

Predicting Mission Success in Small Satellite Missions

Mr. Mark Saunders

Mr. Wayne Richie

Mr. John Rogers

Ms. Arlene Moore

NASA Langley Research Center

Hampton, VA

USA

Abstract

In our global society with its increasing international competition and tighter financial resources, governments, commercial entities and other organizations are becoming critically aware of the need to ensure that space missions can be achieved on time and within budget. This has become particularly true for the National Aeronautics and Space Administration's (NASA) Office of Space Science (OSS) which has developed their Discovery and Explorer programs to meet this need. As technologies advance, space missions are becoming smaller and more capable than their predecessors. The ability to predict the mission success of these small satellite missions is critical to the continued achievement of NASA science mission objectives. The NASA Office of Space Science, in cooperation with the NASA Langley Research Center, has implemented a process to predict the likely success of missions proposed to its Discovery and Explorer Programs. This process is becoming the basis for predicting mission success in many other NASA programs as well. This paper describes the process, methodology, tools and synthesis techniques used to predict mission success for this class of mission.

Nomenclature

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| AO | Announcement of Opportunity |
| CDR | Critical Design Review |
| CoDR | Concept Design Review |
| EMI | Electromagnetic Interference |
| GDS | Ground Data System |
| NASA | National Aeronautics and Space Administration |
| OSS | Office of Space Science |
| PDR | Preliminary Design Review |
| PRR | Preship Readiness Review |
| WBS | Work Breakdown Structure |

Background

In response to the constrained budgets and the science communities need for more frequent scientific flight investigations, the Office of Space Science has developed an acquisition strategy designed to reduce the overall cost and schedule of small satellite missions. This reduction has been achieved by soliciting entire science investigations from the scientific community, capitalizing on the strengths of open competition and peer review. The science investigator is responsible for the total mission, including the development of the science objectives, the design of the instruments, spacecraft, and mission operations centers and the collection of science data and the subsequent data analysis. A process for evaluating these science investigations from a technical, management and cost perspective has been developed by OSS and NASA Langley Research Center to allow the best achievable science to be conducted.

To ensure equivalent science investigations can compete on an equal footing, the Explorer Program is divided into three different classes of missions: Medium Class Explorers (MIDEX), Small Class Explorers (SMEX), and University Class Explorers (UNEX). OSS solicits proposals for each of these about every two years. The Discovery Program is not divided into different programs and solicits proposals approximately every 18 months. The Discovery Program and MIDEX solicitations are usually conducted through a two-step process with formal proposals submitted in response to an Announcement of Opportunity followed by a competitive funded study period with 4-6 proposals selected from the first step. The Small Explorer and University Explorer investigations are usually selected for flight after only a single proposal stage.

When acquiring science investigations through this technique, the Office of Space Science typically assesses science investigations proposed to Discovery and Explorer Program series with 4 evaluation criteria:

1. Scientific merit of the investigation
2. Feasibility of achieving that science objectives
3. Feasibility of the mission implementation approach
4. Social benefits of the investigation

Typically, two separate panels conduct the evaluations. A science peer review panel is responsible for assessing the scientific merit of the science investigation and the feasibility of achieving the science objectives. A technical, management, cost and other program factors (TMCO) panel assesses the feasibility of the mission implementation approach and the social benefits of the investigation. For proposals that respond to the second step of the two-step approach, OSS usually convenes a single panel to assess the results of the funded study. In general, this second review examines the higher fidelity designs and development plans, but does so in a similar fashion to the initial evaluation. Unless the science has changed, the scientific merit of the investigation is not reassessed. Once selected for flight, the mission is subjected to at least one more formal confirmation review. Again, this review will look at the same elements of the mission, but at the level of fidelity at the Preliminary Design Review (PDR). This review is consistent with NASA's review requirements specified in the NASA Procedures and Guidelines (NPG) 7120.5A, Program and Project Management, dated April 3, 1998.

