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Paper Session II-B - NLS Cost Containment

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ABSTRACT

Growth in costs and schedules of aerospace projects is all too commonplace. Within NASA, about 70% of cost growth is attributed to underestimation of technical difficulty, 20% to major scope changes and 10% to external impacts. Schedule duration has increased by 50% over the last 15 years. Most growth problems can be traced to incomplete Phase A/B requirements definition, coupled with the resulting incomplete cost estimates.

NLS must be a cost effective, low cost transportation system to be viable. To achieve this goal a cost containment system is required which forces cost, technical and schedule to function together interlocked in a controlled management system.

INTRODUCTION

Cost growth in aerospace programs seems to be the norm these days. Hardly a week goes by without some news article detailing a horror story on a space project involving large cost growth and schedule slips, often coupled with poor technical performance and perhaps even a hint of an attempted cover-up of the matter. These stories imply NASA, DOD and aerospace contractors can not or will not manage their resources effectively.

A recent study by the Federation of American Scientists indicates *the average space project cost 2 1/2 times as much as promised and was 58% behind schedule.* My data base generally supports these factors, however, much depends on what is considered to be the initial estimate. Some programs are tracked against the initial contract value, others from the congressional commitment made at the time the program is approved, and others to early Phase A and Phase B estimates.

Anyway, many of these accusations of large cost growths are all too true. Aerospace "new start" program managers seem to eternally believe they can do the impossible in providing high tech products in record time at garage sale prices. Nevermind that similar programs took twice as long and cost twice as much. This time "we are going to do it differently", "we will freeze the design early and allow no changes", "we will cut out the fat", etc. So they say, but somehow in the real program execution it never seems to work out that way.

Once the program begins, the overzealous claims are quickly overtaken by the grim realities of program turbulence, technical complexities, interfaces, personnel turnover, changing budget priorities and emerging requirements. The inevitable growth in problems, weights, requirements, manpower, costs and schedules, coupled with reduction in margins, performance and planned capabilities has lead to many cost reduction ideas and techniques.

None of these "cure alls" really attack the root cause of cost growth as we will discuss later. Nevertheless, many techniques have come to the forefront as cost reduction tools. In fact, it seems as though a new one is invented everyday. Some of these concepts currently in usage are displayed in Figure 1.

Total Quality Management
Financial Farsightedness
Taquchi Method
Factory of the Future
Design To Cost
Continuous Process Improvement
Technology Advancement
Automation/Robotics
Culture Changes
Quality Functional Deployment
Concurrent Engineering
Skunk Works
Should Cost
Operability Focus
Just-In-Time Delivery
Ship and Shoot
Platform Teams

Figure 1. Samples of Current Cost Reduction Concepts

While each of these has cost saving potential, they must be pursued vigorously and continually if any actual savings are to materialize. They must be undertaken with management conviction which lasts throughout the program. *None of these are easy, some have significant up-front costs, most require personnel training and all require constant monitoring and evaluation.* They represent a management commitment to invest in the present for greater rewards in the future.

One recent success story was the Upper Atmosphere Research Satellite (UARS) which was launched this past September and stayed within its $630M budget. Program officials offered the following reasons for good programmatic performance:

1. Use of off-the-shelf hardware
2. Initially planned 4 satellite program reduced early on to a single satellite launch
3. Spacecraft design based on a design that had been used before
4. Interfaces between spacecraft and instruments known early and remained constant
5. Proposed improvements over the basic design and capabilities were not accepted.

These reasons could be called TQM or the like, but it seems more like common sense and technological conservatism that did the trick and, of course, maybe luck.

Other space programs, such as Space Station, Earth Observing System (EOS), New Launch System (NLS) and Space Exploration Initiative (SEI), which initially promised all things to all people appear doomed to major down scoping, delayed starts and price tags larger than the Congress will support. The Space Station's initial technical content and advertised $8 billion cost were totally incompatible from the start. This has kept the program in internal conflict as it has tried to do too much with too little. The downsizing and program rescoping has cost millions and years which could have been more prudently applied to a Space Station whose cost and design were congruent.

