MANAGING A MAJOR TECHNICAL PROGRAM

Comparisons in Dealing with Changes

Dr. Raymond B. Gavert

Although it is not a military system, the Space Station Freedom Program (SSFP) provides some interesting technical and management comparisons in dealing with the changes of a major technical program.

The space station program is a major technical effort involving funding of approximately $2 billion yearly. Scheduled for completion around the year 2000, the program is global and includes international partners from Japan, Canada and the European Space Agency. It also includes work with Russia. The closest comparison to a military program office would be that of a joint program office with participation of allied forces.

This article will make some comparisons of the National Aeronautics and Space Administration (NASA) SSFP with two major military devel-

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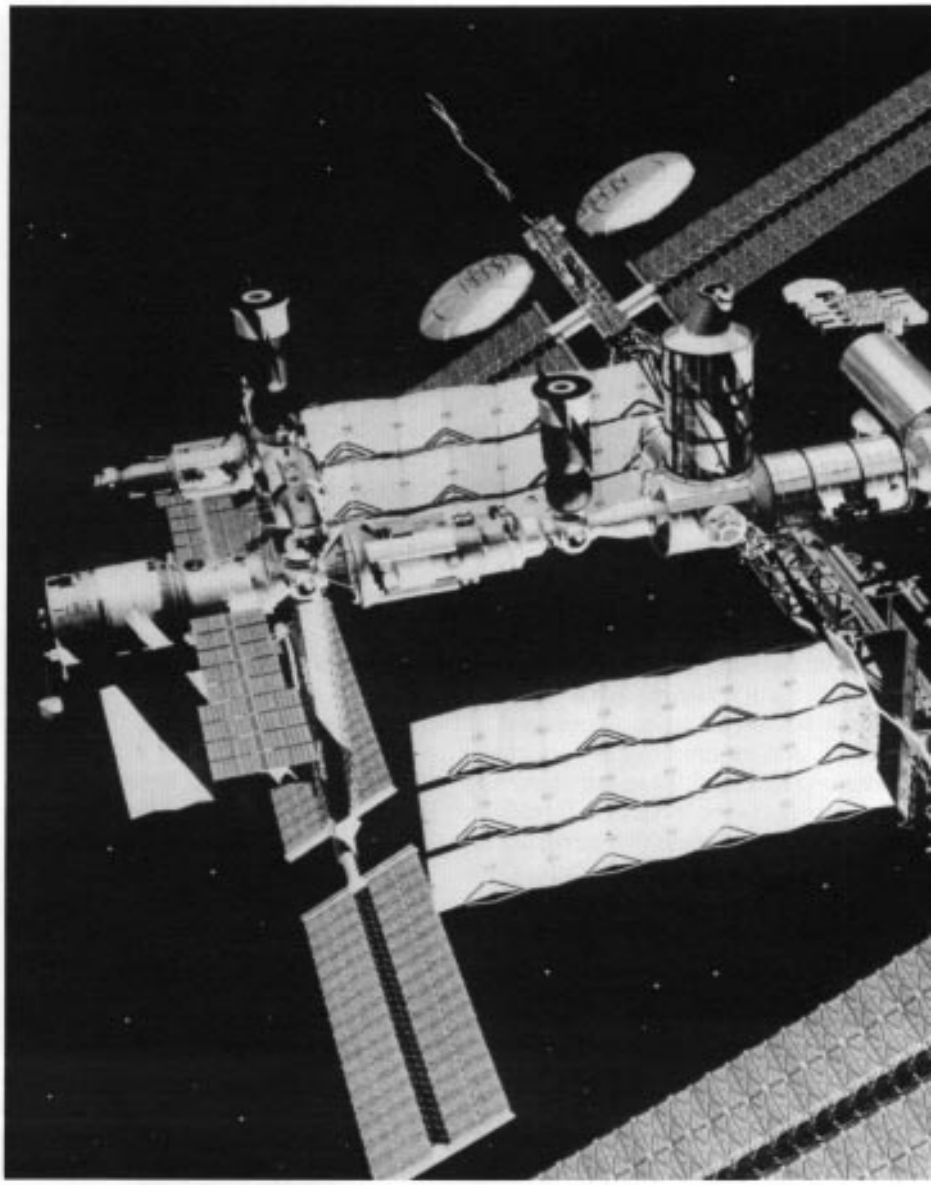


