HOW DO YOU GO FROM A CONCEPT IDEA TO A NASA SELECTED MISSION? FORMULATING THE PSYCHE DISCOVERY MISSION WITH JPL'S CONCURRENT ENGINEERING TEAMS

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ABSTRACT

JPL's Office of Formulation provides continuity of support and access to domain subject matter experts, as Principal Investigators mature their mission concepts from "cocktail napkin" ideas to Preliminary Design Reviews [1]. Using NASA's Psyche mission as a case study, we will describe JPL's concurrent engineering A-Team and Team X support to the Psyche competed concept study team in the areas of 1) Science Feasibility, 2) Trade Space Exploration, 3) Spacecraft Point Design and Cost Estimate, 4) Science, Technical, Management, and Cost Review, and 5) Strategy and Communication Development.

NASA's Psyche Discovery class mission started as a grassroots idea in our A-Team facility, and in less than five years was selected as a mission under NASA's Discovery Program. While Psyche had a dedicated concept development team [2], they utilized JPL's concurrent engineering teams, methods, analysis tools, and experts throughout their mission concept lifecycle.

1. SCIENCE FEASIBILITY

Prior to investing time and resources into a concept idea, it is critical to consider the science feasibility, which has two aspects: science merit and science implementation. Science merit is determined by the compelling nature of the investigation and the prioritization defined by Decadal Survey science committees. ***Is the science worth doing?*** Science implementation is determined by the likelihood to succeed and the probability of technical success based on the scientific and technical approach. ***Will the science objectives be achieved?***

The first step on Psyche's road to success was an A-Team study focused on science feasibility. A-Team was conceived to tackle mission architecture-level trades. The study was conducted in a workshop style format with participation from scientists and engineers, but leveraging concurrent engineering methods, experts, and analysis tools. The purpose of the study was to assess whether to proceed with the Psyche concept of exploring a metal asteroid (Fig. 1). Study objectives were to refine the science questions, then generate several potential architecture "seeds" that would address those science questions, and identify the driving factors between the architecture seeds. It is critical for the scientists to understand what is technically feasible and for the engineers to understand the science questions.

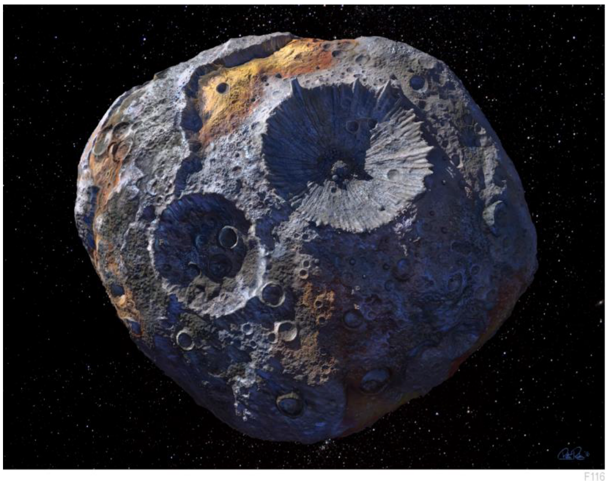

Figure 1. The largest metal asteroid, Psyche preserves a key step in the formation of terrestrial planets including Earth. The first mission to a metal world will map features, structure, composition, and magnetic field.

The Psyche mission concept was well aligned with priorities from the National Research Council (NRC) Decadal Survey, Vision and Voyages [3]. Psyche's science team ultimately chose the following science questions [4]:

1. Is Psyche the stripped core of a differentiated planetesimal, or was it formed as an iron-rich body?
   - What were the building blocks of planets?
   - Did planetesimals that formed close to the Sun have very different bulk compositions?
2. If Psyche was stripped of its mantle, when and how did that occur?
3. If Psyche was once molten, did it solidify from the inside out, or the outside in?
4. Did Psyche produce a magnetic dynamo as it cooled?
5. What are the major alloying elements that coexist in the iron metal of the core?
6. What are the key characteristics of the geologic surface and global topography?
   - Does Psyche look radically different from known stony and icy bodies?
7. How do craters on a metal body differ from those in rock or ice?