Evaluation Overview

The ability to predict the successful achievement of space science missions proposed to the Discovery and Explorer programs requires examination of all elements of these proposed science investigations. These facets include: scientific objectives; scientific instrument capabilities and development; mission design; spacecraft design, development and integration; launch integration and operations; mission and science operations; and finally science

data analysis and archival. Each of the implementation aspects is examined by scientific peers and technical and management experts to determine the likelihood that the element can support the scientific objectives. The results of these analyses are synthesized and integrated into cohesive conclusions. Since the uncertainties driving a team's ability to deliver the hardware and software necessary to achieve scientific success become clearer as the science investigation/mission proceeds through its design and development, the ability to predict improves as the development progresses. To compensate for uncertainties early in development, the technical, cost and schedule resources are examined carefully to ensure that there are adequate reserves and margins for the current stage of development.

- The technical approach is examined in detail to determine the level of understanding and feasibility of the technical design details, the areas of unknowns, the trades necessary to resolve those unknowns, and the technical resources (for example, mass, power, data), particularly the reserves and margins that are available to handle the uncertainties and risks;
- The management and organization are examined to determine if the project organization matches the development approach and provides adequate skills, processes and management tools to ensure problems can be foreseen as they arise; and
- The costs and schedules are analyzed to ensure that there are adequate resources to meet the engineering, manufacturing, integration, operation and data analysis elements of the project required to achieve the scientific objectives.

Since the success of the technical development and subsequent mission and science operations depends on both the management and organization and the cost and schedule resources, all analyses are synthesized and integrated through a comprehensive process of examining the interrelationships between the three different areas. This *synthesis* is the essence of NASA's ability to predict mission success. Each of the three areas (technical, management and cost/schedule) will be described in detail, followed by a description of

how these three areas are integrated to arrive at an overall prediction of mission success.

Predicting Technical Success

Most space mission teams proceed through a similar and standard design and development process. Once the team has established its scientific objectives (or other objectives such as commercial communication) and the payload necessary to meet these objectives, they begin to look at the overall requirements that the payload will place on the rest of the system architecture. From this the team can develop a mission concept and a system architecture which satisfies the basic system requirements. This typically includes the weight, power and data requirements for the payload. From this the team can estimate the weight, size, power, data and communication requirements for the spacecraft and ground systems. Given the weight and size of the spacecraft the team can determine the appropriate launch vehicle and mission design to meet the technical objectives. Following the development of the system architecture, the team refines the design through increasing technical definition, system trade studies, and subsystem design. This process usually follows a similar path from the concept development and technical definition, through preliminary design, detailed design, fabrication, assembly, integration and test leading up to delivery of the system to the launch site. At each stage of design and development the unknowns are reduced and the margins for uncertainty are better defined. If teams are using the current state of the art, there is no reason why they shouldn't be able to deliver the planned system (with all technical objectives met) on schedule and within budget. If this is true, then why are some missions successful and others not. Although technical difficulties do not in themselves lead to failure, there are generally three reasons that contribute to why missions are not successful. First, mission teams assume that they understand their mission well enough to ignore the standard rules of thumb on design margins such as mass margins. Second, teams assume that they will not encounter significant difficulties in developing new technologies or advancing the state of the art necessary to enable their mission. Third, teams do not methodically, rigorously, and judiciously control and safeguard project resources (margins for

mass, power, cost, schedule etc.) throughout the project life cycle. As the realities of system design and development occur, teams are forced into using up margins and taking greater risks to overcome development problems.

The OSS/LaRC technical evaluation process is a systematic approach to examining each element of the system design, development approach, and operations plans. The evaluation teams include experts in management, mission design, spacecraft design and development, instrument design and development, mission operations, and ground data system design and development. Since OSS examines missions at various stages of development, these evaluation teams expect the level of design/development maturity to be commensurate with the point of the planned overall development schedule.