<u>COST GROWTH</u>

Space projects have never been without cost growth, but this growth has increased over the years in number and percent. Figure 2 indicates the average percent cost growth for 20 NASA projects launched in the 1970's and for 18 post-1980 projects. The judged cost increases associated with the Challenger accident have been removed from the applicable projects to normalize the data. *Major reasons for the cost growth are (1) underestimate of the program difficulty (complexities, design requirements, interfaces, schedule) 70%, (2) major scope changes 20%, and (3) external impacts (constrained budget, Congress) 10%.*

Part of this increase in cost growth is due to a slow culture change in NASA. NASA now has much less in-house technical capability and has become older, more conservative and is less willing to accept risk or failure. It has lost the boundless

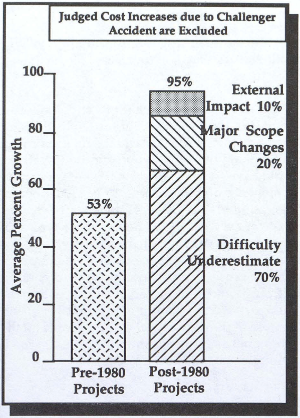

Figure 2. Past and Current Cost Growth Trends in NASA

enthusiasm and air of excitement that was exhibited by its personnel in the 1960s. NASA projects are now more encumbered with bureaucratic processes, documentation, and reporting systems which add cost and manpower. Technology advancements have offset these cost increases to a degree, but not enough to turn the trend around. For example, in today's dollars, the development cost of Space Shuttle's SSME engine was about 30% greater than either of Saturn V's F-1 or J-2 engines. The explanation was that the SSME was considerably more technically demanding. Now, however, the new STME which purports to be a return to a simpler, less technically demanding, low cost system is expected to have the same development cost as the SSME.

The seemly inevitable aerospace cost growth clearly makes the case for adequate program cost contingencies or reserves. I recently added on a major addition to my house. At the outset, I made a detailed cost estimate using the best, most reliable data possible. After all, people have been adding on to their houses for thousands of years so the task appeared simple. A line by line estimate was compiled using vendor quotes, inputs from knowledgeable tradespeople, rules of thumb and actual hardware prices. To this I initially added a 30% cost contingency, but as my planning list grew the dollar total exceeded my budget so I was forced to cut back contingencies to 10%. After the work was complete I compared my estimate to the actual costs line by line. As it turned out I was extremely close (2-3%) on every item which I had estimated. The problem was that there were a large number of items required which I, at the outset, had no idea I needed and had made no estimate for. These more than consumed my meager contingency and made for an overrun. Fortunately it did not make the newspaper headlines.

The point is there is no way to totally quantify the unknown. No matter how much you spend in planning there will still be unexpected discoveries in the execution phase. (Incidentally, a later Figure will address this point.) *The bottom line is that a reasonable cost contingency (20-30%) in a space program is a must.* It is a place holder for the unknown. It is not an optional item "which will get spent up if you include it" — it will get spent regardless! But at dire consequences to the program if it was not included.

SCHEDULE GROWTH

Aerospace projects also now take considerably longer to develop which account for part of the increased cost. Figure 3 indicates the enormous growth in development time for NASA spacecrafts. The schedule slips associated with the Challenger accident have been removed from this data. *Nevertheless, average development time has increased by 50% in the past fifteen years.* The UARS, mentioned earlier, actually was proposed

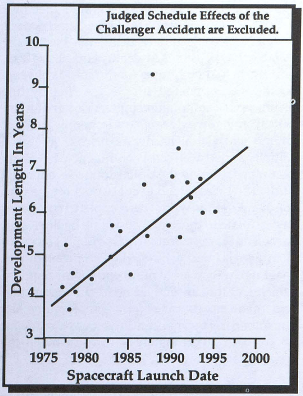

Figure 3. NASA Development Time Trends

in 1978 and took 13 years to gain approval, be built and launched — four years longer than it took to go to the moon.

