DRAFT

How to Plan and Manage Reserves Effectively

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Abstract— Three categories comprise the major project manager (PM) responsibility. To be successful, he/she has to control quality, schedule and budget. When these come together inside an agreement with a customer/sponsor, all is well. NASA has been transitioning from the paradigm of implementing a few "large" (> $1B) projects to one of more "smaller" (< $600M) cost-and-time-constrained projects. Of course, science results of the highest caliber are the basis of all agreements. In other words, cheaper, faster, better are still fundamental ... to wit, quality, schedule and budget. The challenge for modern PM's is clear. To maximize the likelihood of success, the PM needs a strong buffer of margin and reserves. However, having a buffer does not necessarily translate into understanding whether it is enough, or how and when to release/spend reserves. Thus, a PM needs a well-developed reserves management plan, a.k.a. cash flow planned inside the time boundaries to defeat threats. A technique is offered to plan for cash flow of reserves that can pay great dividends in confidence and eventual success.

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1. INTRODUCTION

Over the past decade of robotic space exploration, NASA has been transitioning from the paradigm of implementing a few "large" (> $1B) projects to that of more "smaller" (< $600M) cost-and-time-constrained projects. NASA's 2003 Strategic Plan for the Space Science Enterprise still aims at the objective of lower mission costs while preserving, to the greatest extent possible, mission performance in terms of science return. In other words, cheaper, faster, better are still fundamental ... to wit, budget, schedule and quality.

The PM needs a strong buffer of margin and reserves to maximize the likelihood of success. The question is how one arrives at the buffer. How much is enough? How does a project manager develop a plan for expending the reserve? The roads to failure and "Chapter 11" are paved with enterprises that spent too much, too soon, or waited until no amount of reserve could save the situation...it was too late to spend it and affect a recovery. Today's culture is still wedded to "Rules of Thumb" on reserve and schedule margins that become a problem for proposal teams competing under the constraint of very tight cost constraints.

2. DEFINING SCOPE

The first step on the way to answering the questions posed above is to understand the job and its requirements. This might easily go without saying as obvious. However, this step seems too often to be an obstacle for many project managers. They don't see this as the cornerstone for building and implementing a project successfully. In the early phase of development (e.g. Phase A), the inherent optimism in the aggressive, "can-do" nature of most leaders makes them eager to please the customer/sponsor. This results in lack of attention to the details of what constitutes mission success. The "big picture" is exciting and there is pressure to get more out of every dollar. Both customer and implementer want it to be the best. Requirements at this stage are often vague and the impact on whatever project element has to meet them is even fuzzier. It is common and insidious that requirements "creep." A requirements-driven environment emerges that often produces a very large mismatch between the resources available in money and schedule and the objectives.

The PM must counter this by careful consideration, discussion and documenting of measurable criteria that, if achieved, will equal mission (or project) success. In fact, in the spirit of building an acceptable buffer, a good technique for scope definition is to set up categories for prioritizing success criteria, for example ... primary, secondary and tertiary. (**Figure 1**) The primary category contains the limited number of measurable statements that comprise a floor or minimum to make the project worth doing at all. The secondary category houses criteria that are very important and will be included in the baseline scope, but are such that if not all are achieved, an acceptable (even though disappointing) outcome still

results. The third category, also in the baseline, contains those criteria that are important, but will be the first to be re-examined if unforeseen events make it clear the full suite of criteria is not achievable. In other words, in the context of the PM's "big three" items for success...on schedule, within budget, at acceptable quality...a buffer, or margin, is developed regarding quality.

Seriously considering what quality is acceptable under the paradigm of constrained-cost-and-schedule programs, addresses exactly what is worth doing, and how to approach the "push back" on requirements, should it become necessary. It defines the commitment of the customer/sponsor. It sets the framework for following a specific criterion through derived requirements to the supporting project elements. This, in turn, provides data on options to reduce the overall scope in an acceptable way and stay within the available reserves pertaining to the other two PM success criteria...budget and schedule. It clearly develops the answer to the question every project manager should ask before agreeing to take on the job, "How do I win the 'gold star'?"

Once the prioritized success criteria are complete, they must be documented in a clear and simple agreement. This becomes the central element of the *Mission Definition and Requirements Agreement (MDRA)* (**Reference [1]**) and gets all stakeholders as signatories. The analog, from our personal experience, is the simple contract for building a pool, garage, house, etc. Key is to keep the verbiage in the document crisp and clean, not obscuring the success criteria. A rigorous change-control discipline is placed on the agreement, since in the final accounting, this will define whether the "star is won."

Of course, there are projects that involve only a single quality objective, virtually negating the ability to develop an acceptable de-scope[1] in quality. This condition takes the PM closer to the unacceptable over-constrained, boundary-value problem in optimization theory. With the quality criterion already at the performance floor, the PM is stuck with ensuring that enough reserves are in the schedule and the budget to still allow a high achievability path to success. The inflexible requirement constraint makes planning and managing the reserves crucial and the constrained optimization problem more difficult. It is then DOUBLY necessary to have a strong technique to plan and manage the budget and reserves.

