

SOFIA Non-Sidereal Pointing and Tracking

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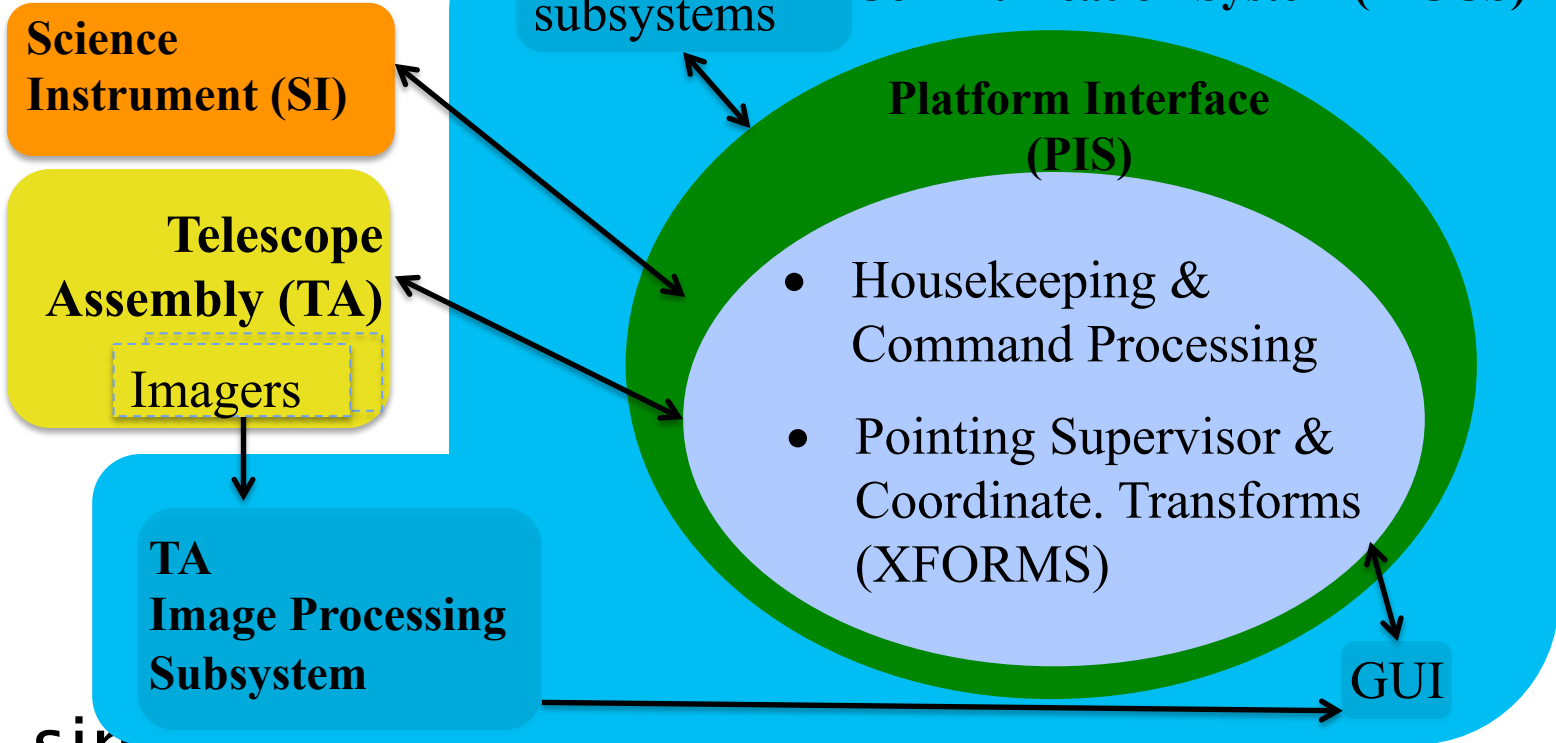
Executive Summary

