Shared Experiences from NASA Programs and Projects: 1975

by Frank Hoban

This paper summarizes the lessons learned from two workshops held at the National Academy of Sciences in 1975. The workshops were sponsored by NASA in conjunction with the National Academy of Engineering. Vince Johnson, former deputy administrator of the Office of Space Science and Applications, chaired the sessions. The National Academy of Engineering was represented by retired NASA executives Robert Gilruth and Abe Silverstein, retired USAF General King, and Sid Metsger of COMSAT.

The first workshop was held on February 24 and 25, 1975. The second workshop was held on June 3-4, 1975. Again, the National Academy of Sciences hosted the session. In order to provide more time for discussion, the number of projects to be covered was reduced from nine to six.

Orbiting Solar Observatory
Goddard Space Flight Center
Robert Pickard, Manager

The first project discussed was the Orbiting Solar Observatory-I (OSO-I). The OSO Project, dating back to 1959, consisted of a series of seven satellites prior to OSO-I. Ball Brothers had built all previous spacecraft; however, due to major changes, the I, J, and K spacecraft were competed, with the Hughes Aircraft Company the winner.

The primary objective of the OSO-I mission was to investigate the lower corona of the sun, the chromosphere, and the interface in the ultraviolet spectral region, to better understand the transport of energy from the photosphere into the corona. The secondary objective was to study solar X-rays and Earth-Sun relationships and the background component of cosmic X-rays. OSO-I consisted of one mission, using a 2,340-pound spacecraft with a corresponding payload of 827 pounds, carrying eight experiments. Orbital altitude was to be 320 miles circular at 33° inclination. Delta was the launch vehicle.

Prior to OSO-7, the costs of all previous spacecraft in the series were well below the $20 million level. OSO-7, the most expensive spacecraft of the series cost approximately $33 million; however, OSO-I costs were estimated at $58 million because of the complexity of the spacecraft and greater pointing accuracies. Spacecraft weights ranged from approximately 600 pounds for OSO 1-6 to 1098 pounds for OSO-7 and 2,340 pounds for OSO-I.

The project manager identified the following cost drivers:

- Control system complexity and precision.
- Stored command processor.
- Development of special integrated circuits.
- Inability of Government to maintain funding when needed.
- Experimenters building their hardware.

Elements of cost control exercised by the project were:

- Freezing the design.
- Descoping.
- Establishing cost ceilings on experiments and spacecraft.
- Use of financial management reporting on major contracts.

- Weekly manpower tracking at spacecraft-contractor.
- Frequent reviews with the contractor.

Recommendations:

(1) Use standard components and subsystems.

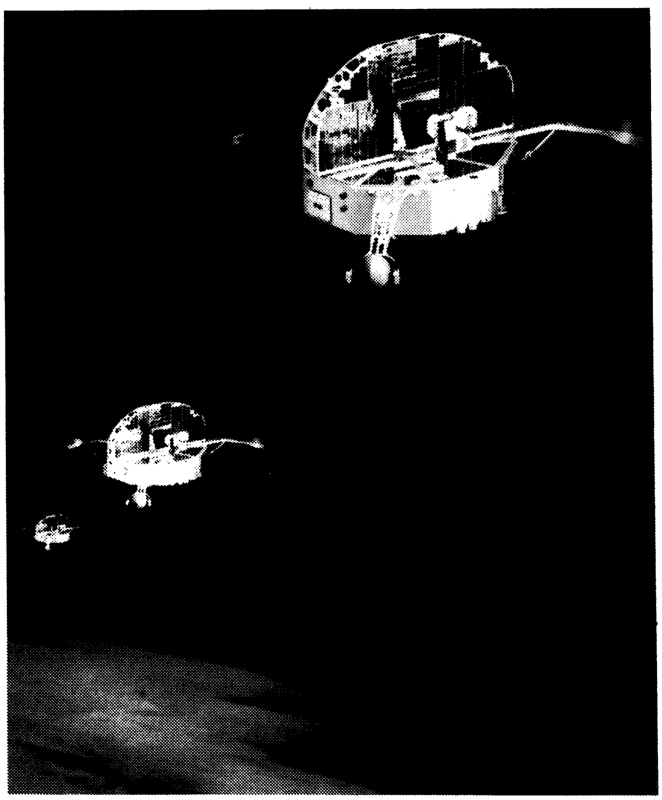
(2) Build experimenters' hardware to their specifications.