Mission Design. The evaluation begins with examining the overall mission architecture to ensure that the mission team has considered all the elements of the system completely and correctly. In early stages of concept development, it is not uncommon for teams to develop architectures which have elements that do not work well together. The criticality of this mistake depends on the degree of freedom that the team has left themselves in terms of technical, schedule and cost margins to solve problems. If teams have adequate margins, this type of mistake may not be considered a showstopper, but developing workable architectures will ensure that the mission is viewed in a positive light. The system architecture is also examined from a complexity and flexibility standpoint. How hard is the mission to accomplish correctly and what degree of flexibility does the team have if problems occur during the mission? After examining the system architecture, the technical parameters of the mission design (launch energy and trajectory, orbit parameters, deep space trajectories, etc.) are verified through orbital mechanics analytical tools. In the early stages of development these analytical tools require definition of assumptions (e.g., propulsion Isp) which can affect the outcome. It helps when the teams provide sufficient information to minimize the assumptions made by an evaluation team. This is particularly critical when discussions between the proposing team and the evaluation team are limited.

This case usually occurs during the formal solicitation process. For OSS missions the follow-on reviews usually allow adequate discussion to illuminate misunderstandings. However, in attempts to maximize the return on investment in terms of the maximum payload, many teams make overly optimistic assumptions which may erode mass and power margins later in the development. Finally, mission duration and launch window constraints are considered when assessing the likelihood that the mission can sustain long operations periods or be launched during tight launch windows.

Spacecraft Design. The level of maturity of the spacecraft design is evident by the depth of the system and subsystem descriptions, block diagrams and equipment lists. Experts familiar with spacecraft design determine if the various sub-systems interface appropriately, are composed of appropriate hardware and software and have adequate contingencies for the heritage and complexity of the design and the development stage (See figures below. Note: these contingency represent minimum reserves for expected growths. *Margins for unplanned/unexpected growths must be added on top of these contingencies*). In addition, the level of redundancy and reliability is examined in light of the length and risk of the mission. When new technology or advances in the current state-of-the-technology are required, back-up alternatives to these technologies are reviewed to ensure that they are feasible and can be implemented at the proper time. If no back-ups are planned, the schedule and cost margins are particularly important as the methods for managing the technology risks.

The mission duration and the design life of the spacecraft are carefully considered when examining the levels of redundancy, reliability and parts quality planned for the spacecraft. The ability of the spacecraft to gracefully degrade can alleviate some reliability concerns, but the level of spacecraft reliability needs to be commensurate with the mission duration and impact of failure to accomplish the mission objectives.

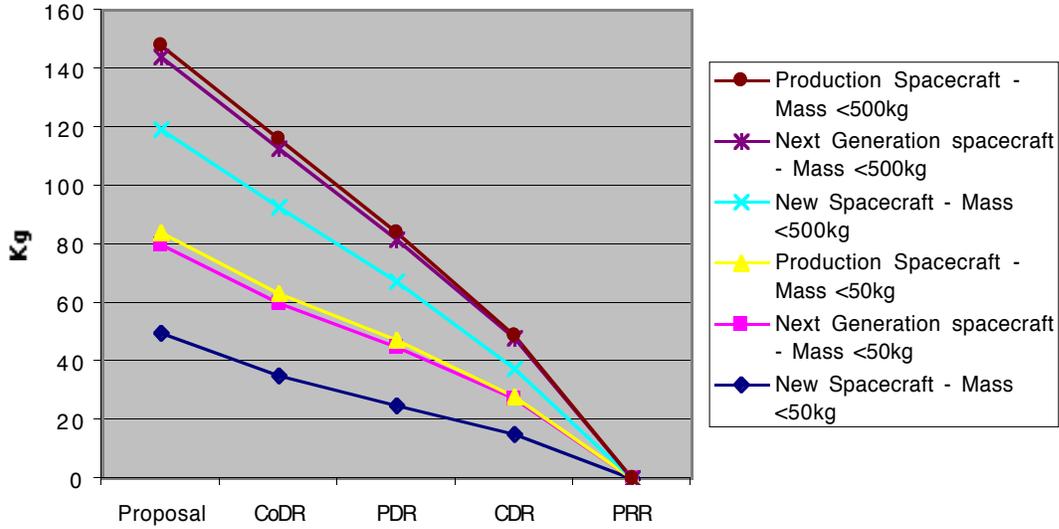
Although the trend is toward integrated hardware and software development, software development is sometimes overlooked by proposers as a critical development area. Review teams expect to see a rational sequence and approach for developing, testing and verifying the flight hardware and software.

