaining in operation for 33 months, oversees the program's systems engineering: directs subsystem development, conducts systems tests and system integration, and sees that necessary systems analyses are carried out. Other functions in this office assumedly will require approximately three man-years each.

Amplifying on the systems engineering tasks a little, they consist of:

- a. Integration
- b. Identification of interfaces
- c. Accessibility
- d. Assembly schedules
- e. Prelaunch testing
- f. In-orbit testing
- g. Reliability and quality assurance
- h. Failure mode operations
- i. Configuration management
- j. Interface with NASA tracking networks
- k. Communications support analysis

Carrying out the managerial functions of the foregoing tasks, are:

a. Systems Engineering Managers

Four senior-level engineering managers. Serving under a systems engineering manager at \$30,000 annually are three assistant managers at \$25,000

each annually, who, individually, oversee RF systems, spacecraft vehicular systems, and mechanical design.

b. System Integration

Coordination of subsystem integration to take three man-years at \$21,000 annually.

c. Systems Tests

Coordination of all-up satellite systems tests to take three man-years at \$21,000 annually.

d. Systems Analysis

Conducting necessary design analyses for various satellite systems to take three man-years at \$21,000 annually.

e. Systems Coordination

All other aspects of systems coordination performed by the systems engineering office to take three man-years at \$21,000 annually.

2.1.3 Engineering Components

Covers all aspects of breadboarding and preliminary analysis and design not covered in the PDAB contract, including preliminary component testing and building of a thermal structural model. Breakouts under design and fabrication are based on industry estimates or Lincoln Laboratory experience. The four design and fabrication breakouts over \$200,000 each, although considered low risk development areas, require substantial preliminary design and development.

2.1.4 INSAT A (prototype)

Prototype satellite construction represents the largest single subdivision expense in the prime contract. Costs include initial building of prototype systems and higher costs for first-time integration of subsystems. Design and fabrication estimates are based on NASA, Lincoln and industry experience.

Costs of subsystem testing, integration of systems, and systems tests have been extrapolated from information supplied by the NASA ATS Project Office.

2.1.5 INSAT I (flight model)

Second largest expense in the prime contract reflects reduced cost of building subsystems and of integrating and testing these combined systems a second time. Cost estimation sources are the same as those for Sect. 2.1.4.

2.1.6 Ground Support Equipment/Bench Test Equipment

Equipments in this section are necessary for satellite development and testing of satellite subsystems and the final assembled satellite, and includes all specialized satellite handling equipment. After the program is completed, all equipment purchased under the contract is to be shipped to India unless indicated otherwise by Indian representatives. The mechanical breakout is a rough estimate; the electrical breakout is more specific:

a. Transponder Simulator

Checks all interfaces with ground transmitters and receivers. (Actually, engineering model of the transponder.)

b. Telemetry Command Simulator

Checks satellite interfacing with the command RF transmitter and telemetry ground receiver.

c. Ground Command Station

Exercises all command functions on the satellite to simulate adequately that of the planned Indian ground station. (Although not necessarily the exact configuration of the Indian ground command facility, a basic piece of equipment built by the satellite manufacturer for subsystem and all-up satellite tests. Indispensable to a proper satellite test.)

d. Telemetry Ground Station

Handles all data required for all-up satellite systems checkout: tape

recording facilities, interaction with prime contractor's general-purpose computer, moderately sophisticated readout techniques, etc. (During many of the all-up satellite tests, the telemetry ground station will be the major, and in some cases, the only information source on electrical occurrences within the satellite's subsystems. While the Indian telemetry ground station will have a minicomputer dedicated to the telemetry ground station operation, such a computer need not be part of the telemetry ground station used by the prime contractor.)

e. Bench Test Equipment

Subsystems tested by special bench test equipment that must be purchased, and a number of small test systems that must be built.

2.1.7 Reliability and Quality Assurance

These somewhat arbitrary estimates were assumed to be 14 percent of the cost of major hardware contained in sections 300, 400 and 500 (Fig. 2.1-1).

2.1.8 Launch and Support of INSAT I

A nominal cost item that includes: (a) liaison with the launch vehicle manufacturer, (b) support at the US ETR, (c) use of NASA/STADAN facilities during launch, and (d) some data reduction and analysis to be done by the manufacturer. This latter item is substantially larger in many program estimates, but assumedly, the major data reduction and analysis will be carried out by Indians in India, and as such, was not charged against the prime contract costs.

