



# United States Department of the Interior

GEOLOGICAL SURVEY



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December 4, 2015

TO: ARM FAST Leadership  
FROM: USGS Astrogeology Science Center  
RE: Comments on the Draft ARM FAST Report

Before suggesting any changes, I would like to congratulate the FAST team on a thorough and rigorous report on the seven topics formulated to support the ARRM Requirements Closure TIM. It is a remarkable document to produce in so short a time.

After discussion with others on my staff, I am submitting two suggestions. The first is related to revisiting the architecture of the ARRM and the second delves into the details of measuring the topography of the target asteroid accurately.

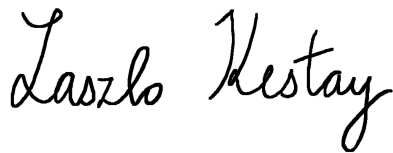
In regard to the architecture, the report discusses the pros and cons of sending the ARRM to an asteroid that had been previously surveyed by another spacecraft (e.g., Bennu after it is visited by OSIRIS-REx). However, another alternative, splitting the ARRM into two missions, is only briefly mentioned. We suggest it is important to more fully discuss the concept of sending one or more smaller surveyors to identify the best target for a later boulder-extraction mission. This architecture would essentially zero the risk of not finding an appropriate boulder when the ARRM arrives. Additionally, key uncertainties about material and geotechnical properties can be greatly reduced with even relatively simple interactions with the asteroid surface. The report does an excellent job of quantifying the uncertainties facing the ARRM if it is the first mission to the target asteroid. But it does not investigate how much these uncertainties would be reduced with a survey conducted with a relatively small (Clementine or NEAR scale) precursor mission. We strongly encourage a more thorough cost-benefit analysis of splitting the ARRM, taking into consideration the possibility of schedule slips for the ARCM.

In regard to topography, the report repeatedly points out that accurate knowledge of topography is essential for the success of the ARRM. However, the report is not consistent about *how* to measure topography (i.e., one section refers to exclusively to LIDAR while another section discusses stereogrammetry). Most importantly, quantitative requirements for the quality of the topographic information are not clearly established. The best method for measuring topography is to merge altimetry (typically from RADAR or LIDAR) with stereogrammetry sharpened with photogrammetry. However, this “gold standard” is extremely difficult to achieve and has never been fully realized with planetary data. For example, the Mars rovers landing sites have photogrammetry sharpened stereo elevations that are checked and aligned with laser ranging data

without creating a data single solution that truly combines both imaging and altimetry data. The choice of techniques, types of instruments, and specific instrument requirements depend on the level of precision required by the mission. Even if the most sophisticated “fused” topographic products are not required, considerable pre-flight calibration, data collection, and analysis are required to generate quality products with quantified uncertainties. It is essential to collect images under varying viewing and illumination conditions, which can take many weeks as the spacecraft is positioned in multiple positions relative to the asteroid. After data acquisition, with current tools, it takes many months to complete the topographic analysis, which does not fit within the notional ARRM concept of operations at the asteroid. The processing could be accelerated with new photogrammetric techniques and tools. However, this is a significant new R&D effort that would take some years to complete. Alternatively, the ARRM mission would need to spend more time at the asteroid (with a timeline more similar to the OSIRIS-REx mission) or a precursor “surveyor” mission could be used to characterize the topography. We strongly encourage the report to consider these matters in more detail.

Thank you for this opportunity to comment on the excellent draft report and we (USGS) would welcome detailed technical discussions with the ARM mission on these and other topics.

Sincerely,

A handwritten signature in black ink that reads "Laszlo Kestay". The signature is written in a cursive, flowing style.

Laszlo Kestay  
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