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# POLITICAL AND INSTITUTIONAL FACTORS AFFECTING SYSTEMS ENGINEERING

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by John F. Yardley

Most systems engineering courses and textbooks discuss only the engineering aspects of the subject and are silent about the non-technical world's influence on the planned project. This approach, although entirely satisfactory for many engineering programs, including smaller NASA programs, leaves out a significant element affecting large NASA programs. Some traditionalists believe these nontechnical aspects should not even be considered in the systems engineering process. However, if we take the broad view that systems engineering should take into account all significant requirements in order to produce the proper end-product, then it should include consideration of those outside non-technical parties who can levy requirements on NASA programs. This paper identifies these elements, discusses their viewpoints and probable influence, and reviews some past case histories as illustrations of these problems. It also presents some suggestions for working with these non-technical groups, which may better achieve overall optimum systems engineering and integration (SE&I) solutions.

## THE NON-TECHNICAL GROUPS

There are many outside parties that provide inputs to NASA program requirements.

The public at large can have a profound influence on whether large sums are appropriated for NASA's major programs. They respond to NASA triumphs and disasters and are sensitive to NASA's role in projecting the American image around the world. Their influence is exercised by letters to Congress and the White House, by public appearances (interviews and speeches, for example), and through public opinion polls

regarding the space program. All of these methods influence both the executive and legislative branches of our government.

The President and his staff are very important to NASA's programs. They must make a positive decision to include money for specific NASA programs in the budget request before it is even considered by Congress. In these times of large government deficits, which makes starting new programs very difficult, NASA is pressured to cut back requirements and save money. This pressure even results in the stretch-out and cancellation of some ongoing projects. Sometimes in negotiations with the Office of Management and Budget, NASA is asked to choose between programs.

The Congress is one of the most significant groups that has a major impact on NASA's requirements. In addition to representing their constituents' opinions, members feel it is their duty to closely watch the details of NASA's large programs. In the last several decades, they have acquired the technical staff needed to exercise this detailed oversight. As a result, they are in a position to demand program requirement changes, and they have the appropriation muscle to back up their demands.

The Department of Defense (DoD) and other national security agencies often get involved in NASA's programs because they have agreed to participate in a joint development or because they plan to use the end-product. They are involved in monitoring NASA's projects from a national security viewpoint, and they sometimes require changes in NASA programs if they see potential security problems. DoD is always included as a major player in any high-level White House space study or committee.

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Some NASA partisans feel that certain DoD offices take a biased view and try to reduce the NASA program so DoD can play a larger role in space study.

Other executive departments substantially involved in NASA program matters include the State Department, the Commerce Department, the Transportation Department, and the Office of Management and Budget.

Government agencies and national commissions that fact-find, study and advise the executive and legislative branches upon request include the General Accounting Office, the Office of Technology Assessment, the National Academy of Sciences, the National Academy of Engineering, the National Research Council, the National Commission on the Challenger Accident, the Advisory Committee on the Future of the U.S. Space Program, and a number of other ad hoc committees.

International cooperation agreements often involve political considerations, and the foreign parties usually desire a part of the job that interfaces with many of the mainstream elements. If these agreements are not structured with the interface problems in mind, they can have major effects on systems engineering.

Scientific specialist groups feel they could more wisely spend the money appropriated for the large NASA manned space programs on their own research or on unmanned scientific space programs. This group sometimes works through "associations" seeking to plead their case in the media.

Local communities near NASA centers often inject themselves into the process of dividing the program work between Centers. The actual division of work can have a substantial effect on the efficiency of the collective NASA effort and can make the systems engineering effort much more difficult than a distribution based on technical merits. The political realities usually result in a "technically non-optimum" work split.

## EXAMPLES FROM THE PAST

History provides examples of political and institutional influences that illustrate how these factors affect NASA's programs. After the first Sputnik launch, the basic thrust to start the space agency, as well as to initiate the Mercury Program, came mostly from Congress, with lukewarm support from the Eisenhower administration. NASA's founding organizations, the National Advisory Committee for Aeronautics (NACA), was used as a technical staff; decisive actions were primarily political in nature.

