

A Cure For Unanticipated Cost and Schedule Growth

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ABSTRACT

Delivering programs with less capability than promised, while exceeding the cost and planned durations, distorts decision making, contributes to increasing cost growth to other programs, undermines the Federal government's credibility with taxpayers and contributes to the public's negative support for these programs.

Many reasons have been hypothesized and documented for cost and schedule growth. The authors review some of these reasons, and propose that government and contractors use the historical variability of the past programs to establish cost and schedule estimates at the outset and periodically update these estimates with up-to-date risks, to increase the probability of program success. For this to happen, the authors recommend changes to estimating, acquisition and contracting processes.

INTRODUCTION

Publically-funded programs have consistently delivered less than originally planned capabilities and cost more than planned and are late. Because public funds are limited, new programs cannot be started, or worse, they are started and then must be stretched out to fund the overruns of programs that are being developed. In short, the entire portfolio of programs is affected when most of the programs require more funds and take longer than planned. Funding authorizers become skeptical of new proposals because the estimates are not deemed credible. Decisions of choice are distorted since the estimates are in error, or worse, decision-makers know the numbers are biased low and make best guesses which result in poor choices. Furthermore, excessive growth in public programs damages the credibility of the estimating community and contributes to the public's negative support for these programs.

This paper discusses the never-ending problem of cost and schedule growth in publically funded programs and offers some recommendations to improve performance within the current Department of Defense (DOD) acquisition environment. This paper highlights the magnitude of cost and schedule growth within the DOD and the National Aeronautics and Space Administration (NASA) and summarizes some of the known and hypothesized reasons for growth. The paper also summarizes some of the initiatives that have been put in place to address estimating issues but suggests more can be done to improve them, effectively communicate them, and set these estimates high enough to reflect the historical experience so as to minimize or eliminate growth in future programs.

The authors recommend specific changes to the way initial estimates are created and agreed to. In particular, this paper discusses the value of developing activity-based estimates adjusted to account for issues that have occurred on past similar programs.

The authors propose that programs be budgeted at the 70 percent probability of meeting both cost and schedule targets – Joint Confidence Level.¹ They show how this can be done, including active input from the contracting community, and how contract management can be improved through the use of risk registers and periodic probability statements about Estimates At Completion (EAC) and Estimated Completion Dates (ECD). They also enumerate the implementation challenges, and how they can be overcome.

¹ The Joint Confidence Level connects Schedule, Cost, Risk, and Uncertainty in a single assessment of the probability of program success, http://www.nasa.gov/pdf/724371main_76646-Risk_Analysis_Brochure-Final6.pdf

COST AND SCHEDULE GROWTH – A PERSISTENT PROBLEM THROUGH THE DECADES

“In 1982, an unnamed witness at a House Armed Services Committee stated, ‘enough material has been written on the subject of cost growth during the last ten years to fill a Minuteman silo. Unfortunately, cost growth is still with us. In a decade since that testimony enough additional information on cost growth has been written to fill a second minuteman silo.’”²

Table 1 summarizes cost growth associated with NASA and DOD research programs.³ Although this information is somewhat dated, the growth trend has not been materially reduced since the time this study was completed. **Figure 1.0** below illustrates the cost and schedule growth of 30 NASA missions that were developed in the 2007 – 2009 time frame.⁴

| Study | Cost/Budget Growth | | Percent of Projects Which Experienced |
|-----------------------|--------------------|--------|---------------------------------------|
| | Average | Median | |
| NASA in the 90s | 36% | 26% | 78% |
| NASA in the 70s | 43% | 26% | 75% |
| NASA in the 80s (GAO) | 83% | 60% | 89% |
| DoD RDT&E | 45% | 27% | 76% |

Table 1.0. Cost Growth Experience, 2004 NASA Study showing increasing growth over the decades in spite of all efforts to control this growth through improved insight and management processes.