(3) Establish adequate funding contingencies.

(4) Freeze designs early and do not over-design.

(5) Make subsystem engineers fully responsible for cost, schedule, and performance.

(6) Believe the cost model, not the proposal.



Orbiting Solar Observatories advanced our understanding of the Sun's structure and behavior, thus indicating the physical processes by which the Sun influences the Earth. This early NASA project was directed by the Physics and Astronomy program division.

Small Astronomy Satellite Project
Goddard Space Flight Center
Marjorie Townsend, Manager

The Small Astronomy Satellite (SAS) project consisted of three spacecraft: SAS-1, launched December 1970; SAS-2, launched November 1972; and SAS-3, launched May 1975. The philosophy of the SAS program was to build a basic spacecraft and attach an experiment to it. The SAS-3 mission objective was to survey the celestial sphere for sources radiating in the X-ray, gamma-ray, ultraviolet, and other spectral regions, both inside and outside of our galaxy. The spacecraft weighed approximately 262 pounds with a 169-pound experiment package. The orbit was a 300-mile circular equatorial. The launch vehicle was a Scout.

The main elements of SAS management were:

- Management is not by committee—one leader makes final decisions.
- Close teamwork by a small project team of high quality.
- Conservative design concepts.
- Control of workforce.
- Parallel design on critical items.
- Careful selection of parts and materials.
- Good communications with contractors.
- Selective testing program to minimize cost.
- Ability to predict problems.
- Good schedule control.

Recommendations for future projects:

(1) Start experiment development before spacecraft development.

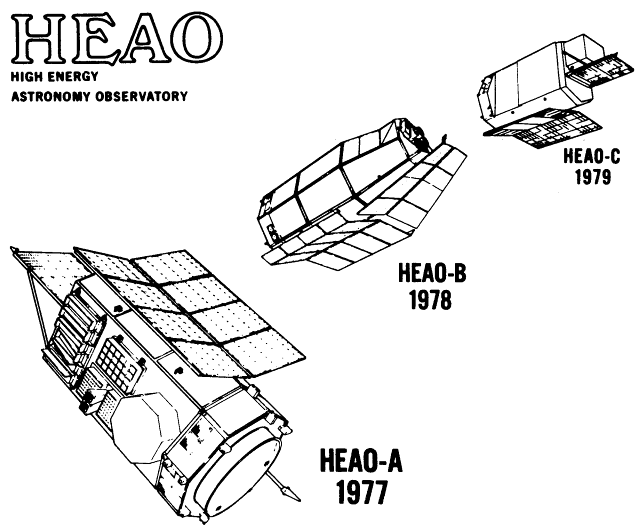
(2) Buy items requiring long lead times early.

(3) Implement configuration management after design phase; i.e., control changes.

(4) Have good business people on the project to help control costs and predict overruns.

(5) Work closely with contractor.

(6) Use existing design where practicable, but don't force-fit an old design.



HEAO Experiment Package
Goddard Space Flight Center
Ronald Browning, Manager

The next project discussed was the HEAO Experiment Package. The Marshall Space Flight Center (MSFC) was responsible for the management of the HEAO Project; however, the Goddard Space Flight Center (GSFC) provided two scientific experiments, a cosmic X-ray and a solid state spectrometer that were built in-house. The GSFC project office provided management of the hardware development and was the single point of contact with MSFC for all matters related to GSFC's HEAO experiments. The goals for the project office were to accomplish the program on schedule and within cost, incorporating maximum hardware commonality between experiments, and eliminating unnecessary redundancies in the design of each experiment.

