

## FY24 R&TD Innovative Spontaneous Concepts (ISC)

# **Removing Navigation Biasing During Close Proximity Operations**

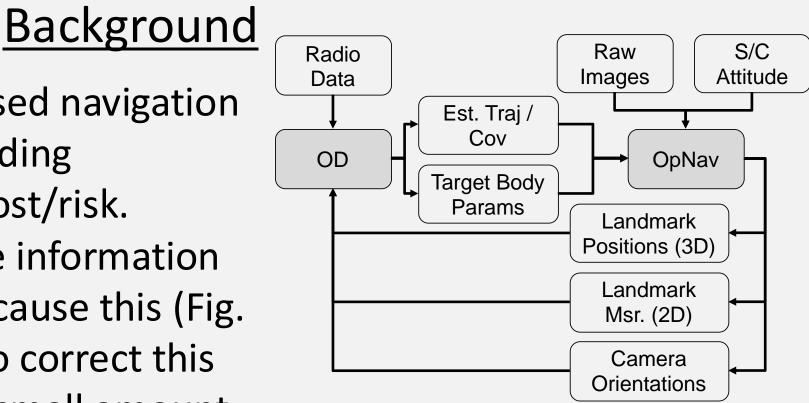
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#### Strategic Focus Area: Innovative Spontaneous Concepts

### Objectives

Goal: Develop an optical landmark-based navigation framework that consistently yields unbiased solutions and can be applied to all phases of prox ops. Research will involve:

Standard optical landmark-based navigation yields biased solutions - degrading performance and increasing cost/risk. Jnmodeled correlations in the information flow between OpNav and OD cause this (Fig. 1). The OIDA was developed to correct this problem; however, it leaves a small amount of bias and cannot process dense datasets.



- Leveraging OpNav Information Distillation Algorithm (OIDA)
- Developing data partitioning capability for reduced runtime
- Minimizing information loss with dataset partitioning
- Conducting thorough error analysis to identify lingering bias
- Validating approach against real flight data

We re-parameterized the OIDA to give it the ability to estimate with or without inertial attitude information. This provides estimation flexibility that can be used to identify potential biasing. We also developed a data partitioning algorithm called Landmark Community Tables (LTC, Fig. 2). With a LTC, datasets are depicted in a 2D binary table where the rows/columns can be interchanged to reveal information concentrations for optimal dataset partitioning.

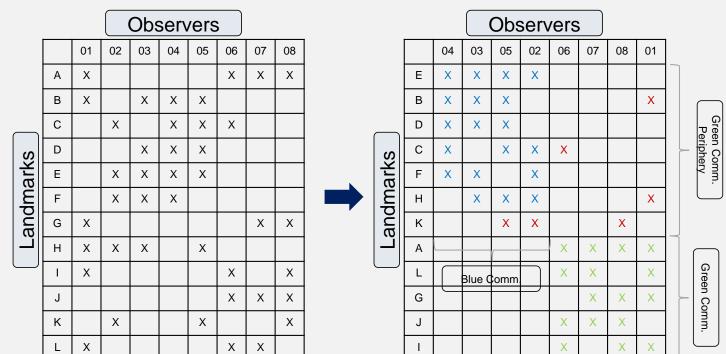


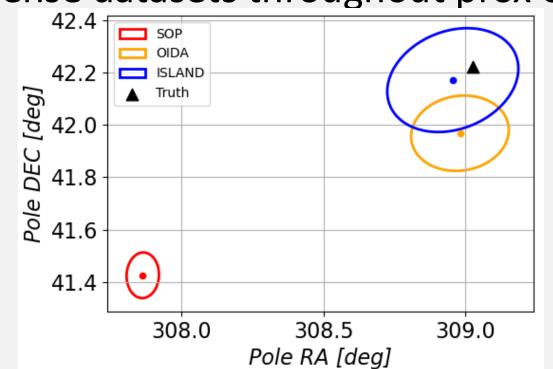
Figure 1: Standard OD-OpNav framework.

in-flight star field alignmer calibration error rule of thumb for SPC mod accuracy is 1-5x the mean pixel scale thermal distortion o GNC system (star precision is 0.5–6x the best pixel scale tracker + IMU) error pacecraft structur ror in reflectance mode ultiple reflectance. spacecraft attitude general differences vs rea error in pole world environment star tracker camera camera frame calibration last pole/pole alignment rolling rate/prime meridiar shutter correction fron DSN OD error last target shape adjacent long resolution and pole mode of images xposure star image: image noise landmark/maple a priori image attitude last spacecraf knowledge definitions target images trajectory sing between pole solution and andmark height and SPC estimated PC: maplets identified in cross-correlation fit of mage data, sampled, solve observed and rendered r map slopes/albedos landmark maps SPC: cross-correlation fit of PC: global solution of landmark vectors, camera attitude, observed and rendered landmark pixel/line amera position, (pole? andmark maps locations and sigmas landmark pixel/line body-fixed landmark spacecraf updated image position<sup>3</sup> position and covariance locations/sigmas attitude\* data set metrics new pole/pole OIDA accuracy is 1–5x the mean pixel scal rate/prime meridiar precision is 0.5-6xthe best pixel scale SPC formal uncertainty (FormU) new shape and new spacecraf Irue error expected to be within 1-2x DTM Monte OD Filte

Figure 3: OpNav Error Flow Chart.

A complete error investigation was also performed as outlined in Fig. 3, which

Combining the re-parameterized OIDA, the LTC, and the novel optical data weighting scheme, we obtain the Information Sieve for Landmark (ISLAND) Navigation Framework. Applied to Dawn flight data (Fig. 4), the ISLAND completely removes solution biasing and drastically improves raw error relative to the state-of-practice (SOP). We have significantly decreased runtime (>100x) to enable usage for dense datasets throughout prox ops.



#### Approach & Results

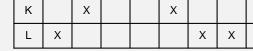


Figure 2: Landmark Community Tables.

resulted in a novel per-landmark weighting scheme to reduce biasing.

Figure 4: Vesta Approach Pole Estimate Comparison.

### Significance / Benefits to NASA/JPL

We conclude that we have identified and removed the underlying cause of biasing with optical landmark-based navigation. This offers many benefits, including lowered development/ops cost, simplified requirements verification, and improved robustness/accuracy. This work will directly improve navigation for Psyche and MMX as well as future NASA/JPL missions. It also offers a pathway for more robust autonomous navigation.

### References

[1] Lubey, Daniel and Bradley, Nicholas, "Improved Covariance Realism for OpNav-Informed Orbit Determination: The OpNav Information Distillation Algorithm," IOM 392J-21-001, May 2021. [2] Ernst, Carolyn M., et al. "High-resolution shape models of Phobos and Deimos from stereophotoclinometry." Earth, Planets and Space 75.1 (2023): 103. [3] Mastrodemos, Nickolaos, et al. "Optical navigation for the

Dawn mission at Vesta." 23rd International Symposium on Space Flight Dynamics, Pasadena, CA. Vol. 29. 2012.

#### **National Aeronautics and Space Administration**

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#### **Publications:**

[A] Lubey, Daniel and Mages, Declan, "ISLAND: Removing Biasing from Optical Landmark-Based Navigation," Hockney Seminar, Jan. 2025.

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