During the sixties, the Kennedy Administration's decision to land astronauts on the Moon and return them safely was political; namely, to catch up with the Russians and get back U.S. world technological leadership. NASA provided a large part of the technical staff work, which consisted of preliminary analyses and estimated success probabilities.

In the case of the Space Shuttle start decision, interaction increased between systems engineering and the non-technical world. Richard Nixon had become President in early 1969, just a few months before the lunar landing. He requested the National Space Council to study and report on the options for the next phase of space flight and the long-term future. NASA was heavily involved in this year-long study. The report recommended that development of a Space Station and a fully reusable Space Shuttle be undertaken in parallel as the next step in manned space flight and as the precursor of later lunar colonies and manned Mars expeditions. At this point, a political decision was made to continue study of the Space Shuttle but to defer the Space Station. Work then proceeded on the Shuttle with Phase A contracts and then Phase B contracts. It soon became apparent that the Shuttle development cost was more than double the original preliminary estimates used in earlier decision making. Much interaction ensued between

NASA, the Office of Management and Budget, and Congress, with NASA trying to get the added funding commitment. When this was not forthcoming, the program management exhorted the projects to reduce cost without changing the basic concept.

After more work confirmed that the cost ceiling could not be achieved with the two-stage fully reusable Shuttle, it was finally decided by NASA management that the concept had to be changed in order to stay within funding limitations imposed by the Administration. Phase B contracts were extended, a major realignment of contractor teams was required, and the current Space Shuttle configuration (solid first stage, parallel burn) emerged. After the Apollo program and its blank check atmosphere, NASA was not used to this limited funding approach.

This process left much to be desired from many points of view. It delayed the program, caused a lot of wasted effort, and contractors formed teams and wasted a lot of their discretionary funds (estimated at $100 million). No one is to blame for this, since everyone was feeling their way in a new environment. A better process, however, would have been very worthwhile.

In contrast to the Shuttle, the Space Station did have strong support from President Reagan. This support was not for short-term political gain but rather because President Reagan believed it was in the best long-term interest of the country, despite the fact that most of the President's cabinet members and his close advisors were against starting the space station (Hans Mark's book).

The fragmented nature of the final Space Station hardware split between Centers resulted from an intense tug of war for appropriate shares of the program between the NASA Centers and their supporting political communities. Some NASA Centers felt that much of this struggle was for their very survival. Others in NASA felt this type of work distribution was necessary for broad Congressional support. While the final system is probably workable, it certainly is not considered optimum from a technical or efficiency viewpoint.

## MINIMIZING DISRUPTION FROM POLITICAL AND INSTITUTIONAL SOURCES

We have identified many of the outside sources of SE&I requirements and have given some examples to illustrate how important these inputs can be. Although most of these examples involve major program changes, many smaller requirements are questioned and changed. Now we will discuss methods of dealing with these inputs efficiently, minimizing disruption and avoiding adversarial relationships with these outside organizations.

Good two-way communication between NASA and these outside groups is one of the major keys to negotiating proper agreements on these external requirements. In order to properly deal with these outside inputs, we need to know what new requirements they are considering before these requirements are placed on NASA as irreversible demands. If we wait until then, it is very probable that we will develop adversarial relationships with the requester who has "gone public" and will be embarrassed to lose the argument. This will make the requestor very difficult to deal with during subsequent negotiations.

This means NASA must be organized and managed in a manner that facilitates communication of both internal and external pertinent information.

Most of these outside inputs are discussed at lower levels during interface or coordination meetings as "what if's." They rarely first surface at the NASA decision level in the program office or the SE&I management. This means that the lower-level NASA people interfacing with outside organizations must be trained to recognize these potential inputs at the beginning, and the overall NASA organization must have good communications at all levels so these issues can get

to the appropriate level early, a strategy can be developed, special analyses can be performed, and contacts to discuss the issues can be planned.

When preparing the material for discussion with the requester, NASA must be very careful to consider the requestor's point of view objectively and not just from the NASA parochial viewpoint of pure engineering ease, i.e., the "invented here" syndrome or the "bad for the Center" rationale. NASA must remember it is not the user or the owner but rather the implementor of someone else's requirements. When presenting the material, NASA must be careful to avoid patronizing the requester. If the requestor senses a patronizing attitude, the relationship rapidly becomes adversarial.