Space Station: U.S./International partners preliminary design concept.

opment activities; i.e., submarine construction and the work of the Strategic Defensive Initiative (SDI). General comparisons are made between the military and NASA program life cycles. Comparisons are shown in software management in the NASA SSFP with military software management. Life-cycle organizational change comparisons are made.

The configuration of Space Station Freedom (SSF) has changed many times during its development cycle. The version in the photograph is a restructured design concept. Like military programs, constant pressures to cut costs exist. Even with major restructuring to save money the space station has general features still including: a Truss for mounting station elements; a U.S. laboratory module; a habitation module; an airlock enabling transfer of crew and equipment between pressurized and unpressurized areas; major subsystems for providing power, thermal control, data handling, environment control and life support; Canadian rail-mounted mobile transporter; pressurized and unpressurized logistics supply elements; a Japanese experiment module, and a European Space Agency attached pressurized module for laboratory work.

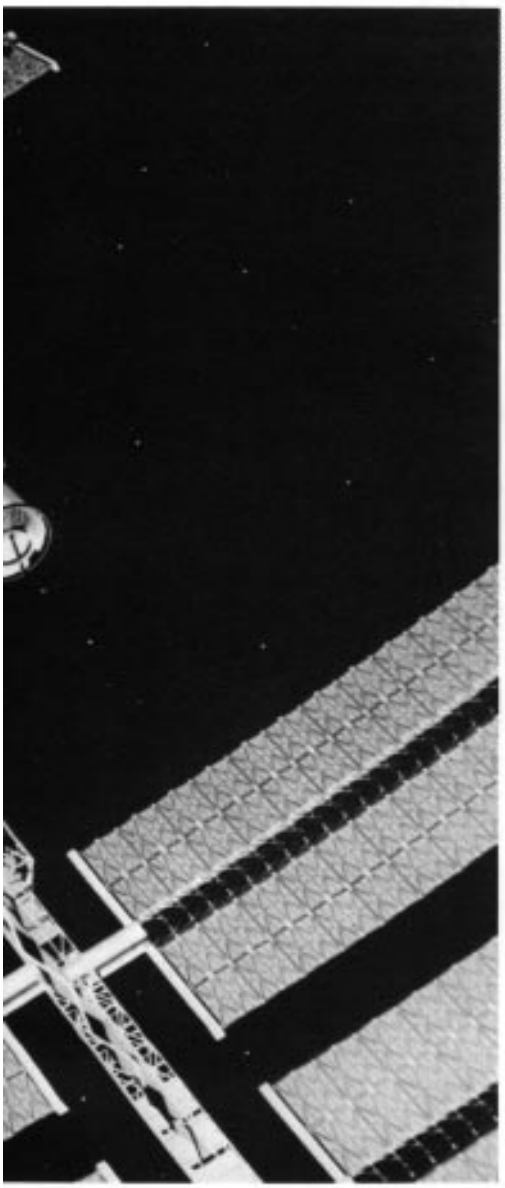


Photo courtesy of NASA

Like the military, adversaries suddenly can become friends. With the collapse of the Cold War, negotiations are now underway to use the Russian Soyuz spacecraft as a "lifeboat" for emergency crew return. Plans also continue for considering further changes that involve greater cooperation with the Russian Space Station Mir program.