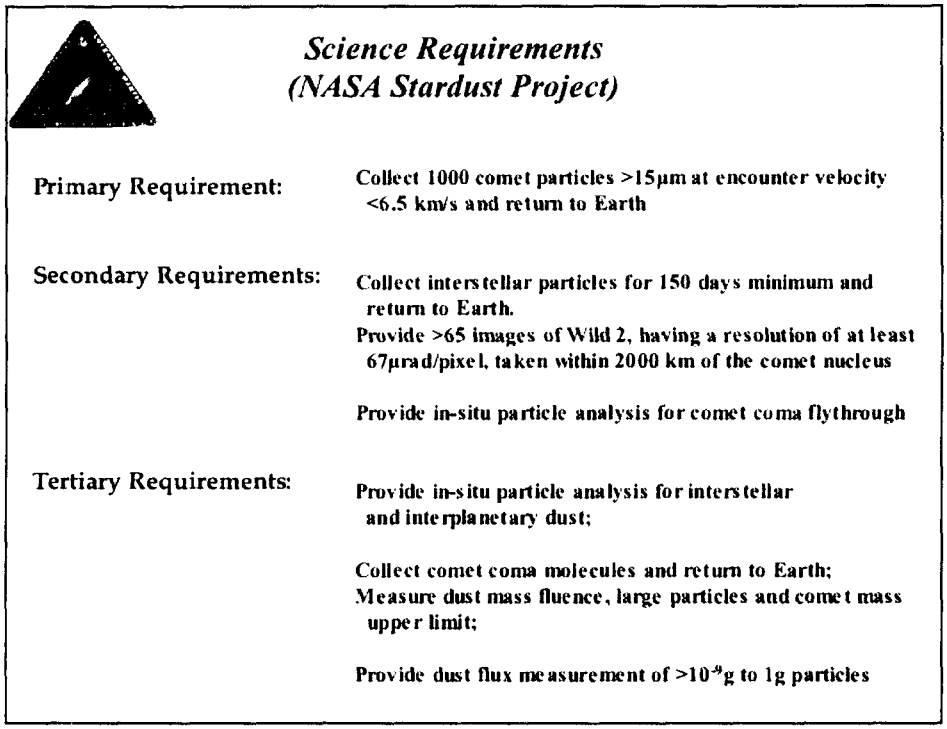


Figure 1 – E.g., Prioritized Top-Level Success Criteria

3. Capabilities vs. Requirements

Once the PM knows the job scope, next is to marshal the experience and tools available to meet the requirements.

[1] Changing the scope of work by giving up some of the less important criteria for mission success, e.g. those that are "tertiary."

In fact, under the paradigm of cost and schedule constrained projects, the approach shifts from requirements-driven to checking whether available capability can capture an acceptable level of the success criteria. The more capability already available, the less effort (schedule benefit) and budget is necessary. For the PM, the key theme in this consideration is "do-ability." In other words, can designs, equipment, testing approaches and facilities that already exist provide an adequate capability to do the job, e.g., capture the requirements? If so, the cost of acquiring them, and the companion schedule for use, is well known. A significant inheritance of capability reduces unknowns and risk (**Figure 2**).

Design-to-Cost Process

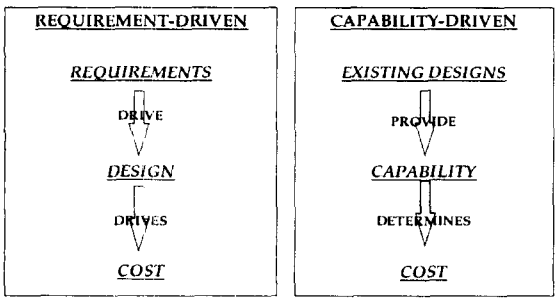


Figure 2 - Comparison of Capability-Driven and Requirement-Driven Approaches

The capability-driven (cost-and-schedule-constrained) approach demands a strong focus on this aspect to develop a clear understanding that there are categories of "secondary" and "tertiary" requirements. Of course, there will most likely be gaps between an easily acquired capability and the subtle, unique impacts of a new and different application. Everyone wants to get "the whole enchilada" of the baseline if possible. However, modifications and some new elements are usually necessary to bridge the gaps. A 'negotiation' between capabilities and requirements emerges. With NASA's emphasis on cost and schedule in the 1990's, much rhetoric has emerged on the concept of "design-to-cost" (DTC). Unfortunately, it has been much easier to hear the rhetoric than find details on the process and procedures to implement it. In other words, it seems DTC has been "easier said than done." The capability vs. requirements approach provides the key to how to do it.

Specifically, with the clear understanding of the baseline scope and the priorities for reductions that still protect a "success" in hand (the MDRA) , the PM's process calls for an exercise ending in a Capabilities vs. Requirements Review (CRR). The first step is to review the available capability against the requirements. The existing design may meet all the requirements (miracles can happen); however, more than likely it won't. So, modified and new features will have to be considered. Thus, the second step is to examine the impact of modifications and new items to see if the estimates for them will still fit the cost and schedule constraint. Because any of the changes or additions will have some uncertainty, reserve considerations have to be included. If everything fits, all is well. If not, then de-scoping must occur. The CRR provides a very early trade study at the cost account level with the intent of developing justified reserve requirements and causing any necessary de-scope decisions to protect the cost constraint. Thus, for real DTC, either the reserves are "lush," or there are enough de-scopes (revisions to the MDRA) to allow a legitimate claim to success. To be serious about DTC, the CRR must replace the traditional System Requirements Review (SRR) and "muscle-up" any Inheritance Review (IR).

The format of the CRR calls for each of the project elements to come in with a review package displaying three categories for the element or subsystem development. First comes the result of the collection and inventory of what pieces exist and are available for producing a capability to capture the baseline requirements. All the tools of the development are included; hardware, software, support equipment, test matrices, facilities, and personnel. This kicks off the "inheritance" validation. Some items in the set will be useable as is. Some may require modification. There will still likely be gaps or new things the subsystem needs in order to capture the full baseline. The information should provide pedigree such as mass, power, performance and quality of the item. For software, it would be the code language, version, and functionality plus the application experience and the availability of personnel who developed it (a good principle to hold for software is that software per sé is not very inheritable; you really need to inherit the people who built it). Testing approaches, support equipment, and facility availabilities are also important considerations in answering the question, "What do I already have?"

Second, the presenter turns to the issue of gaps and modifications. In examining the target requirements, the provider may find some items in the element that are close to the ability to capture, but need some modification to do it. Clearly, an item that can be inherited by modification of its existing status is likely to be better understood, less costly, and, therefore, bring less risk than something that must be totally new.

