PROJECT MANAGEMENT
in
Research and Development

WHITE PAPER

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1. BACKGROUND

This white paper was developed by the Energy Facility Contractors Group Project Management Working Group as a collaborative effort among U.S. Department of Energy (DOE) contractors, subcontractors, and the Project Management Institute government international representative. The white paper was developed to explore approaches, benefits, and limitations in the application of project management principles and practices to DOE research and development (R&D) projects and programs (Figure 3). A generally accepted tenet is that the application of appropriately applied project management principles and practices enhance technical, cost, and schedule performance and provide predictability in the execution of all projects. The proposition of this white paper is that providing a project management approach to DOE R&D work will benefit DOE, the DOE contractor, the R&D community, and the public.

The focus on cost-effectiveness of program expenditures is increasingly being called into question. There has been congressional interest over recent years in improving DOE project management focused on capital construction projects. A DOE Corrective Action Plan currently is being implemented and championed by the DOE Office of Engineering and Construction Management. Although DOE capital construction projects grab the spotlight, most projects under DOE management are in the R&D environment. With shrinking federal budgets and considering the substantial DOE R&D scope, at this time, it is prudent to explore best practice project management models in the R&D environment for broad application, including consideration of a standards-based approach.

1.1 Requirements and Standards

DOE Order 413.3A, "Program and Project Management for the Acquisition of Capital Assets," provides DOE project management requirements and guidance for using a graded approach; however, the order and application to R&D type projects is not specifically mentioned. The requirements set forth by DOE Order 413.3A support following universally accepted project management principles applicable to the full range of DOE projects, including the following:

- Line management accountability
- Sound, disciplined, up-front planning
- Development and implementation of sound acquisition strategies
- Well-defined and managed performance baselines
- Effective project management systems (e.g., quality assurance, risk management, change control, and performance management)
- Implementation of an Integrated Safety Management System
- Effective communication among all project stakeholders.

There is general agreement that application of project management skills, tools, and techniques will increase the probability of success over a wide range of projects. The Project Management Institute (PMI), for example, publishes *A Guide to the Project Management Body of Knowledge* (PMBOK® Guide), which is recognized as a best practices standard for project management. While not specific to the type or nature of the project, it is up to the user to apply these best practices in a manner that befits the project.

1.2 Noteworthy Precedence

Other government agencies and private industry have successfully applied project management processes to benefit R&D objectives for a number of years. The National Aeronautics and Space Administration (NASA) is a forerunner in successfully applying project management to R&D. NASA has used a project management organizational model on R&D projects to provide benefits through a sound project management approach.

Individual contracts within the DOE community, either through contract clause or best practice, have developed project management techniques for managing R&D projects. DOE has experienced successes in the application of project management methodology to R&D projects conducted at some of the National Laboratories. This paper provides some examples of graded project management enterprise approaches to R&D type work .

1.3 Research and Development Project Characteristics

R&D activities can be characterized as complex, interdependent, responsive to sudden research environment changes (e.g., breakthroughs, new barriers, and collaboration changes), and heavily reliant on expert judgment to maintain quality, relevance, and performance. The technical excellence of R&D activities is largely assessed through peer review of projects and the use of review of programs by advisory committees (or other outside expert panels). The output from merit evaluations, workshops, expert panels, and other pieces of information are combined by knowledgeable and experienced technical program managers to ensure that R&D programs remain relevant. While the process is largely qualitative in nature, results are often quantitative. The quality of R&D projects can be measured by assessing the degree to which the project has met or exceeded customer requirements. Federal R&D project customers may prioritize which of the triple constraints are most critical to their efforts (i.e., scope – specifications and capabilities; cost – in various units of resources; or schedule – both interim milestones and completion of final deliverables). When federal funding is fixed annually at the beginning of each fiscal year and customers require deliverables by a certain date, R&D projects frequently are required to offer maximum scope flexibility for a negotiated cost and schedule.

The process by which R&D activity performance is monitored and documented, by necessity, varies greatly across projects and programs. Large-scale, complex construction projects follow clear and validated processes with quarterly milestones and regular review cycles. This method is neither appropriate nor meaningful for an R&D program typically one of a kind that measures progress toward answering a list of key questions through a variety of approaches for periods that may not have a hard-fixed end date.

DOE and NNSA offices are increasingly demanding a more structured (project) approach to R&D work, recognizing that one size does not fit all. Development (research) and deployment (traditional construction) projects are characteristically different in objectives, structure, and methods; they require a different level of rigor in the project management process as discussed in this white paper.

1.3.1 Development (also termed Research and Development) Activities

Development activities are conducted to acquire and disseminate new knowledge of a theoretical or experimental nature**.** Several sets of attributes may apply to these projects, including the following:

- Project end goals (a well-defined set of milestones and deliverables) may be well known but the method and path for achieving them (e.g., research, engineering, and fabrication) are not
- Project execution methods may be well known but the end goals are not
- Neither methods nor goals may be well known.

1.3.2 Deployment Activities

Deployment activities are conducted on fixed scope projects using established knowledge. Attributes that apply to this type of project include the following:

- Goals (e.g., scope, cost, and schedule baseline) are well known
- Methods (execution process) for achieving those goals are well known
- Methods for quantitatively measuring progress against the goals (e.g., unit rates, volumes of materials, and length of installed materials) are well known.

Unlike construction-type projects, R&D projects are not defined, repeatable processes. Attempting to create detailed, task-oriented plans for R&D projects early in their life cycle is likely to lead to frustration and time spent updating plans rather than managing the project[1]. Traditional project management, as defined for example in the PMI PMBOK® Guide, is focused on planning. The underlying assumption is that planning enough, tracking against the plan, and taking corrective action when work deviates from the plan will result in a successful project. Plan the work and work the plan. Control of the project is done by checking progress against the project plan and, when necessary, taking corrective action. The assumption is that the underlying plan is correct. If things go wrong, then it is likely not enough time was spent in upfront planning and understanding the requirements and risks. Using agile project management principles is an alternative to traditional project management and is better suited for R&D projects. This approach has been successfully applied to product development projects, such as software development. Agile project management employs techniques that are very different from those of traditional project management. In fact, some of the agile project management concepts are diametrically opposed to traditional project management concepts, such as the following:

- Not attempting to finalize requirements early in the project
- Promoting incorporation of change requests throughout the project life cycle
- Less emphasis on rigid upfront planning.