2.1.9 Spares

Few spares have been assumed. All INSAT I logic systems and RF electronic systems are backed by those for prototype INSAT A. Items in section 900 (Fig. 2.1-1) are easily backed up separately or are not conveniently available from the prototype spacecraft.

2.1.10 Program Management for INSAT II

Program management for refurbishment of INSAT A as INSAT II is basically a continuation of INSAT I program management with appropriate reductions. All base salaries are the same as in section 100. Certain program management areas do not apply to refurbishment and have been deleted.

2.1.11 Systems Engineering Office for INSAT II

The systems engineering office should continue at the INSAT I level except for systems analyses, which should have been carried out for INSAT I.

2.1.12 INSAT II (INSAT A refurbishment)

Refurbishment of INSAT A as INSAT II can be carried out at relatively nominal cost. Only two major expenses appear under design and fabrication:

- a. The prototype solar array is only a portion of an array and not of flight capability so a full-sized solar array must be supplied for INSAT II.
- b. The 27-ft UHF reflector used for the prototype will probably have been deployed enough times so that it cannot be considered spaceworthy and will have to be replaced by a new antenna.

Other less expensive items include:

- a. New flight-quality solar array deployment booms
- b. Reworked solar array drive system, if necessary
- c. Disassembly, checking and reassembly of the gas propulsion system.

All other items necessary for checkout purposes represent basically minimum costs. Subsystem testing and systems integration, having been basically carried out on the prototype, are included as a minimum expense item. All-up systems testing that must be carried out still represents a major expense.

2.1.13 Launch and Support of INSAT II

Duplicates section 800 (Fig. 2.1-1).

2.1.14 Prime Contractor's Fee

A prime contractor's fee of 8 percent has been assumed, which is slightly higher than that currently existing in the U. S., but this figure could exist in the U. S. at the time the final prime contract is negotiated. The panel does not believe any manufacturer will bid a contract of this magnitude at fixed price on a 27-month schedule, and thus have assumed the cost-plus-fixed-fee basis to determine the cost estimates. An incentive fee system should be considered, where the manufacturer receives an initial fee – on the order of 4 percent – at the time of launch, and receives additional payments of fee for some period as long as the in-orbit satellite functions properly. Under an incentive fee contract, the total fee could exceed 8 percent.

2.1.15 Total Satellite Construction Cost

The sum of items 100 through 900 on the prime contractor analysis chart, plus an 8 percent fee, represents the cost of building INSAT I – \$34,587,000. To refurbish INSAT A for a second launch as INSAT II in 1977 represents \$4,660,000, which is only 12 percent over the cost required to deliver INSAT I to the launch pad. Obviously, this 12 percent increment is not a true representation of the cost for INSAT II when launch costs are taken into account.

3.1 PRELIMINARY DEVELOPMENT, ANALYSIS AND BREADBOARD (PDAB) CONTRACT ESTIMATE

Assuming two contractors are involved in this portion of the INSAT program, the estimate for this contract cost has been derived by the four-phase procurement technique that is used as a program basis to develop some satellites in the U. S. Tasks involved in a four-phase procurement procedure are listed in Table 3.1-1. The percentage cost is indicated in units that total 100 units or 100 percent. (Percentage or unit breakdowns are based on discussions with NASA and a number of U. S. industrial concerns.)

TABLE 3.1-1 FOUR-PHASE PROCUREMENT			
Phase	Task	Units/Contractor	Total
A	Feasibility study	1	1
B	Systems analyses	2	4
C	Preliminary breadboards, configuration design	13	26
D	Flight satellite construction	69	<u>69</u>
		Total Units	100

TABLE 3.1-2 THREE-PHASE PROCUREMENT			
Phase	Task	Units/Contractor	Total
A	Feasibility study	1	1
B/C1	Preliminary systems analyses, some breadboarding, long lead item breakout, configuration	9	18
C2/D	Remaining analyses and breadboarding, flight satellite configuration	75	<u>75</u>
		Total Units	94

However, as INSAT program timing does not allow four-phase procurement, a three-phase procurement was derived (Table 3.1-2) from the numbers in Table 3.1-1. Phase A, the feasibility study, corresponds to the ISRO-MIT study in the four-phase procurement. Phase C of the four-phase procurement has been split into two parts; a B/C1 phase that contains some systems analysis, breadboarding, breakout of long lead items, and configuration design. The remaining part of Phase C is included in the final contract. The units breakdown in Table 3.1-1 provides the numbers in the three-phase procurement. The total units do not add to 100 because there is no contractor duplication of the C2 part in this procurement procedure.