2. TRADE SPACE EXPLORATION

Science implementation is evaluated on the merit of the instruments and mission design for addressing the science goals and objectives. Prior to the A-Team study preliminary solar electric propulsion (SEP) trajectory analysis was performed to identify potential target destinations. Options were identified to tour one or more asteroids. Ultimately, the Principal Investigator (PI) and science team decided to focus the investigation on 16 Psyche.

A-Team facilitated a session focused on the instrument trade space that would define a complimentary payload suite. Potential instrument partnerships and contributors were identified. In collaboration with the Psyche team, A-Team provided the assessment value framework that informed and assisted the Psyche team's ultimate payload suite decisions. Assessment factors were two-fold, and included both the technical ability of the instrument to achieve the science objectives and the associated cost to develop, build, and V&V the instruments. Instrument cost data was based on the NASA Instrument Cost Model (NICM) database.

3. SPACECRAFT POINT DESIGN AND COST ESTIMATE

After the architectural-level trade space decisions were completed, the Psyche team began their initial baseline concept development, defining the major subsystem elements with acceptable margins and reserves. They issued a Request for Information (RFI) to commercial vendors, including some non-traditional NASA industry providers.

Team X conducted a concurrent engineering study for a hybrid spacecraft design built jointly by an industry partner and the NASA Jet Propulsion Laboratory (JPL). The industry partner would provide the SEP chassis and JPL would provide the avionics. While Team X has collaborated with many commercial vendors over the years, this study was unique in that this industry partner had nearly a one-to-one ratio of technical subsystem subject matter experts (SMEs) to match the Team X SMEs. This study was challenging because in some cases, the Team X design subsystem models did not encompass the industry partner's technical capabilities. In real-time the Team X SMEs adjusted their models and/or provided data "over-rides" to incorporate the industry partner's technical design information.

JPL's Institutional Cost Models (ICMs), embedded within Team X, were used as a proxy for the overall lifecycle mission cost estimate. The ICMs represent the "doing" organizations best estimate to perform the task statement for the Work Breakdown Structure (WBS), based on the scope of work and the cost/risk profile.

4. SCIENCE, TEHCNICAL, MANAGEMENT, AND COST REVIEW

Technical reviews are typically time consuming and inefficient given the ratio of the small number of critical findings identified to the large number of Review Item Discrepancy (RID) items. Team X routinely performs instrument and mission concept reviews using concurrent and collaborative engineering techniques and subject matter experts. This method has been demonstrated to improve both the efficiency and effectiveness of scientific, technical, management and cost (STMC) internal JPL reviews for major spaceflight mission and instrument proposals.

Team X modelled their STMC review process from the NASA review process, instantiating both a science review panel and a technical review panel of SMEs.

5. STRATEGY AND COMMUNICATION DEVELOPMENT

NASA's Discovery Program is a competed opportunity that involves a two-step proposal process. Twenty-seven proposals were submitted to NASA during Step-I. After a thorough review process, NASA down-selected to five mission concepts for further consideration. The proposal strategy employed during Step-I differs from the proposal strategy approach required in Step-II. First, in Step-I the competition of the other concepts is unknown; however, in Step-II the mission concepts are announced in a press release. Therefore, the communication strategy, e.g., win themes and death threats, needs to be tailored based on the other competing mission concepts. The JPL Innovation Foundry provided experienced coaching to the Psyche team in the development of their Step-II proposal to communicate their concept successfully.