The science mission demands change, over-the-horizon outcomes, and routine technical integration among geographically and intellectually dispersed disciplines. It also puts a high premium on innovation. To be used most effectively in achieving results, application of project management methods, tools, and techniques must accommodate these needs and satisfy risk-based prerequisites.

The key to successful management of an R&D project is to recognize that change is an integral part of the process and then manage change to the benefit of the project. R&D has been described (not as a progressive process [i.e., the ladder analogy]) but as a continuous, iterative process (i.e., the cycle analogy).

2. OBJECTIVE

The objective of this white paper is to develop a clear and concise value proposition for the use of project management principles in the delivery of R&D projects that is universally acceptable to the principal investigator/scientist and the activity customer. This white paper also will expand on previous papers developed along these same lines and provide some examples of tools/templates and guides that currently are being used in a tailored fashion within DOE and other government sector R&D projects.

It is recognized that R&D projects have unique attributes as a category within the DOE portfolio. A structured approach and framework for execution of smaller, non-DOE Order 413.3A R&D projects

[1] Presentation by Mike Griffiths, "Utilizing Agile principles alongside the PMBOK® Guide for better project execution and control in software development projects," Proceedings of PMI® Global Congress 2004-North America, Anaheim, CA, December 2004.

can provide beneficial results. Using tools and techniques that allow for common R&D characteristics (such as greater scope variability at later stages of project execution) and managing risks within the discrete cost and schedule parameters are desirable results.

A substantial investment is being made in R&D projects. A recent U.S. General Accounting Office finding indicated the need for a more structured approach to managing R&D projects. The ability of researchers to use the existing highly structured approach (DOE Order 413.3A) on smaller projects is problematic. Tailored processes and tools are needed. Establishing an acceptable structure for managing projects in the R&D environment will increase opportunities for success. Providing a safe framework in which the R&D project manager or principal investigator can take risks in an acceptable manner is a high priority. Tools to help the R&D project manager take risk in a controlled and effective manner are valuable.

One of the bigger challenges to the manager of an R&D project is to quantify achievement in a discrete way. An objective approach to measuring achievement is essential if the data produced by a reporting system are to have any meaning. Cost and schedule reporting systems are excellent means of identifying the first sign of a problem, usually a schedule slip, in time for the project manager to initiate corrective action. This is only possible if meaningful indicators of performance are established jointly with the R&D project team to permit evaluation of progress against a valid baseline.

The early life cycle for science mission projects must look for new solutions that cause rapid change in project plans, substantial swings in the earned value management system information, increased project management labor to keep track of the changes, and project management to “cost too much.” The traditionalist model, by itself, becomes a self-defeating argument very quickly.

This white paper explores the merits and limitations of traditionally “projectizing” R&D and draws attention to the need for a more appropriate and tailored application of project management techniques across the spectrum of R&D work and the DOE R&D community.

3. DISCUSSION

3.1 Technology/Research Readiness

The use of a structured evaluation of technology readiness in the project execution realm has been shown to be helpful when dealing with first-of-a-kind technologies. NASA developed and the U.S. Department of Defense later adopted a process to measure and communicate technology readiness with a nine-point scale for assessing the Technology Readiness Level (TRL). The scale is graded starting from the lowest level of technology readiness, TRL-1, where scientific research begins to be translated into applied R&D to the highest level, TRL-9, where actual application of the technology in its final form has been proven through successful mission operations. Project teams can identify critical enabling technology to accomplish project goals and use a TRL to describe the level of technology maturity needed. It provides a common understanding of technology status and can be used to make decisions concerning transition of technology.

The U.S. General Accounting Office identified a need for a consistent approach for assessing technology readiness on DOE’s major construction projects in their 2007 audit (GAO-07-336). Because the broader R&D project portfolio within DOE, in many cases, involve use or expansion of recent technology developments, it would be useful to have tools that facilitate a consistent approach to assessing the TRL for projects with critical technology constraints.

DOE has recently included the TRL process as an element in the NNSA Project Definition Rating Index (PDRI) Manual in June 2008. The PDRI process is very comprehensive and technology readiness is just 1 of 44 rating elements that are evaluated during the design phase of a project. Target scores are established for the mission need, conceptual design, and preliminary design stage gate decisions. The targets are as follows (summarized):

1. Mission need:
   - Technologies planned for the facility are identified as not less than TRL-3 (validated the "proof-of-concept").
2. Conceptual design completion:
   - Technologies have been demonstrated at TRL-5 or higher (components can be tested in a simulated or somewhat realistic environment)
   - Any technology that does not fully meet the TRL requirements is specifically analyzed in the risk assessment; no less than TRL-4 accepted
   - Technology maturation plan to meet mission needs developed for technologies not at TRL-7 (demonstrated prototype).
3. Preliminary design completion:
   - Technologies demonstrated with a TRL-7 (demonstrated prototype) or better.
   - Any technology that does not fully meet the TRL requirements is specifically analyzed in the risk assessment; no less than TRL-4 accepted.

Use of the TRL process also has been identified as an element of improving front-end project planning as a part of the DOE Corrective Action Plan aimed at improving DOE project management in general.

Tailoring the TRL and PDRI tools for use on smaller R&D-type projects would help to standardize the terminology, make technology assessments more transparent, and improve communication among project stakeholders in the decision-making process. Similar processes and tools could be considered for evaluating "research readiness." Gaining an understanding of the maturity of existing research in a structured way would allow project teams to align the expectations of what is probable through research, not just what is possible.

3.2 Progressive Scope/Baseline Definition

The concept of progressive baseline definition is essentially application of rolling-wave-based planning methods to projects of an R&D nature. R&D projects are generally characterized by higher degrees of scope, schedule, and cost uncertainty and risk than is typical of projects that are well defined (such as construction). Key performance parameters of construction and other deployment-type projects are sufficiently known in the development phase of the project in a way that detailed planning results in well-defined scope for the facilities, products, systems, or processes that comprise the project.

R&D projects, however, by their nature, develop and incorporate new ideas, concepts, and techniques. Often, this involves experimentation and pushing the frontiers of science and technology to develop new systems, products, or methods. In the commercial sector, outputs of R&D projects are unique products for the marketplace. In the government sector, R&D projects may result in new weapons systems, experiments that prove new concepts, unique prototypes, or previously unavailable data that can then be used to confirm or deny hypotheses. The defining characteristic of all R&D projects is that the scope of the projects is significantly indeterminate at the outset of the project and may continue so into the project execution life cycle.