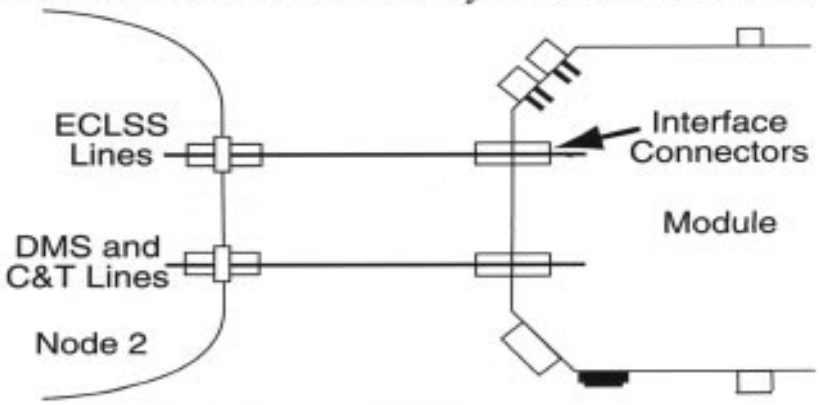
Comparison with Submarine Construction

Commander S.M. Jarrett in his Naval War College paper, "The Application of Submarine Experience and Technology to the Space Environment," pointed out that the submarine force of the United States has operated in a closed environment for almost 80 years. Further, he stated that submarine patrols simulate space travel more closely than any other type of operation.[1]

Developing and constructing a submarine, however, differs from developing and constructing the SSF. For example, the SSF Environmental Control and Life Support System (ECLSS) has atmosphere control and supply, nitrogen support, pressurized element temperature and humidity control, atmosphere revitalization, and fire detection and repression. Designed to be a distributed system, the equipment will be assembled in space during several shuttle flights. Figure 1 shows an example of the ECLSS distributed systems lines and other distributed system lines that need to be connected in space between a node and module sent up on different flights.

In submarine development and construction, the life-support systems are designed to be assembled at a naval shipyard with all the conveniences of a permanent facility. Although the ECLSS system has had some shuttle carryover in technology, it has been designed as a completely new system. By comparison, in a submarine program, changes to a system are more gradual. A new class of submarine might be built, for example, with no major changes in the life-support system.

FIGURE 1. SSF Distributed Systems Connections.



Although differences exist between development and construction for operations in space vs. underwater, Commander Jarrett, in his thesis, discusses opportunities for sharing technologies. This type of cooperation can benefit both the NASA and military program managers (PMs).

Comparison with the SDI Program

The SDI (renamed the Ballistic Missile Defense Organization), a major military program, has seen many changes. Even with the current emphasis on ground defense systems, the program involves on-orbit spacecraft and is useful for making comparisons with the SSFP. Like the SSFP, the SDI has an annual budget in billions of dollars and involves many government organizations and contractors.

The SDI military mission has been to develop a defense against nuclear missile attack. Space-based satellites in the defense system are used to spot launches, track targets, prioritize and control kills. The weapons for kills may be space or ground based. Although astronauts may be military and the experiments may be of use to military research, the space station is not a part of any weapons system.

The space station program will have men permanently stationed in space. On the other hand, the SDI program does not involve permanent presence in space to operate the system. Space Station Freedom has a long-term mission in space of 15 years or more. The SDI has a long-term commitment to protect our nation's assets from missile attack, but it would not necessarily have to have the same spacecraft in orbit for long periods of time. Should an SDI element have a long-term presence in space, it can learn from the space station's designs and operating experiences in on-orbit maintenance involving robotics and manned extravehicular activities.

Both being major billion dollar programs, the space station program and the SDI have been in the public eye constantly and open to public attack. Throughout the program life cycle, critics present other systems and ways to spend the money, and may time their attack to just before congressional hearings. The PM may not have much time to respond to a headline in the morning newspaper when hearings begin the same or following day. Generally, the PM must be aware of these critics in advance in order to best defend his program decisions. Sometimes public debate may be necessary. Program officers must make no out-of-place remarks or those that can be misinterpreted.

