National Aeronautics and Space Administration

Time Out – Recovering Time & State for Autonomous Navigation Systems in Deep Space

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Program: SURP

Project Objective:

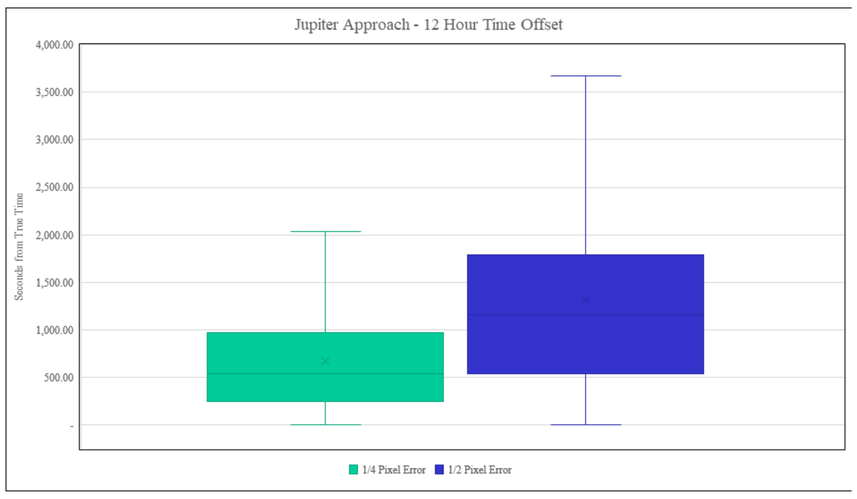
- The Lost-in-Space Problem (No time, position or velocity knowledge)
  - Remedy a deficiency of capability by providing a “cold start” independent determination of time and state (position and velocity) of a deep space spacecraft.
- Add robustness and enhanced fault-to-recovery capability to deep space spacecraft.
- Solve for CubeSat hardware
  - Solution for CubeSats immediately apply to larger systems

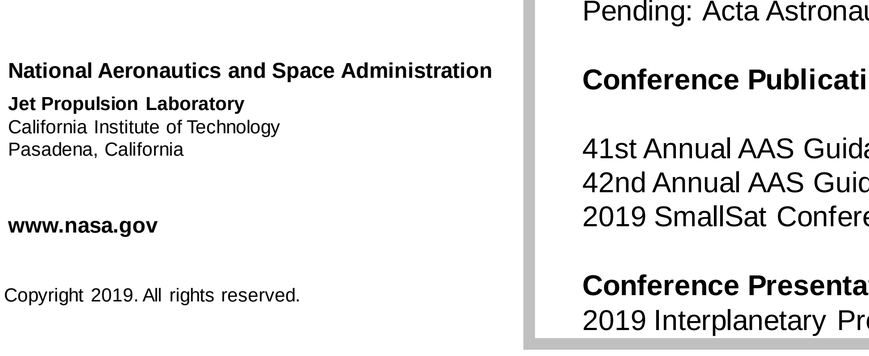
FY18/19 Results:

- Development of Algorithms to solve for Time given an offset in known time.
- Successful modification of the Optical Navigation Program software
  - Time offset variable is a function of the velocity of the spacecraft and the celestial bodies used for the navigation solution.
- Implemented scripting and program that can run unlimited simulations while implementing a time offset into the scenario.
- A comprehensive covariance study on different simulation parameters
  - Time offset, pixel error, simulation time frame, number of images, planet distance, and planet location
- Proven time solution that can recover from a time offset.
- Unknown Time, Position, and Velocity study

Benefits to NASA and JPL:

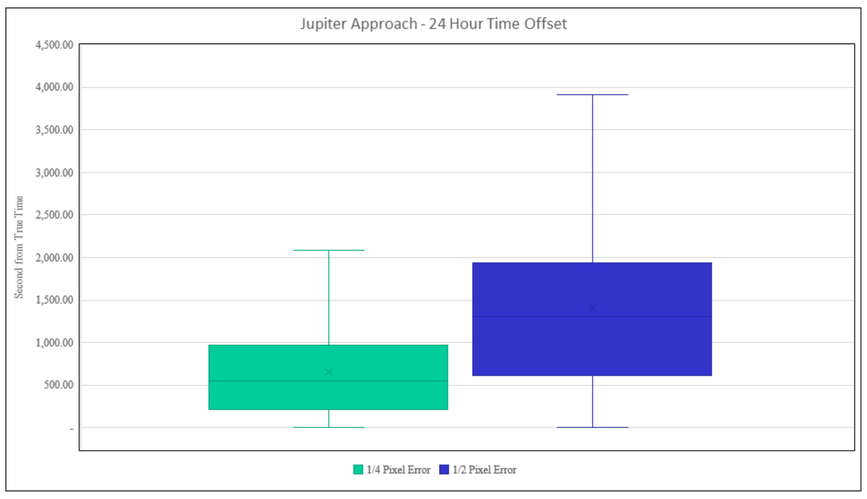
- Wished for feature has been added to ONP software, namely to solve for time biases.
  - This problem, for example, had been suspected on the Dawn mission, but no means existed to analyze it.
- With this already implemented on the mission, the robustness for detecting timing errors and recovering faulted systems is significantly increased.
- This new feature will be added to any mission that planes to do deep space navigation as another fail safe in the JPL arsenal to recover from faulted states.

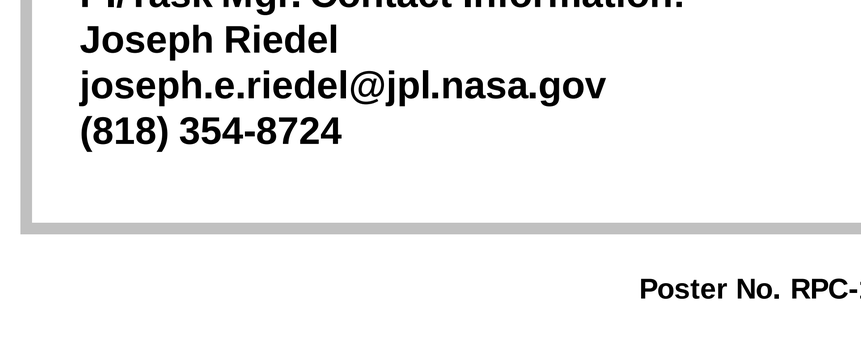




Results

- The main significance of these results and research is the fact that it has been proven that time can be solved for with a best known state (position and velocity) of 12 and 24 hours prior. This was able to be solved within a 1-sigma of 30 minutes of the actual time with the average being 10 minutes for a ¼ pixel error case.
- The formal 1-sigma uncertainty with a limited estimation set shows time recovery of 1700 seconds at a distance of 1 AU from Jupiter depending on the simulation pictures run through the filter.
- Multiple scenarios were run using picture sets of Jupiter, Saturn and Mars
  - 1-7 days simulation
  - 9 and 180 pictures per simulation
  - Error was added to the filter in the form of random white noise and a ½ and ¼ random pixel error on objects in the field of view.
  - All simulations were run with the Sinclair Cubesat star tracker
- Simulation showed a slight bias towards the direction of the time offsets, as shown in the Histograms





Publications:
Pending: Journal of Small Spacecraft
Pending: Acta Astronautica

Conference Publications/Presentations:

41st Annual AAS Guidance, Navigation and Control Conference-2018
42nd Annual AAS Guidance, Navigation and Control Conference-2019
2019 SmallSat Conference

Conference Presentations:
2019 Interplanetary Probe Workshop

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