Unlike fixed-scope deployment projects, the scope baseline for R&D projects is not able to be frozen early in the project life cycle because there is insufficient information to do so. Artificially freezing the scope before the results of research are known would inhibit the usefulness of the project's final result. For instance, freezing the design for a new product may reduce the product's sales potential by antiquating it relative to consumer preferences in the marketplace at the point the product is introduced. On a government project, the final result may not meet full mission requirements and cause funding agencies, or the public, to legitimately question why the project expenditure does not have the desired functionality and does not represent a good return on investment. One approach that has been employed is to "get something built" (for the predefined scope, schedule, and cost) and then hope for follow-on funding to enhance the product over time; however, these events do not result in quality outcomes and leave all involved dissatisfied. Progressive baseline definition essentially negates the need for this kind of approach.

The challenge met by progressive baseline definition is to define scope so that it is not artificially constrained, while at the same time not have the project represent an open-ended "blank check." For R&D projects, scope is added to and deleted from as results from research become known. Scope development becomes a progressive and iterative process and is cycled until either time restrictions or research results enable the next increment of scope to be planned in detail. Eventually, the project scope does have to be frozen, but progressive baseline definition allows it to be kept open to accommodate change and to incorporate current, evolving, and most competitive science, technology, and engineering solutions into the project's deliverables.

The core feature of progressive scope/baseline definition is to define the baseline later than on traditional projects and to allow the scope baseline to evolve through incorporation of detail that results from the R&D elements of the project. Representation of this concept can be viewed through use of progressively narrowing ranges for scope, and, concomitantly, for schedule and cost. At the beginning of the project, the ranges are broad; they narrow as research results are obtained. These results may contain surprises that cause other parts of the project to be replanned (e.g., such would be the case if an experiment confirmed that proposed equipment could not achieve operational specifications). As the scope and corresponding schedule and cost range narrows, the baseline for scope, schedule, and cost is not frozen until requirements are matured. At this point, final scope requirements are defined and agreed to by the customer and the project team as a two-tier set consisting of the following:

- Minimal requirement – the features or operational performance that is the minimum acceptable for the project to be considered a success
- Reach goal – the features that are desirable and attainable if all research and development objectives are realized.

Theses concept are represented by Figure 1.

A very important point is that development and progression of the baseline on R&D projects must still be managed, but in a different way than on deployment projects, which generally follow a neat orderly process (design, bid, and build). In the case of R&D, managers (i.e., customers, project sponsors, and the project manager) must do the following:

- Establish parameters that frame the scope, schedule, and cost boundary conditions for the project (the project plan)
- Identify, in advance, research elements of the project
- Use design-of-research/experiments concepts to frame the research
- Establish overall scheduled review dates to assess progress
- Approve, incrementally, the project detailed scope as results of research become known.

The overall representation of these concepts is shown in Figure 2.

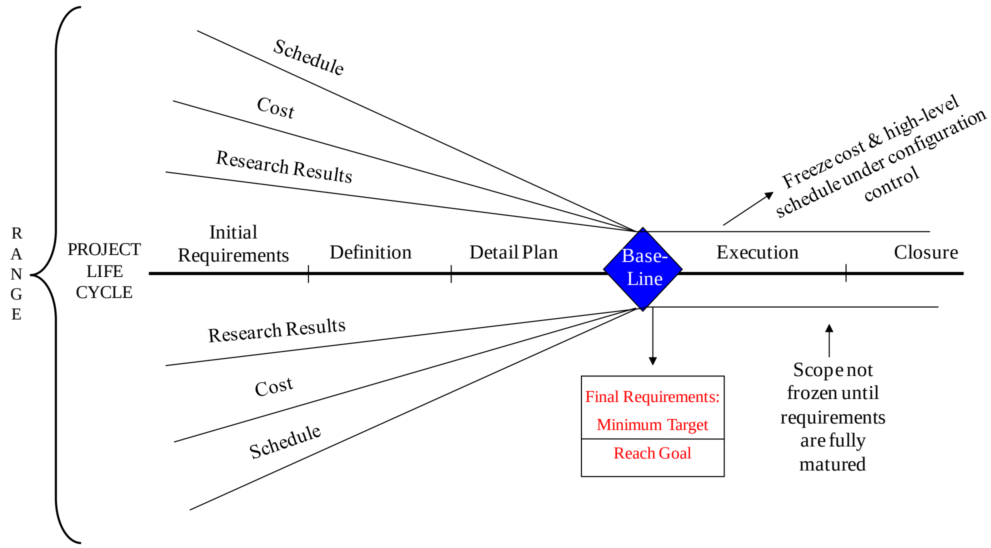

Figure 1. Progressive definition narrows, but delays freezing of requirements.

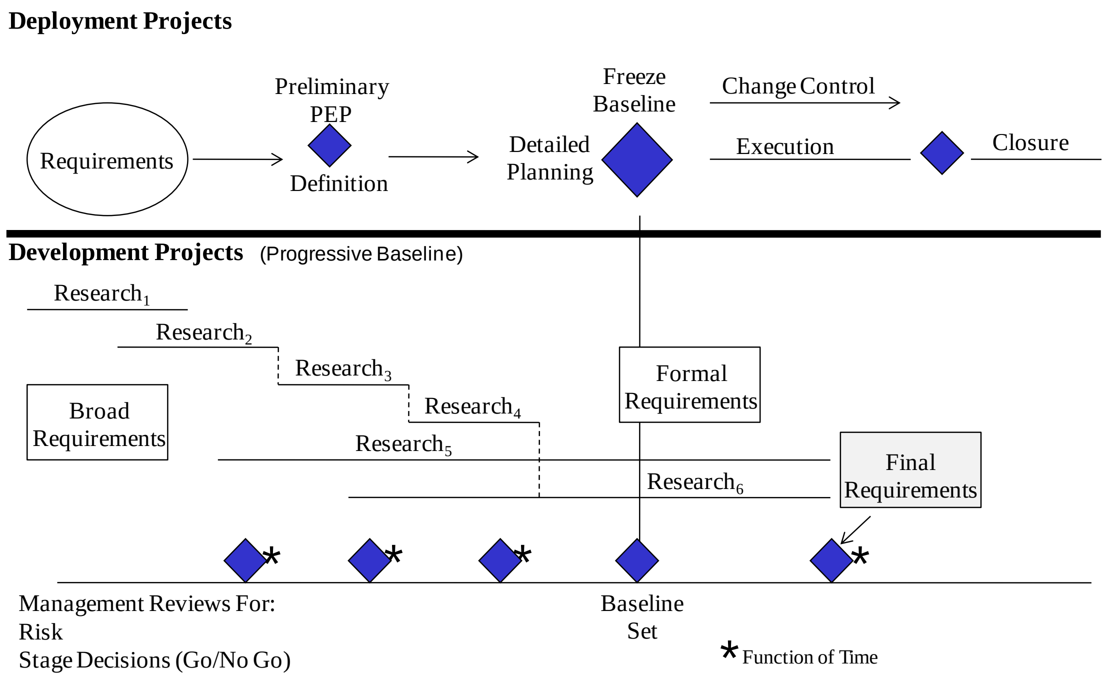

Figure 2. Deployment versus development project life cycle comparison.

