Guiding Principles for the Space Station Program

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When I came on board in early April 1988, I set aside time to reflect on the principles that so far have guided my career and would be applicable to my new job. I was very comfortable with the configuration and management organization of the Space Station Freedom program. In the few years of its existence, the space station program had accomplished much, and becoming part of the "next logical step in space" would be personally gratifying. However, managing a program that would spend approximately $20 billion in the next 10 years would be a real challenge for me. I knew that the amount and complexity of hardware and the necessary interfaces were beyond anything I had worked on, including Apollo, Hubble Space Telescope, and the Space Shuttle External Tank programs. I concluded that to pull these thousands of pieces together and make them fly would demand strong leadership at all levels, good communication, and some rather innovative ways to define accountability, responsibility, and authority.

Any leader can get bogged down in detail and micromanage a program to death. What I needed last April were guiding principles, based on lessons I had learned, to apply to the challenges awaiting me. I'd like to very briefly share these principles with you and suggest that, in my experience, better decisions and actions result from such clearly defined principles.

1. Mission success is number one. This almost goes without saying in NASA. It's part and parcel of the NASA culture. For the Space Station Freedom program, however, mission success is not merely a single launch or even the final construction of a laboratory in space. Rather, Space Station Freedom will be multi-purpose, international, and evolutionary. It may be three decades before we can declare total mission success, and what we do today will determine tomorrow's successes. Mission success will be measured by a number of parameters; among these are crew safety, research capability, ease of maintainability, economy of operation and ability to evolve to meet future national goals.

2. Quality is planned in, designed in, and built in. Quality is not inspected in. Quality starts before designs are drawn and well before "metal is bent." The main message here is that each person and organization in the program must understand and believe in the need for quality performance from the onset of the program. You cannot wait until the hardware is built to decide you want quality and then attempt to "inspect" it in. I have often seen this tried but never successfully or economically.

The Technical Management and Information Systems (TMIS) will be a significant asset for collecting and disseminating information on our quality efforts. Quality encompasses more than just the delivered hardware. It includes management, requirements, design, development, testing, and documentation. Simply stated, the quality of every person's output is very important to the outcome of the program.

3. Keep it simple. As engineers we have a tendency to make systems more complicated than necessary. Our challenge is especially to make flight systems simple, thereby increasing reliability, minimizing training and crew on-orbit support, and reducing development cost. When we succeed, we get the added bonus of reducing on-orbit and ground logistics support costs. The most expensive component in orbit is the one that is not mandatory for mission success.

4. Minimize organizational and hardware interfaces, and maximize clear hardware and software accountability. An undisputed fact of

NASA culture is that our strength resides in our field centers. On the surface it may appear that a single management team would be preferable to the three management levels currently in place. However, many of NASA's past successes have had multiple field center involvement. Each participating field center brings much added value to the program by the center management review process and the personnel and facilities which could not be duplicated at any single NASA installation or prime contractor's facility. We have established a clear requirements chain-of-accountability by having the appropriate requirements derived, controlled, and accounted for at the appropriate management level, In doing this we have placed the top level program responsibilities at Headquarters (Level I and II) and taken maximum advantage of the field centers' management and engineering expertise in design, development, manufacturing, and operations. Now, to further ensure that the program is fully integrated at the field centers and prime contractors, we have implemented an associate contractor role among the four major work package contractors. This means that the contractors share much more responsibility in the design and functioning of "components" and "boxes" that are delivered from one contractor to another. This was done to mitigate the thousands of pieces of government-furnished equipment identified for delivery between the work package contractors. Simply stated, the receiving contractor and the delivery contractor are jointly responsible for the item until the item is fit or functionally demonstrated in the next level of assembly. This is true for both hardware and software. This is the first time NASA has utilized an associate contractor role to this degree.

Another extremely important element initiated very early in the program is the Software Support Environments (SSE). The SSE will establish a program-wide set of rules and tools for software architecture and production. The SSE is mandatory for a highly software-driven program such as ours. I believe the SSE will be a model for large, complex programs of the future.

With the above plans in place, program requirements can be established and managed, and the proper accountability can be identified.

5. Maximize Margins. Margins of safety, cost, schedule, quality assurance, and the like must be maximized to the greatest extent feasible. The real costs and dangers come when things don't fit or work as they should. Add-ons or corrections after the hardware and software are developed are major cost drivers, time wasters, and sources of future problems. The best time to effectively manage resources is early in the program in order to ensure maximum safety, reliability, maintainability, and quality assurance in hardware and software. To over-subscribe such valuable resources as weight, power, volume and crew time early in the design without the ability for later add-ons will significantly complicate the job.

The long life of this program brings with it the necessity to intelligently provide the "hooks and scars" for future growth and subsystems upgrading. This is one of the most complex tasks facing us, and one of the most important.

6. Maximize redundancy. But also manage it. The space station program has built triple redundancy into critical systems. To extend redundancy further would make the system less manageable. Once backup systems are in place, you have to "manage" them to know you will be able to depend upon second and third levels of redundancy when called upon.