During the last 10 years, the size and cost of missions have come down considerably. This has allowed more missions to be accomplished. Since this has permitted the simpler missions to be accomplished, new missions are beginning to be significantly more complicated. The number and complexity of the mechanisms are risk factors that must be handled appropriately. In these cases, the degree of hardware qualification for the planned environment and operation is particularly important. Accommodating failsafe features into these complex systems enhances the mission's reliability by providing opportunities to continue other portions of the mission when failures occur. If failsafe features are not incorporated, missions may not be successful.

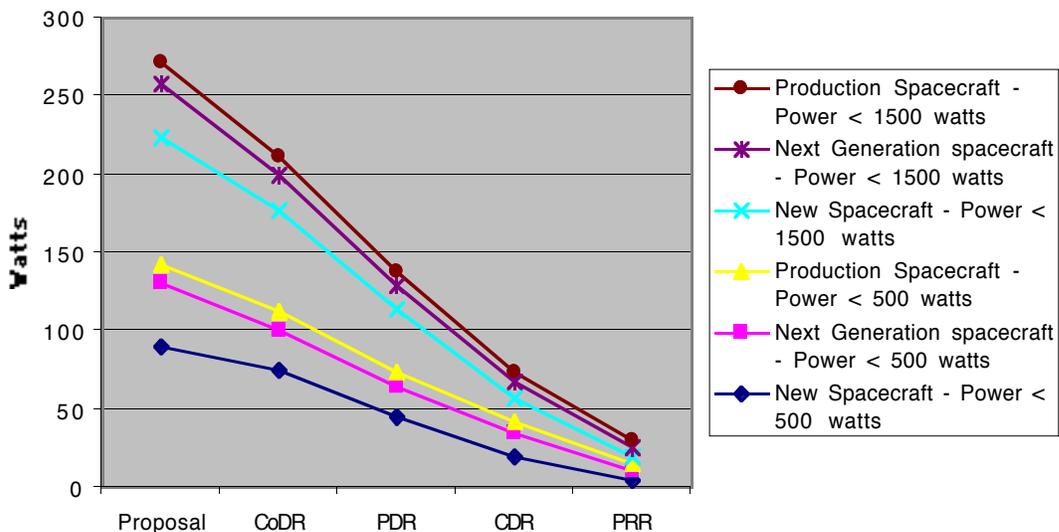
In the early stages of the design process, the mission team is faced with many system trades in arriving at the most optimum design. The plan for and the status of these trades, the conclusions drawn and the processes used to conduct these trades reveal how well the team is addressing the many design decisions.

To substantiate expert opinions and to ensure thoroughness in our reviews, analytical design tools are used to verify that the proposed spacecraft has the resources necessary to meet system requirements during mission operations. Although these tools are not perfect, they highlight design areas where resource stresses occur and allow reviewers opportunities to examine, in depth, how well the design operates. Thus, mission teams will benefit from including the best and most complete information in proposals or review packages.

Minimum Standard Weight Contingencies (Percent Ref. 1)



Minimum Standard Power Contingencies (Percent Ref. 1)



Payload Design (including Payload to Spacecraft interfaces). The payload is examined in much the same way as the spacecraft. The maturity and completeness of the designs are compared to the postulated point in the development process to ensure that planned development activities are appropriate. Margins, technologies and redundancies are evaluated in light of the payload complexity, technology readiness and heritage. The complexity of the payload is compared to the state of development and qualification plans. Finally, the payload requirements on the spacecraft and ground systems are compared with the level of technical resources (e.g., power) available to ensure that the payload will be allowed to perform as specified. The payload-to-spacecraft interfaces are examined for complexity and thoroughness. A traceability matrix, which starts with the science objectives and walks through the mission, instrument, spacecraft and ground system requirements is extremely helpful in understanding how well the system is designed to meet the mission objectives.