The overall philosophy and "rolling wave" planning concept of progressive baseline definition is rooted in and consistent with the earned value management system. The National Defense Industrial Association ANSI/EIA-748-A, "Standard for EVMS Intent Guide," (January 2005) is a reference for this concept and includes the following provisions that validate rolling-wave planning:

- Control Accounts – planned at least to a summary planning level to the end of the project; any control accounts that cannot be established in the initial planning effort have the critical defining event(s) necessary for planning identified and made an item of continuing management interest

- Planning horizons can be used to establish reasonable control account level assignments of work and budget; summary level planning packages may be used until the information needed for detail planning becomes available
- Management reserve for budget of unknowns within the overall project scope.

3.3 Configuration Management/Trending

The process of progressive scope/baseline definition desirable for providing essential flexibility for managing R&D projects recommends elements that provide the ability to do the following:

- Incorporate new ideas, concepts, and techniques by embracing change and flexibility in a controlled and documented manner
- Add or delete scope as results from research or development become known
- Delay "freezing" of the baseline for scope, schedule, and cost until requirements are sufficiently matured to achieve a technically competitive deliverable.

As previously mentioned, progression of the baseline on R&D projects must still be managed but in a different way. Ultimately, what is desired is a method that incrementally identifies, manages, and approves the detailed project scope as the baseline approaches maturity. This type of method would use expanded configuration management to proactively track trends (forward looking) leading to a more flexible baseline, as compared to a more traditional approach (such as a structured change control using tools such as a baseline change request and approval formalism) that tends to be more reactive.

3.3.1 Configuration Management

The PMBOK® Guide incorporates configuration management as a tool and technique within integrated change control as a subset of project management integration. Sister elements to configuration management include a change control system, performance measurement, additional planning, and a project management information system. The PMBOK® definition of what is meant by configuration management is "any documented procedures used to apply technical and administrative direction and surveillance to" the following:

- Identify and document functional and physical characteristics of an item or system
- Control any changes to such characteristics
- Record and report the change and its implementation status
- Audit items and systems to verify conformance to requirements.

In many application areas, configuration management is a subset of a change control system and is used to ensure that the description of the project's product is correct and complete. In other applications, change control refers to any systematic effort to manage project change.

The PMBOK® definition of what is meant by change control is "a collection of formal, documented procedures that defines how project performance will be monitored and evaluated, and includes steps by which official project documents may be changed. It includes paperwork, tracking systems, processes, and approval levels necessary for authorizing changes."

3.3.2 Trending

Trending also appears as an example in the PMBOK® Guide as a quality control tool and technique within project quality management, in project communications management as a performance reporting tool and technique, and in project risk management as a risk analysis output. The guide contains less definition of how trend analysis can be deployed for purposes in addition to prevention of errors and monitoring of tolerances and performance. Trending is a tool, a methodology, and a process to capture changes that are about to happen (i.e., it is predictive and forward looking). Project trending provides an effective forewarning of potential changes and cost/schedule forecasts. Some useful concepts to consider are[2]:

> *"A trend log serves as a discussion paper to discuss changes within the project team and with higher management for alternatives or decision makings. It records the impact of additional cost and extra time required if the change is physically implemented.*
>
> *The highest value for trending in agile project management lies in its application to real-time and forward-looking prospective changes as a consequence of R&D outcomes rather than being used to increase a budget request or capture what has already occurred."*
>
> *Some additional trending attributes in managing "traditional" (deployment) projects include[3]:*
>
> *A trend is an idea or change, whether or not the change is fully accepted or developed, that has been directed or contemplated as a result of legislation, management action, more definitive design, design changes, field condition changes, etc." Trending is a tool, a methodology, and a process to capture changes that are about to happen. These changes may have either a positive or a negative impact to overall project cost and schedule. Trending programs have been widely used in cost reimbursable Engineering, Procurement, and Construction (EPC) contractual relations and accepted by both owner and contractors as an effective tool to forecast cost growth and deviation. "Trending" is a mechanism that is used to forewarn the project management team of any unwanted deviation from the baseline. It also provides back-up documentation for cost variance analysis. Variances are reported over time to indicate "trend" for cost control purpose. Trending is a vital part of the cost management system, which is "the process of comparing actual performance with planned performance, analyzing variances, evaluating possible alternatives, and taking appropriate corrective action."*

In the context of developing a tailored approach to the management of federal R&D projects, trending for purpose of cost growth, deviation, unwanted deviations from the baseline, and cost variance analysis would still be applicable; however, the value would be more closely related to how to embrace and accommodate desired changes from outcomes of research or development advancements during the project life cycle rather than as a controlling mechanism for policing changes to an already frozen baseline or as a tool for assessing how changes may impact a project's gross profit margin.

3.3.3 Key Points

Essentially nothing in the above change control concepts cannot be incorporated into R&D project management, but application is intended to nurture a streamlined, flexible, fluid, graded/tailored, and real-time execution of managing the configuration elements of a project during progressive establishment of an R&D project baseline. The project's "agility" and the technology of the deliverable are not constrained or adversely compromised. The focus of a streamlined configuration management and trending application to the project manager is not on a paper product or a formal approval of change

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[2] John G. Zhao, "Marrying Risk Register with Project Trending, AACE June 2005 presentation, http://www.aurora-aace.org/user/AACE%20Risk%20Register_Trending%20Presentation%20March%2006.pdf

[3] John G. Zhao, ibid., paper that accompanies slide presentation, http://www.icoste.org/aace2005%20papers/risk06.pdf

requests but rather on the ability to juggle real-time tradeoffs between known and unknown and desired and undesired changes to the original project concept of scope that arise from the nature of R&D activities.