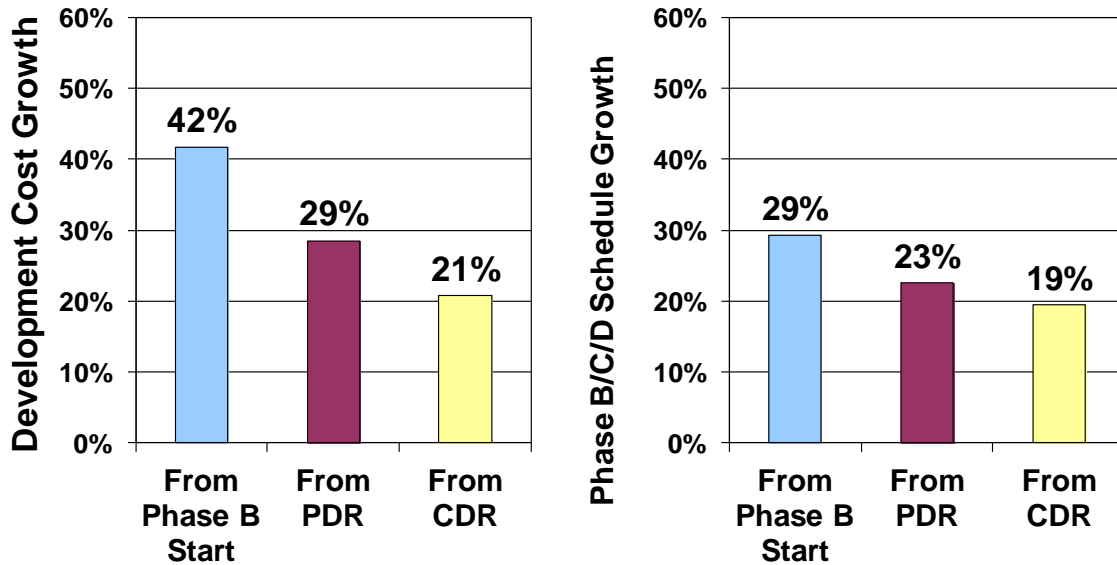


Figure 1.0 – Cost and Schedule Growth of 30 NASA Missions, 2007 - 2009

² Cost Growth in DOD Major Programs: A Historical Perspective, Col. Harry Calcutt, April 1993, <http://www.dtic.mil/dtic/tr/fulltext/u2/a276950.pdf>

³ Unpublished 2004 NASA study performed by Drs Joseph Hamaker and Mathew Schaffer.

⁴ Unpublished 2009 NASA study

Reasons for Cost and Schedule Growth

As stated earlier, volumes have been written about programs failing to provide promised capabilities at the agreed cost and projected completion dates. Most of these studies attempted to categorize the root causes, so corrective actions could be taken. Some of the causes are related to estimating and acquisition initiation activities while others focused on issues associated with management and / or contract execution. One of the more comprehensive studies was performed by Colonel Harry Calcutt in 1993.⁵ Following are Col. Calcutt's reasons for growth organized into five categories.

- Requirements:
 - Poor initial requirement definition
 - Poor performance/cost trade-off during development
 - Changes in quantity requirements
- Estimating:
 - Errors due to limitation in estimating procedures
 - Failure to understand and account for technical risks
 - Poor inflation estimates
 - Top down pressure to reduce estimates
 - Lack of valid independent cost estimates
- Program Management:
 - Lack of program management expertise
 - Mismanagement/human error
 - Over optimism
 - Schedule concurrency
 - Program stretch outs to keep production lines open
- Contracting:
 - Lack of competition
 - Contractor buy-in
 - Use of wrong type of contract
 - Inconsistent contract management/admin procedures
 - Too much contractor oversight
 - Waste
 - Excess profits
 - Contractors overstaffed
 - Contractor indirect costs unreasonable
 - Taking too long to resolve undefinitized contracts
- Budgeting:
 - Funding instabilities caused by trying to fund too many programs
 - Funding instabilities caused by congressional decisions
 - Inefficient production rates due to stretching out programs
 - Failure to fund for management reserves
 - Failure to fund programs at most likely cost

⁵ Ibid, Calcutt, p.17

A second study from DOD's Office of Program Assessment and Root Cause Analysis (PARCA) published a recent report, which categorized growth into two broad categories:⁶

- Inception:
 - Unrealistic performance expectations
 - Unrealistic baseline estimates for cost or schedule
 - Immature technologies or excessive manufacturing or integration risk
- Execution related
 - Unanticipated design, engineering manufacturing or technology integration issues
 - Changes in procurement quantities
 - Inadequate program funding or funding instability
 - Poor performance by government or contractor personnel

INITIATIVES TO REDUCE COST AND SCHEDULE GROWTH

Over the last five decades, the DOD, NASA, and other civilian agencies have implemented numerous policy and regulation changes to reduce growth. This paper does not attempt to enumerate all the initiatives nor assess their effectiveness in combating growth. However, this paper does address those initiatives dealing with estimating and the processes used to establish and manage contractor baseline estimates.

A few of the more important initiatives to improve the ability of the cost estimating community to produce better estimates were:

- Need for independent estimating at all levels;
- Standardized Work Breakdown Structures (WBS) for military systems e.g., MIL-STD 881, and similar structures for NASA and the National Reconnaissance Office;
- Routine cost collection of analogous historical systems upon which to base future estimates;
- Use of a Cost Analysis Requirements Description (CARD) (or similar documents) to be used as a basis for the estimates;
- Use of technical and program management subject matter expertise to assist in developing estimates; and
- Policy requirements to budget to higher confidence levels (80 percent cost confidence level within DOD and 70 percent joint cost and schedule confidence level for NASA projects).

These initiatives are believed to have helped estimators create more credible estimates. Using the actual experience of similar past projects has been particularly useful as it helps estimators explain the basis for their estimates and provides leadership with a reference by which to judge the proposed new systems. However, these data are product-based (based on the systems' WBS) and Program Management Offices (PMOs) often think in terms of the materiel developers (contractors') activities so they find the product-based estimates difficult to consume, particularly when the independent estimates are higher than those the PMO receives from one or more contractors. PMOs frequently discount the independent estimates in favor of the contractor-developed estimates they find easier to understand.

Figure 2 depicts the traditional method in which the cost estimating community develops its estimates. The chart shows that the cost estimate is a function of the value of the cost driving parameter as well as the variability of the costs that have been incurred for the product in the past. The figure illustrates that the higher the input parameter, the higher the cost, but that the estimated cost also depends on the point within the distribution of cost values that have been incurred on past similar programs. Cost estimators prefer to provide estimates at the mean or higher for a given WBS element. Estimates created in this way are considered to be standard acceptable practice and result in credible estimates. However, as noted earlier, the estimates are not always in the same language as the PMO or the contractors and thus are difficult to consume.