- Complex changes to MCCS and the TA TRC and TASCU are underway to achieve high velocity non-sidereal pointing and tracking.
- The design provides a simple interface to the operator and/or observer to request such pointing and tracking.
- Prototype developments appear to achieve relatively high computational accuracy
- MCCS/*TASim* interaction is robust and mature

Acknowledgments

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- Dr. Elizabeth Moore, USRA – User Interface development and ISD Manager
- Dr. Holger Jakob, DSI – TA Lead
- John Rasmussen, Critical Realm Corp, algorithm development, Scenario/algorithm lead
- Chris Luk, Wes Patterson, Todd Jenkins, L3 Communications – Software Development Team

Simplified Context



- A simplified presentation of SI, TA, and MCCS command and housekeeping relationships.
- The MCCS PIS XFORMS processes convert observer coordinates to TA coordinates

Non-Sidereal Tracking Use Cases Analysis

Track vs. Target Type	Track Object is Sidereal	Track Object is Non-Sidereal
Target is Sidereal	“Typical” – e.g. observe stellar nebula using nearby track star	<p>Is there a case here? Seems <i>contrived</i> (i.e. not necessary)</p> <p><i>...but, contrived case may help in verification since target location (track point) is well known...</i></p>
Target is Non-Sidereal	Lowell Observatory method – use track <i>stars</i> to guide observations of a non-sidereal target	Observe an asteroid/comet/planet that could be used to guide as well