Similar concepts for configuration management, change control, and trending have been applied to management of software projects in that their dynamic product environment can be similar to that of R&D.

As an example[4]:

> *Agile methods are sometimes characterized as being at the opposite end of the spectrum from "plan-driven" or "disciplined" methods. This distinction is misleading, as it implies that agile methods are "unplanned" or "undisciplined." A more accurate distinction is that methods exist on a continuum from "adaptive" to "predictive." Agile methods lie on the "adaptive" side of this continuum. Adaptive methods focus on adapting quickly to changing realities. When the needs of a project change, the adaptive team changes as well. An adaptive team will have difficulty describing exactly what will happen in the future. The further away a date is, the vaguer an adaptive method will be about what will happen on that date. An adaptive team can report exactly what tasks are being done next week, but only which features are planned for next month. When asked about a release six months from now, an adaptive team may only be able to report the mission statement for the release, or a statement of expected value vs. cost. Predictive methods, in contrast, focus on planning the future in detail. A predictive team can report exactly what features and tasks are planned for the entire length of the development process. Predictive teams have difficulty changing direction. The plan is typically optimized for the original destination and changing direction can cause completed work to be thrown away and done over differently. Predictive teams will often institute a change control board to ensure that only the most valuable changes are considered.*

3.4 Application of Earned Value Management Techniques to Research and Development Projects

The benefit of applying earned value management techniques to augment project management methods has been widely accepted by both the government and commercial industry. Earned value management techniques provide an accurate measure of a project's past and can be a reliable predictor of future success against the baseline plan, enabling early initiation of management corrective actions as necessary. The application of earned value management to R&D projects can be equally beneficial provided that one acknowledges the differences between traditional projects using the waterfall method to achieve well-defined and predictable outcomes (technical performance) versus R&D projects that often use an iterative process (an exploratory and discovery process with uncertain outcomes that may be more akin to the scientific process) in search of technical performance.

The application of earned value management techniques to any project is based on a fundamental prerequisite, which is the ability to define the work scope and plan its execution. A baseline must be established consisting of a resource-loaded (assigned value), logically-linked (time-phased) schedule of activities representing the project's work scope and deliverables. This, of course, is based on the premise that measuring project performance is desirable; either from the customer's perspective to control investments, or from the project manager's perspective to control scope creep.

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[4] http://en.wikipedia.org/wiki/Agile_Project_Management

The ability to confidently develop a life-cycle baseline for R&D projects may be constrained by the lack of final requirements and the inability to predict specific outcomes during the R&D process. Whereas, some elements of the project may be well understood (e.g., constructing a building to conduct an experiment, obtaining environmental permits for an experiment, or defining the resources required to conduct and experiment), planning other elements (such as defining the number of iterations required to achieve performance objectives) may not be reliably predicted. Baseline changes should be expected for R&D projects.

Development of a R&D project baseline may include greater use of planning packages and undistributed budget to accommodate planning uncertainties, where near-term activities are well defined and measured, and far-term work scope will be replanned (via change control) within the project's baseline prior to execution.

It is recognized that the iterative nature of R&D projects necessitates agile project management techniques. One such technique may be to establish baseline plans for each phase of development (e.g., each element of a technology development roadmap, development of a prototype, or construction of a pilot plant) rather than the entire life cycle. The overall value of earned value management data is directly related to the confidence in a project baseline (which is only as good as the ability and discipline demonstrated to plan and measure the work), and the validity of assumptions made in developing the plan. Establishing reliable baselines for R&D projects should reflect and be constrained (duration of the plan) by the confidence level in the planning.

Moreover, also because of the iterative nature of R&D projects, it should be understood that successful baseline execution does not necessarily predict successful achievement of the project's technical performance goals. Technical performance measures should be coupled with earned value management data and be identified as triggers for baseline change control to incorporate baseline changes necessary to meet performance goals.

Application of earned value management techniques to R&D projects also may be tailored. It has been advocated that effective earned value management can be achieved on any project, of any size, in any industry, by simply applying the following 10 steps[5]:

1. Define scope (objectives and deliverables) of the project
2. Determine who will perform the defined work, including identification of all critical procurements
3. Plan and schedule the defined work
4. Estimate required resources and formally authorize budgets
5. Determine metrics to convert planned value into earned value
6. Form a performance measurement baseline and determine the points of management control referred to as control account plans
7. Consistently record all direct cost by project with the authorized baseline budgets, in accordance with the organization's general books of accounts
8. Continuously monitor the earned value performance to determine cost and schedule departures from the baseline plan and both schedule variances (earned value less the planned value) and cost variances (earned value less the actual costs)

[5] Quentin W. Fleming and Joel M. Koppelman, Primavera Systems, Inc., *Start With "Simple" Earned Value On All Your Projects*, CrossTalk – The Journal of Defense Software Engineering, June 2006

9. Using earned value data, forecast the final required costs based on actual performance and keep management apprised so they can take corrective actions if necessary
10. Manage the authorized scope by approving or rejecting all changes, and incorporating approved changes into the project baseline in a timely manner.

After a baseline has been established, earned value management techniques can provide an accurate measure of baseline performance, and are a reliable predictor of future baseline execution success. Using even a minimum application of earned value management (e.g., level-of-effort measurement of a resource-loaded schedule), there are clear benefits related to resource management and the ability to eliminate the continuing confusion surrounding fiscal year “carryover,” where earned value management provides clear definitions between scope, assigned budget for the scope, and funding.

3.5 Project Controls in Research and Development

An essential part of project planning is ensuring that project risks are identified, analyzed, determined to have been eliminated, and mitigated or are manageable. The project technical, cost, and schedule risks must be identified, qualitatively assessed, quantified, and mitigated as appropriate. Risk response strategies need to be developed, documented, and implemented. A risk screening and identification checklist is included in Appendix A that can be used as a tool in the initial screening process to identify significant risks and establish a risk level for the project.

Based on the complexity, risk, and size of a project, a tailored approach to project controls can be implemented for projects and research activities. The application of basic project management principles, as outlined in the example of a tailored controls matrix (Table 1), to research and development activities provides a level of rigor governed by risk elements to sufficiently plan and manage the work to achieve the desired requirements and deliverables.

