Managing Complex Technology Innovation: The Need to Move Beyond Stages and Gates

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ABSTRACT

R&D management practices in engineering organizations typically conceptualize complex product innovation as a Stage-Gate process whereby novel concepts are matured through successions of development stages and progressively winnowed down at each sequential gate. This view assumes that maturity is a monotonically increasing function of the technology, and that the active process of winnowing is administrative decisions. This paper tests those assumptions using detailed evidence from six longitudinal case studies of technology innovation at NASA.

Keywords: Innovation, Linear Model, New Technology, Space, Stage-Gates

INTRODUCTION

Managing the process through which new technical capabilities are continuously developed and infused into ever more ambitious flight projects, is fundamental to NASA’s, and more generally space agencies’, mission. Yet, despite a rich legacy of impressive technological accomplishments (e.g., project Apollo, the Hubble Space Telescope) in recent years, the ability of government space agencies to deliver on their technological promises has increasingly been called into question (Augustine et al., 2009; Lawler, 2009). Part of the problem is that current R&D management strategies presume a project-based systems engineering view that may no longer apply. To the extent that the innovation processes in government agencies has been studied in the literature, it has been at the project (Peck & Scherer, 1962; Sapolsky, 1972; Beard, 1976; Lindsay, 2006) or force structure level (Posen, 1984; Rosen, 1994; Farell & Terriff, 2002), not the evolution of the constituent, enabling technologies.¹

Outside of the government setting, innovation processes have been studied in the context of corporate venturing within commercial firms (Utterback, 1994; Van de Ven et al., 1999; Henderson & Clark, 1990; Langley & Truax, 1994), but unique characteristics of the space

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sector may limit the transferability of those insights (Szajnfarber, Richards, & Weigel, 2011). This paper uses new empirical evidence on the paths taken by particular technologies developed for, and infused onto, NASA Science missions, to re-examine the assumptions of the traditional Stage-Gate approach. It finds that key assumptions are not respected in practice, with important implications for the effectiveness of technology management strategies.

STAGE-GATES: UNDERLYING ASSUMPTIONS

R&D management practices in engineering organizations typically conceptualize complex product innovation as a Stage-Gate process. As illustrated in Figure 1, the model consists of a series of stages – during which technology is matured – separated by gates – decision points, where progress is reviewed and the set of maturing capabilities that will go on to the next level are selected, while the rest are shelved (Cooper, 1990; NASA, 2007). By conceptualizing the process in this way, the innovation management problem reduces to an optimization problem: Given a fixed set of resources, choose (a) the number of stages, (b) the relative resources allocated to each stage, and (3) the gate decision rules, such that the desired flow of new capabilities is achieved.

Despite the considerable evidence that the innovation process is neither segmentable nor sequential (Rothwell & Zegveld, 1994), Stage-Gate, and Stage-Gate-derived, views persist as the modus operandi at NASA and other space agencies. Not surprisingly, with Stage-Gates as the working model, NASA’s historical efforts to restructure its technology development process have centered on shifts between more or less emphasis on basic vs. applied R&D and the extent to which the R&D buckets are explicitly linked both to each other and to flight projects (Szajnfarber, 2011). Recently, discussions have also centered on redefining the buckets and adding additional buckets to smooth transitions among them (Braun, 2010). However, for interventions of this kind to lead to the intended outcomes, several key underlying assumptions must hold.

Specifically:

1. Technologies must mature from left to right. If they don’t, promotion decisions at gates will have limited impact in terms of flow-control.
2. Stages must be mutually exclusive (at a given time). If a particular technology can exist in multiple stages simultaneously, it pre-empts the ability of decision makers to exert control through resource allocation decisions.
3. Shelving must be an active process. This is another way of saying that Gate decisions are made by managers.

METHODS AND DATA

In order to test the validity of the above assumptions, six instances of the paths taken by
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