⁶ Report to Congress on Performance Assessment and Root Cause Analyses, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, March 2014, p. 7, <http://www.acq.osd.mil/parca/docs/2014-parca-report-to-congress.pdf>

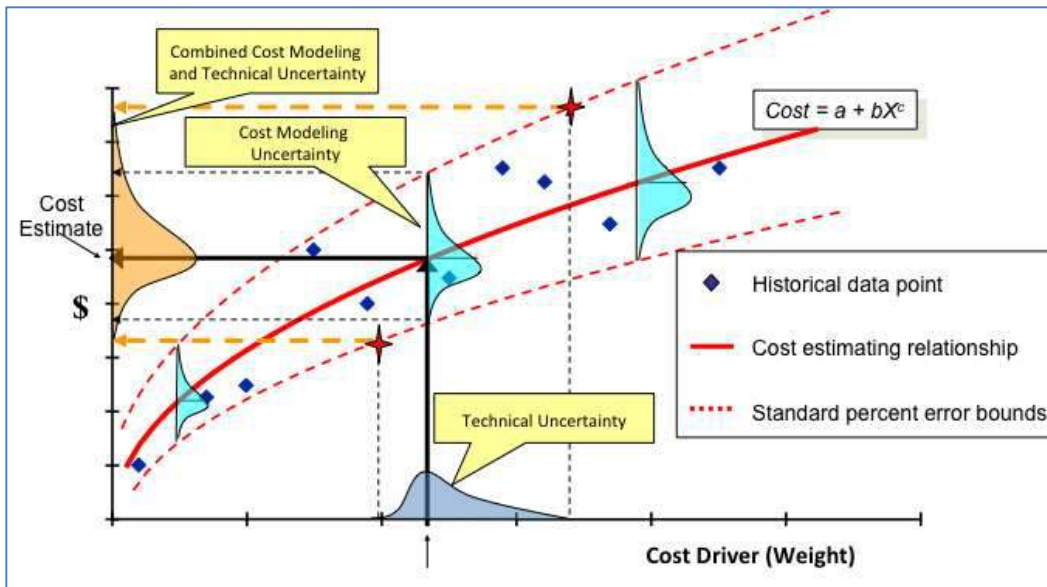


Figure 2.0 – Traditional method of estimating by the WBS product or process defines the variances on the cost estimate compared to the drivers of the cost, in this example the “weight” of the product being produced. The weight becomes a “technical performance measure. Being outside the weight bounds will cost more for the product to be produced.

Figure 3 depicts an activity-based estimate built up using the schedule of activities and the resources associated with the activities. This is known as a cost or resource-loaded schedule that is based upon a set of expected activity durations and costs for the resources. This is the type of estimate that contractors submit in response to RFPs and used to set contract baselines for reporting progress to the PMOs. When independent WBS-based estimates are higher than those submitted by contractors, PMOs find it near impossible to analyze where the extra cost should be added to the contractors' activity-based estimates. Thus, the WBS-based estimates are not as "consumable" as ones that are based on a set of generally agreed activities.

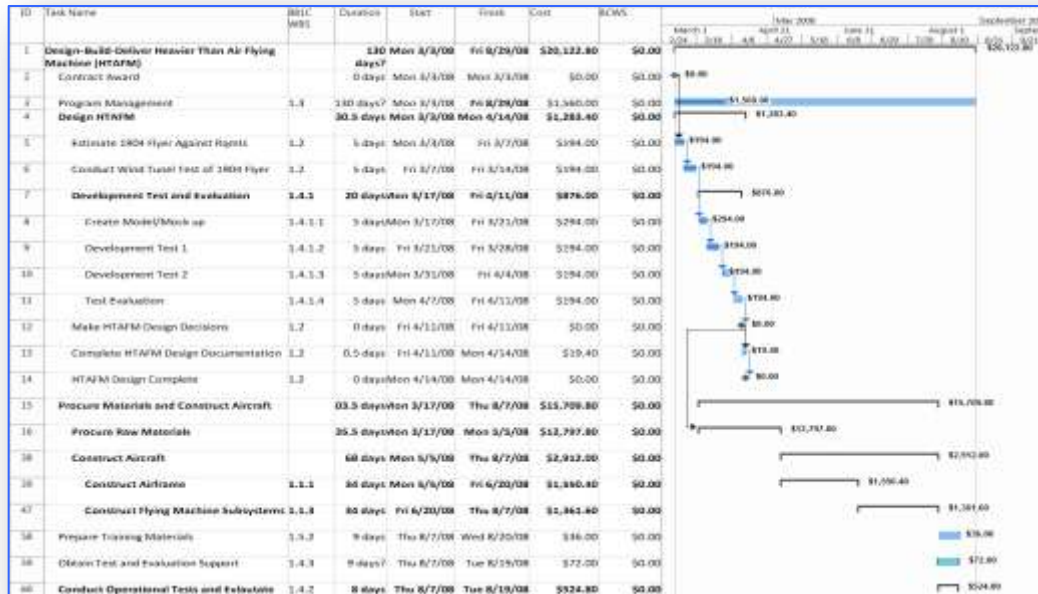


Figure 3.0 – Sample Activity-Based Estimate derived from the Integrated Master Schedule (IMS). Costs are assigned for each work element in the IMS, usually within a Work Package, using the WBS number to identify this unique assignment. These costs are then “rolled” up to the Control Account and then the program at the top. These costs are reported in DI-MGMT-81861’s IPMR Format 1.

