Project Management for R&D and Innovation

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ABSTRACT

Research and development (R&D) efforts differ from traditional projects in a number of ways. The desired result of R&D may be intangible with desired outcomes including increased knowledge, a design or prototype, or an initial version of a new product or process. The outcome of the project and the steps to get there may be ill-defined or even unachievable. This paper presents distinctive characteristics of R&D projects and a set of guidelines, gleaned from experience, which apply to managing such projects.

INTRODUCTION

The triple constraint of project scope, time, and cost is well-known in project management (PM), and project management generally assumes that the dimensions of these constraints are well-known and generally well-balanced at the start of a project. Research and Development (R&D), which develops new knowledge and matures that knowledge into products and capabilities, may be undertaken without knowing whether the planned scope is at all achievable and with an incomplete understanding of what it will take to achieve the project's goals.

The Project Management Institute's (PMI) definition of a project as, "a temporary endeavor undertaken to create a unique product, service or result," does incorporate research projects in that PMI's definition of a *result* can include creation of new knowledge or publication of a paper (Project Management Institute, 2013). However, R&D covers a much broader swath, wherein a project will typically have concrete but potentially poorly understood or articulated goals and products. This paper describes approaches that have been successfully employed in managing a spectrum of R&D projects within the technology domain.

CATEGORIES OF R&D

The Organisation for Economic Co-operation and Development (OECD), and the U.S. government-wide Office of Management and Budget (OMB) each define three sub-categories of R&D, including Basic Research (the earliest stage, consisting of "experimental or theoretical work undertaken primarily to acquire new knowledge"), Applied Research (which retains the goal of acquiring new knowledge, but is "directed primarily towards a specific, practical aim or objective"), and Experimental Development (which draws upon knowledge gained from research to improve or produce new products or processes) (OECD, 2015)(US OMB, 2016). The U.S. Department of Defense offers a finer-grained categorization with five sub-categories of R&D, as shown in *Table 1*. (US DoD, 2016)

Table 1: U.S. Department of Defense R&D Categories

Category	Description
Basic Research	Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts.
Applied Research	Translates basic research into solutions. Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
Advanced Technology Development	Focused on development and integration of hardware for field experiments and tests with a goal of providing proof of technological feasibility and assessment of operability and producibility.
Demonstration/ Validation	Includes all efforts necessary to evaluate integrated technologies in a realistic operating environment to assess performance and cost impact of the technology.
Engineering and Manufacturing Development	Translates integrated technologies into product designs through engineering and manufacturing development.

Figure 1, adapted from (Wingate, 2015), represents characteristics across the R&D continuum. Basic Research may have an end product that is defined only by outcomes such as increasing knowledge or testing a hypothesis. As such, the project contains a great many unknowns and the project plan is expected to undergo considerable change in ways which cannot be completely forecast *a priori*. Each step through the R&D continuum builds on the knowledge gained in previous steps, leading to reductions in uncertainty and more concretely definition of the desired outcome. Put another way, research creates technological possibilities, while development is the set of applying a stable set of technological possibilities to the complex requirements of an application context (Iansiti, 1997). The characteristics of the phases of R&D drive differences in project management approaches across the

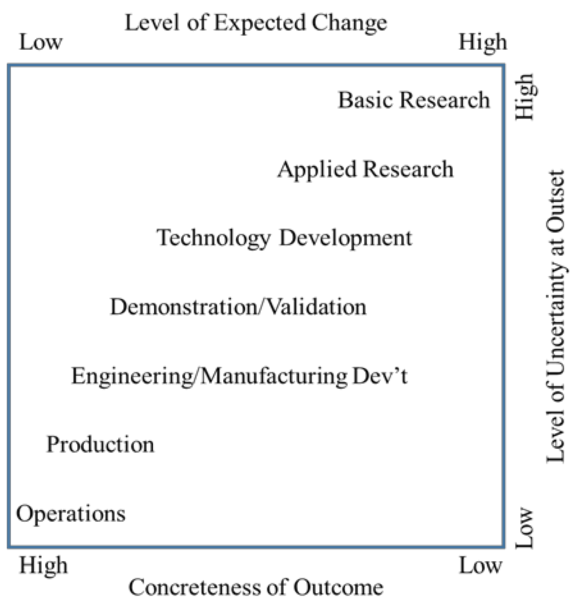

Figure 1: Characteristics of the R&D Continuum

continuum, which will be discussed in subsequent sections.

DISTINCTIVE CHARACTERISTICS OF R&D PROJECTS

Distinctive characteristics of research and development projects, as noted in (EFCOG, 2010), (Jain, 1990) and (Cassanelli, 2017), include:

Uncertainty/Risk: The scope of an R&D project may be incompletely understood at initiation. Project end goals may be well defined but the path for achieving them may not be known, and it may not be clear that the goals are even achievable. Conversely, technical approaches may be well known but the goals may be poorly understood. Scope may be expressed in terms of vision, operational objectives or performance goals rather than hard definitions, with requirements defined only in general terms.

Instability/Change: The internal discovery process that is an inherent part of R&D projects will change the project over time, as may external factors such as shifting application needs or changes in technologies. Changes in the research environment such as sudden breakthroughs, unexpected barriers, or changes in collaboration, can all induce significant change.

People: Freedom of action and a high degree of autonomy and control have significant value for all knowledge workers (Badawy, 1978); this is particularly true for the highly creative, inquisitive, “outside the box” thinkers who populate research and development environments. Teams made up of free-thinking researchers can have dynamics including experts who work prefer to work individually, strong personalities who force their ideas in the project, collaborative teams, internally competitive teams, disciplined or undisciplined teams, and drift (Kuchta, 2017).