Elements of management of the experiment package were:

- Development of experiments consistent with established GSFC in-house mode and acceptable to MSFC.
- Response to MSFC requirements.
- Coordination of project requirements.
- Configuration management.
- Systems engineering and design.
- Systems integration.
- Systems tests.
- Scheduling.
- Financial planning and monitoring.

Recommendations:

(1) Establish necessary resources early to meet other Center requirements.

(2) Thoroughly review experiments prior to Headquarters submission.

(3) Have better defined statements of work and specifications.

(4) Establish understanding at the begin-ning between Centers as to how the project will be managed and controlled.

(5) Keep spacecraft development more in parallel with experiment development, rather than one year behind.

Air Density/Hawkeye Project
Langley Research Center
Claude Coffee, Manager

The Hawkeye/Neutral Point Explorer Project was a 68-pound Scout-launched spacecraft built by the University of Iowa. The mission objectives were to study the topology of the magnetic field at large radial distances over the Earth's North Polar Cap and the interaction of the solar winds with the geomagnetic field.

The University of Iowa was given total responsibility for project implementation with overall management responsibility at Langley. The university did an excellent job; the project came in ahead of schedule and under cost. Ball Brothers provided engineering support to the university. Unique features of this project included:

- A one-year Phase B study effort prior to project approval.
- An understanding with the university that funds were extremely tight, and overrun would not be funded by NASA.
- The university's use of contracted engineering services in areas in which the university had no expertise, and to augment key project technical personnel.
- Desire of principal investigators to launch at the optimum time (April through June).

The Dual Air Density Explorer Project (DAD) consisted of two satellites to be launched into coplanar polar orbits by a single Scout launch vehicle. The two satellites were a .76mm diameter spun aluminum sphere and a 3.66m diameter aluminum/mylar inflatable sphere. Each sphere contained a mass spectrometer furnished by the University of Minnesota.

The objective of the DAD mission was to study the vertical structure of the density, composition, and temperatures of the upper atmosphere. The two spheres were the instruments for inferring the atmospheric density, while the mass spectrometers measured the atmospheric composition. The molecular temperature was inferred by the change in vertical composition.

Project cost drivers identified were:

- Cost limitations resulted in an 11-month slip in schedule. The greatest impact was in-house manpower, resulting in increased institutional management charges.
- Institutional management system was Center-controlled with methodology changing from year to year.
- Project management must be critically aware of manpower loadings to hold down the institutional management changes.
- Problem solving by increasing in-house manpower tends to impact total project costs.
- Principal investigator did not establish firm cost estimates for data reduction and analysis.

Problems encountered were:

- Lack of early engineering support because of other in-house flight projects.
- Viking problems that impacted project manpower at various times.
- Inflation of sphere, coupled with the problems of procuring high-quality aluminum/mylar laminates materials for the inflatable satellite.

Recommendations:

(1) Extensive Phase B type studies should be performed for both the in-house and contracted effort. This means both manpower and funds availability.

(2) Develop "baseline" design specifications and interfaces early.