It is also important for NASA to advise and sell the appropriate outside groups on any requirement changes they feel are necessary before the action has been taken beyond the point of reasonable return. This is particularly true when NASA wants to relax requirements that were important to outside groups once the program was begun. Many examples exist where Congress finds out after the fact that the program can no longer meet the planned launch rate or some other fundamental requirement, and the original "NASA promise" must be broken. This has a very negative effect on rapport with Congress, the scientific community or any other major stakeholder. It is therefore important to level with these outside groups as quickly as possible after deciding to revise a basic requirement.

NASA must also develop harmonious relationships with the pertinent outside groups and individuals. This can be done, among other ways, using a network of committees or scheduled small meetings among selected individuals. The important thing is to plan for relationships and have the meetings regularly. These meetings should be used to bring the groups up to date, to permit them to ask questions and critique the activity, to smoke out impending requirements, changes

or additions, and to develop rapport. While doing these things, it is very important for NASA individuals to come across as open, forthright, and on top of their jobs. If the outside participants sense ulterior motives that are not discussed, or evasiveness and bluffing, trust cannot develop. In fact, many of these groups currently have a "corporate memory," which includes perceptions of many NASA Center biases. These must be overcome by careful and fair negotiations, bending over backward to diffuse any biased reputation.

NASA Centers have tended to think of many of these non-technical meetings as NASA Headquarters' responsibility (and a big, time-wasting nuisance), believing the Center's only role should be the engineering and management of the program. For NASA to do the most efficient and effective job, this concept must be changed. Whereas NASA Headquarters should participate in many of these contacts, the Center people who best know the subject and have prepared the material should present it. This is also an excellent training mechanism. The younger Center people will rapidly develop a much broader view of the outside world from interacting with NASA. Working with the centers in this manner, Headquarters also facilitates better internal communications.

Interfacing with Congress presents some special problems, particularly when NASA is trying to sell them a new program. There are laws prohibiting government employees from lobbying, and the line between lobbying and briefing on the merits of a new program is somewhat blurred. NASA must use its legislative and legal offices to help the program people properly interpret the law. In all probability, NASA will not be able to communicate with Congress on critical subjects in the manner and with the frequency they desire.

An alternative to direct NASA communication with Congress is for NASA to work with its contractors and keep them informed. The contractors are not bound by any laws

against lobbying and can communicate more freely with Congress. The contractors will contact the appropriate Representatives and their staffs with their own messages, in any case. It is not necessary for NASA to direct them to lobby (this being illegal), but NASA should inform them of its position so that if the contractors do contact Congress, they have the correct information.

On some past programs, all of the prime contractors informally worked together to keep Congress informed. One technique that has been popular with Congress is an "Information Notebook" on a given NASA program. This notebook is kept in the Congressional member's office for easy reference and is updated monthly, providing a useful monthly resource for informal discussions.

## NATIONAL STRATEGIC PLANNING FOR SPACE

After the Apollo program and President Kennedy's clear mandate to land astronauts on the Moon and return in the sixties, the U.S. space program suffered from a lack of clear national goals and a strategic plan to achieve them. In the Apollo era, all of the diverse forces involved coalesced behind President Kennedy because they wanted to beat our superpower adversary, the U.S.S.R., in the technological war. Since that time, we have been unable to generate such a unifying environment. If this could be done, and a framework for future space activity could be agreed on in the form of a strategic plan, the problems of interfacing with the outside groups would be much easier.

As of this writing, the Bush administration has outlined a long-range plan for exploration that includes colonizing the Moon a and a manned exploration of Mars, which could form the framework for a good strategic plan. However, it must be accepted by these outside parties and backed with appropriations by Congress before any plan can realistically be made. During this period of a growing national deficit, tensions in the

Middle East, and the bail-out of the savings and loan industry, such an ambitious plan will be difficult to accomplish.

## SUMMARY AND CONCLUSIONS

External groups have a significant impact on NASA's programs. Ten groups affecting NASA are identified, and examples are given for some of the them. Methods of dealing with these external inputs are discussed, the most important being good and open two-way communications and an objective attitude on the part of the NASA participants. The importance of planning ahead, of developing rapport with these groups, and of effective use of NASA contractors is covered. The need for an overall strategic plan for the U.S. space program is stressed.