A POSSIBLE SOLUTION TO SOLVE COST AND SCHEDULE GROWTH

While activity-based estimates are easier to explain, they still need to be credible and to do so, they too must be informed with the variance of the activity durations and costs from similar historical programs. The variance of the cost associated with an activity-based plan has two components – costs that vary with the passage of time and cost that are independent of time. A good example of a cost that is time independent is material. An example of a cost that is time dependent would be systems engineering or program management which must be in place as long as the program is under development. Similar to the variance in the cost of each WBS element, each activity has a variance in duration and the cost associated with those durations (both time dependent and time independent). In the end, the cost and cost variance of a given system that is aggregated by WBS must be the same of the cost and cost variance that is collected by activities. This concept is depicted in **Figure 4.0** below.

It should be noted that variance of cost and schedules reflect the variation that occur in the “normal” process of developing similar programs. This is referred to as the natural uncertainty that occurs and estimates of future programs must take this into account. Some researchers have labeled this uncertainty as “irreducible” because a manager cannot take specific actions to reduce the “risks”; rather, the manager must just recognize that this variation occurs as part of the normal process of development.⁷ The amount of

⁷ Irreducibility Uncertainty – A Fact of Life for Reserve Estimates, John D. Wright, SPE Annual Technical Conference and Exhibition, 5-8 October, Denver, Colorado, Society of Petroleum Engineers, 2003.

uncertainty that “should” be included has been discussed within the community within the past ten years. The Weapon Systems Acquisition Reform Act of 2009 specified that all major programs within DOD should be budgeted at the 80 percent cost confidence level. That policy for the DOD was recently rescinded in favor of point estimates that reflect “... a confidence level such that it provides a high degree of confidence that the program can be completed without the need for significant adjustment to program budgets.”⁸ NASA requires all programs to be budgeted such that the programs possess a 70 percent probability of achieving both cost and schedule targets. Assuming cost and schedule are independent, identically statistical distributions, this implies an 84 percent confidence level for cost separately.

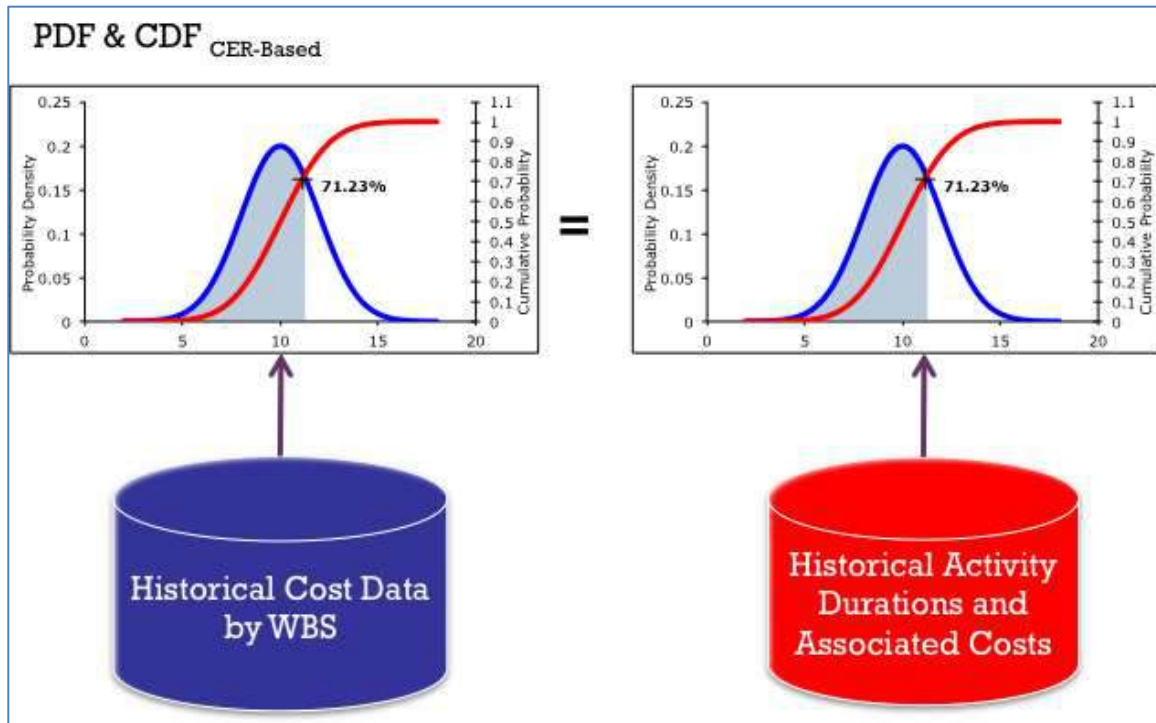


Figure 4.0 – Cost Distributions Are The Same Regardless of Estimating Technique

Some have advocated that estimates just need to be conservative. Others have argued that probabilistic estimating should not be done at all since the historical data are scant and therefore, assessed values reflect the estimator’s judgment and those could be biased and difficult to explain. Yet still others have advocated budgeting programs a high confidence levels (above 80 percent) and perhaps raise it higher if the growth is not contained. Still others have advocated that budgeting programs at high confidence levels is inefficient as certain programs will be over-budgeted and other worthy programs will not be started. Others have argued that high confidence levels will only result in higher costs over time as program managers will expand requirements to use up any funds that appeared to be in excess of those required.