6. NASA SELECTS DISCOVERY MISSION

On January 4, 2017 NASA issued the following press release, "The Psyche mission will explore one of the most intriguing targets in the main asteroid belt – a giant metal asteroid, known as 16 Psyche, about three times farther away from the sun than is the Earth. This asteroid measures about 130 miles (210 kilometres) in diameter and, unlike most other asteroids that are rocky or icy bodies, is thought to be comprised mostly of metallic iron and nickel, similar to Earth's core. Scientists wonder whether Psyche could be an exposed core of an early planet that could have been as large as Mars, but which lost its rocky outer layers due to a number of violent collisions billions of years ago. The mission will help scientists understand how planets and other bodies separated into their layers – including cores, mantles and crusts – early in their histories."

7. CONCLUSION

Concept ideation, feasibility assessment, broad trade-space exploration, mission architecting to generate requirements, facilitation of technical discussions, and strategic communication are essential. A structured method to expand the trade space followed by a systematic assessment to contract the options (Fig. 2) was critical to identify the concept design that delivers the best science per value for the Psyche mission [1].

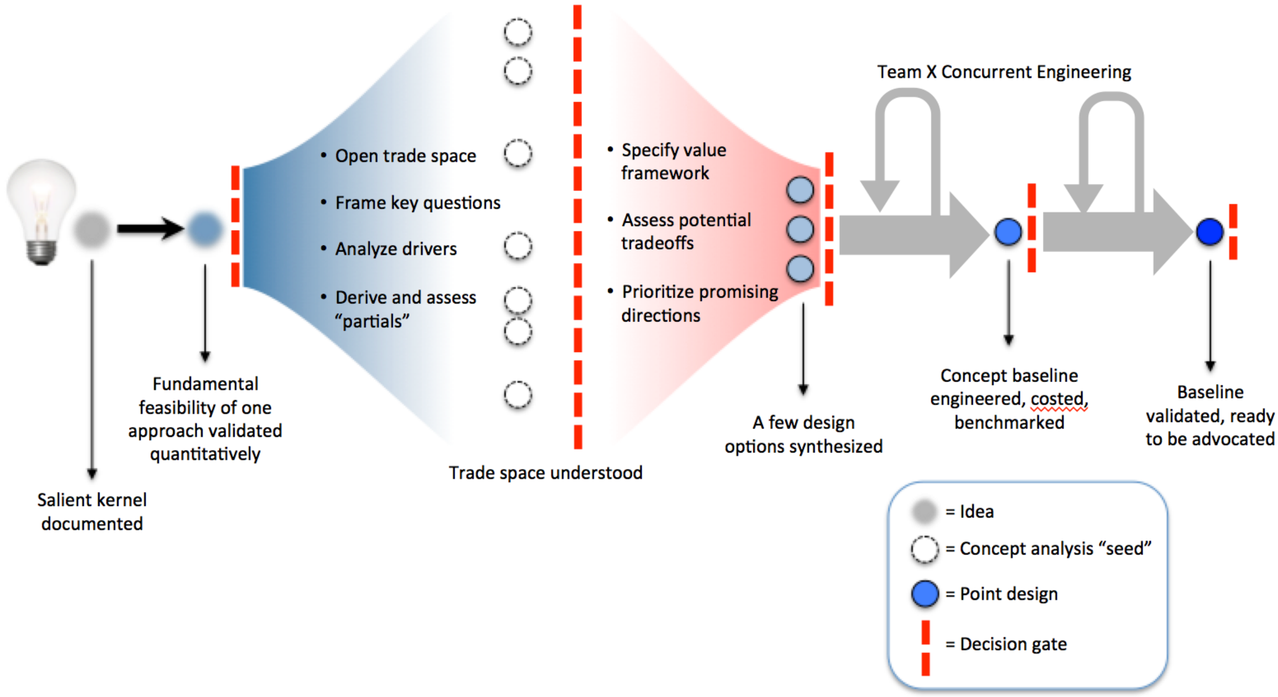

Figure 2. Systematic evolution of an idea yields a robust concept that can be advocated successfully, and provides an organizing structure for the formulation lifecycle. [1]

8. ACKNOWLEDGMENTS

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9. REFERENCES

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