Science Objective Summary and Science Weekly Debrief

DOY 300–307: Nominal scenario was that OCAMS and OTES would perform post-TAG checkouts on DOY 301/302. However, stow was moved left from WOY 45 to DOY 301/302, owing to regolith mass leaking from the TAGSAM head after sampling, and checkouts and other maneuvers were waived off or postponed until after stow.

Science Weekly Debrief

For slides and the WebEx recording on ODOCS, click here then follow the path: Folders \ Documents and Drawings \ OSIRIS-REx Bennu Proximity Operations \ Science Status \ Science Weekly \ 2020-10-26.

Sampling success assessment & decision to stow early

Overview [Dante Lauretta]

Data collected during and after the TAG event indicate that sampling was successful, with a high probability of having collected a high mass of regolith. The four lines of evidence are:

(1) Surface interactions indicate favorable conditions.

Movement of material all around the TAGSAM head at contact indicates that the head was flush with the surface. The penetration depth achieved before the gas bottle fired was ~4.5 cm; the total penetration depth is estimated at 48.8 cm (though it is not certain whether TAGSAM was passing through regolith for the full depth or falling into a hole of its own making). The head continued to move into the surface at a downward velocity of 4 cm/s after surface contact. It is likely that most of the material in the head was collected pre–gas firing. A dust cloud precedes particle ejecta debris in post–gas release imaging, and SamCam and NavCam 1 optics are degraded; this indicates production, or a reservoir, of dust. Finally, conditions were similar to a ground test that obtained 400 g of material.

(2) The surface location contacted by TAGSAM was a location with a high sampleability score.

Thirty-five particles <2 cm were visually identified at the contact point in pre-TAG images. The sampleability algorithm predicts a corresponding 258 to 575 g of sample, where the low end assumes basaltic properties.

(3) A large amount of material, including sampleable material, mobilized before, during, and after the gas bottle fired.

(4) We have visual confirmation of abundant sample mass, assessed three ways: direct measurement of five visible particles (28 g, assuming a particle density of 1.8 g/cm3); estimation of minimum mass required to render the screen opaque, as it appears in images (57 g); and estimation of mass based on the visible portion of the TAGSAM head at the smallest wrist angle

(312 g, assuming a bulk density of 1.2 g/cm3), which is 17% of the fillable volume — such that the total could be ~5 times as much.

The Mission Planning Board unanimously agreed that there is support for >60 g collected, in most cases with high confidence.

A contingency was identified in post-TAG SamCam images, namely, mass loss from the sampler head as a result of the mylar flap being pinned open by particles. Particles seem to be released every time the TAGSAM arm moves. In response, spacecraft movements have been minimized. The orbit braking maneuver was waived off, so the spacecraft is still backing away from Bennu and will stay in its stable Earth point position. The SMM was canceled, OpNavs are suspended, and spacecraft and instrument checkouts are postponed until after stow (except StowCam, which showed moderate degradation).

The SamCam images of particles emanating from TAGSAM reveal their aspect ratios via shadows on the TAGSAM head. Particles generally appear to be flaky. This provides valuable calibration information for the particle ejection database.

NASA AA Thomas Zurbuchen agreed to the project's proposal to proceed with stow operations as soon as possible to preserve as much sample as possible. The spacecraft team will be working a three-shift 24-hour schedule to complete stow between Tuesday 27 October and Wednesday 28 October. Other missions have relinquished DSN time to facilitate this effort.

The implications of a leaky TAGSAM head for safe and successful stow have been considered. The particles are likely soft and crumbly (based on the interaction of TAGSAM with Bennu's surface) and appear to be primarily flaky—thus, they are unlikely to mechanically obstruct the stow process. We may end up with less than 60 g of sample stowed because of the leak, but this outcome will be mitigated as much as possible by the minimized spacecraft movements and early stow. Stow is a stepwise tele-robotics process that will allow us the opportunity to respond at each downlink and adapt for contingencies or new commands. See the slides for the step-by-step stow procedure, which will involve some shock events likely to release particles.

If we execute multiple failed stow attempts, and they are determined to be due to obstruction, we will execute defined contingency procedures to liberate particles. Hardware models of the TAGSAM and SRC are available in Denver for trouble-shooting mechanical issues. Several mitigations were considered but rejected due to risk (see the slides). We have ample mass margin for the safe delivery of the SRC to Earth. It might be possible to spin the spacecraft for a mass estimate after stow.