The authors assert that it is not possible to predict in advance which of these scenarios will occur unless setting the budget at some confidence level is tried. The authors observe that the community has never really tried budgeting programs at confidence levels that are based on well-understood historical data. (NASA has only recently done so and it is too early to conclude whether this has had a positive impact on cost and schedule growth). Anecdotal information suggests that some programs within the DOD have been budgeted at a stated 50% confidence level, yet experienced rather significant over runs in costs and

Innovative Design Manufacturing Research Center (IdMRC) – Cost Modeling, 24th International Forum on COCOMO – November 2009.

A Framework for Considering Uncertainty in Quantitative Life Cycle Cost Estimation, *Proceedings of the ASME 2009 Design Engineering Technical Conferences & Computers and Information Engineering Conference, IDETC/CIE 2009*,

⁸ FY2011 Annual Report on Cost Assessment Activities, Director, Cost Assessment and Program Evaluation (CAPE), February 2012, p.7-8.

completion dates in excess of plan. The authors take the position that programs should be budgeted at a higher confidence level (above 80 percent for cost and schedule separately) using agreed to historical data and then observe if this controls the unanticipated growth.

IMPLEMENTATION DETAILS

Setting the budgets at a high confidence level will necessitate modifications in estimating methods (noted above), the contracting process, and implementation. These are described below.

The first step requires that government program offices (PMOs) take a more active role in clarifying requirements, and developing the top-level plan (cost-loaded schedule) with an associated statement about the probability of success (technical, cost and schedule). This top-level plan ought to form the basis for the first draft of the annual resources required. The second major step involves getting feedback from the contracting community concerning the probability of delivering program capabilities for the targeted cost and delivery date. The government will do this by issuing a Request for Information (RFI). PMOs will then analyze industry’s feedback, modify the requirements, budget or time (or all three) and then issue a Request for Proposal (RFP). And finally, along with their technical approach, contractors will submit their cost-loaded plans, risk registers, and probability statements in response to RFPs.

The processes to complete the first major step – development of the RFI – are depicted in **Figure 5.0** below and described in the following paragraphs.

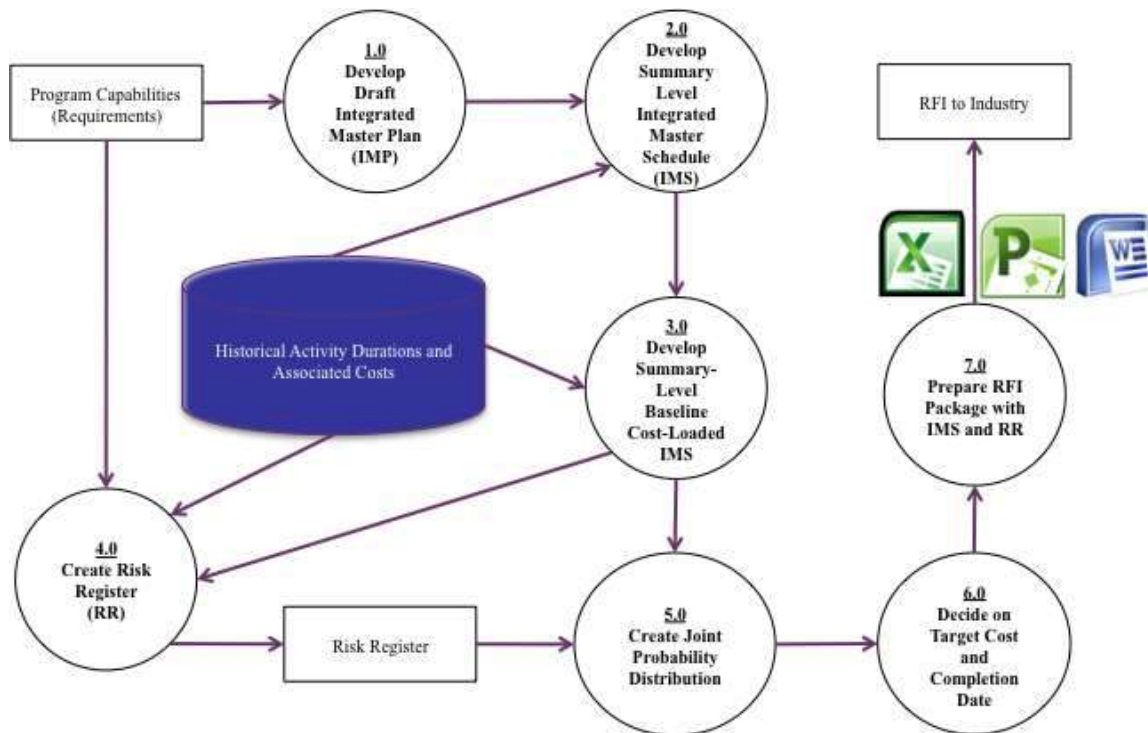


Figure 5.0 – Develop draft plan and obtain industry feedback. This feedback will confirm if the government generated cost-phased estimate is credible from the past experience of industry. This approach is used in Japan’s defense acquisition system. It engages the government and the providers in a dialogue in search of a phased plan that can increase the probability of success for the program