Major programs like SSF and the SDI seek technical and programmatic advice from many consultants and outside experts. Generally, these people come under two categories — those under PM control and independent experts chosen by others at higher levels including the President and Congress. Those in the first category can be a big help in resolving problems where the existing organizational staff is deficient in capabilities saving time, money and improving quality. Those in the second category often require the PM to divert precious manpower into gathering information for the experts.

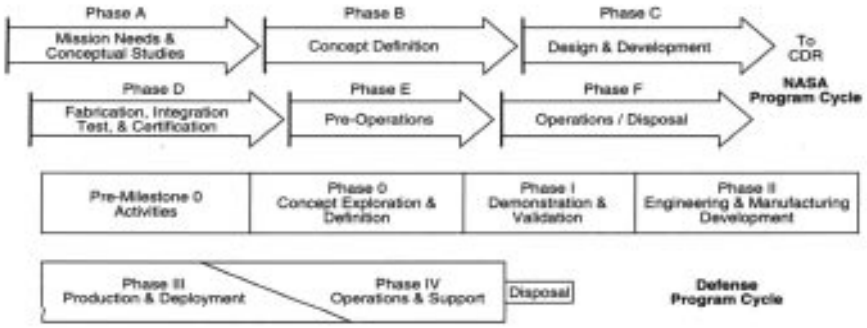
A negative report by the experts can hurt the PM's career. In addition, the results of independent studies limit the PM's decision-making flexibility. In one case in the space station program, the outside consultants were not pleased with the reception their study received by the program management. To strengthen their point, the consultants released their views to the New York Times. This forced the program to move in the direction desired by the consultants.

Lobbying the Congress is not an option of a NASA or military PM, even though Congress with its larger support staffs, tends to be moving beyond establishing policy and funding legislative work to directing program office actions. Program contractors can lobby the Congress. For example, a contractor might place an advertisement strategically in the Washington Post just before a congressional hearing. Even unions can help the PM promote his program. In both cases, however, the PM has no control over what they say or their priorities. The PM's best defense for his program is a good presentation at the congressional hearings and to be trusted.

Comparison of Program Life-Cycle Phases

The military program life cycle and the NASA life cycle have different terms and groupings for the program phases as shown in Figure 2. The military groups the program life cycle into: the Pre-Milestone 0 Activities, Concept Exploration and Definition,

FIGURE 2. Comparison of the NASA Program Cycle with the Defense Program Cycle



Demonstration and Validation, Engineering and Manufacturing Development, Production and Deployment, Operations and Support and, finally, Disposal. The phases apply to all types of weapon systems from helicopters to ships, tanks and satellites.

The NASA program life cycle is geared ultimately to launching something into space and retrieving information from the space activities. The NASA program phases are termed: Phase A, Mission Needs and Conceptual Studies; Phase B, Concept Definition and Preliminary Design; Phase C, Design and Development, leading to Critical Design Review; Phase D, Fabrication, Integration, Test and Certification; Phase E, Pre-Operations, including deployment and performance validation; Phase F, Operations and Disposal, including sustaining engineering and phase out. The program is currently in Phase C with partial work being done in Phase D.

In both NASA and the military program cycles, change flexibility becomes more confining as the program cycle progresses, because decisions made continually reduce options and alternatives. This is true particularly as hardware production begins and software is in advanced testing. Like the military, NASA must respond to threats and opportunities as the life cycle unfolds. Military programs usually are impacted by changing threats from external military powers. The NASA threats tend to be related to things like funding indecision. For example, if a heavy lift vehicle is not funded for SSFP use, more shuttle flights will be needed to get the total number of payloads into space. Software phases differ somewhat from the phases just described, as the following section will explain.

Software Management Comparisons

The System Software Development Standard (DoD-STD-2167A) applies directly to military software development. In NASA, DoD-STD-2167A provides supporting and background information but is not a requirements document. The NASA Software Management and Assurance Program (SMAP), out of the Office of Safety, Reliability, Maintainability and Quality Assurance, has created standards documentation called the "Information System Life-Cycle and Documentation Standards." The SSFP has used these standards including many of the NASA Data Item Descriptions in its management planning and requirements development.