In order to obtain the broadest range of opinions on the political and institutional factors that affect systems engineering, the writer requested thoughts from a number of senior individuals who have been involved in the interfaces between NASA and the outside world.

In any subject as complex as this one, there are always some differences of opinion. The viewpoints expressed above are those of the writer and sometimes agree with the majority, and at other times do not. To provide the reader with another viewpoint, an additional paper by David Wensley is reproduced in its entirety in the appendix to this chapter. Mr. Wensley examines the subject through the eyes of a prime Space Station contractor executive.

The author concludes that NASA does not pay sufficient attention to the impact of political and institutional factors in conducting its business and is being hurt by this attitude. NASA should therefore focus on working with these outside groups, adjust NASA policies and organizations to facilitate interfacing with them, and train NASA personnel to conduct themselves appropriately in this environment.

# POLITICAL AND INSTITUTIONAL FACTORS AFFECTING SYSTEMS ENGINEERING: AN INDUSTRY PERSPECTIVE

by David Wensley

The "nominal" or "idealized" systems engineering process must take into consideration the political and institutional factors that have become prevalent in the government funded and, to a certain extent, the privately funded civil space activity. Attempts to ignore these influences may result in delay and frustration of the systems engineering process.

NASA programs are currently growing larger in scope, longer in duration and fewer in number. The increasing number of participants includes NASA Centers, other U.S. agencies, international agencies and contractors. NASA programs are also characterized by higher public visibility, and are more costly and more politically sensitive.

In this environment, the Congressional committees that appropriate and authorize budgets will demand more justification for expenditures, more political return from the investments and more oversight of ongoing activities.

## POLITICAL FACTORS

Space projects have always been an instrument of domestic politics and a tool of political influence in international relations. As the scope and importance of these projects increases, we can expect more political influence on the systems engineering process.

The political influence may take any of several forms:

- Geographical distribution of funds to gain political support.
- Creation of international partnerships.
- Insertion of technical requirements to satisfy strategic national goals.
- Increased Congressional and Administration involvement in the technical decision-making processes.

- Funding constraints used as a mechanism of technical and political control.

An effective project management and systems engineering process must deal constructively with these influences. They may affect program content, allocation of responsibilities, schedules, interface definitions, optimization and trade-off criteria, and technical decisions. They may even affect mission definition, and they most certainly will affect funding availability versus time. Effective management must provide for flexibility to react to these influences without undue penalties on performance, cost or schedule. A constructive and cooperative relationship between the legislators and program management can minimize the impact of these interactions on planned efforts.

Many examples of the influences noted above can be cited in the Space Station Freedom program, including:

- Legislated use of a Flight Telerobotic Servicer to advance U.S. robotic technology.
- Allocation of responsibilities to international partners.
- Political influence on the work distribution between NASA Centers.
- Increased complexity of interfaces and management processes resulting from distributed responsibilities.
- Funding constraints (fencing) in budget authorization bills.
- Oversight committees and hearings to critique technical progress and to influence resolution of technical issues.

The systems engineering process must stand the tests of external review and critique. The assumption that technical management and decision making is part of an

immune internal process is, unfortunately, unrealistic. Techniques for effectively managing the external factors include:

- Open communication between project management and stakeholders to understand needs and develop trust.
- Realistic planning to support schedule and cost commitments.
- Disciplined control of requirements to avoid unwarranted cost and schedule growth.
- Effective use of risk management techniques to minimize iterations on design and testing.
- Cost-effectiveness and life-cycle cost analysis to substantiate trade decisions.
- Early emphasis on operations, maintenance and logistical support to avoid unpredicted support costs.
- Early constructive resolution of responsibility conflicts between NASA Centers and between NASA and international partners.

These features are characteristic of traditional management and represent the expectations of legislators and budget authorities. Deviations from these norms, especially if uncovered through Congressional or media probing, can be disruptive and potentially dangerous to the stability and continuity of a program. The systems engineering process can significantly reduce these risks by staying on track and by making summary data available to project managers to use in open dialogue with legislators.