The first step in this process (1.0) is to develop an Integrated Master Plan (IMP). This is a top-level picture of the general sequence of activities needed in order to mature the capabilities desired. This should be developed per the Department of Defense's (DOD's) Integrated Master Plan and Integrated Master Schedule Preparation and Use Guide.⁹

The second Step is to develop a top-level Integrated Master Schedule. This schedule is notional but reflects the PMO's thoughts on how the system capabilities ought to be developed. By its nature, the schedule is high level, but still includes a logical structure of activities. It ought to reflect the PMO's thoughts about which activities can be performed in parallel and which must be serial. The activity durations are based on the amount of time of similar past programs.

In Step 3, the PMO adds the resources (costs) associated with the high level schedule developed in step 2. Ideally, the cost associated with the activities will be available from databases. However, if they are unavailable, the PMO should estimate the costs. Some of the cost information could come from the developed independent estimates but transformed into the number of people, labor rates and material costs. Ideally, these discrete estimates ought to be equal to or higher than the mean of the historical data.

The fourth step is to create a risk register (RR) that will be used along with the top-level cost loaded schedule (developed in step 3) to develop cost and schedule confidence levels (step 5) for the PMO's draft plan. The risk register should contain, at a minimum, information about the variation of the activity durations and associated costs from the historical database. As discussed earlier, this uncertainty represents the "natural variation" associated with developing similar programs, i.e., the irreducible risks. The risk register should also include the specific discrete risks that the PMO feels is unique to the program. This uncertainty (risk) should have an associated probability of occurrence and a cost and/or schedule consequence if it does occur.

In the fifth step, the PMO should use appropriate Monte Carlo simulation software with the Risk Register developed in Step 4 and the top-level cost-loaded plan developed in step 3 to develop cost and schedule confidence levels for the targeted budget and development duration.

In sixth step, the PMO adjusts cost and or program duration to achieve a "reasonable" confidence level. The authors believe that PMO should select a targeted cost with at least a 70 percent joint cost and schedule confidence level (above 80 percent for cost and schedule separately).

Once the RFI has been issued, contractors are expected to review and comment on the PMO's draft plan and answer the following questions:

1. Is the top-level plan logical given the technical challenges and capabilities required? If no,
 - a. What other activities should be included or dropped?
 - b. What changes in logic are required?
2. Are activities durations "consistent" (within family) of their experience?
3. Are the costs "consistent" (within family) of their experience?
4. Is the PMO's perspective on risks realistic? If not,
 - a. Which risks are overstated?
 - b. Which risks are understated?
 - c. Which risks were missed? What is the contractor's assessment of probabilities and consequences for those risks? (Included in their risk register).

Contractors are expected to provide an updated high-level cost-loaded schedule, updated risk register, and associated probability statement of achieving the desired capabilities within the desired budget and duration. These submissions are not considered proposals; rather, they are considered inputs to the PMO on how the contractor might proceed, along with the associated confidence levels for the stated resources.

Upon receipt of the contractors' responses to the RFI, the PMO modifies the top-level plan and creates a Request for Proposal (RFP) that reflects the contractors' concerns and notional plans. This process is depicted in **Figure 6.0** below.

⁹ Integrated Master Plan and Integrated Master Schedule Preparation and Use Guide, October 21, 2005