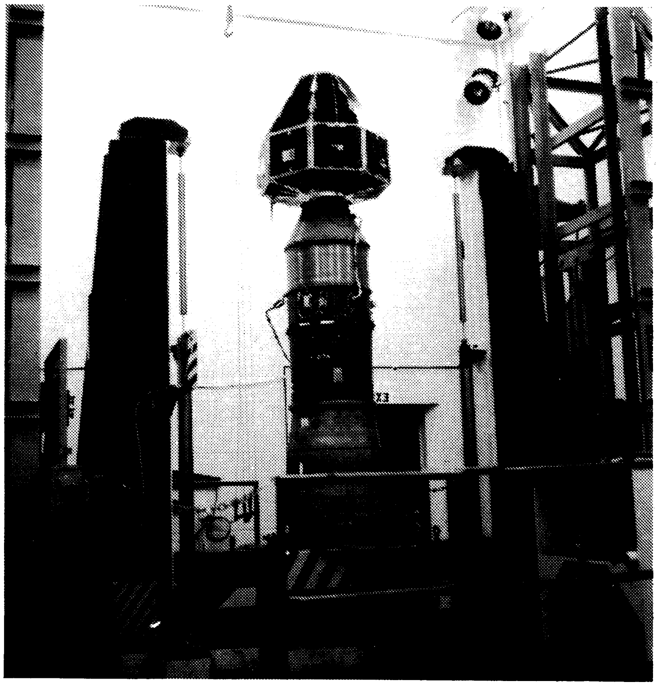
(3) Use fixed-price subcontracts.

(4) Be cost conscious and impress this on contractors.

(5) Avoid research and development after the project starts.

(6) Establish a realistic schedule.

(7) Develop a good relationship between project/contractor teams.



The Hawkeye Spacecraft is shown on the spin table during final systems tests before mating to the first five-stage version of the Scout rocket. Hawkeye-1 was launched June 3, 1974 to investigate the interaction of the solar wind with the Earth's magnetic field, with emphasis on the North Polar Cap. Hawkeye continued the University of Iowa's Injun series, which provided a comprehensive study of charged particles trapped in the Earth's magnetosphere.

Centaur D1 and Centaur Standard Shroud Projects Lewis Research Center
Andrew Stofan, Manager

The original Centaur stage was designed in the late 1950s and by the middle 1960s it needed updating. Several small study efforts were conducted in the 1966-69 time frame. An initial development contract was awarded to Convair in September 1969 to design, develop, manufacture and deliver one improved Centaur D1 upper-stage qualified vehicle. Included in the contract were special test equipment, a ground station at launch complex 36, tooling, and flight software. The basic negotiated contract was for $24 million with a period of performance from September 1969 to April 1972. The contract, which included a cost-plus incentive fee/award fee, was unique for its time.

The contract was later modified to provide a D1 Titan proof flight vehicle and a D1A vehicle for Pioneer-G. The total contract cost increased to $50 million. The total program was completed 4.8 percent under cost, the end items were delivered on schedule and the D1A vehicle met all objectives. Although the D1T vehicle proof flight was terminated by a Centaur hydrogen boost pump failure, the validity of all the new developments was demonstrated.

The project manager detailed major project elements in the development shop organization:

- Simplified procedures and paperwork.
- Fewer formal documentation and reports (from 260 to 105).
- Segregation of program activities in controlled plant areas.
- Direct association of design engineers with fabrication, assembly, and test personnel.
- Simplified drawing system.
- Contractor program manager with overall responsibilities for technical, schedule, and financial aspects.
- Highly motivated government-contractor team with excellent communications.
- Government-contractor team uses identical controls:
  - Schedules by Statement of Work (SOW).
  - Financial data by SOW.
  - Technical requirements by SOW.
- Designation of contractor engineers for total SOW responsibility—technical, schedule, financial.

Other successful project management elements included:

- Task definition thoroughly understood.
- Cost definition based upon realistic goals with detailed backup rationale.
- Motivating contract features.
- Proper program management organization at NASA and contractor.
- Appropriate management systems and tools.

Studies of the Titan/Centaur launch vehicle indicated that a combined payload nose fairing and Centaur insulation system was desirable. Later studies defined the concept of the Centaur Standard shroud (CSS) to fulfill the study requirements. The Shroud was sized approximately 18.3m in length, 4.3m upper diameter and 3.35m lower diameter to accommodate the Viking payload and Centaur and Viking lengths. Requests for proposals were issued in July 1969. Lockheed Missiles and Space Company, Inc., was awarded the contract. Lockheed had extensive experience in building similar large shrouds for the Air Force and had a proven separation system. A cost-plus incentive fee/award fee contract was again used; however, this contract experienced a large cost overrun and cost growth. The major reasons for the growth were that the 4.3m constant diameter Lockheed design caused extensive Shroud/Centaur interface revisions and that the Viking Program slipped two years. The overrun was caused by contractor's military shroud program development problems, the contractor scrapping the "development shop" approach, extensive personnel turnover in manufacturing, and overhead and labor rate increases due to reduced business volume.