Note: The samples of tailored approach to project controls are not intended to be comprehensive. The rigor of each control function is tailored to mitigate the level of risk for projects assessed to be in groups of having “low, medium, or high risk” elements.

Table 1. Sample of tailored approach to project controls.

Project Control Function	General Activities	Projects		
		Low Risk	Medium Risk	High Risk
Technical Baseline and Work Scope Definition	WBS identification Control account and work package documentation	Project WBS Control account and work package documentation Unique project number Tailored PEP	Project WBS Control account and work package documentation Unique project number Tailored PEP	Project WBS WBS dictionary Control account and work package documentation Unique project number Tailored PEP
Roles and Responsibilities	Designated control account manager and work package manager R2A2s	Designated project manager Designated control account manager and work package manager Project team identification R2A2s	Designated project manager Designated control account manager and work package manager Formal organization breakdown structure R2A2s	Designated project manager Designated control account manager and work package manager Formal organization breakdown structure Formal responsibility assignment matrix R2A2s Identification of critical resources and responsibilities

Project Control Function	General Activities	Projects		
		Low Risk	Medium Risk	High Risk
Cost Estimating	Current fiscal year resource-loaded priced schedules	Life-cycle estimate Informal estimate for less than $5M TPC Informal estimate for greater than or equal to $5M TPC - cost estimating review required Formal estimate for DOE Order 413.3A projects Current fiscal year resource-loaded priced schedule	Life-cycle estimate Informal estimate for less than $5M TPC - cost estimating review required Formal estimate required for greater than or equal to $5M TPC Formal estimate for DOE Order 413.3A projects Current fiscal year resource-loaded priced schedule	Life-cycle estimate Formal estimate Current fiscal year resource-loaded priced schedule Independent cost estimate review
Scheduling	Level III logically linked resource-loaded schedule For work performed in a nuclear facility requiring radiological control, craft, or operations personnel, develop and work interfaces with facility Level IV and V resource-loaded schedules	Level III logically linked resource-loaded schedule Level IV logically linked key resource-loaded schedule for facility operations interfaces and resources, aligned with the Level III schedule Identify interfaces with other projects on the Level III schedule Documented performing organizations resource commitments (facility, equipment, and personnel)	Level III logically linked resource-loaded schedule Level IV logically linked key resource-loaded schedule aligned with the Level III schedule Identify interfaces with other projects on the Level IV schedule Documented performing organizations resource commitments (facility, equipment, and personnel)	Level III logically linked resource-loaded schedule Level IV logically linked key resource-loaded schedule aligned with the Level III schedule Identify interfaces with other projects on the Level IV schedule Documented performing organizations resource commitments (facility, equipment, and personnel)
Work Authorization	Approved control account and work package	Approved project authorization documentation Approved control account and work package	Approved project authorization documentation Approved control account and work package	Approved project authorization documentation Approved control account and work package
Baseline Documentation Configuration and Change Management	Maintain baseline documentation and performance records Identify change control threshold and authorization levels Change control log	Maintain baseline documentation and performance records Identify change control threshold and authorization levels Change control log Formal Change Control Board Project risk management addressed in the PEP	Maintain baseline documentation and performance records Identify change control threshold and authorization levels Change control log Formal Change Control Board Project risk management addressed in the PEP	Maintain baseline documentation and performance records Identify change control threshold and authorization levels Change control log Formal Change Control Board Formal project risk management plan

Project Control Function	General Activities	Projects		
		Low Risk	Medium Risk	High Risk
Cost Accounting	Discrete charge numbers established at the work package level or below	Discrete charge numbers established at the work package level or below	Discrete charge numbers established at the work package level or below	Discrete charge numbers established at the work package level or below
Performance Measurement, Evaluation, and Reporting	Earned value method identified for Level III schedule activities (fiscal year PMB) Monthly schedule status based on the earned value method Variance analysis reporting threshold definition Monthly accomplishments, and cost and schedule variance analysis report at the control account level	Earned value plan based on the Level III schedule (PMB) Monthly schedule status based on the earned value plan Variance analysis reporting threshold definition Monthly accomplishments, and cost and schedule variance analysis report at the control account level	Earned value plan based on the Level IV schedule, aligned with the Level III schedule (PMB) Monthly schedule status based on the earned value plan Variance analysis reporting threshold definition Monthly accomplishments, and cost and schedule variance analysis report at the control account level	Earned value plan based on the Level IV schedule, aligned with the Level III schedule (PMB) Monthly schedule status based on the earned value plan Variance analysis reporting threshold definition Monthly accomplishments, and cost and schedule variance analysis report at the control account level Independent project reviews

Notes:

Project risk is a measure of the potential inability to achieve overall project objectives within defined cost, schedule, and technical constraints.

Additional requirements for capital asset projects shall be met in accordance with DOE Order 413.3A.

The level of detail for planning and execution within each functional area is further tailored based on the level of rigor required by the quality level determination.

PEP = project execution plan

PMB = performance measurement baseline

R2A2 = roles, responsibilities, accountabilities, and authorities

TPC = total project cost

WBS = work breakdown structure

4. VALUE PROPOSITION

4.1 To Customer

1. Provide R&D products and services that meet or exceed customer requirements for each deliverable and that are responsive to customer prioritization of scope, cost, and schedule constraints.
2. Provide reliable delivery of functionality, cost, schedule, safety, and environmental needs.

4.2 To Program Managers, Project Managers, Direct Managers, and Principal Investigators

1. Provide project management processes, training and tools that are useful and continuously improved on.
2. Remove manual steps by implementing a guided system to plan and manage projects.
3. Enable timely and tailored delivery of tools and processes to the project manager.
4. Provide easy access to accurate, timely, and understandable project status.
5. Provide usable and timely performance data to enable monitoring, oversight, and effective corrective action.

6. Provide baselining and estimating processes that match cost accounting and reporting processes.
7. Obtain tool that provides performance data that can be used to communicate project success.

4.3 To Enterprise Level Project/Program Management

1. Provide accurate and useful views of whole project performance.
2. Provide a system for optimizing project manager capability to project risk and complexity.
3. Ensure institutional integrity and organization learning in project management.
4. Provide technically qualified project managers for executing work in an R&D environment.
5. Provide scheduling capability that can be integrated above the individual project level.
6. Provide understandable and useful data on institutional risks encumbered by all projects.
7. Provide support and foster a "project management" culture.
8. Provide qualified project managers with "competence commensurate with responsibilities."