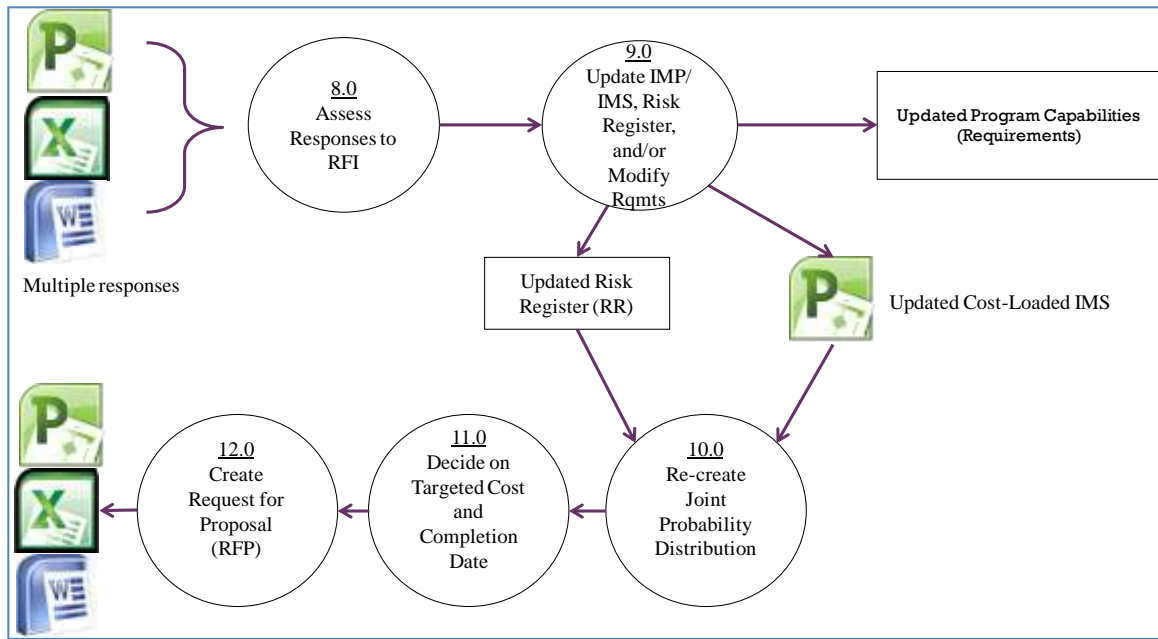


Figure 6.0 – The process to improve the Request for Proposals (RFP) starts with an assessment of the responses from the Request for Information, where contractors provided their cost estimates.

In step eight, the PMO assesses the contractors’ concerns and evaluates their top-level plans, risk registers, and confidence levels on the risk and their reduction through the handling plans. The PMO evaluates and synthesizes the concerns expressed about the capabilities, top-level plan; the risk registers and revises the PMO plan including the budget profile (step 9). Certain capabilities might be dropped or revised to reduce the development risk. The PMO will re-run their Monte-Carlo simulations to determine the confidence levels for the original budget and duration. PMOs increase the budget and/or development period in order to achieve at least a 70 joint cost and schedule confidence level (step 11). Once this is done, the PMO prepares and issues the RFP.

Contractors develop their responses the RFPs in the normal fashion, but will include their final risk registers along with their implantation plans contained in a schedule model instrumented with Monte Carlos Simulation software. The response will include probability statements about the achieving the cost and schedule targets. This response and deliverables should be similar to the cost-loaded schedule submitted in response to the RFI. This process is depicted in **Figure 7.0** below.

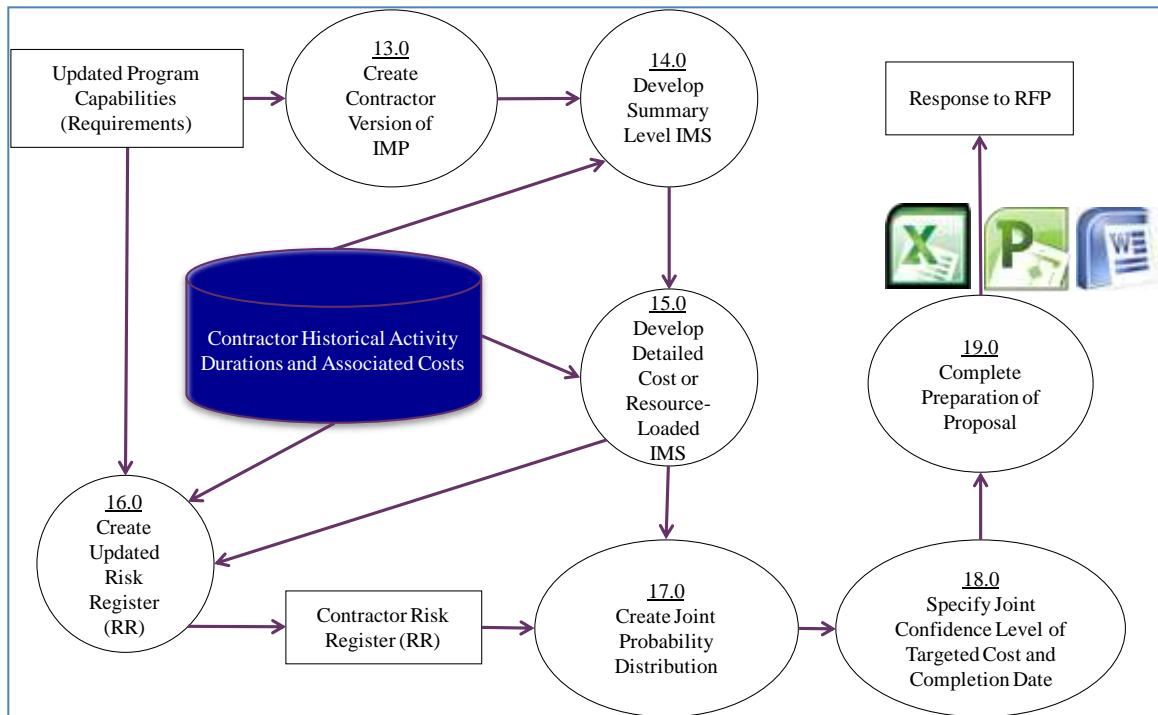


Figure 7.0 – Contractor process to generate responses to RFPs using the earlier cost estimates developed and shared by all the participants in the acquisition process. The government now has a credible estimate of the cost, schedule, and technical performance and makes the selection on “Best Value.”