Technical results:

- CSS passed all qualification tests successfully and with relative ease. Only minor problems occurred with insulation and backup separation systems.
- CSS performed flawlessly on proof flight and Helios-A launches.
- All hardware was delivered on time and all major milestones were met.

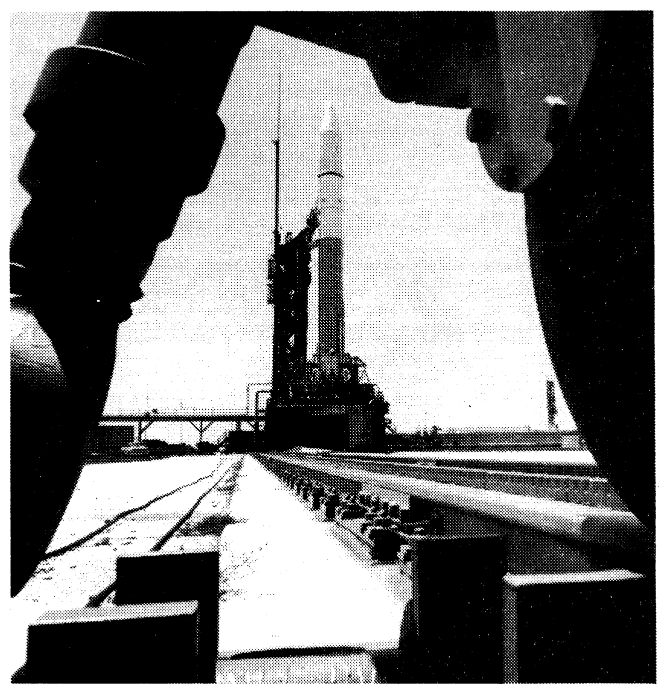
Recommendations:

(1) Contract should not be started with major inadequacies in the work statements.

(2) A "development shop" contractor organization is mandatory to control costs on contracts with a potential for engineering or schedule changes.

(3) Contractor top-level management attention and authority are vital in controlling expenditures of contractor organizations not under direct control of the project office.

(4) Defining sound interfaces between contractors is often the critical factor in controlling overall project costs, and is worthy of the utmost attention of contractor and NASA upper management.



An enhanced Centaur rocket with a resized shroud stands ready at Kennedy Space Center's complex 36 in 1978 to launch the Pioneer Venus Multiprobe, carrying four probes to enter the Venusian atmosphere.

Mariner Mars 71
Jet Propulsion Laboratory
Robert Parks

The final project discussed was Mariner Mars 71 managed by the Jet Propulsion Laboratory (JPL). The Mariner Mars 71 spacecraft weighed 2,266 pounds with an instrument package weight of 151 pounds. The primary mission objective was to study the dynamic characteristics and to provide broad area observations of the planet Mars from Martian orbit.

The project was formulated in the face of a threat that no new planetary programs would be approved unless attractive low-cost systems could be provided. During this period, both the Mars 71 Probe and the Voyager projects had been canceled.

A study of the Mariner Mars 71 launch opportunity revealed that it was the lowest energy year in the 15-year cycle and the Atlas Centaur could be used as the launch vehicle. The original approach was to use the Mariner Mars 69 science payload with no significant modifications. However, this approach was subsequently changed to include additional instrumentation, modifications to the Mariner Mars 69 instruments, and broader involvement of science investigators. These changes resulted in a cost increase from the initial estimate of $93 million to $106.3 million. JPL managed the project in the subsystem contracting mode.