OCAMS [Bashar Rizk]

Bashar showed before and after SamCam images at various wrist angles that indicate the presence of material in the TAGSAM head (evidenced by opacity). A very bright area in the interior of the head that is visible pre-TAG is absent post-TAG, meaning it is either directly covered, or the light cast on it is being obscured, by sample. There may be ~10 particles jamming the mylar flap open. Some particles are visible along the edge of the head. Two large particles,

and possibly as many as 11 smaller particles, are stuck to contact pads. Particles seem to preferentially affix to the edge of the contact pad near the circular wall (or possibly they are most visible in this position). In addition, multiple small particles are also observed clinging to the head but not on contact pads. The apparent motion of particles suggests that they are clinging to and being liberated from other parts of the spacecraft (Dante will follow up with Christine Hartzell regarding electrostatics). Bashar's estimate of mass in the head is 446 g, assuming a particle density of 1.8 g/cm3. See the slides for analysis and an imaging timeline of TAG arm/wrist movements.

TAGSAM [Beau Bierhaus]

Beau reported that surface material was mobilized, compressed, and shifted before the gas bottle fired (see the slides for images and GIFs). The U-joint changed direction by about 6 degrees. After the gas bottle fired, significant material mobilized, TAGSAM continued to penetrate the surface, and the arm moved as if TAGSAM was interacting with larger particles. Gas and most mobilized material moved radially away from the head. The arm did not compress (no pogo spring). The overall surface response is consistent with weak, essentially cohesion-less material.

Regolith with a fine-scale granulated texture can be seen around the TAGSAM head pre-contact. Images show the head in shadow soon after contact, and the shadow remains until some time after backaway, consistent with an ejecta curtain as observed during ground testing with polystyrene beads.

Ground testing in reduced gravity showed that the first contact of the TAGSAM head could mobilize surface material and push larger rocks into the subsurface via momentum transfer, before the gas fires; and after the gas fires, regolith is fluidized, resulting in further penetration.

Material from the full depth of penetration (nearly 50 cm) may have been captured, as though TAGSAM cored Bennu, but that subordinate last-in material is likely to be the first-out material from the leaking sampler head.

Thruster plumes appear to have excavated surface material, as predicted from ground tests. We may have left five craters: one from each of the four thrusters and one from TAGSAM. There is some uncertainty in the images about what is shadow vs. topographic depression, but there is compelling evidence for at least some excavation. A compression wave may have been in effect on the surface. IPWG and AltWG are working on fixed-in-space image products to help understand surface movement.

Almost all material coming from the head is thought to be exiting via the mylar flap, not through the screen. In the SamCam post-TAG images, a population of particles was observed moving in the background that did not come from the sampler head, indicating that particles are being shed from other parts of the spacecraft.

Characterization of particles around the TAGSAM head [Coralie Adam, Carl Hergenrother]

Techniques developed to analyze the particle ejection events from Bennu were applied to the particles moving out from and around the sampler head. Manually linked tracks and first-cut results from algorithmic linking were similar; the manual links were delivered for subsequent analysis. Results (15 and 50 ms) for release time, range to SamCam, and velocity were delivered from Coralie's team to Carl for photometric mass estimation. See slides for the details of detections and tracks.

The total mass of the subset of lost particles tracked to date (not complete) is 8.2 g. An upper bound of 56 g is estimated for total mass loss during the 10-minute SamCam imaging activity. Particle loss appears to decrease at the end of an arm/wrist movement. Most imaged particles seem to be new (rather than persistent), but this remains uncertain. The majority of persistent particles are moving slowly in the background, not emanating from the sampler head.

The largest tracked particle has a long axis of 25 mm, and particles as small as one-tenth of a millimeter may have been detected. One particle can be seen leaving the outside of the head on a curved trajectory. Particle collisions have been observed. Most particles are flaky; some seem to be more rounded, but we may not be seeing the short edge. Carl expects to be able to derive an albedo of the particles. The entire particle ejection database can be revisited with the information from resolved photometry.

Upcoming meetings

The next meeting will be Thursday 5 November.