Using the three-phase procurement, and considering that the delivery to launch and ensuing data reduction of INSAT I represents the 75 units in the Phase C2/D part, the individual contractor cost for the B/C1 phase is 12 percent of the INSAT I cost, or about \$4,150,000 per contractor.

4.1 CONTRACT MANAGEMENT OFFICE ESTIMATES

Contract management office cost estimates are based on the manpower estimates for this office (Vol. II, Fig. 6.1-1) shown here, for convenience, as Fig. 4.1-1. These estimates represent only the American portion, and do not include costs for Indian personnel in the U. S. Participating U. S. personnel in the CMO must have a fairly broad and experienced technical background to cope with the required functions. Although salaries will vary, an average salary of \$18,000 annually and a combined overhead and G&A cost of 60 percent were assumed. The low level of overhead and G&A reflects the lack of capital investment for hardware required. On these assumptions the cost of operating the CMO through the end of 1977 comes to \$2,535,000. If the cost through May 1975 applies to INSAT I, this comes to \$1,760,000; the remaining amount of \$775,000 pertains to INSAT II.

5.1 FIRST-CHOICE LAUNCH VEHICLE COSTS

Although a number of launch vehicles are discussed in Vol. II, Sect. 5, the panel recommended vehicle (Atlas-Centaur-Burner II) is the most probable costing guide. Integration costs between Burner II and Centaur are estimated

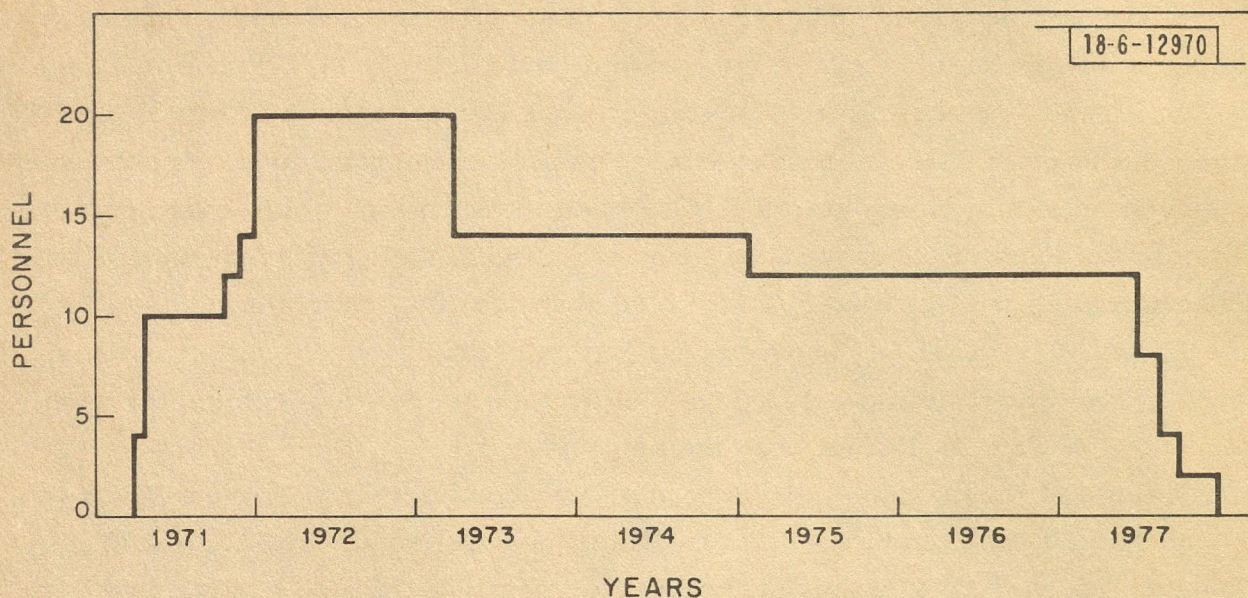


Fig. 4.1-1. American personnel requirements in CMO.

on the order of \$3,000,000. Some or all of this cost could be absorbed in a program requiring a prior Atlas-Centaur-Burner II launch. Additional nonrecurring costs for INSAT are estimated at \$1,150,000. Recurring costs for launch are \$14,850,000, General Dynamics Corporation's best estimate based on anticipated frequency of Atlas-Centaur launches which, naturally, is subject to change should this expectation vary.