Another example of schedule slips and cost growth is the Skylab Program Payloads chart shown in Figure 4. This actual data is more unreal looking than any hypothetical illustration I could have created. The actual cost expenditure is plotted along with some 15 NASA Program Operating Plan (POP) requirements over time. There are several trends here that are typical of most space projects. First, in the early years it is usually not possible to spend all the money allocated because of the delays in getting organized and hiring and training personnel. Second, in the later part of a program it is easy to over spend because of the difficulty of getting people off the program. Lastly, the slow ramp-up causes schedule stretch out and cost growth.

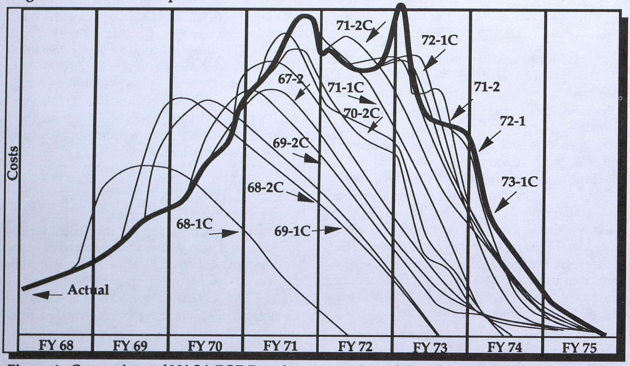

Figure 4. Comparison of NASA POP Requirements to Actual Cost for Skylab Program Payloads

PRIMARY COST GROWTH CAUSE

The causes of cost growth — internal and external, technical and management, foreseeable and totally unforeseeable — are innumerable. *But the primary root cause, I believe, is incomplete technical definition early on.* This leads to requirements understatement; incomplete and inaccurate cost and schedule estimating, and program redirection, growth and downsizing as previously unknown requirements surface. Figure 5 indicates that funds spent in the definition phase can have tremendous payoff in total program cost savings. This plot, with some 25 NASA data points, indicates that if 8-10% of the total program cost is invested in Phase A/B definition, total program growth is held to around 30% above the final Phase B estimate. Spending more dollars and effort on definition seems to offer little payoff, but spending less definitely has a very significant impact on the program total cost.

A number of very important actions should occur during the critical definition period to set the stage for cost containment. These are:

1. Actual user needs are solicited and accomodated.
2. Bona fide requirements established.
3. A workable, conservative preliminary design developed with margins.
4. A streamlined, astute management structure formulated.
5. A total program plan developed.
6. A realistic and inclusive cost baseline estimate made.

If these are done well, the battle for cost containment is half won.

The other half of the battle is to (1) resolutely maintain this baseline and not to let the better become the enemy of the good; (2) establish and utilize powerful management systems which provide program status, tracking, control and sound basis for timely corrective actions as required; and (3) instill within the total government and contractor workforce a desire, a will, a motivation to do things right the first time — on time

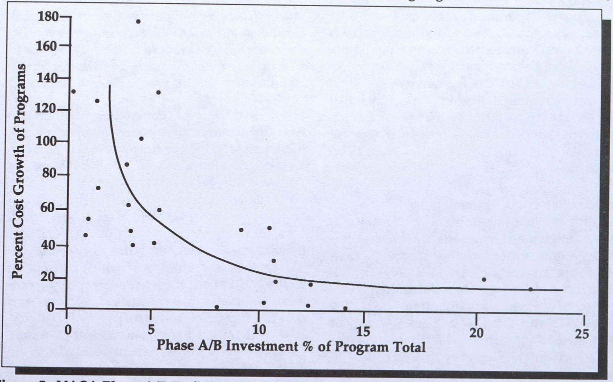

Figure 5. NASA Phase A/B Definition Investment versus Program Total Cost Growth from the Final Phase B Cost Estimate.

with minimum expenditure of resources. Some programs have this technical and management pride, this drive for excellence — many do not.