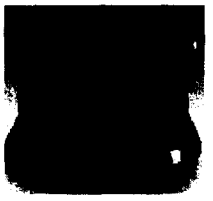
Attitude Control Component Maturity			
Component	***Existing Hardware*** (CDR -Level)	***In Development*** (PDR -Level)	***New/Unique*** (Reqmts-Level)
STAR CAMERA - OCA Star Tracker Camera - CDR 2/96 - EDU 7/96			
IMU - Honeywell MIMU YG9666B - Qualification In Progress			
ACS Algorithms		• RCS 3-Axis Control • Sensor Processing • Attitude Determination • TCM Control • Ephemeris Generation	• Encounter ACS • NAVCAM Point

Figure 3 - Example Data Format for CRR

The "new" category takes the development plan to the point of capturing the objective … the "baseline" scope of the project. In focusing on this third issue, the provider grapples with the items that have the most uncertainty. Since new development is required, the specifics of how the thing will be produced are not known well.

In these last two categories lie the significant threats to the baseline scope for the element and possibly for the project. By going through the details of stepping from what is surely known to the unknown, the element provider is asked to become a risk assessor and develop a logical picture of the element's development plan as it relates to capturing the assigned requirements. The departure from the traditional requirements-driven approach is chiefly in the emphasis on understanding just how much of the baseline a known and inheritable set of hardware, software, etc. can capture. This develops the known "cost" of the inheritance. Then a focus on the needed modifications and new items departs in logical steps under a natural pressure to make the step as small as possible from the known. The idea is to hold the design close to the known cost and challenge the requirements strength. Thus, a capability vs. requirements perspective becomes key to a real DTC technique. An example of data presented as part of the *Stardust* project's CRR is shown in (**Figure 3**).

4. Risk Adjusted Baseline

The previous section implies that risk is a factor in matching the capabilities against the set of baseline requirements. Recall, the three success categories are quality (a.k.a. technical performance), schedule, and budget. Certainly, an implementation of designs inherited without modification offers the lowest risk to meeting the criteria in all three categories. In theory, the quality, schedule and cost on these are well known. There are probably still some risks, perhaps in whether a vendor loses a key person during the production of the "clone", overhead rates are unexpectedly adjusted, etc. These pose manageable problems and might well be classified as "non–significant." This means a reserve level of 5-10% margin on schedule and budget will give a very high probability of success. From the standpoint of efficiency in managing reserve (paperwork, etc.), tasks with uncertainties in this range include this reserve in the baseline work agreement (WA)[2] for that unit in the

[2] Work Agreement (WA) for each lowest level WBS task (or Cost Account) documents the Scope, Schedule and

project's work breakdown structure (WBS). In other words, it is und
the provider of t
held in the base
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formal request
level pool requi
Request (ECR),
and an update/re

Most of the
everything on a
items that provi
of an earlier
modification to
risk. While the
cost inside the b
opens the door
provider of the
source for con
probability that
how complex t
threats to his ba
may be that the
only be determi
the plan. That

Elements of the Significant Risk List (SRL)

- **Description of each risk item**
- **The area (e.g., system/ subsystem) that would deal with this risk**
- **Estimated cost to recover from the risk if no mitigation occurs (optionally - a description of what would need to be done to recover after the risk event takes place)**
- **Estimated probability of the risk occurring if no mitigation action occurs**
- **Any mitigation decision made (accept risk, mitigate now, or mitigate if some criteria is met)**
- **Any decision dates, if the mitigation decision is deferred**
- **Any mitigation costs**
- **Residual risk after mitigation, in terms of probability and cost of the risk occurring despite mitigation**
- **Whether the risk has been retired.**

-- Risk Management Handbook for JPL Projects, D-15951, October, 1998

Figure 4 - Guideline for Preparing the SRL

The PM, project business manager (controller) and other risk management stakeholders might assign a range of 15 to 50% margin for items on the "modification" list. Further, some of the modifications may be tightly coupled to the project's ability to succeed. These are considered "significant" risks and are entered on the initial release of the project's Significant Risk List (SRL) ...(**Figure 4**), along with the subjective probability that things might not go as planned. These are singled out as needing more attention in the reserve management process. The initial SRL is a product of the CRR. The Project System Engineer, or equivalent, develops and maintains the SRL.
In a similar fashion, the items falling in the "new" category have a characteristic estimate of the complexity and risk.
Since the lack of experience and understanding is highest for these uncharted paths, they represent the most risk and argue for still higher percentages of reserves. Here the levels should be 50 to 100%, based on the expertise of the provider and the estimate of the complexity.

As each project element is considered, a matrix emerges comprising all the project WBS elements, e.g. structure, thermal, avionics, power, navigation, science instruments, software, etc. Each element poses three specific cost constituents: 1) inherited w/o modification, 2) modifications, and 3) new. Each has been analyzed for significant risks, given a reserve recommendation (%), and a preliminary probability that it will be needed. The project has gone through an exercise to inventory its capability to successfully do the job and has "adjusted" its WBS elements for their unique risk-level. The CRR determines and documents which have the highest percentage of inheritance therefore the lowest risk-level. It highlights the modifications and new items needed for capturing the project success criteria (quality/performance) and assesses the associated complexity and risk. It delivers and validates development plans/agreements represented by the WA's. These document the baseline budget and reserve requirements based on the modifications and new items, adjusted for the experience-based risk assessments. The project then integrates the risk and reserve data across the full WBS to arrive at a reserve plan characterized by knowing what the "tent poles" are, how tall they are, how likely they are, and when threats might emerge. The "suspects" that bear most watching are collected on the initial release of the SRL where their probabilities of causing problems can be tracked and adjusted consistent with the realities in the development cycle.

Cost Estimate or Budget agreement.

[3] Murphy's Law – "Anything that can go wrong, will."

Note that this step in the reserves planning process aims at capturing the full baseline, e.g. all three hierarchies of the mission success criteria ... primary, secondary and tertiary. Recall that these represent "quality" in the three elements of success for the PM, the other two being schedule and budget.

The specter of "de-scoping" emerges if the reserves become depleted (any time in the project life cycle) such that the remaining costs to achieve success exceed the budget (e.g. cost-capped by a competitive selection program such as NASA's Discovery, Mars Scout, Small Explorer, etc.). The tertiary success criteria then enter the equation as the avenue to stay on the design-to-cost path. If, as mentioned earlier, there is a single category for mission success, e.g. the performance floor, then the PM *must* consider this in the reserve plan and add to the percentages of the tallest tent poles. Beware of projects with inflexible, single success criterion. Preserve the "do-ability" and expand the potential for "getting the gold star."