Mission Operations and Ground Data Systems (GDS) Design. The mission operations and ground data system designs must be compatible with the spacecraft and payload designs so the mission planning and subsequent operations plans are evaluated to ensure they reflect a reasonable and adequate approach. The mission operations and ground data system architecture can be as important as the flight hardware and software and can have as big an impact on mission success. Missions have a better chance of succeeding when the mission operations and ground data systems are developed concurrently with the flight system. This allows both systems hardware and software to begin working together early enough to identify problems that might occur. Mars Pathfinder used this technique to reduce the cost of the GDS by several factors by using existing hardware and software as part of the flight system test equipment, and most of the Discovery missions are following this example.

The technical aspects of the mission design affect how well the mission can be operated and thus must be carefully examined against the operations concept. The spacecraft operations can be complex requiring very sophisticated software that must be verified prior to use. If the software is not planned to be loaded on the spacecraft prior to launch, then

a version of the spacecraft hardware and software is required on the ground. Having this type of capability has also proven very effective when trying to resolve spacecraft anomalies after launch. The communication links between the spacecraft and the ground stations must have sufficient margin to ensure that the data can be adequately retrieved. The geometry between the spacecraft, the Earth and the Sun can affect this greatly. Since the ground antennas can be heavily committed, the need for these assets or the need to build new ones must be planned. When existing facilities are a significant part of the mission operations strategy, it is important to demonstrate the availability of these assets through commitments by the asset owners.

Finally, the drive for lower cost mission operations is leading to more innovative approaches. These new approaches must be carefully thought out and tested before fully implementing. CONTOUR (Comet Nucleus Tour), Discovery's sixth mission, is designed to go into a hibernation mode between comet encounters. During this period, the spacecraft is placed in a safe mode and left unattended for months at a time. Given the recent Lewis spacecraft failure, where the spacecraft was left unattended for brief periods; i.e.; weekends (and subsequently lost), this method will need to be carefully proven prior to full implementation.

Development Approach (including manufacturing, integration and test).

The development approach is considered as important to mission success as the ability of the design to meet its requirements. Having an adequate approach and sufficient time to accomplish the development is critical to success. Many mission teams are going to a protoflight development approach (where the development unit is ultimately flown). Although this increases risk somewhat, it is proving acceptable in missions where technology is not a big driver. When new technology is required, more traditional development strategies with prototypes, brassboards, breadboards, engineering models, etc. allow development problems to be rectified prior to investing in the flight hardware. Regardless of the development strategy chosen, each element of the development plan is carefully looked at to ensure that implementation of the design can be achieved.

The schedule is compared to the planned development activities to ensure that sufficient time is available to meet delivery requirements and to overcome development problems that will occur. Depending on the degree of difficulty of the development, one month of schedule slack per year of development time is a reasonable rule of thumb. If the development is particularly difficult, at least 1.5 months of slack/year may be necessary.

The methods for hardware flight qualification are an important aspect of the development plans. If heritage hardware is planned, the team needs to consider how close the qualification of the original hardware matches the planned usage. Many teams are now routinely performing heritage reviews to identify how well the hardware meets the planned system performance. Part of the Lewis failure, however, has been attributed to inappropriate use of heritage (hardware use did not match the original usage) which resulted in a flawed attitude control system design. For new pieces of hardware, particularly mechanisms, lifetime testing is also needed to enhance the likelihood of successful operation in orbit. The Genesis spacecraft (Discovery's fifth mission), which has extensive mechanisms, is planning life testing at over 2 lifetimes to ensure confidence that the hardware will work on orbit.

As always, software development and testing must be matched to the hardware development. Concurrent software development allows the hardware and software to be tested in testbeds early in the development flow so that the bugs can be worked out. When software development is decoupled from the hardware flow, additional schedule reserve needs to be included to work out the software bugs. Early testing also allows for more burn-in of electronic components. Adequate burn-in is often overlooked or considered a luxury. Increasing the burn-in can increase confidence that the early failure modes have been eliminated, particularly for single string systems.