NLS COST CONTAINMENT

Enough background and preaching on causes of cost growth. What can be realistically done in the NLS program to contain cost and avoid the turmoil associated with other programs? Already there are forces at work which cause the NLS new start grief. These include the massive federal budget deficit, the severe domestic economic recession, the major perturbations of other programs within NASA and DOD, the election year, the lack of strong NLS "users" or proponents, the uncertain NLS technical baseline and the already advertised $10.7 to $12.2 billion DDT&E cost. NLS is being touted as cost-effective and offering low cost transportation. In fact, this has become a major thrust of the NLS new-start justification and these claims must be addressed in a persuasive and business like manner.

On the one hand, the Space Shuttle is a very expensive system to operate and the Titan IV is technologically antiquated in many ways. Therefore, it would seem logical that a new system could easily beat both of them in cost per flight and cost per pound delivered. Especially if that new vehicle was, in fact, a system with common hardware, facilities, manpower and management for a family of vehicles with different payload capabilities.

On the other hand, if the new vehicle has demanding and costly requirements placed on it such as engine out, two separate launch complexes, engine separation system, advanced avionics, Shuttle compatible payload bay, STS heritage, man-rateable, etc., then suddenly its competitive advantage is greatly diminished. The present STS and Titan IV vehicles — costly or antiquated as they are — don't require major DDT&E money nor are they that inefficient in operations cost by comparison to NLS, especially if projected launch rates are modest. The STS operations cost reduction effort, which is now underway here and at other NASA centers, is intended to reduce STS operations cost 3% per year for 5 years or $1.8 billion overall. These efficiencies will surely be applicable to NLS as well. They also free up money which hopefully can be applied to a NLS new start.

W. Edward Denning, the father of TQM, says *"If you always do what you've always done, you'll always get what you always got."* Clearly we must do something different if we are to make NLS a reality. For NLS to attain congressional and national approval, it must show technical and cost advantages over the present launch systems. I will leave the technical superiority discussion to others and concentrate on the cost justification. NLS must be capable of providing low cost transportation for payloads and yet achieve this aim within a DDT&E budget which will surely be constrained both in total and year-by-year costs. *To fulfill this difficult goal, NASA and the Air Force must put major emphasis on cost containment and adopt a new development culture where (1) the cost impact of every program decision is carefully weighted before implementation, (2) where low operating costs drive every design trade, and (3) where NLS management make design and program architecture converge on costs rather than vice versa.*

I envision a NLS cost containment system which would be an interactive process forcing cost, technical and schedule to function together, interlocked in a controlled and viable management system. While "zero cost growth" is not possible, "cost containment" within acceptable bounds is an achievable management goal. NLS which involves many program elements, centers, contractors and a NASA/Air Force partnership, has unforeseens and unknowns which can not be totally anticipated. Even with descoping of technical requirements, schedule adjustments and cost contingencies, some cost growth is likely. With an integrated cost containment plan fully supported by NLS management, such cost growth can be minimized and contained. This managed containment will permit a viable NLS program to proceed in a very cost effective manner.

STEPS TO NLS COST CONTAINMENT

The proposed cost containment framework consists of five key steps as shown in Figure 6.

1. **Establish the baseline program.**
2. **Establish cost targets and contingencies.**
3. **Establish cost containment management systems.**
4. **Perform tracking, analyses and evaluation.**
5. **Make timely, informed decisions.**

Figure 6. Five Steps to Cost Containment

The approach for NLS cost containment is an evolutionary process starting with program definition and continuing through design, development and operations. Cost containment can best be achieved through a systematic approach for establishing meaningful and achievable technical, schedule, and cost baselines and the effective integration and implementation of this program.

The NLS cost containment system is obviously considerably more involved than can be detailed in this short paper. Many on-line, existing mangement systems would be utilized, although in a more coupled and dynamic manner; several new systems would be introduced; more emphasis would be placed on cost and schedule estimating; techniques such as risk assessments, trend and variance analyses, action tracking and independent evaluations would be used to a greater degree; and fall-back and alternate solutions would be developed ahead of any need. In summary fashion, the five steps to achieve the NLS cost containment goal are explained below.