A distinction between military and NASA management in software and hardware development is that in NASA consensus of management is a more dominant influence than following a strict set of regulations. The military rotating assignments create a greater need for following formal directives and standards. In NASA, employees remain for long time periods and have considerable influence in new-program decision making. In the case of the SSFP, experiences of shuttle program personnel have had a strong impact on SSFP software requirements and management practices.

One example of the influences of previous experiences is the SSFP Flight Systems Software Requirements (FSSRs). Unlike DoD-STD-2167A, which sets requirements by individual Computer Software Configuration Items (CSCIs), the FSSRs set requirements by systems which may have several CSCIs. What is gained by a systems perspective, however, is offset by the greater difficulty in judging the maturity of requirements compared to evaluating individual CSCIs.

Many of the contractors that work software development for the SSFP have experience based on military software systems. They tend to follow the military standards like DoD-STD-2167A whenever they can, thereby providing another source of influence on NASA procedures.

Working Avionics Problems

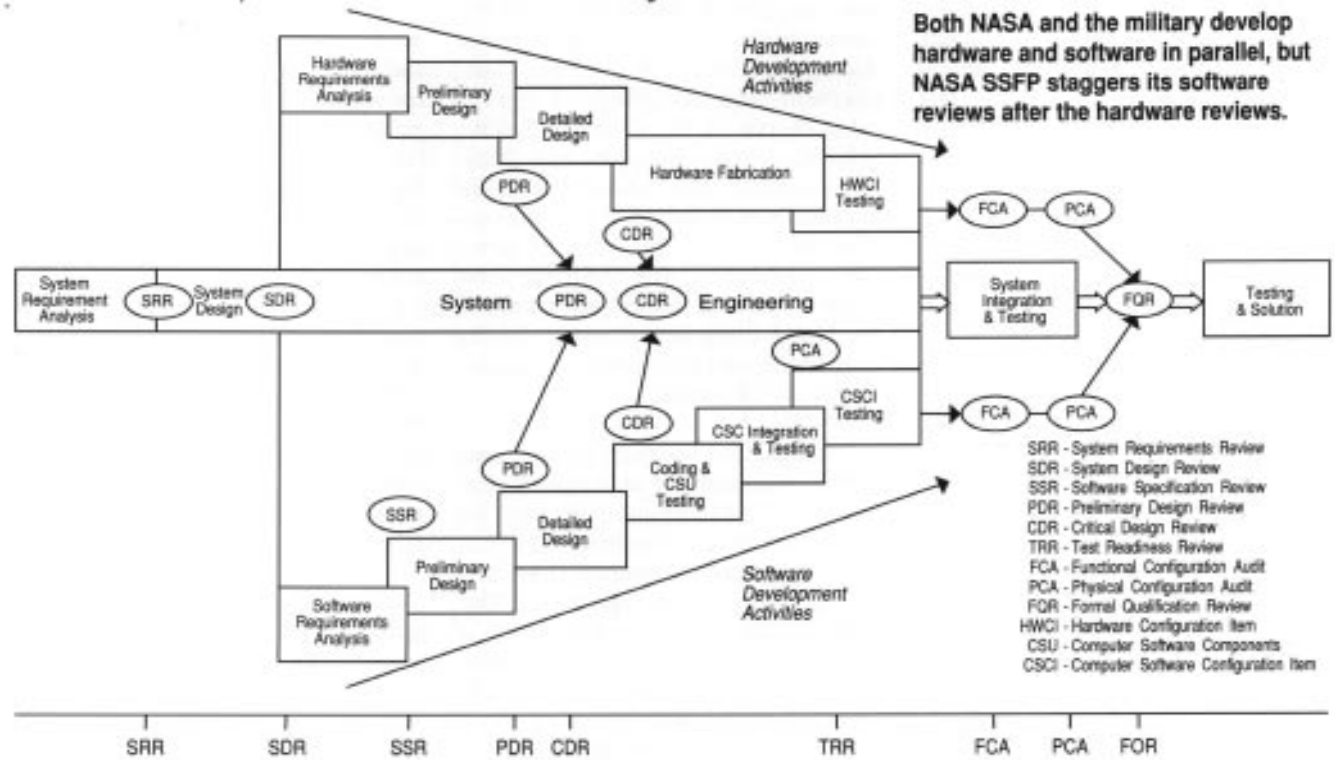
The SSFP software development management, software engineering and software test and evaluation responsibilities fall under the same groups that work avionics problems. For example, the largest software effort in SSFP is the Data Management System (DMS) which is organizationally placed under Avionics Systems. Before restructuring to reduce costs, the DMS, including applications software, had more than one million lines of code required to integrate, test, verify and maintain the system. The DMS uses 1,553 data bus architecture. For example, the system controls sensors and effectors in pointing an antenna, through the use of Multiplexer Demultiplexers (MDMs).