5. CONCLUSION

Effective application of project management techniques on R&D projects can result in improved project performance (cost and schedule) while achieving technical performance goals. Providing R&D products and services that meet or exceed customer requirements for each deliverable and that are responsive to evolving customer prioritization of scope, cost, and schedule constraints has been achieved on projects at NASA and within the DOE complex.

The key to successful management of R&D projects is recognizing that change is an integral part of the process. By successfully adapting and tailoring project management processes to the unique attributes of R&D projects, a more structured (project) approach and framework for their execution can be achieved with beneficial results.

The application of the tailored project management techniques for the delivery of R&D projects discussed in this paper warrant additional assessment as more lessons learned from the application are known:

- Structured evaluation of technology/research readiness
- Progressive scope/baseline definition (using a rolling wave approach)
- Configuration management and trending
- Implementation of a tailored approach to project controls and risk identification

These techniques will be further developed as the application expands and can be applied to improve the success of R&D projects within the DOE complex.

6. REFERENCES AND ADDITIONAL READING

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Appendix A

Risk Screening and Identification Checklist

	Risk Categories	Risk Type	Potential for Risk? No	Yes: Low	Yes: Med	Yes: High
1.	TECHNOLOGY					
	New technology?		☐	☐	☐	☐
	Unknown or unclear technology?		☐	☐	☐	☐
	New application of existing technology?		☐	☐	☐	☐
	Involves modernized/advanced technology in existing application?		☐	☐	☐	☐
	Significant modification of existing technology?		☐	☐	☐	☐
	Technical strength of the performing engineering team inadequate?		☐	☐	☐	☐
	Efficient application of existing technology?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
2.	INTERFACES					
	Multiple systems?		☐	☐	☐	☐
	Multiple project interfaces (external)?		☐	☐	☐	☐
	Multiple technical organizations?		☐	☐	☐	☐
	Multiple projects?		☐	☐	☐	☐
	Multiple customers?		☐	☐	☐	☐
	Multiple end users?		☐	☐	☐	☐
	Multiple agencies/contractors?		☐	☐	☐	☐
	Near Safety Class systems?		☐	☐	☐	☐
	Interface with operating SSCs during installation/testing?		☐	☐	☐	☐
	Special work control/work authorization procedures?		☐	☐	☐	☐
	Co-occupancy of facilities required?		☐	☐	☐	☐
	Potential for operational activities to have priority over project activities?		☐	☐	☐	☐
	Outage requirements?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
3.	QUALITY					
	Does NQA-1 or DOE RW-0333P apply?		☐	☐	☐	☐
	Precision work required?		☐	☐	☐	☐
	Rework expected due to nature of tolerances?		☐	☐	☐	☐
	Significant quality work that is (or will be) inaccessible?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
4.	SAFETY/RADIOLOGICAL (see also Category 13 below)					
	Criticality potential?		☐	☐	☐	☐
	Any impact to the Facility Authorization Basis (e.g. new DBAs or USQs generated)?		☐	☐	☐	☐
	Hazardous material involved?		☐	☐	☐	☐
	Confinement strategies required?		☐	☐	☐	☐

	Risk Categories	Risk Type	Potential for Risk?			
				Yes		
			No	Low	Med	High
	Will hazardous materials inventories exceed the OSHA TQs?		☐	☐	☐	☐
	Fire watch required?		☐	☐	☐	☐
	Emergency Preparedness impacts/concerns?		☐	☐	☐	☐
	Is low-level waste, TRU waste, or HLW involved?		☐	☐	☐	☐
	Radiological conditions (current and future) Contamination? Radiation?		☐	☐	☐	☐
	Significant exposure/contamination potential?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
5.	ENVIRONMENTAL COMPLIANCE					
	Environmental assessment/impact statement required?		☐	☐	☐	☐
	Potential for additional environmental releases?		☐	☐	☐	☐
	Undefined disposal methods/potential for orphan wastes?		☐	☐	☐	☐
	Permitting and notifications required?		☐	☐	☐	☐
	State inspections?		☐	☐	☐	☐
	Regulatory oversight?		☐	☐	☐	☐
	Agency (i.e., EPA, State, NRC, or DNFSB) participation in decision-making?		☐	☐	☐	☐
	DOE Order compliance?		☐	☐	☐	☐
	Performed in a CERCLA/RCRA-permitted facility?		☐	☐	☐	☐
	Mixed waste involved?		☐	☐	☐	☐
	Uncharacterized waste involved?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
6.	DESIGN					
	Undefined, incomplete, or unclear functions or functional requirements?		☐	☐	☐	☐
	Undefined, incomplete, or unclear design criteria?		☐	☐	☐	☐
	Numerous or unclear assumptions?		☐	☐	☐	☐
	Numerous or unclear engineering change bases?		☐	☐	☐	☐
	Special or unusual engineering analyses required?		☐	☐	☐	☐
	Complex design features?		☐	☐	☐	☐
	Reliability issues?		☐	☐	☐	☐
	Inspectability/testability issues?		☐	☐	☐	☐
	Maintainability issues?		☐	☐	☐	☐
	Availability issues?		☐	☐	☐	☐
	Operability issues?		☐	☐	☐	☐
	Safety Class systems?		☐	☐	☐	☐
	Errors and omissions in design?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
7.	TESTING					
	Construction turnover/other testing required?		☐	☐	☐	☐