(1) *Establish the baseline program*
The crucial program definition work cited earlier must be done for NLS. Requirements definition and preliminary design work must establish a baseline which (1) supports user needs and (2) is operability focused. Critics of NLS would say that neither of these keystones are presently in place. Now is the time to focus on these two areas in sufficient detail to allow the program to move through what has almost become a "go-no go" gate. This baseline provides the basis for detailed and realistic schedule and cost estimates. Obviously this is an iterative task with many trades performed to insure that NLS requirements are cost optimized. Appropriate design margins must be included and the operations and user impacts of requirements and preliminary design work must be given the highest priority. Cost analysts and designers must work closely together in a proactive environment. Mission success should continue to be the primary emphasis, but with a proper balance of schedule and cost considerations. Contingency plans should be developed at the outset for each program element that would allow for fall-back positions in the event technical problems or budgetary ceilings are encountered that impact established technical, schedule or cost baselines.

(2) *Establish cost targets and contingencies*
A tailored design-to-cost approach should be implemented where specific cost goals are assigned, ownership assumed, designs traded and cost maintained within these target values while still meeting technical requirements. Adequate cost reserves should be established and used very judicially. For the most part, cost increases in one area must be offset by reductions in other areas. A concerted effort should be made to instill in all NLS participants the idea that the challenge of cost containment can be met. Appropriate rewards and incentives would have to be incorporated at all levels to motivate participants. Education and training programs would be required to influence, or perhaps even change, individual mind-sets in order to achieve the desired results.

(3) *Establish cost containment management systems, controls and reporting requirements*
Program management processes, tools and techniques that are currently being used would have

to be augmented with new and innovative ideas. In this enlightened age it is now possible to develop interactive cost, technical and schedule reporting, planning, tracking and control management systems complete with projected alternatives and options and their associated risks and costs. Problems could thus be identified and fixed early before they create "show stoppers". Likewise, resources could be allocated to the choke points and technical and management talent directed to the high priority tasks.

(4) *Perform tracking, analyses, assessment and evaluations.*
Cost containment cannot be accomplished from tracking and statusing alone. Nor can it be accomplished if cost, technical and schedule are dealt with as individual entities. This step provides the data and recommendations used for NLS program decisions and problem resolutions.

The program control tools, procedures and processes, cost estimating models, and the program status and tracking system would be used to manage the NLS program, identify potential problems and to develop alternative approaches. The baseline would be in the form of a logic network model, resourced, time phased and risk quantified. Individual nodes with the greatest risk would be analyzed for alternative approaches to eliminate or abate risk. Development of alternative approaches would be a continuous process. Network modeling and simulations would reveal areas of greatest risk to cost and schedule. In addition, trend analyses would reveal unfavorable cost or schedule trends which would be evaluated. Potential problems would also be identified from such sources as program reviews and program documentation or from the program status tracking effort. From these, alternative approaches would be developed and iterated until the most suitable approach is attained within cost containment consideration. Of course, the key to identifying alternative approaches lies not in the automated system or model but in the "human element"; the ability of the engineer/analyst to identify those areas where risk may be excessive and to formulate alternative solutions.

(5) *Make timely, informed decisions.*
Containing cost while maintaining program continuity is a difficult undertaking. However, decision making when supported by timely and accurate data, trades studies, and risk analyses as described above, would become a far less hazardous(and sometimes, haphazardous) endeavor. It still would require experience, common sense, management and technical judgement — and the ability to say "no" to good ideas and proposals if they exceed the program's requirements or costs. Given these attributes, plus immediate access to valid, timely and concise data, NLS technical and management personnel can provide this nation a needed and cost effective new launch system.

BOTTOM LINE

NLS must take full advantage of the "age of information" in which we live and use this information to plan, to execute and, if necessary, to change. NLS must begin with well-grounded requirements which are consistent with user needs and operability considerations optimized to acceptable low cost solutions. NLS must stay the course with cost, technical and schedule interlocked and armed with good data to support every decision.

Cost containment has never been easy. Cost containment will never be very easy. *But cost containment within acceptable limits is achievable with good data, good tools, good people and determination.*

The views and opinions expressed by the author in this paper are his own and are based on his 30 years of experience in aerospace cost estimating and analysis. They do not necessarily reflect any official position of ARI, USBI, NASA or the U.S. Air Force.