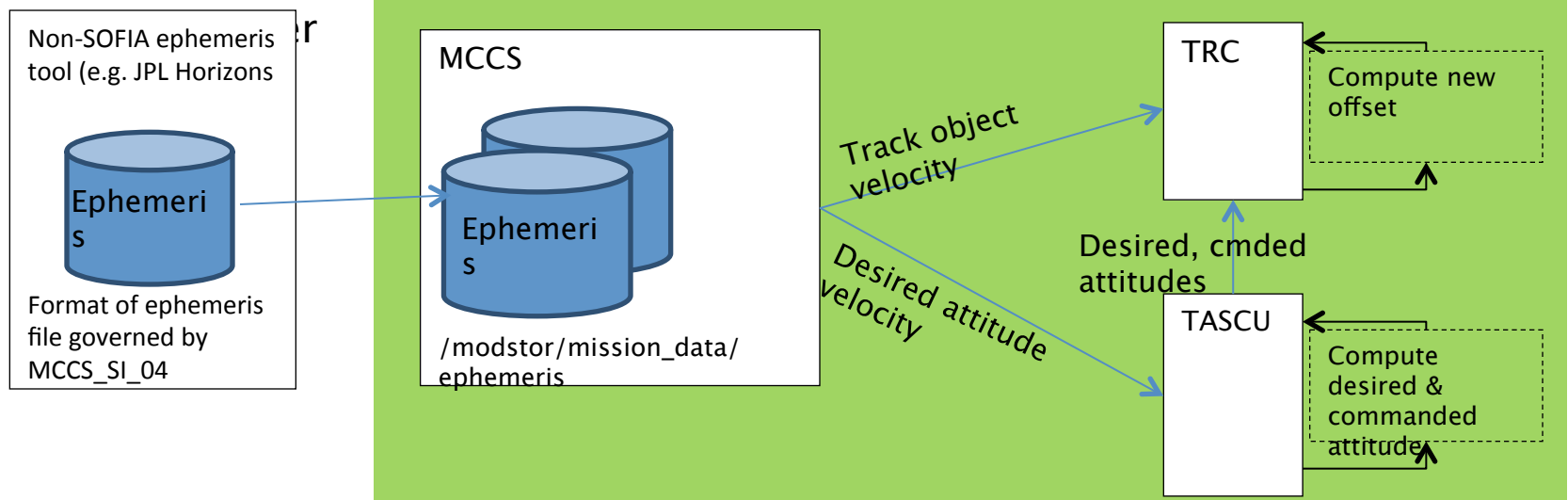
Design Approach

1. Non-sidereal observing utilizes geocentric ephemeris files in JPL format (first phase --- osculating elements will be prioritized for a later phase)
2. MCCS interpolates ephemeris for the given time and converts geocentric ephemeris to topocentric coordinates using current SOFIA longitude, latitude and altitude
3. MCCS will compute TA velocities of Tracker Area of Interests (AOIs) and Fine Drive controller and provide velocities to the TA Tracker and TASCU
4. TA will propagate velocities and change guide object-to-target offset as needed during tracking
5. Subsequent nods, dithers, tweaks, or pointing in SI coordinates leave velocity in place

Data Flow

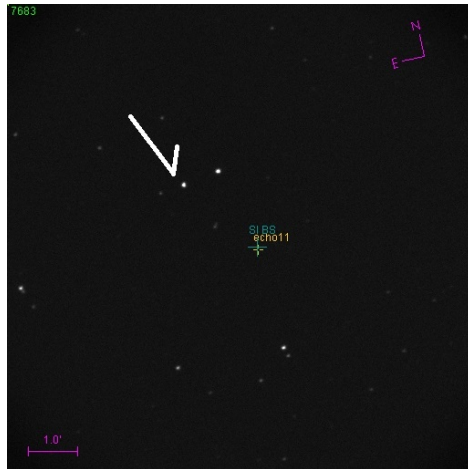
- From some external source (e.g. JPL Horizons)
 - Create ephemeris file for object to observe and track object (if non-sidereal)
 - Use stepsize per required accuracy (i.e. moons will change velocity)
 - Recommend 15min to avoid significant error in apparent velocity determination
- Transfer to SOFIA
- Create positions and go
 - coord.position name=jupiter (ephemeris={xyz file})
 - ta_pos.goto pos=jupiter
 - New command to associate ephemeris with an AOI coord.aoi_create

PDR

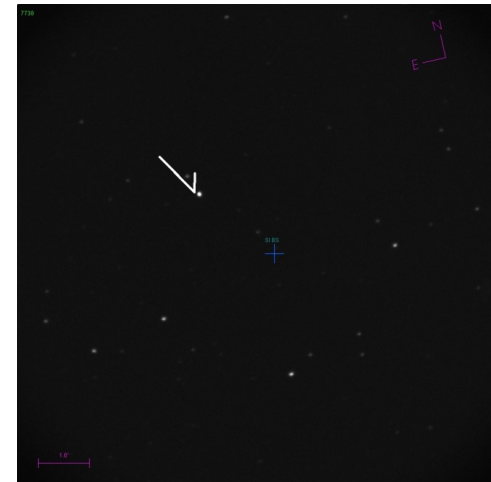


Geosynchronous Satellite (August Line Ops)

JPEG1



JPEG2



Not a Science test case; just a validation of MCCS and TA coordination

- After pointing with MCCS satellite, TA was in inertial mode with all stars moving in focal plane except “one”
- Pointing was generated from an approximation of satellite’s position (i.e. not precisely generated from a known orbit vector or authoritative source akin to JPL Horizons).
- See Doug Hoffman’s movie at:

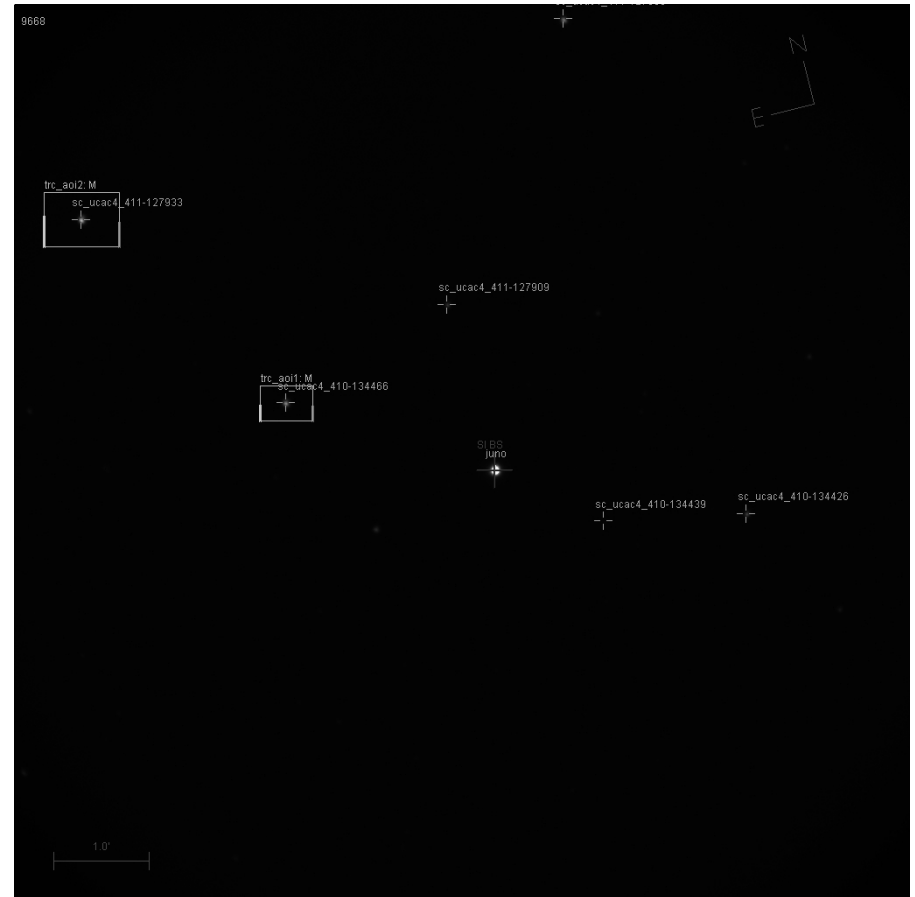
<https://wiki.sofia.usra.edu/twiki/pub/EngDataAnalysis/S3postDeployRawData/GeoStationary.mov>

Stable results at velocities much higher than Science use case
(15"/sec vs 1"/sec)

Juno Observation

This observation was completely unplanned.

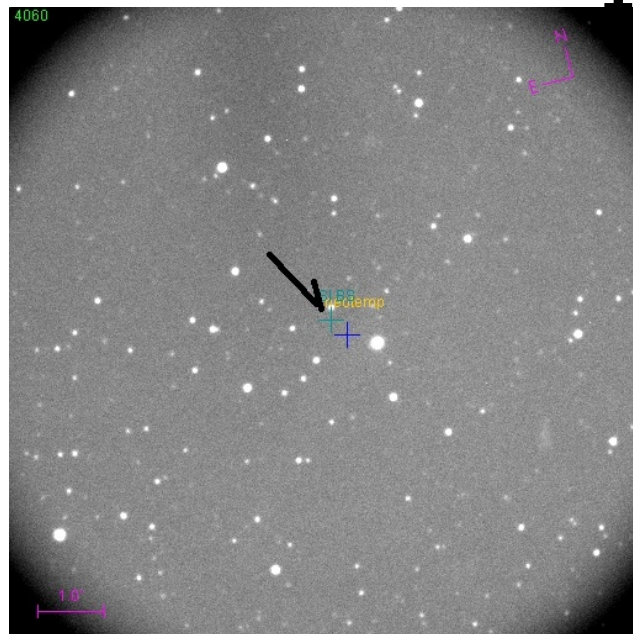
- While performing other tests, observed via Stellarium that Juno was approaching the azimuth that SOFIA was observing during the line operation
- Quickly generated a JPL Horizon's ephemeris file since we had internet connectivity
- Transferred file to MCCA via MD
- Created "Juno" position
- Pointed to MCCA "Juno" position and placed image