The completeness of environmental testing to verify that the system will operate as designed in the various mission environments (radiation, temperature, solar, vibration, acoustic, EMI, etc.), is also examined. Skipping tests when schedule or cost pressures arise increases the risk to mission

success. Equally important is having adequate time in the schedule to resolve flight system anomalies found during testing. Invariably, workmanship or design flaws are found during this period that must be resolved prior to launch, and if at all possible, retested.

Finally, the launch site activities are examined to ensure that the team has allowed adequate time for shipping, flight system to launch vehicle integration, hardware testing, fueling, etc. For many missions, the launch window is very short, therefore it is critical that launch preparations have adequate schedule time with margin to accomplish these tasks.

When examining the development approach, the review team also looks carefully at the various development plans and processes to ensure that they are appropriate and complete for the given stage of development. Adequate systems engineering is an essential part of both the design and the development process. Through this discipline, integration and orchestration of the entire design/development is accomplished, and resolutions to development problems can be worked without inadvertently impacting other parts of the system. In addition, system engineering maintains track of system resources and configurations. Test and verification plans reveal the degree to which the mission team plans to qualify, test and verify system performance. Adequate configuration control gives confidence that what is being tested matches plans. Finally, the quality assurance program is examined to assure that the plans and processes will ensure an acceptable quality product. ISO 9000 certification is now becoming a requirement and the degree of certification improves confidence that the mission team has the right processes in place.

Predicting Management Success

The successful execution of the design and development processes are dependent on an effective management approach. The organizational structure needs to be matched to the work and should be as simple as possible. Simplicity allows less complicated project control techniques and processes, but is not always possible. Many projects have large organizations

with each organization responsible for an element of hardware or software. As the complexity of the organization grows, the importance of effective project control techniques and tools is increased. Appropriate performance measurement systems and receivable/deliverable systems go along way to keeping management informed of development progress. Coupled with these, a good systems engineering team and systems engineering process will ensure that decision data is the best information available. In both large and small organizations responsibility, authority and accountability need to be matched and the decision-making process clear to all members of the team. Many development problems can be attributed to confused lines of authority, which inhibit decisions necessary to move through the development process. A key indicator of the quality of the management approach is how well the work breakdown structure corresponds to the organizational structure. When these are poorly matched, the lines of authority and responsibility are obscured.

Despite the desire by organizations to want to move into new business areas, successful past experience in performing the functions assigned is a very good indicator of the likelihood of success in similar functions for new missions. Unfortunately, organizations without experience, do not usually fully understand all the pitfalls related to a given task. The quality and experience of key personnel is equally important. Most of the new smaller mission are fast tracked with little margin for error. Individuals in leadership positions must have adequate training and experience if the project is expected to be delivered on time and within budget. The project personnel can expect to work overtime so full time or near full time commitments are important to ensure adequate attention to details. As obvious as this may seem, the continuing pressures to do more with less encourages organization to assign more responsibilities than is sometimes prudent.

Procurement strategies and subcontract management cannot be overlooked since much of the mission hardware will be procured. Mars Pathfinder assigned a procurement manager to track the progress of procurements, and this proved extremely beneficial. This person assisted the project manager in deciding the best procurement

strategy, including incentive plans, and reported on the progress of hardware development and deliveries. This allowed early warning of procurement problems so that adequate management attention could be applied to mitigate delivery issues and to develop work around plans.