Careful treatment and documentation of the scope, followed by the CRR treatment of requirements and capability arm the project manager and his team with a rationally developed reserve plan where reserve targets elements of concern consistent with their inherited maturity and adjusted for risk considerations.

5. Earning Value

The next step in the process of planning and managing reserves effectively involves managing. For NASA's paradigm of more, smaller cost-and-time-constrained missions, effective management of schedule and budget reserves is vital. It is one thing to develop a reserve plan with a framework of weighted threats and some probabilities of when and where they might occur. It is quite another to work the plan through a reality that is never exactly the plan, and still achieve the mission success criteria. Projects cannot afford to manage only comparing the "actuals" with the planned cost and schedule. That's like trying to drive a vehicle looking in the rear-view mirror. Without a forward-looking integration of the road ahead (schedule and events) with the available controls, e.g. money (baseline plus reserves) and workforce, it is impossible to know whether planned work in fact has been accomplished. To effectively manage reserves, a *clear* correlation is required between work planned and work accomplished, as well as between work accomplished and actual cost.

Today there are a number of commercial-off-the-shelf software tools available for this purpose. For getting an overall picture of a work plan, the "PERT" chart has formed a foundation for competing software providers. PERT stands for "Program Evaluation and Review Technique." The technique actually involves constructing an integrated network (e.g. "roadmap") of events characterizing the planned work and sequenced by a priority or precedence of what has to be complete before other work can progress. Most automated PERT programs do not show a calendar time scale. They are valuable in producing the "critical path", or crucial interdependencies, between WBS elements. The critical path is determined by adding the times for the activities in each sequence and determining the longest path in the project. The critical path determines the total calendar time required for the project.

Microsoft Project™ is a popular networking package for determining the earliest finish and critical path for a set of tasks representing the project scope ... e.g., the baseline. While MS Project is probably not the most flexible networking tool on the market today, it is relatively easy to use and operates equivalently on Windows™ and Apple™ computer platforms. However, for complex multi-network projects, MS project offers only a limited ability to link a task in one network to another task in a second network. Such links are critical when numerous products are fabricated in shops not necessarily under the control of the end-product producer. The key to the success of any networked schedule is the accurate modeling and control of hand-off points between task/budget owners. NASA's *Stardust* project developed a semi-manual approach for handling this successfully; details of the "how" are in **Reference [2]**. Working through the network integration and critical path analysis will produce information regarding "slack time"[4] for various network tasks that are not on the critical path. If activities outside the critical path speed up or slow down (within limits), the total project time does not change. However, as noted in the discussion of WA's and dependence on the expertise of the providers, the time estimates for the activities are somewhat subjective and depend on judgment. In cases where there is little experience in performing the "new" activity in the work element, the estimate is, at best, an educated guess and there may be bias in the estimate. Because other paths can become the critical path if their associated activities are delayed, PERT consistently underestimates the expected project completion time. Therefore, adequate schedule reserve must be available and planned to protect the success criteria, e.g. on-time completion or, for NASA, launch.

[4] The amount of time that a non-critical path activity can be delayed without delaying the project is referred to as slack time.

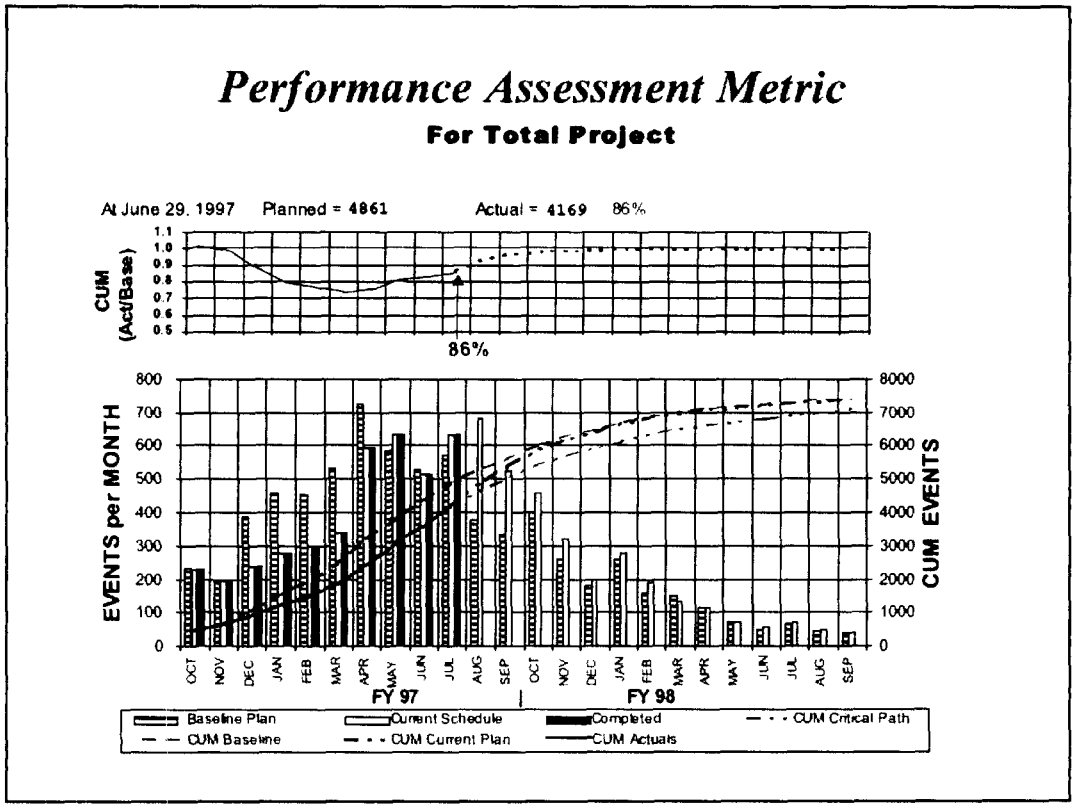


Figure 5 - Stardust Performance Metric (PAM

Next, an exercise, external to the networking software, sums the workforce and baseline costs of all the WA's in tools such as Microsoft Excel™. The workforce, budget data, and the integrated network schedule are then loaded into a financial data processing package such as Microframe Project Manager™ or Cobra™. This sets up the baseline work and cost plan. Recall, the baseline is the foundational "job" and is protected as the actual work progresses.