7. Automation, robotics and Artificial Intelligence capability not built in will be accommodated by hooks and scars. We can build the Freedom station with today's technology. We need to push hard on automation systems, robotics and expert systems, but not too hard. We plan in the future to incorporate new technologies, thus reducing long-term operations costs. On the other hand, Freedom can, through the use of hooks and scars, be designed to accommodate breakthroughs, and we are committed to incorporating such advances as they become available.

8. Authority will be delegated to the lowest level practical and commensurate with the demonstrated real accountability. Unnecessary layers of bureaucracy take too much time to unravel. People take real pride in their work when they are given the tools and resources commensurate with the job--and the ultimate accountability for its success. Finding the right mix of accountability, responsibility and authority is no easy task, but emphasizing the necessity to do so to each program and project manager is mandatory. The management structure clearly identifies the

management levels and their accountabilities. If the accountability is not accepted, that portion of the program will be relocated.

9. Life-cycle cost will always be a key decision driver starting with development cost. The space station program spent much time and money in early definition work to identify and establish detailed designs that meet user requirements and life-cycle cost objectives within total and annual budgets. We know where we're going and what it will take to get there. We are saving a lot of time and money by preparing detailed plans, and listening to the good advice of potential users. An extensive cost model is being put in place to price all major program decisions that have an impact on development and operations. Close attention to detail in the development phase will save enormous amounts of time and money in the operational phase.

10. Space Station Freedom is not an end product but a key element of NASA and our nation's future. This principle could be considered a subset of number 9 above. I have identified it separately to give it the emphasis it deserves. In the early days it is easy for an organization to be buried up to its elbows in day-to-day problems, and equally easy to focus on the near-term solution that compromises future operational costs and performance.

Space Station Freedom will likely be our nation's gateway to planetary exploration, lunar bases, or missions to planet Earth. Therefore, we cannot over-emphasize the need for attention to growth capability or economic operability.

11. The international elements are vital to Space Station Freedom's success. For many years the United States and our international partners have successfully conducted complex joint space programs, and I am sure that this cooperation will continue and expand in the years to come. Freedom, however, will be the largest, most difficult and complex international cooperative space venture to date. Our international partners are contributing approximately 30% of the program development cost and will make a similar investment in the operational cost. They are significant members of the team.

There will be complications, of course. The interleaving of sub-systems, crew roles, training, and a very distributed science and station ground operational system are some that come to mind. We have dealt with similar problems before, and learning to do this effectively may be one of the best avenues for cooperation in many future peaceful initiatives.

12. Space Station Program Levels I and II manage the program; Level III and the prime contractors design, develop and fabricate Space Station Freedom. This principle was explicitly added to reinforce the fact that Levels I and II are management overview functions, and design and development responsibility rests with the Level III centers and their contractors.

13. Space Station Freedom Requirements. Space Station Freedom requirements are developed and managed by Levels I and II and satisfied and verified by Level III (a subset of number 12 above).

14. The Technical Management and Information System (TMIS) will be the key management tool, and the sooner the better. A program as large as this, as distributed as this, interleaved as this, requires an information system to gather, sort, compile, display, and disseminate current and accurate information. This includes requirements, design drawings, test, quality, and schedule and cost data, to name a few. Automated systems and software exist or can be built to perform this function in a highly automated mode. When you put them all together they are called TMIS. TMIS will allow the entire program to operate using timely and consistent information, with minimum input and retrieval effort. The extreme interdependence of each work package on at least one other work package requires current development status to be available across the program at a much lower level of detail than frequently required. TMIS will make this possible. Without this system in place, I do not believe it would be possible to maintain a proper program balance.

15. Every person in the Space Station Freedom organization must think and perform as a systems engineer or manager. This principle is most important but very difficult to implement. I cannot direct or legislate this to happen. I can, however, encourage our people to adopt this mindset. Most of NASA's large programs in the past consisted of major elements such as launch vehicle stages or spacecraft buses that accommodated a series of experiments delivered to an integrating contractor or center for assembly and check-out. In other

words, there were easily identified and defined interfaces. This program has anything but clean hardware/subsystem and management interfaces. Virtually all decisions made at the component and black box level can potentially affect another system component design or the attendant station operation. Significant changes can be controlled by the Interface Control Document and Architecture Control Document systems. However, lower level changes are not controlled in this way. These changes require the engineer and manager to think and function as a systems engineer and to question the real effect each minor change has on other elements of the program. This process is counter to the natural inclination to get the hardware delivered on cost and schedule. The need for this "system level" consciousness is present in this program more than in any previous NASA program. This management and engineering discipline will be even more necessary as this program continues to develop.

Here then are my guiding principles for the management of Space Station Freedom. It would be difficult if not impossible to codify any or all of these principles into hard, fixed policy. But I think we can benefit from knowing what and how a manager thinks and what is expected. It is part of the communication process.