Program changes are unavoidable, and systems engineering and project management must be equipped with the analytical tools to respond effectively to these changes. The ability to re-prioritize and reschedule activities rapidly and with reasonable accuracy is essential, especially in response to funding adjustments emanating from the annual budgetary process. More often than not, these events are unanticipated and result in traumatic and costly adjustments. A pre-

planned strategy for deferral of less critical elements, retaining the systems engineering effort to establish interface requirements and essential design definitions, can minimize such effects.

## INSTITUTIONAL FACTORS

Numerous institutional factors will affect the systems engineering process, principally those inherent in NASA and the participating Centers. Examples include:

- Accepted standards, design criteria, and specifications.
- Design, management and operational preferences of the Center functional divisions.
- Availability and preference for use of Center test facilities.
- The organization and management structure adopted for the program.
- Traditional practices such as use of committees, panels, boards, documentation formats and integration processes.
- Use of support contractors to supplement NASA staff.
- NASA and Center policies and priorities that may influence, for example, technology selections, responsibility issues and requirements decisions.

The above considerations can have a major impact on systems engineering requirements derivations, trade studies, architecture and design selections, test plans and operational concepts. They will also affect the schedule and effort required to evolve the design baseline, to resolve integration issues and to establish interface agreements. The potential magnitude of these effects dictates early planning for their accommodation in the systems engineering process. It is virtually pointless to embark on a systems engineering process that ignores these considerations. The institutional characteristics have evolved over time and are the product of many successes and failures. It

is unlikely that personnel assigned to new projects will adopt practices that violate tradition. Contractor personnel should be prepared to adapt to customer preferences, but customer (NASA) personnel should be prepared to consider new alternatives as part of a continuous improvement process.

## THE SEARCH FOR IMPROVEMENT

Increased budget pressures and heightened concern for foreign competition create a demand for NASA to seek new methods of achieving quality and reducing costs. Industry is similarly under pressure in these areas and is rapidly adopting techniques such as Total Quality Management (TQM) principles. NASA is beginning to apply TQM criteria in new procurements and has started to look for TQM opportunities within its organizational structure. Conversion to these principles represents a major cultural change and, in many respects, is contrary to recent trends within NASA. TQM teachings emphasize reduction in top-down management direction, preferring increased delegation and empowerment of the lower tier personnel. Since the Challenger accident, the tendency within NASA has been to increase management and technical oversight. In the Space Station Freedom program, for example, many layers of management and technical oversight exist within the Level II and Level III organizations above the prime contractors and their subcontractor teams. Although contractors are generally committed to cost and schedule objectives, their progress is often controlled by the efficiency and speed of the NASA management and systems engineering processes and integration. If the involved participants agree that improvement is essential to create an environment of credibility and trust at the political level, recognition of these relationships can lead to constructive changes.

Measurement of performance is essential in the search for improvement. Both NASA and contractors must be measured as elements of a closed-loop process that affects the efficiency and quality of our space activities. The identification of improvement candidates should focus on the inanimate process, not on the organizations or people. This allows the people to conduct constructive problem identification and resolution without personal implications.

## CONCLUSION

NASA stands at a crossroads. The opportunities for space exploration and the exploitation of space attributes and resources have never been better. Public acceptance of space projects and reliance on space technology as a means to resolve worldwide environmental and resource issues have never been higher. Yet NASA lacks credibility with the legislators of this country who are eager to voice criticism of NASA's planning and implementation of space projects. Their depth of penetration into NASA's technical activities is increasing. Not only is the continuity of NASA funding at risk, the scope of NASA's responsibilities is also threatened. Transfer of responsibilities to other agencies and even the creation of new agencies is topical conversation. Resolution of this dilemma requires more than a willingness to communicate and to negotiate differences; it requires a change in the NASA management culture that recognizes the degree of maturity of the space industry. The mystery of discovery and the complexity of space technology is no longer an adequate defense for cost or schedule overruns. Critics demand performance that meets expectations. NASA has the opportunity to lead the family of federal agencies in demonstrating fiscal responsibility combined with technical achievements. Systems engineering will be a major contributor to this success by providing the guidance for timely decisions leading to effective project management.