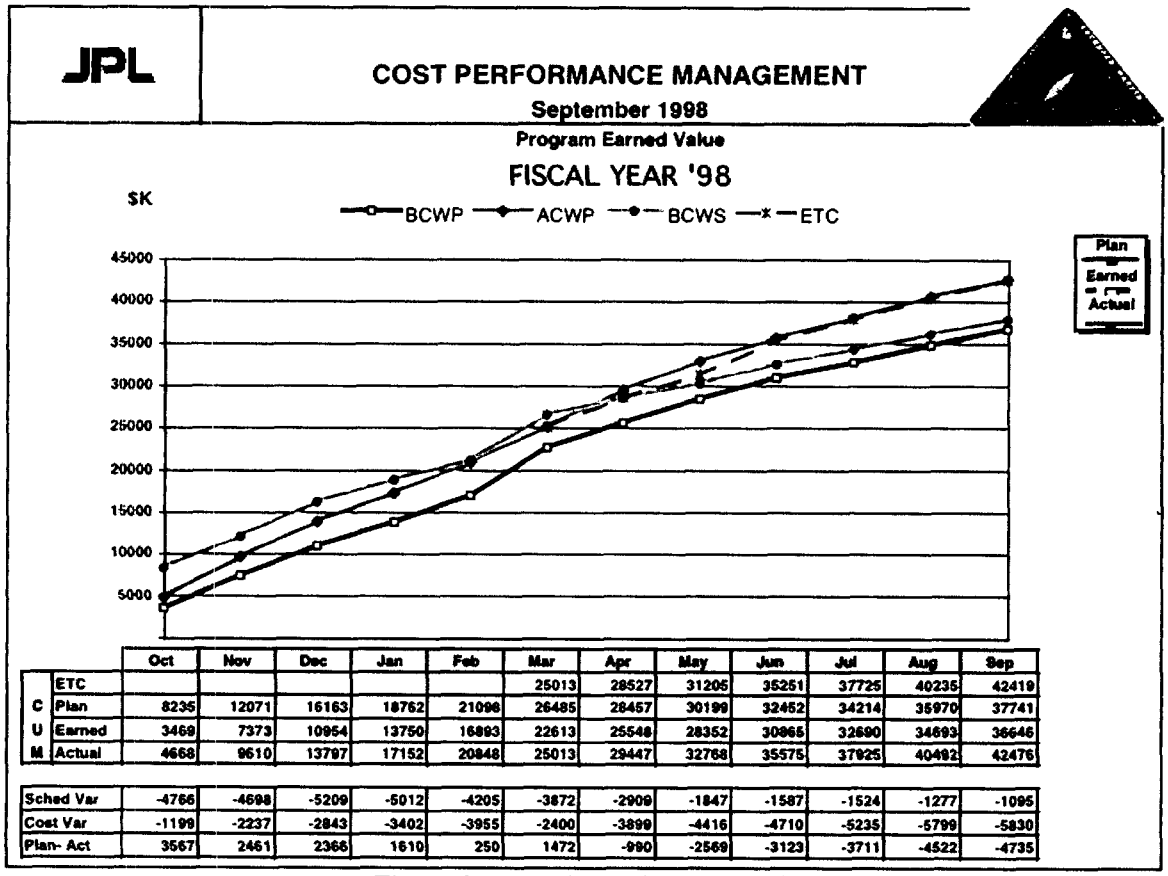
These management programs perform the integration of the work planned (baseline) against the work accomplished and the actual cost of the work accomplished. At regular intervals, usually once a month, the project control team meets with the task performers to assess progress in the form of value earned for the cost expended. With inputs from this process, the management software produces earned-value management (EVM) metrics for the constituent WBS cost elements and rolls the data up to different levels to produce a picture of the project's progress against the baseline plan. EVM metrics are central to the PM's ability to effectively manage reserve. It is important to note at this point that setting up and using EVM is definitely an art rather than a science. If the "chunks" of work are taken at too high a granularity ... e.g., $millions ... then the size of the effort masks the level of detail where problems may be emerging. The activity looks like it is on budget until it becomes too late for the manager to take effective action. On the other hand, if the size of the effort is taken at too low a level, it is likely that too many insignificant events are being tracked that report trouble almost at once. The project is either not in trouble until it's too late, or it is in trouble almost immediately. Just as in the children's story of "Goldilocks and the Three Bears," the set up of the earning events for a task has to be "just right." A successful approach to getting it "just right" builds on the interval of a month (Reference 2). The project financial and engineering team performs an analysis of each detailed network schedule. For tasks of 1month or less, start and finish events are assigned. For tasks taking more than 1month, events are assigned for each month during the task. This method avoids a 1-month task having the same earning weight as a 6-month task. A metric emerges showing the number of events the project baselines to complete each month. The team plots the baseline number of events per month over the project life cycle. Then they graph the cumulative completion, getting two curves, one showing the project proceeding ideally, on the baseline, and the second based on the latest-possible finish data showing the critical path. The actual completion curve should fall between the two.

Figure 5 is a performance assessment metric (PAM) counting the monthly event totals on the left ordinate, while the cumulative progress of planned completions and the latest finishes is measured on the right ordinate. If the actual curve then is superimposed and shows whether the project is ahead, on, or falling behind the baseline. If it falls on or below the late-finish curve, then schedule reserve is used and critical path has changed. The networks need rebalancing with the late finishes matching the new allowable time (added from reserve). When reserve goes to zero, then the project will fail the success criterion of schedule.

Examining the actual accomplishments compared to schedule, the baseline as shown in **Figure 5** offers insight on how the reserve is being managed. It is time and event oriented providing no numerical data on how the budget is faring. For that, the team needs the companion metrics available from the financial management software mentioned earlier, e.g. Microframe Project Manager™ or Cobra™. These integrating tools also offer a process for looking forward in a way that can navigate the project through the flexing networks, avoiding the "potholes," and keeping the implementation targeted squarely at the success criteria of acceptable on time and on budget delivery. But there's a "catch."