Organizationally, SSFP Avionics includes the DMS, Communications and Tracking System (C&T) and Guidance, Navigation and Control (GN&C). Other systems such as the Electrical Power System (EPS), and the Environment Control Life Support System (ECLSS), for example, are not in Avionics Systems but require software controls. These systems rely on the software community for software engineering and testing support. Because they are in different organizations, more integration is required than where the system is directly in avionics.

Software Configuration Management (CM) in the SSFP does not follow DoD-STD-2167A. Requirements for CM are patterned after the space shuttle program. Software change control and hardware change control follow traditional CM procedures of establishing configuration identification, configuration control, status accounting and verification.

Baseline distinctions like functional, allocated and product are not followed rigorously. The main Software Change Control Board for the SSFP has been located physically at the NASA center having the most software expertise. This board has had

FIGURE 3. Software/Hardware Development[2]



baselining authority. However, if a software issue is sufficiently controversial, particularly in terms of cost impacts, the Change Request will be brought up to the Space Station Control Board — the main board for all changes.

Requirements for software quality assurance generally include the essentials of DoD-STD-2167A, although some differences exist. For example, in the software product assurance evaluation of nondevelopmental software (NDS), the military and SSFP both want evidence that the NDS works, that it is under configuration management, and that data rights are consistent with the contract. The DoD-STD-2167A goes further, requiring government approval to use NDS; otherwise, their documentation requirements apply.

Figure 3 shows an example of system development reviews for software/hardware development in the military. The diagram is from DoD-STD-2167A with the addition of a systems engineering timeline.[2] The NASA and military software and hardware are developed in parallel. The diagram shows military hardware and software being integrated at major milestones such as Preliminary Design Review (PDR) and Critical Design Review (CDR).

In the SSFP case, the software major reviews are staggered later than the hardware major reviews. This allows the software developers to see the hardware detail before they finalize their codes. This makes sense in terms of system safety. Software alone is not safe or unsafe. However, if there are some wrong assumptions made in writing the codes about the operations of the hardware, safety could be affected.

In the SSF Man Tended Capability CDR, for example, software people were well represented and they made status presentations. The software, however, was not baselined at that time. Thus, the software people were able to evaluate carefully the hardware with which they would be working before they baselined the software. Eventually, hardware and software must be tested together in both NASA and military systems, similar to the right side of the diagram.

Life-Cycle Organizational Change Comparisons

In the military and in NASA major programs, the expectation is that organizational changes will occur as the program shifts to new phases. Organization changes can help create, in a better way, products expected from the succeeding phases.

The SSFP organizational history goes back to the early 1980s. In the conceptual stage (Phase A) the organization began as a small task force, which funded studies on attributes, architectural options and international participation. Similar to the military, a working group was established to set mission requirements. In

the mid-1980s, the President introduced the space station program to the nation including the intent for international participation.