Regardless of the management approach, risk management and mitigation is critical to the success of any project. Without adequate risk management, it is impossible to predict whether a given mission can be successful, and NASA has now made this mandatory for all NASA projects. A comprehensive and tailored risk management plan should be developed as soon as possible in the project life cycle, and then followed rigorously until the project is complete. This plan needs to encompass not only technical issues, but schedule and cost as well. Risk management and mitigation involves understanding the project's entire technical, cost and schedule envelope (all margins) so that problems may be resolved through the application of the appropriate resource. For example, mass problems might be solved through the application of cost reserves, or technology development problems might be overcome with schedule reserves. Review teams look for evidence that the mission team understands the risks associated with their individual mission and have planned actions to deal with them. The identification of appropriate specific risk items, the affects of those risks on the project and the methods for analysis, tracking and mitigation (e.g., fallback options) indicate a good understanding of the problems ahead and how to keep them constrained. Descope plans are also a necessary part of the risk management plan, but these should be used as a last resort. When descope plans are developed, it is very important to identify for each descope item the appropriate decision date and the impact on the mission.

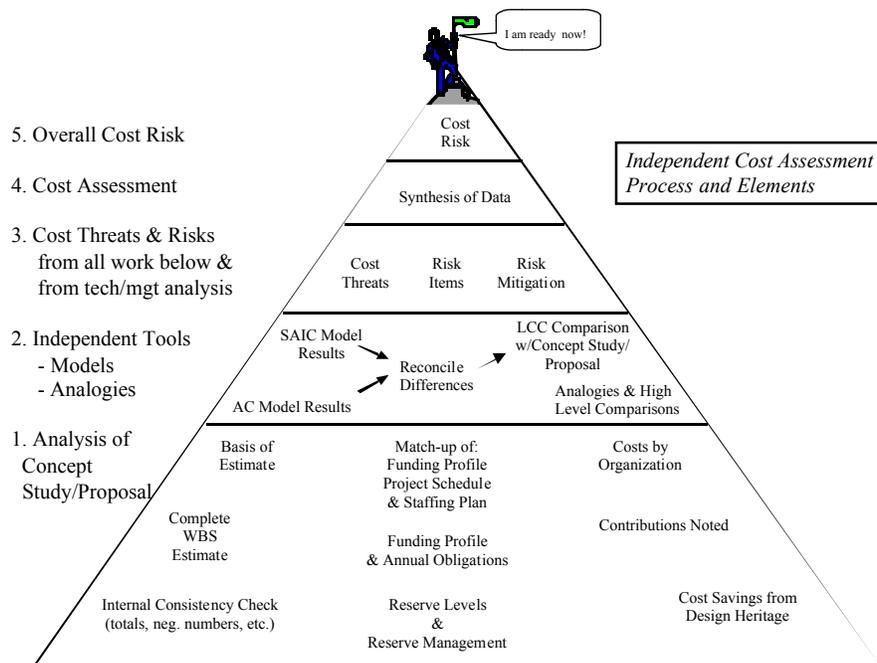
Predicting Cost Success

Predicting cost success is one of the most misunderstood elements of predicting mission success. Most of this can be attributed to a lack of understanding on how good cost analysis is conducted. This lack of understanding comes in part from the decoupling of cost from the technical aspects of the mission and from a lack of proper

utilization of analytical cost tools. However, cost modeling is no different than technical analytical modeling. The results are only as good as the correlation of the analytical model with the system being measured. Unfortunately, correlation of cost modeling is not as easy as it may seem. The OSS/LaRC cost analysis method is designed to provide the most complete assessment possible. The figure below is a graphic representation of the elements of good cost analysis and how each element builds to form a comprehensive view of a given mission's budget. The objective of this cost analysis is to verify the mission team's cost estimates, not to develop a NASA estimate for what the mission should cost. As always, it behooves the proposer to provide as much and as convincing data as possible to substantiate their proposed costs. However, many teams assume too much optimism in the development process without supporting evidence. This usually leads to a higher risk assessment conclusion by the evaluation team.