Summary of major cost drivers:

- Inflation.
- Mission scope changes:
  - Science experiments.
  - Adaptive mode for mission operations.
  - Science data analysis expansion.

Experience with handling cost drivers:

- Inflation—per direction, initial cost estimate stated in 1968 dollars with no allowance for inflation.
- Unanticipated technical problems.
- Scope changes—additional science instrumentation.
- Costs partially offset by deleting third spacecraft.

Recommendations:

(1) Initial cost estimates should include an allowance for inflation.

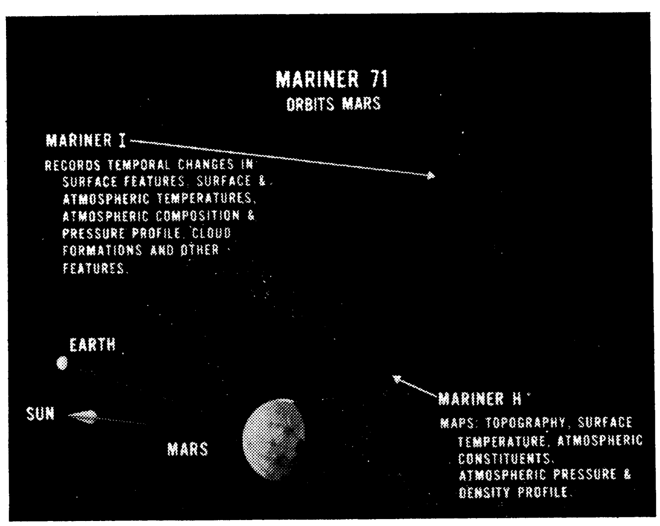
(2) A definitive statement of science payload requirements, with an estimate of instrument development costs and their effects on spacecraft costs, is needed.

(3) Include some funding contingency to cover costs of unforeseeable problems.

(4) Standardize, wherever practical, on designs, components, and test procedures.

(5) Undertake block buys of identical hardware subsystems.

(6) Share mission operations costs associated with personnel and software.



Summary

These programs and projects—ranging in cost from $1 million to $2.5 billion—show not only the vast diversity of NASA activities but also the wide differences of opinion and strong, independent thinking on the part of NASA program and project managers. No two sets of cost drivers or sets of recommendations are identical, but a pattern does emerge. That pattern can best be summed up in one word: planning. Good plans make good projects. And good planning starts with the selection of well-trained, competent program and project management leaders and teams.

All too often, especially in the early days, program managers learned on the job. Experience is a good teacher, but there are other ways to learn. There is no logical reason why we must learn only from our mistakes when we can learn from the mistakes—as well as successes—of others. In this article, we have lists and lists of reminders and suggestions from program and project managers, many of whom have gone on to lead bigger programs within the agency and in industry. Their wisdom is valued and can be worked into the curriculum of any upcoming NASA project or program managers. Comparing and contrasting methods and techniques in the lists shows that while there is no one way to plan a program and manage it, some ways may be certainly better than others, and some are lessons learned, never to be repeated.

The following recommendations were made to the Deputy Administrator upon completion of the workshops:

- Initiate training for project personnel
- Hold periodic meetings with project personnel
- Prepare "lessons learned" reports at the completion of projects
- Establish independent cost review teams to verify estimated projects costs
- Establish an agency-wide piece parts purchase and qualification program
- Conduct a definitive reliability study
- Establish a policy regarding research and development in flight projects versus "enabling technology" under SR&T
- Initiate pre-project approval buys and block buys
- Establish and manage funding contingencies
- Consider cost-at-completion versus cost-per-FY for total cost management
- Define Headquarters role in project management

It is interesting to note that only the first recommendation was fully implemented and even it failed for a time. The other recommendations were well thought out and made excellent sense but there were no sponsors to carry them out.