OSIRIS REx
Science Processing & Operations Center (SPOC) and Science Engineering Peer Review

April 21 - 23, 2015

OSIRIS-REx™
ASTEROID SAMPLE RETURN MISSION

Science Team TAG Reconstruct
Kevin Walsh – RDWG lead scientist

TAG Reconstruction Driving Requirements

- Science Team effort to determine the Asteroid's response to the Spacecraft immediately following TAG
  - MRD-105 "Return greater than 15 g of bulk material for analysis of mission science objectives
  - MRD-106 "Return greater than 45 g of bulk material to support NASA objectives"

- PI requested Science Team TAG Reconstruction Plan
  - Project launched by PI in December 2013
  - Data Product requested June 2014
  - Plan submitted Feb 1 2015

- Expeditor is Science Team Regolith Development Working Group, led by Kevin Walsh

Motivation - Short Term

- Assess likelihood that sufficient material was mobilized to collect baseline sample
  - Quick (<1 week) assessment of the TAG event to determine the likelihood that the baseline mass of material was collected.
  - Support the Sampling Success Review,
  - This analysis will be presented in conjunction with the following to the PI prior to the Sampling Success Review
    - TAG Reconstruction from the spacecraft,
    - Results of the moment of inertia measurements,
    - TAGSAM imaging campaign

- <u>Delivered within ~7 days of the TAG event</u>

Motivation – Second Assessment

- The second assessment will only occur in the event that the previous analyses suggests that a second TAG attempt is needed.

- In this case, this team must compile all relevant data,
  - To determine why the first attempt was unsuccessful,
  - To produce data products that will improve our safety and sample-ability maps.

- *Timescale of weeks*

Motivation – Long-term Science

- The final assessment will take place over an extended period of time after sample stowage with the intent of understanding the nature of regolith on Bennu for scientific inquiry.
- Year long timescales suited for long-term scientific investigations
- We will have prepared tools to understand precisely what happens during TAG, so we can use these to get scientific value from the combination of all of the TAG-event data

Data Inputs for TAG Reconstruct

The TAG Reconstruction plan requires

Data Product	Source/ Expeditor	Nominal delivery	Interfaces
Post-TAG Telemetry Report	TAGSAMWG	TAG + 3 days	OIA accepted
Post-TAG Imaging Report/ Movie from SamCam (MRD-380)	IPWG/SPOC	TAG + 5 days	Science Data
Trajectory Reconstruction based on the NavCam and Radio Tracking data	SPOC/LM	TAG + 5 days	*TBD*
Sample Mass Measurement Report	LM	TAG + 5 days	*TBD*
Post-TAG NavCam and G&C Lidar imaging reports	LM	TAG + 5 days	Lidar OIA accepted; *NavCam is TBD*