The next step is the selection of the winning contractor. In addition to other selection criteria, the government will include “Implementation Plan Realism” as part of its selection criteria. Inclusion of the cost-loaded schedule and the contractors’ risk registers will permit the government evaluators to assess the credibility of the contractors’ plans and perspective on risks. Plans which reflect documented actual historical experience, control for the discrete risks, i.e., include resources in their plans to address or control them, and possess a joint cost and schedule confidence levels in excess of 60 percent, should be awarded higher scores.¹⁰

At the Integrated Baseline Review, the contractor will:

- a) Show how progress will be objectively measured in units of measure meaningful to the decision makers, through Technical Performance Measures derived from the Integrated Master Plan. It is essential that technical progress be the driver of the reported cost and schedule progress. Without progress measures that are meaningful to the PMO, the contractor will be unable to propose corrective actions to keep the contract effort “on-track”; and
- b) Develop a Performance Management Baseline (PMB) such that it has at least of 50 percent probability of meeting both cost and schedule targets and demonstrate the contractor possesses sufficient Management and Schedule Reserves (schedule margin) to maintain a minimum of a 60 percent joint probability of meeting cost and schedule targets in its baseline, the contract should be amended (reduce capabilities, increase cost and/or schedule), or be cancelled. Contracts should not be started if the PMB has less than a 50/50 change of success.

¹⁰ The selection of the joint confidence level could vary, but 60 percent is chosen as an absolute minimum. In order to tame cost and schedule growth, contracted efforts ought to have better than 50/50 change of meeting targets.

After the contract is awarded, the PMO and the contractor must actively manage the risks and attempt to develop the desired capabilities while maintaining a high probability of meeting cost and schedule targets. The PMO must do its part by holding firm on requirement changes – a well-known cause of cost and schedule growth. The contractor must communicate progress based on the pre-approved TPMs, and evolving risks. The contractor should submit updated plans every six months to the PMO along with his risk register and communicate the probabilities associated with its “Best Case”, “Worst Case” and “Most Likely” Estimates at completion and the Estimated Completion Date. These terms mean little to the PMO or other stakeholders without associated probability statements and the drivers of cost and schedule from the risk register content. This information should allow the contractor and PMO to focus on the future risks and revise their plans to keep the contracts on track.

THE CHALLENGES

There are several challenges that must be addressed in order to implement these recommendations. These are briefly discussed below.

First, the estimating community must broaden its data collection effort to capture the durations and associated costs of common high-level development activities. Some of these data may already exist within the native schedules contained with the Earned Value Management Central Repository (EVM-CR). Comparison of initial and final schedules could provide useful analogies for future systems. All programs, regardless of size, have some form of schedule and the community should make a concerted effort to collect, store and share these data. The authors assert that the contracting communities, particularly those involved in the construction industry, have done a better job of collecting these data and effectively using these data, than the government.

Second, PMOs must take more active roles in creating realistic plans for their programs. As noted above, this means PMOs must create Integrated Master Plans – the architectural document to develop the required capabilities. They also need to assure themselves that issued RFPs possess an “achievable” outcome within the resources available. This means that PMOs must develop a top-level cost-loaded plan and compute probabilities for meeting the cost and schedule targets. Given limited internal resources, PMO will likely need to obtain outside assistance to perform this function. This is an additional expense to the PMO, but one that is easily justified.

Third, asking the contracting community for their top-level picture of probabilities in advance of the RFP might come at a cost. Serious interested vendors will likely make the investment to develop a summary-level plan, Risk Register, and model to calculate probabilities, but perhaps not. PMOs might have to contract for systems engineering contracts to provide their perspectives, but cost should be minimal – less than four staff months worth of effort, each. This will be a small price to pay to obtain FRPs that have a higher probability of success.

Forth, the IPMR Data Item Description (DID) will need to be updated to require: a) submission of the IMP in responses to RFPs, b) EAC and ECD probability statements in Format 5, and c) inclusion of risk registers and instrumented schedule models every six months. Requesting the IMP within the RFP should never be optional as it provides the architectural framework for delivering the desired capabilities. As noted earlier, it provides the foundation for the contractors’ plans – the cost or resource loaded schedule.

Including the probability statements in Format 5 appears to be fairly straightforward and be could be done with minimal expense, but will be of marginal value to the PMO without the accompanying schedule model and associated risk registers. A PMO should be able to see the impact to the cost and schedule outcomes if changes in schedule logic are made of if they have a different perspective on risks. PMOs (or other stakeholders) should be able to independently exercise the contractors’ models. However, this requirement could be negotiated in such a way that the contractor will merely be required to develop the model and be ready to address PMO “what-if” questions.

CONCLUSION

This paper discusses the perennial problem of cost and schedule growth in publically funded programs and offers recommendations to improve performance within the DOD environment. This paper proposes that programs be budgeted (with active inputs from industry partners) at a 70 percent joint cost and schedule confidence level and that contracts be periodically reassessed to ensure high probabilities of success.

The authors observe that few programs have been budgeted for high confidence levels and cost growth continues. They assert that setting a relatively high probability of success is necessary to attempt to control growth and restore credibility with authorizers and taxpayers. The authors also address a number of the challenges to implement their recommendations and offer suggestions to overcome them.