Dual Control: An R&D project may separate technical and project management by having both a Principal Investigator (PI), who is responsible for the technical activities of the team, and a Project Manager (PM), who has responsibility for elements including cost, schedule, scope, and risk. There may be a tension between the two as the PI defines and executes a technical plan subject to project constraints. In addition, it may be the case that the PI and PM each have relationships with different subsets of stakeholders, creating factions affecting project governance.

Transition and Relationship of R&D to the Enterprise: Unlike many projects, the product of an R&D effort is not an end unto itself. R&D must be sensitive to its context (such as a market need or operational requirement), and R&D outcomes must be structured to feed into subsequent development cycles.

R&D MANAGEMENT TECHNIQUES

The characteristics of R&D projects result in a need to apply techniques beyond those used in well-specified, lower risk projects. Some useful approaches include:

#1: Even if you don’t know how you’re going to get there, define “there”. The desired end state of an R&D project may not be completely known at the outset. Still, R&D

should rarely be unguided exploration. An important step is to define the outcome as best as possible at the outset. Examples include an increase in understanding of a phenomenon (define what you want to learn), an increase in technology maturity (such as an increased Technology Readiness Level) (United States Department of Defense, ASDR&E 2011), and development of a prototype (define the goal).

#2: Plan your route like an explorer: Research can be trajectory-oriented. You might know the direction you want to go, but not necessarily how far you can get down the path. Whether or not the desired end-state is believed to be achievable, it's important to analyze and decompose what it would take to get there, even if one or more steps are undefined. Such a decomposition can be by one or more of system function, product breakdown structure, technology area, and phase (e.g., product R&D vs. production R&D). It is important to understand where the complexity and risk are and where the decision points are along the way. There should also be a Work Breakdown Structure (WBS) guiding the work, though it will be more dynamic than the typical WBS. Adequate decision points need to be included in the plan to avoid excessive expenditure of resources trying to overcome obstacles.

#3: Measure the unmeasurable: It is important to assess results in R&D even though quantitative measures of outcomes can be elusive, particularly at the research end of the R&D spectrum. Measures can be indirect (for example, the number of publications generated is an indirect measure of the amount of knowledge generated) or direct (such as the number of experiments performed or the number of sub-system designs completed). Recognize that key metrics may comprise the results of multiple elements of the Product Breakdown Structure or even multiple projects (e.g., a decrease in the cost per lumen of solid state lighting may be the result of a combination of advances in both materials science and manufacturing) (United States Department of Energy, 2016) or a coordinated R&D strategy (such as the number of clinical candidate molecules generated in a year from an entire drug research portfolio) (Pisano, 2012). R&D metrics should consider the larger context of the organization; the best outcome for a business may be based on revenue rather than technical elegance.

#4: Plan for risks and reflection: While every project has risks, fundamental assumptions within R&D may turn out to be in error, resulting in major changes in the project plan. In addition, even when project activities are successful it's important to plan in time to reflect on the outcome: for example, why was a test successful: for the expected reasons, or was luck involved? Sometimes, R&D yields a feasible design, but not necessarily the best solution. Therefore, it's appropriate to routinely ask questions like: with the understanding gained from the work so far, would another approach have been better and is it worth re-working the effort accordingly? Overall, for R&D projects it is important to recognize that the project will be incrementally defined and serially redefined, and therefore projects require a significant risk reserve plus a reflection and re-work reserve. This make sure that there are resources

available to take advantage of knowledge gained during the project. There also need to be both internal informal checkpoints and formal, external reviews. The R&D project manager must be prepared to re-work and re-baseline as understanding of the project develops, and should not be overly attached to the initial plan.

#5: Know when good ideas are bad: As already discussed, research and development projects include changes in trajectory based on new ideas generated as the project progresses. However, the project manager must evaluate each idea in light of its contribution to the desired outcome. During initiation of a project and buildup of the initial approach, technical uncertainty (the difference between the information possessed by the team and that required to complete the project) will be high. In this phase, creative ideas contribute strongly to developing an approach. As the project progresses through execution new ideas which perturb the plan should be carefully vetted before being introduced, except at planned milestones such as the reflection checkpoints identified in #4 or if it becomes clear that an execution issue has arisen. The goal is to allow the project to be flexible while controlling tangential work, cycling and drift.

#6: Consider the people: Researchers may desire autonomy and administrative control of their environments and resist accountability to schedules and budgets (Jain, 1990). R&D project management requires diplomacy in terms of holding researchers and teams to the project plan. The R&D project manager should recognize that unstructured slack time, risk taking, mistakes, and "bootlegging" into other areas are all part of the process, but should bound those activities where needed to keep the project on track. The project manager should also be vigilant in fostering an environment that is open to new ideas from all contributors, ensuring that individual strong personalities do not overly dominate the team.

#7: Invite review: The goal of R&D is always to transition the results to subsequent development or research effort. External review by experts and stakeholders serves several goals. First, it provides fresh perspective at reflection points. Second, it helps ensure that the research trajectory is aligned with transition to a product. Third, it serves as a communications mechanism to inform stakeholders on progress, build advocacy, and set expectations.

CONCLUSION

R&D is an umbrella for efforts that range from abstract exploration to the early stages of product development. Success in these types of projects requires adapting project management to the high level of uncertainty and creative effort involved. "Fail fast, fail often" may be a Silicon Valley mantra (Tobak, 2017), but proper application of project management techniques can allow projects to succeed often, even in the exciting and uncertain world of invention and innovation.

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