The companion earned-value metrics provide regular updates of the position and heading on the implementation pathway in terms of the budget (baseline, or budgeted cost of work scheduled (BCWS)), the actual cost of the work performed (ACWP), and the value of the work performed with respect to the original budget (budgeted cost of work performed (BCWP – a.k.a. earned-value (EV)). However, to really gain information the team can use, the EV metrics must be available quickly – within a week after the monthly EV sessions are completed on all the cost accounts. The team must FOCUS on honest, accurate assessments and insist on a common software implementation, or simple electronic file transfer interfaces at all participating organizations. Without the timeliness and the "just right" granularity on the number and separation of earning events, the EV data becomes a "rear view mirror," too late to contribute to effective reserve management.

The EV process requires the regular inputs of actual workforce applied and events accomplished. The software compares with the baseline WA workforce, budget, and time. It provides variance information showing how the realities of workforce effectiveness, network schedule problems, etc., are hitting the project. Timely variance information on each cost account is key to identifying potential problems early and then planning to mitigate them with reserves. The EV example in (**Figure 6**) shows the baseline as the curve of •'s. That's the agreed-to job (scope) and success criteria. The line of □'s is the actual progress, the BCWP, or how much of the job has been "earned."



		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	ETC						25013	28527	31205	35251	37725	40235	42419
C	Plan	8235	12071	16163	18762	21096	26485	28457	30199	32452	34214	35970	37741
U	Earned	3469	7373	10954	13750	16893	22613	25548	28352	30865	32690	34693	36646
M	Actual	4668	9610	13797	17152	20848	25013	29447	32768	35575	37925	40492	42476

Sched Var	-4766	-4698	-5209	-5012	-4205	-3872	-2909	-1847	-1587	-1524	-1277	-1095
Cost Var	-1199	-2237	-2843	-3402	-3955	-2400	-3899	-4416	-4710	-5235	-5799	-5830
Plan- Act	3567	2461	2366	1610	250	1472	-990	-2569	-3123	-3711	-4522	-4735

Figure 6 - Example Stardust EV Metric

As noted above, complex projects with several contributing organizations will have multiple networks with hundreds to thousands of events to be earned in order to achieve success. As reality occurs, the networks will "flex" away from the baseline and the critical path will shift as threats emerge, probabilities change, and the reserves become required and committed. The implementation becomes dynamic. The tautology "Plan the work and work the plan" has little meaning since the actual implementation is never ideal. Reality is more in tune with "How can we focus on the objective of draining the swamp, when we're up to our (bleep) in alligators?"

Effective management of the actual cost line (ACWP => ◆'s in **Figure 6**) involves exploiting the data developed in the CRR exercise. The early task assessment at the WA-level by the best educated guessers (the providers) identifies where most of the unknowns and problems are likely. With that assessment, the project management team prepares a reserve plan showing "soft" liens on the reserve pool with the associated probability of occurrence and timing. A plan with both targets and timing for the deployment of the reserves is achieved. Certainly, there are always the unanticipated surprises and the SRL must be updated regularly and maintain high visibility for effective reserve management. The project's system engineers and element managers (providers) must "sweep" the threat spectrum weekly to fill the gaps between EV-taking sessions, formally updating the SRL at least every two weeks.

BUDGET CHANGE LOG				EST .SOFT LIENS		
	Reason	Date	Date	FY98	FY99	TOTAL
PROBABILITY FACTORS:						
HIGH = 100%						
MED = 60%						
LOW = 30%						
SOFT LIENS		Probability	Originator	FY98	FY99	C/D
Sim Software Resources		High	JPL	150		150
FSW Development Risk		High	JPL	300		300
Nav Cam Sleep Mode Will Not Work		High	JPL	10		10
Open NavCam ICD issues & misunderstandings		High	JPL	10		10
Nav Cam Late Delivery (incl MDI Supplies)		High	JPL	250		250
IMU Leakage Problem		High	JPL	200		200
Aerogel ICD / Contam Requirements		High	JPL	300		300
CIDA Ground Loop		High	JPL	75		75
CIDA - PACI I/F Issues		High	JPL	250		250
Flight Spares Operating Time		High	JPL	75		75
Analysis/Verifications (act or paperwork delay)		High	JPL	200		200
OCA Star CAM Devleopment		High	JPL	75		75
Fuse Rel Questions		Med	JPL	300		300
PACI Board Issues		Med	JPL	200		200
C&DH Backplane Failure		Med	JPL	100		100
Nav Cam Rework/Repair Contingency		Low	JPL	55		55
TOTAL SOFT LIENS				2718	0	2718
TOTAL HIGH PROBABILITY				2020	0	2020
TOTAL MEDIUM PROBABILITY				384	0	384
TOTAL LOW PROBABILITY				18	0	18
TOTAL WITH PROB. APPLIED + Proc O/H				2421	0	2421

Figure 7 - Reserves Plan with Lien Probabilities

While it is prudent to plan for the worst, fortunately some of the risks that get into the SRL will not happen. Pluses and minuses give the potential for some pre-emptive deployment of reserves against threats. **Figure 7** shows an example/template for a reserve plan with probabilities converted into liens against the reserve in dollar amounts. Entries in this table come from the SRL and might include all future or just the current year's threats. Even though some of the liens are noted as "high" probability (100%), in this example they are treated as "soft" until the management team has approved the required paper work to debit the reserve pool. Approval is triggered by an agreement from the provider that the reserve is going against the baseline scope of work or a required change in the scope.

Any change in scope would require the appropriate updates in the related WA's to ensure that EV can be taken against the new work. Unless that step is completed in a rapid way, any effort spent will be on "unscheduled" work, and treated as "over-run" instead of EV against a new budget element ... in other words, EV requires an update in the baseline (BCWS). If, on the other hand, the reserve is being applied without scope change in the task, it is indeed an over-run of the baseline. This has implications for projects involving partnerships and contractors. It is necessary to clearly understand whether the effort covered by the reserve-release is "fee-bearing" or covering over-run that might move the contractor/provider toward a loss of any profit ...e.g., an incentive-fee based contract.