Phase B began with an organizational pattern that differs from a DoD approach. Definition studies were directed not by a central organization but by four NASA centers. Results of the work of eight definition contractors were worked into Requests for Proposals (RFPs) which were issued and controlled by the four NASA centers. In Phase B, NASA Headquarters, working with the State Department, established Memoranda of Understanding with Canada, Japan and the European Space Agency.

Phase C organization was influenced by the Challenger accident. A post-Challenger investigation recommended that better control could be achieved by having the program office near NASA Headquarters in Washington, D.C. Thus, a formal program office structure was established as shown in Figure 4. A three-tier program office included Level I and Level II offices located in the Washington, D.C., area and Level III Offices located at the NASA centers.

The organization was made large in order to provide the design detail needed for CDR. Overall, 2,300 civil servants worked directly or matrixed to the program. These included 292 NASA contractors and 117 international partner contractors. The prime contractors still reported to the NASA centers through the Level III organizations. Figure 5 shows only three prime contractors, since early in Phase C Work Package III was abolished.

The Level I organization, a small office, worked overall policies with NASA Headquarters, coordinated with the Congress, and provided overall program direction. The Level II organization had approximately 250 civil servants supported by an integrating contractor with approximately 850 people. Top-level baseline requirements control was worked by Level II. Organizational elements included: program engineering, utilization and operations, management integration, international programs, integration, safety and product assurance and program control. The international partners had their main integration offices located at Level II.

Early in Phase C, top NASA management began looking ahead to the organization needed for succeeding phases. Development and fabrication contracts eventually were scheduled to be tapered off and replaced by contracts for operation and utilization of the space station, and a new organization would be needed. The new activities were expected to be NASA center oriented involving payload planning, logistics, launch operations and station operations.

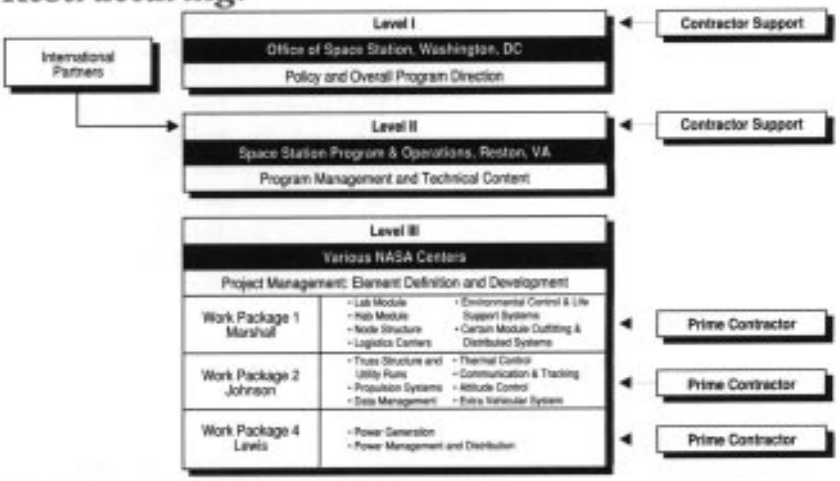
The feeling was that a large Washington-based program office was not needed for these activities. A smaller office located on one of the centers, with people focused more on utilization and operations, was anticipated. The situation might be somewhat analogous to the Air Force approach in the past to moving a program from a development command to a logistics command. When and where was not established.

The NASA, like the military, is subject to budget pressures, administration changes, reactions to cost overruns, and world politics. These factors made the SSFP a target of technical and organization change before Phase C was completed. The uprooting included technical and management changes. Technically, some parts of the program; i.e., structure and mass properties analysis, had to revert back to an earlier stage in the development phase. In some cases, crossing back into the conceptual phase might be necessary.

For the most part, the change philosophy is to use existing technology as much as possible. This includes not only the SSF technology but also the existing DoD technology, and Russian Space Station Mir. For example, propulsion, navigation guidance, and control for the restructured space station might come from a satellite bus built for a DoD program or may come from the Russian "space tug" Salyut FGB.

