Acta Astronautica 118 (2016) 96–108

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Wicked problems in space technology development at NASA

Tibor S. Balint*, John Stevens

Royal College of Art, School of Design, Kensington Gore, London SW7 2EU, United Kingdom

ARTICLE INFO

Article history:
Received 13 October 2014
Received in revised form
26 August 2015
Accepted 30 September 2015
Available online 9 October 2015

Keywords:
Wicked problems
Technology portfolio
Strategy
Budget process
Innovation

ABSTRACT

Technological innovation is key to enable future space exploration missions at NASA. Technology development, however, is not only driven by performance and resource considerations, but also by a broad range of directly or loosely interconnected factors. These include, among others, strategy, policy and politics at various levels, tactics and programmatics, interactions between stakeholders, resource requirements, performance goals from component to system level, mission infusion targets, portfolio execution and tracking, and technology push or mission pull. Furthermore, at NASA, these influences occur on varying timescales and at diverse geographic locations. Such a complex and interconnected system could impede space technology innovation in this examined segment of the government environment. Hence, understanding the process through NASA's Planning, Programming, Budget and Execution cycle could benefit strategic thinking, planning and execution. Insights could be gained through suitable models, for example assessing the key drivers against the framework of Wicked Problems. This paper discusses NASA specific space technology innovation and innovation barriers in the government environment through the characteristics of Wicked Problems; that is, they do not have right or wrong solutions, only improved outcomes that can be reached through authoritative, competitive, or collaborative means. We will also augment the Wicked Problems model to account for the temporally and spatially coupled, and cyclical nature of this NASA specific case, and propose how appropriate models could improve understanding of the key influencing factors. In turn, such understanding may subsequently lead to reducing innovation barriers, and stimulating technology innovation at NASA. Furthermore, our approach can be adopted for other government-directed environments to gain insights into their structures, hierarchies, operational flow, and interconnections to facilitate circular dialogs towards preferred outcomes.

1. Introduction

Over the past 30 years in the US, more than 40 studies pointed to a need for regular investments into new, transformative space technologies within NASA. These technologies are required to enable new class of NASA missions beyond Low Earth Orbit (LEO) and to provide innovative solutions to dramatically improve technological capabilities for NASA and for the United States. There are a number of drivers associated with this recommendation. For example, the development of such technologies needs to be affordable and reliable for space exploration. Government funded innovation activities are expected to span across the full scale of Technology Readiness Levels (TRL), starting at fundamental research and early stage innovation. At the fundamental research level the Agency needs to engage the brightest minds from academia to solve the difficult technology challenges faced by NASA's space exploration missions. Furthermore, these technology

* Corresponding author.
E-mail addresses: tibor.balint@network.rca.ac.uk (T.S. Balint), john.stevens@rca.ac.uk (J. Stevens).

http://dx.doi.org/10.1016/j.actaastro.2015.09.019
0094-5765/

development activities can be used to create new markets, while stimulating innovation for traditional and emerging aerospace businesses [9].

To understand the drivers influencing technology development, we need to look beyond performance and resource considerations, and examine a broader range of directly or loosely interconnected factors both inside and outside of NASA. These include, among others, strategy, policy and politics at various levels, tactics and programmatics, interactions between stakeholders, resource requirements, performance goals from component to system level, mission infusion targets, portfolio execution and tracking, and technology push or mission pull. In addition, the process and influencing factors for this dynamic system occur on varying timescales and at diverse geographic locations. Many of these factors are accounted for in the Planning, Programming, Budget and Execution (PPBE) process, which will be briefly discussed in our paper.

The PPBE process is on the planning and execution side of the operations, and if not driven, influenced and supported by appropriate strategies, then such a complex and interconnected system could impede space technology innovation in the government environment. A good strategic approach includes three key elements: a diagnosis, a guiding policy, and a set of coherent actions. Rumelt [16]. This paper contributes to the diagnosis part, by describing the technology development related interactions and influences between NASA and relevant external entities. Subsequently, these interfaces and related constraints will be discussed using the Wicked Problems model [14]. In general, models are created through the reduction of complex systems to simple ones [18], and as George E.P. Box pointed it out, “essentially, all models are wrong, but some are useful” [2]. Therefore, to draw meaningful conclusions from models, the simplifications have to capture and weight all the key influencing factors, and ignore those which have secondary effects on the modeled system. Such modeling is not trivial. As stated by Laurence J. Peter [11], “some problems are so complex that you have to be highly intelligent and well informed just to be undecided about them.” We hope that our simplifications will capture key elements of these complexities facing technology development activities, drivers and influences at NASA, and will help to elucidate the implementation challenges at hand.

We will show that the Wicked Problems model is providing a reasonable framework for the case of NASA's technology development activities. These problems do not have right or wrong solutions, only improved outcomes that can be reached through authoritative, competitive, or collaborative means. With appropriate strategies these problems could solve or at least reduce technology development barriers. To this end, we will further customize the model with additional rules to strengthen the construct for this particular case. Specifically, we will augment the Wicked Problems model to account for the temporally and spatially coupled, and cyclical nature of this case, to promote a better understanding, and subsequently stimulate technology innovation at NASA and other government-directed environments.

1.1. Wicked problems

The phrase “wicked problem” was first used in social planning to describe a problem, which does not have an obvious solution, due to changing requirements, and incomplete or contradictory bounding conditions. Furthermore, as a result of the often-complex interdependencies, a chosen solution to a wicked problem could result in subsequent new problems. Rittel and Webber introduced 10 general rules to describe Wicked Problems [14], which was synthesized and reduced to 6 general characteristics by Conklin [4]. These are:

1. The problem is not understood until after the formulation of a solution;
2. Wicked problems have no stopping rules, difficult to know when the problem is solved or solution is reached;
3. Solutions to wicked problems are not right or wrong;
4. Every wicked problem is essentially novel and unique;
5. Every solution to a wicked problem is a “one shot operation”;
6. Wicked problems have no given alternative solutions.

Wicked problems are not simply too hard or complex, nor require additional considerations or have more stakeholders. In addition, the initial problem definition and the outcome are bi-directionally linked. The various stakeholders may have radically different perspectives, motivations, and drivers related to the issues. Therefore, the assessment of an optimal outcome is dependent on the perspective of the stakeholder, instead of considering it universally right. Because the initial problems and the related resource requirements are often ill defined, they are typically over-constrained, cannot be solved definitively through analytical thinking, and may require innovative solutions.

Roberts identified three strategies to tackle wicked problems [15]. Implementation of these strategies is influenced by management styles and institutional approaches. These are:

1. *Authoritative*: This strategy places responsibility of solving problems to one or a few people. This is perceived to reduce the complexity of perspectives as competing views are being eliminated. The disadvantage is that key perspectives might be eliminated, or not appreciated, which may lead to less favorable outcomes.
2. *Competitive*: This strategy brings opposing views against each other. It requires stakeholders to hold their views and propose their preferred solutions, so the different solutions could be compared and weighted. The disadvantage is the potential of creating confrontations and discouraging knowledge exchange. In turn this may disincentivize the stakeholders to propose solutions.
3. *Collaborative*: This strategy involves all stakeholders working and converges towards a common best solution, agreed upon by all parties involved.

NASA operates in a framework with a broad variety of stakeholders, where the associated problems and challenges