6.1 TOTAL PROGRAM COSTS

Apparent in the estimated total program costs for INSAT I and II (Table 6.1-1) are:

- a. Added cost to place INSAT II in orbit is slightly less than one third that for INSAT I.
- b. Launch costs dominate INSAT II costs.

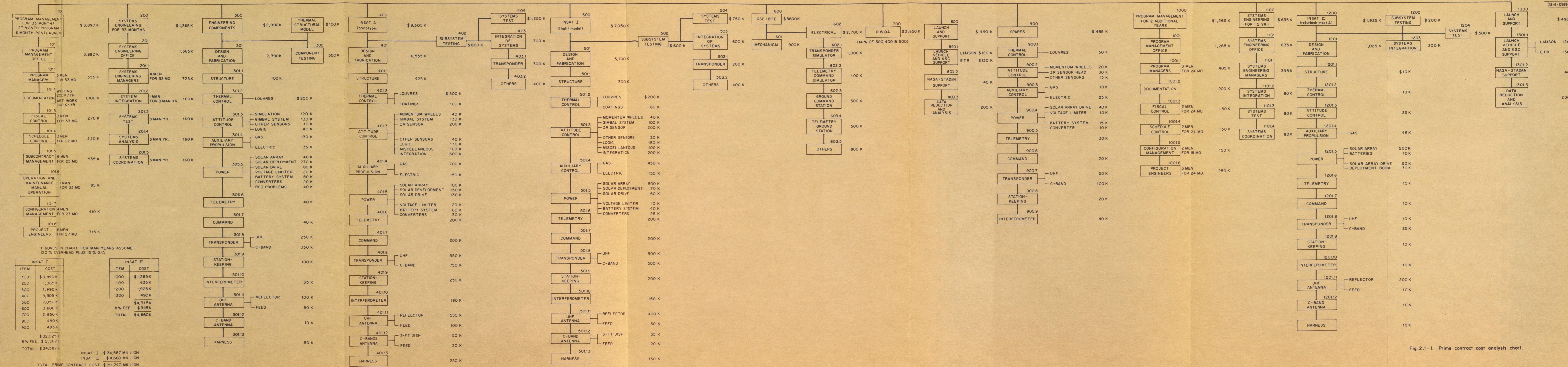
If lower cost launch vehicles are not available to launch INSAT I, they may be available for INSAT II. If so, the increased cost to test INSAT II for a different launch vehicle might be minor compared to lower launch vehicle costs. An obvious candidate, an Atlas-Delta-Burner II combination, even

with a nonrecurring Burner II integration cost, might result in an overall saving.

As launch vehicle costs have a significant impact on this program, a firm launch vehicle decision must be made by fall of 1972. This provides two years in which to observe and evaluate any developments occurring in launch vehicle capability that could cause a departure from the panel's recommendation for an Atlas-Centaur-Burner II.

TABLE 6.1-1
TOTAL PROGRAM COSTS

Major Program Cost Categories	INSAT I (\$M)	INSAT II (\$M)
Contract Management Office	1.76	0.775
PDAB	8.30	—
Prime Contract	34.59	4.660
Burner II integration	3.00	—
Launch vehicle nonrecurring	1.15	—
Launch vehicle recurring	<u>14.85</u>	<u>14.850</u>
Total Cost	63.65	20.285



FIGURES IN CHART FOR MAN YEARS ASSUME
120% OVERHEAD PLUS 15% G/A

INSAT I		INSAT II	
ITEM	COST	ITEM	COST
100	\$3,890 K	1000	\$1,265 K
200	1,365 K	1100	635 K
300	2,990 K	1200	1,925 K
400	9,305 K	1300	490 K
500	7,050 K		\$4,315 K
600	3,600 K		8% FEE \$345 K
700	2,850 K		TOTAL \$4,660 K
800	490 K		
900	485 K		
	\$32,025 K		
	8% FEE \$2,562 K		
	TOTAL \$34,587 K		

INSAT I \$34,587 MILLION
INSAT II \$4,660 MILLION
TOTAL PRIME CONTRACT COST \$39,247 MILLION
NOTE: INTERFEROMETER COSTING ASSUMES PRIOR DEVELOPMENT ON ATS-F PROGRAM

Fig. 2.1-1. Prime contract cost analysis chart.

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