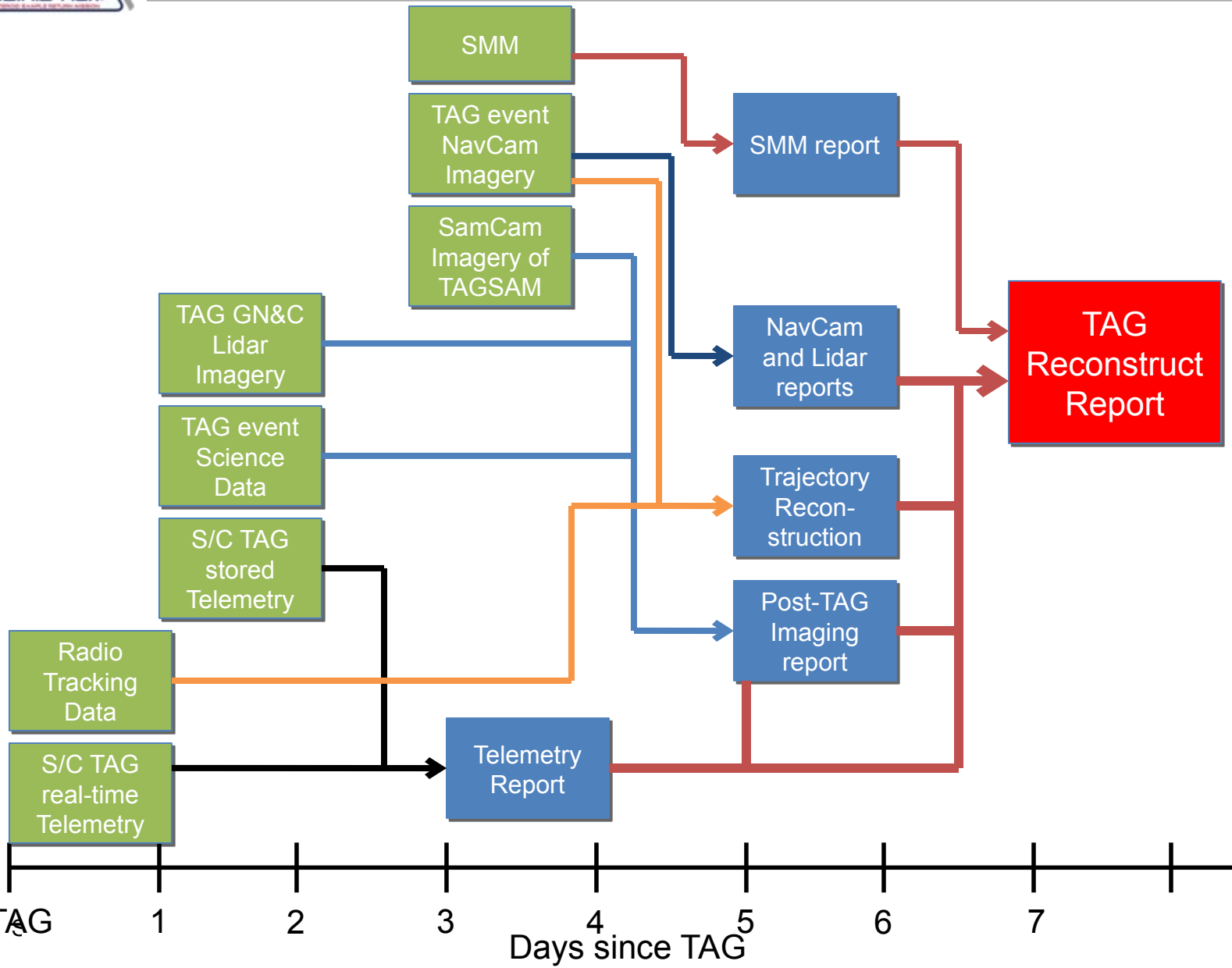
Development Process: Sub-Products

- Spacecraft measurements and Science Product inputs:
  - S/C telemetry - IMU readings of the deceleration of the S/C.
  - TAG telemetry - POGO switch outputs.
  - SamCam imaging
    - Before/after images of the TAG location – IPWG video of TAG.
    - TAG head size over time – pixel size of TAG.
  - GNC Lidar Telemetry.
    - Lidar range over time.
    - Lidar topographic profiles from full-frame images.
  - NavCam imaging
    - Quantification of backscattered particles trajectories.

Development Process: Sub-Products

- Derived Inputs:
  - Material mobilized – combine all derived values to make this estimation.
  - TAG Penetration Depth – combine derived values and modeling.
  - CFS Compression – combine derived values and modeling.
  - TAG translational motion during TAG – derived from S/C telemetry.
  - Backscatter – estimates on backscatter via NavCam.
  - Sampleability Map algorithm estimate – recalculated post-TAG.

Production Timeline/Operation Schedule



Algorithm Dev. - First Assessment

- To produce an answer to "*the likelihood that sufficient material was mobilized to collect the baseline mass of material*", requires two separate questions be addressed:

1) *How much material was mobilized*?
  - Determine TAG head penetration depth and translation motion during contact with Bennu.
    - Analysis of S/C IMUs and TAGSAM telemetry
    - Comparison with Numerical Models

2) *How does sample collection amount correlate with amount of material mobilized on Bennu*?
  - Estimate sampling success as a function of *material mobilization*, which is primarily determined by penetration depth (and possibly gas release).
    - Still being defined– depends on TAGSAM Characterization and numerical modeling.

Minimal Mission Scenario

- TAG Reconstruct depends heavily on products/data that will be available even in a minimal mission scenario
  - All Rehearsal and TAG products are unaffected
  - OCAMS TAGSAM imaging campaign
  - S/C, Lidar and TAGSAM Telemetry

Off Nominal

- The Science Team TAG Reconstruct Plan is focused heavily on Off-Nominal scenarios
  - Heavy reliance on Telemetry in place of OCAMS TAGSAM imaging
  - Numerical modeling efforts are designed to explore a wider range of sampling scenarios than the Laboratory based TAGSAM Characterization Testbed
  - Numerical modeling tools can be deployed throughout the mission, including immediately post-TAG
  - The plan includes numerous inputs whose weighting could be changed in the event that some are compromised or degraded.

Work to Go

- Numerical Modeling – building tools and exploring parameter space
  - Two groups are expanding their Numerical Modeling capabilities to include full range of motion of S/C and Constant Force Spring and simulate IMU outputs
    - Ballouz/Richardson at UMD, and Sanchez/Scheeres at Colorado
  - Combined they will build an “atlas” of S/C response profiles for a wide range of S/C-Asteroid interaction scenarios

- Incorporating TAGSAM Characterization testbed results
  - Understand correlations between sampling success and material/spacecraft response.

- Build a schedule for delivery to the SPOC
  - After completion of Numerical modeling and TAGSAM characterization; post-launch.

Backup

First Assessment ~48hrs

- Use the inputs to constrain the properties of the contacted area of the asteroid
  - S/C Telemetry – compliance of the surface, penetration of the TAG
  - OCAMS imagery – visual inspection of the sample site, size distribution of particles, identification of any large objects, before/after imagery of the contact site
  - NavCam/LIDAR – capture backscatter particles trajectories

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- Use the estimated asteroid surface properties to evaluate likelihood of sampling success
  - TAGSAM characterization over a wide parameter space of surface material properties,
  - Numerical modeling of spacecraft and surface material behavior for a *wider* parameter space of surface properties.

Modeling Effort

- Won't have time to run *large* numbers of simulations or experiments in the 48 hr turnaround time
  - TAGSAM Laboratory experiments are non-trivial to setup and run
    - Only a few/day are possible
  - Numerical models are flexible, but expected run times for useful resolution models will likely be ~hours.

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- We propose to prepare an atlas of modeling/experiment results
  - TAGSAM characterization of the expected regions of parameters space,
  - Numerical models of TAG outcomes of *overlapping and larger* regions of parameter space.

Numerical Modeling

- Following the Regolith Splinter at STM6 further numerical modeling was proposed to extend the Science Team Capabilities to model Spacecraft interactions with the Asteroid
  - Laboratory experiments on simulant materials to create a set of calibration standards for numerical modelers (Holsapple)
  - Extend and calibrate discrete element models (billiard balls) of regolith behavior (P. Michel and D. Scheeres groups)

- Determine a strategy for interpreting the Spacecraft Telemetry (IMU outputs) to determine Asteroid Surface Properties