	Risk Categories	Risk Type	Potential for Risk?			
				Yes		
			No	Low	Med	High
	Subcontractor acceptance/other testing required?		☐	☐	☐	☐
	Facility startup testing required?		☐	☐	☐	☐
	Maintenance testing required?		☐	☐	☐	☐
	SO, system startup, or integrated testing required?		☐	☐	☐	☐
	Difficult to perform functional test?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
8.	RESOURCES / SITE CONDITIONS					
	Adequate and timely resources not available?		☐	☐	☐	☐
	Specialty resources required?		☐	☐	☐	☐
	Adequate and timely material/equipment resources not available?		☐	☐	☐	☐
	Existing utilities above and underground?		☐	☐	☐	☐
	Adequate and timely support services not available?		☐	☐	☐	☐
	Geological conditions?		☐	☐	☐	☐
	Geographic conditions? (e.g., distributed work locations?)		☐	☐	☐	☐
	Temporary resources (power, lights, water, etc.) required?		☐	☐	☐	☐
	Construction/operations complexities present?		☐	☐	☐	☐
	Transportation complexity?		☐	☐	☐	☐
	Critical lifts required?		☐	☐	☐	☐
	Population density?		☐	☐	☐	☐
	Escorts required?		☐	☐	☐	☐
	Personnel training and qualifications required?		☐	☐	☐	☐
	Adequate and timely tools/equipment controls not available?		☐	☐	☐	☐
	Experience with system/component (design, operations, and maintenance)?		☐	☐	☐	☐
	Work force logistics complexities (e.g., rapid buildup required)?		☐	☐	☐	☐
	R&D or Technology Development support required?		☐	☐	☐	☐
	Lockout/tagout support required?		☐	☐	☐	☐
	Facility work control priorities impacted?		☐	☐	☐	☐
	Multiple projects/facilities involved in site logistics?		☐	☐	☐	☐
	Facility infrastructure impacted requiring major improvements?		☐	☐	☐	☐
	Analytical laboratory resources not available?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
9.	SAFEGUARDS AND SECURITY					
	Category I nuclear materials involved?		☐	☐	☐	☐
	Classified process or information involved?		☐	☐	☐	☐
	Special physical security measures required?		☐	☐	☐	☐
	Safeguards or security concerns involved?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
10.	PROCUREMENT					
	Procurement strategy undefined or complex?		☐	☐	☐	☐

	Risk Categories	Risk Type	Potential for Risk?			
				Yes		
			No	Low	Med	High
	First-use subcontractor/vendor involved?		☐	☐	☐	☐
	Adequate and timely vendor support not available?		☐	☐	☐	☐
	Limited availability of qualified vendors or subcontractors?		☐	☐	☐	☐
	Sole source procurement required?		☐	☐	☐	☐
	Long-lead procurement items?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
11.	CONSTRUCTION STRATEGY					
	Turnover/start-up complexities?		☐	☐	☐	☐
	Direct hire/subcontractor complexities?		☐	☐	☐	☐
	Construction/maintenance testing complexities?		☐	☐	☐	☐
	Design change package issues?		☐	☐	☐	☐
	Construction unique to the standard INL practice?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
12.	MANAGEMENT					
	Funding availability uncertainties?		☐	☐	☐	☐
	Multiple funding sources (e.g., State and Federal)?		☐	☐	☐	☐
	Funding provided by foreign countries?		☐	☐	☐	☐
	Project supporting a DOE low-priority program?		☐	☐	☐	☐
	Errors and omissions in estimates?		☐	☐	☐	☐
	Stakeholder program strategy changes?		☐	☐	☐	☐
	Fast track/critical need?		☐	☐	☐	☐
	Infrastructure issues (e.g., processes, procedures, systems)?		☐	☐	☐	☐
	Potential for schedule deferrals?		☐	☐	☐	☐
	Potential for schedule accelerations?		☐	☐	☐	☐
	Management acceptance of identified risk w/o mitigation?		☐	☐	☐	☐
	Technical scope uncertainties?		☐	☐	☐	☐
	Technical roles and responsibilities not well established?		☐	☐	☐	☐
	Potential for changes in priority?		☐	☐	☐	☐
	Potential for changes in strategy?		☐	☐	☐	☐
	Potential for changes in project team members?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
13.	WORK CONDITIONS RESULTING IN UNUSUAL APPLICATIONS OF GENERAL SITE SAFETY STANDARDS					
	Potential for personnel injury?		☐	☐	☐	☐
	Heat stress?		☐	☐	☐	☐
	Exposure to cold?		☐	☐	☐	☐
	Industrial hazards?		☐	☐	☐	☐
	Process hazards?		☐	☐	☐	☐
	Use/creation of carcinogens?		☐	☐	☐	☐

	Risk Categories	Risk Type	Potential for Risk?			
				Yes		
			No	Low	Med	High
	Confined space work?		☐	☐	☐	☐
	Air quality (indoor/outdoor)?		☐	☐	☐	☐
	Exposure to biohazards?		☐	☐	☐	☐
	Exposure to blood borne pathogens?		☐	☐	☐	☐
	Work elevation hazards?		☐	☐	☐	☐
	Personnel protection complexities?		☐	☐	☐	☐
	Adequate and timely access to medical supplies/facilities/personnel not available?		☐	☐	☐	☐
	Adequate and timely protective equipment not available?		☐	☐	☐	☐
	Vehicular hazards?		☐	☐	☐	☐
	Traffic patterns?		☐	☐	☐	☐
	Traffic control?		☐	☐	☐	☐
	Pedestrian areas?		☐	☐	☐	☐
	Unusual vehicles?		☐	☐	☐	☐
	Explosion potential?		☐	☐	☐	☐
	Ergonomic issues?		☐	☐	☐	☐
	Work outside field of vision?		☐	☐	☐	☐
	Work beyond standard reach?		☐	☐	☐	☐
	Weather/climate conditions (impact to temp. sensitive equipment/controls)?		☐	☐	☐	☐
	Natural phenomena hazards?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
14.	OTHER MISCELLANEOUS					
	Schedule uncertainties that might impact on-time completion?		☐	☐	☐	☐
	Adverse weather conditions cause delays that significantly impact schedule?		☐	☐	☐	☐
	Duration greater than 5 years?		☐	☐	☐	☐
	Long-lead procurement on critical path?		☐	☐	☐	☐
	Cost/Budget?		☐	☐	☐	☐
	Cost baseline based on uncertain or high level estimates?		☐	☐	☐	☐
	Cost items subject to higher than normal cost fluctuations?		☐	☐	☐	☐
	Errors and omissions in schedule/cost estimates?		☐	☐	☐	☐
	Housekeeping?		☐	☐	☐	☐
	Political issues or opposition?		☐	☐	☐	☐
	Will advocacy organizations (e.g., Sierra Club, Greenpeace) take interest?		☐	☐	☐	☐
	Oversight Committee/Citizens Advisory Board participate/influence decision-making?		☐	☐	☐	☐
	Other?		☐	☐	☐	☐
Risk Type Key: T = Technical; P = Programmatic; S = Schedule; C = Cost						
				Low	Med	High

	Risk Categories	Risk Type	Potential for Risk?			
			No	Yes		
				Low	Med	High
15.	Results of Risk Screening:			☐	☐	☐
	Analyst: ______________________________ ______________________ ________ Printed/Typed Name Signature Date					
16.	PM: ______________________________ ______________________ ________ Printed/Typed Name Signature Date					