From the project team's perspective, it is important to hold the line on scope-changes. Beware of externally-requested, late-entry increases (e.g. adding an instrument) because the maturity of understanding the impact on the CRR-based reserves plan will be low. Once the project has a good comfort level on ability to succeed, it is dangerous to allow "hitch-hikers" to insert new WA's late in the EV cycle. If such are "mandates," insist they come with added funding and reserves consistent with the "new item" percentages applied at CRR. The use of reserves on added scope is only justifiable if 1) it came with its own, or 2) it is definitely connected to reducing risk and meeting the success criteria. De-scopes are different in that they remain inside the flexibility for success in the original MDRA. They effectively increase or put less pressure on the reserves pool. They, too, however need to be negotiated and processed through the MDRA route ensuring strong communication and clear agreement

between the project and sponsor that the reduction still fits within the "gold star" designation of success.

The effective reserves management process guards the reserve for use on ensuring the baseline is earned in the crucible of reality without the pool going to zero. In the case of 1) above, the PM modifies the MDRA, determines the impacts of the new success criterion, changes the requirements documentation, develops the new, and/or modifies WA's, then updates the integrated networks, financial programs (e.g., Cobra©), reserve plan, contracts, etc. For 2), the success criteria are not changed; only the requirements flow and updates through the WA's, networks, reserve plan, and contracts are required. The point here is that 1) involves a change to the original "deal" involving the MDRA adding, most likely, a new success criterion and must be accompanied by new $, etc. It results in a new, "delta" baseline. In 2), risk reduction (R/R) and over-run (O/R) items are related to the original baseline.

reserve use. It includes a change in scope (C/S) designation that pertains to the system contract. At the level internal to the project, the system contract is the agreement between the partnering organizations (JPL and LMA in the example) and analogous to the MDRA between the project and NASA. This Budget Change Log provides the discipline to ensure the WA's, contracts, networks, and EV system are updated quickly and are consistent. The designation of lien status as hard (approved) and soft (still in work) provides the project team with information on how much of the reserve pool remains un-encumbered and still available for future events.

Effective reserve management requires focus on the notion reserves exist to ensure meeting the MDRA success criteria. They are not available for responding to "creeping requirements" or un-negotiated additions to scope that do not come with new reserves. They result

BUDGET CHANGE LOG				ESTIMATED LIENS				DEFINITIZED LIENS				
	Reason	Date	Account	FY 97	FY98	FY99	TOTAL	FY 97	FY98	FY99	TOTAL	STATUS
TOTAL PHASE C/D RESERVES					12753	0	12753		12753	0	12753	
JPL Project (P)					8947	0	8947		8947	0	8947	
LMA Flight System (FS)					3806	0	3806		3806	0	3806	
LIENS												
EPS Test	R/R	Aug-97	LMA Contract		-150		-150		-150		-150	In Dec MPM Plan
LMA ETC	O/R	Oct-97	LMA Internal		-3806	0	-3806		-3806	0	-3806	In 98 Plan
JPL ETC	O/R	Oct-97	JPL Internal		-626		-626		-626		-626	In 98 Plan
Nav Cam Radiator, etc	C/S	Nov-97	LMA Contract		-37		-37		-37		-37	No Cost Change
SRC Avionics Shock Isolation	O/R	Nov-97	LMA Internal		0		0		0		0	In ETC Plan
Picture Frame for ATLO	R/R	Nov-97	LMA Internal		0		0		0		0	In ETC Plan
Solar Array Diode Addition for Shadowing	C/S	Nov-97	LMA Contract		-213		-213					
Aerogel Recovery	O/R	Nov-97	JPL 51100		-432		-432		-432		-432	In 98 Plan
CIDA Parts	R/R	Dec-97	JPL 60006		-32		-32		-32		-32	Incurred Dec-97
CIDA Mass/Thermal Simulator	C/S	Dec-97	LMA Contract		-85		-85		-85		-85	Negotiated
Breakout Boxes	R/R	Dec-97	LMA Contract		-83		-83		-83		-83	In Feb MPM Plan
Aerogel Spectrometer	C/S	Feb-98	JPL 51200		-177		-177		-177		-177	In Feb MPM Plan
Feb LMA Cost Over Reserve (541K)	O/R	Feb-98	LMA Contract		-577		-577					Noted
HARD LIENS FY98					-6218	0	-6218		-5429	0	-5429	
Reserves - Hard Liens					6535	0	6535		7324	0	7324	
JPL Project (P)					6535	0	6535		7324	0	7324	
LMA Flight System (FS)					0	0	0		0	0	0	
ATLO H/W Delivery Soft Lien ($2M H/W to ATLO less spent)					-1555							
ATLO RESERVES (Less Hardware Delivery Soft Lien)				0	4980	0	4980	0	7324	0	7324	
TOTAL SOFT LIENS (From Soft Lien List)				0	-2421	0	-2421	0	-2421	0	-2421	
TOTAL UNENCUMBERED RESERVES (w/Soft Lien List)				0	4114	0	4114	0	4903	0	4903	

Figure 8 - Translating the Reserve to Hard and Soft Liens

The "Reason" column in **Figure 8** provides evidence of a clear consideration and designation of each type of

from implementation realities (uncertainties) making the actual cost of work performed (ACWP) more than the

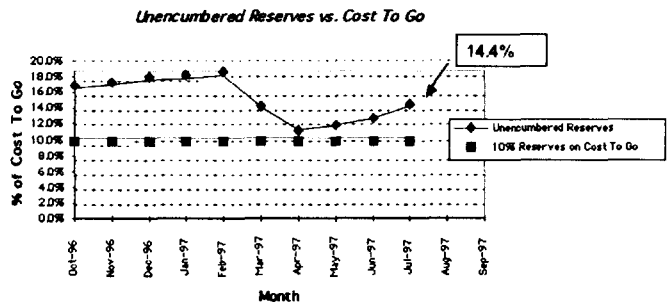


Figure 9 -- Example: Percent Reserve on Cost to Go

budgeted cost of work scheduled (BCWS)...the baseline. Thus in reporting the information in **Figure 6**, a briefer points out the BCWS (the curve of •'s) as the job to be done. The progress earned at the report date is represented by the value earned (BCWP – line of □'s). The actual cost of gaining that progress is the ACWP (line of ◆'s). To complete the picture, a horizontal line or ceiling is added indicating the amount of reserve still available.