Compared with the old Phase C organization in Figure 5, the proposed restructured organization does not have Levels I, II and III. These offices merge into a single program office located at the Johnson Space Center which becomes the lead center. One

FIGURE 4. SSFP Phase C Organization Prior to Restructuring.



of the original three prime contractors is now the prime integrating contractor. This contractor is responsible for making design changes; finishing up the CDRs; managing Phase D involving fabrication, integration, test and certification; and assisting in the preparations for Phases E and F. The new NASA organization emphasizes preoperations activities such as launches, stage assemblies, logistics, science and on-orbit operations.

The difference between the military and NASA at this point is that, in the military, the receiving organization might have the right to refuse transition of a development program. In this case, the new receiving organization takes on an incomplete design package with the intent of streamlining the entire activity.

The streamlining effort is seeking greater management efficiencies. The PM, for example, will have greater budget authority and control over contracts by managing out of one program office. His key managers will report to him and not to the center directors as in the past. The new management approach includes multidisciplinary integrated product teams, which have been used successfully in the military. The idea is to bring together players responsible for a given product or area. For example, design engineering, manufacturing, operations, safety, science and utilization would be on a team that has budget, schedule and technical area of responsibility. The teams will include NASA and contractor personnel.

The new program office is expected to have a core of 300 NASA personnel and be supported by approximately 700 matrixed personnel.

Summary

The SSFP is a major national technical program that provides some interesting technical and management comparisons with major military systems. For instance, the submarine has technical similarities in environmental control for long duration missions that have benefitted the SSFP in information exchanges. The management of a submarine program differs from a space station program. Submarines are developed and built by modifying previous designs. Construction is done in a shipyard on earth, whereas SSF is a completely new design assembled in space with pieces arriving over a period of several launches.

The SDI has some interesting technical exchange opportunities in the areas of maintenance in space using robotics and manned extravehicular activities. Some striking similarities exist between the SDI and SSFP in managing a major program with a large budget.

The PM is in a public scrutiny "fishbowl," and under pressure from groups wanting to take the money away or receive a bigger piece of the program. The PM must engage in public debate with caution and without lobbying. He must be able to utilize consultants and outside experts effectively, and recognize the difference between those who will be on his side and those who might harm him or his program. He must recognize and deal effectively with those who have special interests and those whose political strength may be greater than their capabilities to carry out the program. Finally, he must provide Congress and the President with clear status information and be trustworthy.

The program life-cycle phases of NASA and the military closely resemble one another. The NASA life cycle is tailored ultimately to launching something into space, whereas the military life cycle is geared to a variety of weapon systems and products.

In SSFP software development, DoD-STD-2167A provides supporting and background information but program requirements are based on NASA experience. The NASA and the military develop hardware and software in parallel, but SSFP staggers its software reviews after the hardware reviews.

Organizational changes are a necessary part to keep a program in trim and to effectively meet new problems that emerge in the changing program phases. The space station organization in the Conceptual Studies Phase (A), like in the military, was small.

In the Definition Phase (B), the space station organization became larger but, unlike the military, it was decentralized with different NASA centers directing the definition contracts.

In the Development Phase (C), like the military, a much larger organization had to be established to meet the design detail that ultimately had to be produced before being manufactured. Unlike the military, a decentralized pattern of organization continued with a three-tier program management structure put into place.

The SSFP is being restructured with a new program management organization that is more centralized and has product team concepts used by the military.

The SSFP has a new name, International Space Station Alpha, and a new configuration. The comparisons made herein, however, are useful since, by understanding how major programs change and evolve, better programs can be built in the future.

Endnotes

1. Jarrett, Stephen M., CDR, USN, The Application of Submarine Experience and Technology to the Space Environment, Naval War College, Newport, R.I., March 1992.

2. Courtesy of the Defense Systems Management College.