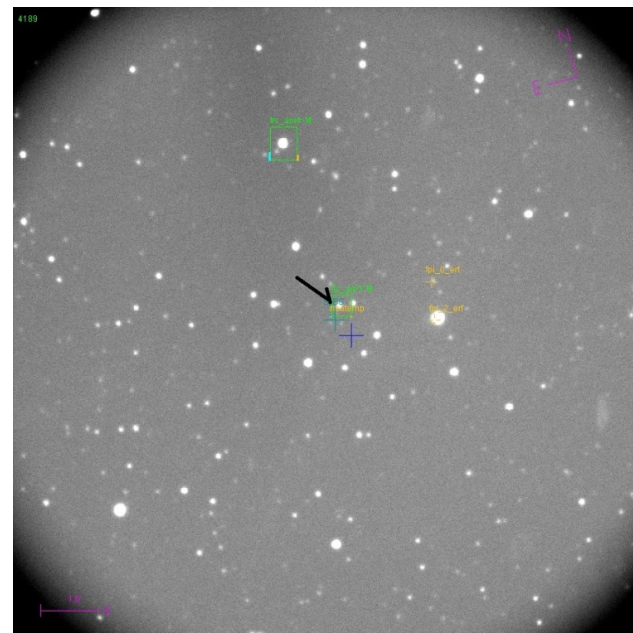
Juno; dist: 1.7 AU, mag: 5.25

GUI/PIS coordination of interfaces presents very low impact to existing operations concepts

1999 CF9



Initial pointing



AOI around asteroid

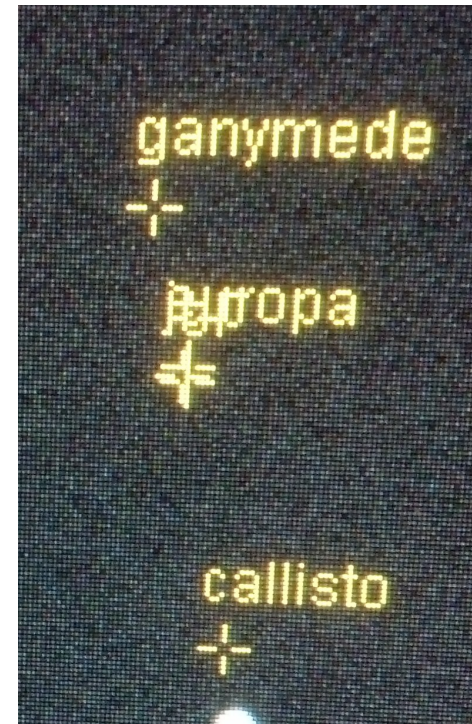
1999 CF9; dist: 0.06AU, mag, mag: 14.8, velocity $\sim 800''$ /hr

Good results on fast Near Earth Object in absence of tracking

Integration Lab Results

Overlays of Jovian moons (before TASim supported the rendering of such satellites)

- Position creation is very slightly slower than sidereal position creation while the MCCS reads the file
- Multiple non-sidereal positions can be created.
- Areas of Interest can be created from such positions.



Integration Lab Results

Guiding on a star in FFI while observing a $\sim 15''/\text{sec}$ object

- Place holder for a separate slide of size 35M with an embedded movie

Next Steps

- Develop, unit-test TA Tracker software
- Integrate MCCA engineering build with actual TA system
- Verify MCCA and TA systems
 - Majority of MCCA verification in Lab with TASim
 - Allows eval during simulated flight at various locations, velocities
 - Allows use of arbitrary non-sidereal objects
 - MCCA-TA interface verification in Hangar with TA
 - Real system to real system for very new command interfaces
 - High Level MCCA validation on sky in a line operation
 - Slow non-sidereal objects
 - Simulated non-sidereal objects from sidereal “ephemeris”
- Verify and validate Observatory capability
 - Repeat and validates behavior in a line operation and in flight
 - Utilizes data analysis team who perform astrometric analysis of images to establish pointing