Cracks Emerging in NASA's Discovery Program

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Discovery is one of NASA's most successful programs. It has funded ground-breaking missions such as **Mars Pathfinder**, **MESSENGER**, **Dawn**, and **Kepler**. Unfortunately, overly simplistic narratives and storytelling in recent Discovery proposals is now leading to unrealistic science goals and much lower return on investment. Problems with some of the most recent Discovery missions and some simple remedies are discussed below.

InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport): Although sold as "Revealing the Heart of Mars" (Figure 1), with objectives of measuring the martian core radius and the planet's heat flux, the seismic station has failed to detect anything remotely capable of determining the core radius. The heat flow investigation has been, to date, a failure. The only major discovery so far is that Mars is a "seismically active world" – unsurprising and unworthy of a \$1B investment.

Psyche: Although sold as a "Journey to a Metal World" (Figure 1), with objectives of determining how an iron world forms, it was known even before selection time that there was a very large chance that the asteroid Psyche is not a metal world. The best estimate for its density is now 3400-4100 kg m⁻³ [Elkins-Tanton et al. 2020]. These values overlap with ordinary chondrites and the recently visited asteroid 21 Lutetia. The density of iron meteorites is >7800 kg m⁻³. The mission's STM and iron-core science objectives are almost irrelevant now. It is uncertain if the science from this body should be a top priority of the United States.

Everybody can agree that it would be very interesting to send a suite of instruments to orbit any of the unexplored asteroids. But the point of the Discovery competition is to determine which investigations are the most compelling. If **Psyche** is now an exploratory survey, instead of a set of measurements to test a specific set of hypotheses tailored for a unique body, the proposed 2015 **Mantis** asteroid mission to survey nine new worlds would have been more compelling. **Mantis** does not have a catchy tag line.

Discovery 2019 selection is still underway but there are again red flags:

Trident: Flying a nearly identical mission profile as **Voyager 2**, this mission advanced to the next round of competition despite its Category 2 rating. By advancing a Category 2 mission, NASA's message is that achieving the highest quality science is not a main driver for Discovery. Proposing centers have usually worked to perfect the STM, but this will no longer be the top priority. Instead, proposing centers will continue to reach for ever more enticing, easy to digest "story lines" despite their lack of realism. More achievable or compelling science investigations may not even advance to the proposal stage.

Could the problems of **InSight**, **Psyche**, and **Trident** have been avoided?

InSight: **InSight's** objective was extraordinarily ambitious - perform teleseismic science with a single station on a planet with unknown seismicity. There is almost no precedent for performing deep interior seismic investigations with a single station, without making many other assumptions that cannot yet be made for Mars. The mission was relying on extreme luck to be successful.

An alternative path forward would have been a lower cost, lower quality wind-protected ground-coupled seismometer flying on another Mars mission(s), such as rovers, to perform preliminary measurements of seismicity, over several months. This could have provided the information needed to design a proper network to actually measure the core radius.

Psyche: As with **InSight**, the most fundamental assumption turned out to be wrong. Estimates of Psyche's density ranged from 2500-7,000 kg m⁻³ at the time of proposal submission [Elkins-Tanton et al. 2020 Figure 2].

An alternative path forward would have been to perform follow up measurements to better estimate **Psyche's** density. Very high density asteroids could have been found, and then the United States could have actually had a mission to a real metal world.

These comments are not meant to speak negatively of the mission teams, as they are composed of some of the world's top scientists.

Recommendations

#1. Provide significant amounts of funding, \$20-50M, to de-risk Step 1 Discovery proposals deemed promising, but are too high-risk to down select. To summarize:

- For **InSight**, a low-cost short-lived seismometer could have been deployed to the surface on a rover mission(s) for preliminary studies at a fraction of the **InSight** mission cost. France could have still provided the instrument.

- For **Psyche**, fund ground-based observations that would have provided superior error bars on the densities of numerous candidate metal worlds.

- For **Trident**, fund modeling studies that could have been used to alleviate the science risks.

This recommendation allows reviewers a chance to decline a proposal while still affirming its importance.

#2. Reviewers should be trained to avoid consuming Hollywood story-telling, and to question the most basic assumptions about the mission. **Most cutting-edge science is complex, uncertain, and cannot be reduced to a tweet or tag line. On the contrary, if it has been so reduced, one should often be skeptical.**

Hundreds of scientists obtain their salaries from the Discovery program, including those on the Decadal Survey board, making it difficult to find critics. An honest assessment is important, however, if we want to again fly missions that offer the best possible return to the United States, such as **Pathfinder, MESSENGER, Dawn, and Kepler**.

Figure 1. Artwork for the *InSight* and *Psyche* missions. The most basic assumptions of these missions could have been demonstrated to be untenable at the time of proposal.

References

Observations, Meteorites, and Models: A Preflight Assessment of the Composition and Formation of (16) Psyche, L. T. Elkins-Tanton et al. (2020). *Journal of Geophysical Research: Planets*, 125, e2019JE006296. <https://doi.org/10.1029/2019JE006296>