The idea of 'reserve still available' turns attention to how much work and uncertainty remain. This is consistent with a future-oriented approach to effectively manage the reserve and meet the project success criteria ... quality, schedule, budget.

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6. Manage Against Cost-to-go

Kelley Johnson, the former manager of the famous Lockheed "Skunkworks," operated from a fairly small set of 14 management and concurrent engineering principles, (**Reference 3**). One of those was, *"There must be a monthly cost review covering not only what has been spent and committed but also projected costs to the conclusion of the program. Don't have the books ninety days late and don't surprise the customer with sudden overruns."* In other words, keep your eyes on the cost to go (CTG) and stay current on where you are." This is crucial for effectively managing to stay on track while keeping an acceptable quality of product delivered on time and within the budget. Following this principle involves a translation of the information described in Section 5 into a metric defining the available reserves as a percentage of the cost-to-go. **Figure 9** is an example showing the unencumbered reserve as a percent of cost to go. A 10% reserve floor is set as a guideline level not to be violated except under circumstances clearly not endangering the ability to successfully complete the job. The example depicts an initial growth in the percent on CTG, perhaps resulting from favorable earlier experience where some anticipated risk mitigations were not required. At the level of 20%, the project either has 1) decided to preemptively "strike" some threats and released reserve to mitigate or retire them, or 2) some set of risks could have demanded action, for example, discovery of a task element that was seriously underbid in the baseline (BCWS). The point here is that a metric like Figure 9 provides a current picture of the reserve pool's strength against the CTG. It offers information on the project's capability to successfully fund the remaining effort. Growth in the index can imply several things. One could be that the project is not being aggressive enough in releasing reserve to mitigate threats. It could mean saving reserve to address an expected need. Conversely, a slope toward the 10% floor may indicate a need to begin consideration of de-scopes to increase the pool, or other major recovery options to reverse the curve and begin a climb to maintain the capability to complete. The regular (monthly) look at the relation of reserve against CTG offers on opportunity or alerts to threats before it becomes too late. The team uses CTG data to develop criteria on when and why to release reserves during the implementation gaining an offensive bias in the reserve management process, preferable to a reactive/defensive bias that lets events control the project team.

7. Summary and Conclusions

In looking back, the discussion describes a process for effectively managing the project reserve. There are ten key steps. They are:

1) Document and agree on the project's scope hierarchy. Take a close look at the success statements; make sure they include objective measures, not subject to misunderstandings or equivocation. Everyone should know what success is when it occurs. The hierarchy should include three levels for de-scope flexibility – primary, secondary, and tertiary.
2) Perform a CRR to determine how much of the success hierarchy is captured by inheriting elements without modification. Then close the gap by determining the necessary modifications and new items.
3) Populate the WBS, assessing and adjusting the constituent WA's for risk (e.g. determine the subjective margin estimates). Sum the negotiated margins to produce a risk-adjusted, justifiable reserve pool.
4) Load the integrating network software to determine the critical path and slack in the project. Add the schedule reserve at the end, protecting the "schedule" success criterion.
5) Next load the financial software to produce the baseline EV structure. Make sure it is "Goldilocks"; having a "just-right" number and spacing of earning events. Start using it in the preliminary design phase as a verification and training device.
6) From 3) document the SRL with features noted in **Figure 4**.
7) Set up the Budget Change Log as the control discipline for release of reserve. With contracts involved, have a clear designation of the incentive-fee structure and what designations of implementation events will earn fee, e.g., R/R, C/S. Certainly, O/R earns no fee and must be a disincentive.
8) Implement – taking EV with fast data processing to provide timely information for reserve effectiveness in mitigating threats.
9) Sweep the project regularly for threats and opportunities to avoid trouble (a.k.a. to use reserve effectively on R/R, C/S, or O/R).
10) Release reserve both proactively and reactively using the reserve on cost-to-go metric as a "governor."

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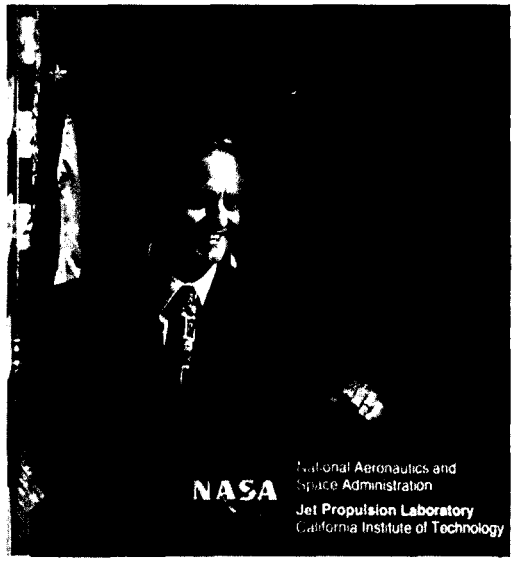
Ken Atkins was the development project manager for the fourth mission in NASA's Discovery program – Stardust. Stardust, developed with Lockheed Martin Astronautics (Denver, CO) as flight system partner, launched on time, February 7, 1999, with a little over one million dollars remaining in the development reserve. Stardust has logged over 4.5 years of successful flight encountering the comet Wild-2 in January 2004. Ken formally retired in February 2002 but continues part-time at JPL providing mentoring/education for project managers. His career spans 34 years at JPL in mission analysis, power systems, avionics, and project management. He holds B.S in AE from St. Louis University ('58), MS in Aerospace Engineering from the USAF Institute of Technology ('66), and PhD in Aerospace Engineering from Univ. of Illinois ('74). He served 9 years in the USAF as an officer and pilot.