The cost analysis begins with a detailed review of the project's cost documentation including: the WBS, basis of estimate (rationale used by the team in developing their estimate), funding profile, project schedule, staffing plan, costs by organization, contributions (elements provided at no cost) and rationale for savings (heritage, new ways

of doing business, etc.). This review is designed to examine the consistency of all the cost pieces and the rationale behind them. Once the review of the team's data is completed, the technical data from the mission are input into two different cost models. These models require a number of assumptions (e.g. heritage and technology readiness levels), and these assumptions are derived from the technical data presented by the mission team. The results of the two cost models are compared, and the differences reconciled. These results are then compared with the mission team's estimate. When differences are observed, the differences are examined by cost and technical members of the review team to determine whether the cause is poor correlation or if the mission team's estimate appears unrealistic. However, the cost model results are never used exclusively. Historical cost actuals for similar items are compared with both the cost model results and with the mission team's estimate. This data provides an independent credibility check of projected cost estimates. Based on data provide by the technical and management teams and data from the mission team, cost threats are identified and quantified, if possible. The analytical cost analysis is combined with the cost threats, risk items and risk mitigation approaches (including cost reserves) to arrive at an overall cost risk assessment and rationale.



Synthesis of Technical, Management and Cost Data

Despite weaknesses and flaws found in reviews of each of the technical, management and cost areas, each area by itself may or may not indicate a poor chance of mission success. However, when viewed in the aggregate, the mission may still be considered to have a good chance of success even when significant technical flaws exist. Experience has shown that all development programs will encounter unforeseen events and problems and that overcoming these are linked to all the pieces. Predicting mission success can be tied to the level of maturity of the design/development in relation to the planned state, the degree of technical, cost and schedule margins for the state of the development, and the quality of the management approach and management team.

This can be boiled down to a few simple questions:

1. How hard is the investigation to implement and how well is it understood? Is there enough “envelope?” What are the inherent risks?
2. Will the overall mission design (spacecraft, launch vehicle, ground system, mission ops) allow successful implementation of mission as proposed? If not, are there sufficient resources (time and schedule) to correct identified problems?
3. Does the proposed flight system design and development approach allow the mission to have a reasonable probability of accomplishing its objectives? Does it depend on advanced or new technology not yet demonstrated, or are the mission requirements within existing capabilities? Does the mission have sufficient resiliency in appropriate resources (e.g., mass, power) to accommodate development uncertainties?
4. Does the schedule reveal an understanding of work to be done, the time it takes to do it, and is there a reasonable probability of launching on time?
5. Will the management plan, organization, roles and responsibilities, and experience allow successful completion of investigation?

6. Does the investigation have a reasonable chance of being accomplished within proposed cost?

7. Does the mission team understand the risks and have adequate fallback plans to mitigate them, including risk of using new technology, to assure that mission can be completed as planned? Are the risks and the risk mitigation approaches adequate to give sufficient warning to ensure that they can be mitigated without impacting the mission objectives?

If the answer to all of these questions is positive, then the mission is likely to succeed. For each negative answer, however, the level of risk must rise.

Despite doing or planning to do everything correctly, mission success cannot be guaranteed. There are many intangibles that can affect mission success that the team may have little control over. Some of these intangibles are:

- Political meddling
- Customer meddling
- Adversarial relationships
- Failure of customer to meet commitments
- Poor Communications
- Geographic dispersion of project elements
- Facility problems

These uncontrollable factors can create problems for an otherwise excellent mission. If there are adequate margins in the critical mission resources (cost, schedule, mass, etc.), even these problems might be overcome.

Conclusions

As can be seen, predicting mission success is as simple as the application of good engineering practices and common sense. Most flaws in missions with poor chances can be traced to trying to do too much with too little, whether it is money, time, technical resources, technology or management. Over the past 5 years, mission teams proposing to Discovery and Explorer Announcements of Opportunities have been learning this lesson, and the trend is for increasing numbers of them to achieve low risk ratings with each AO. This is creating a pleasant but interesting

problem for the Associate Administrator of OSS: an abundance of diverse selectable missions to choose from. Since the discriminators are getting very tight, most successful proposals to NASA's Discovery and Explorer programs are typically well into Phase A at the proposal stage. In the end, if missions are technically equivalent, the final

selection may be made solely on the basis of the best science for the dollar cost.

Reference:

1. Guide for Estimating and Budgeting Weight and Power Contingencies, AIAA-G-020-1992