

# Crew-Aided Autonomous Navigation

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HAT: 4.6

TA: 4.6 Autonomous Systems – Crew Autonomy Beyond LEO

TRL: Start 3 / Current 4

## OVERVIEW

A sextant provides manual capability to perform star/planet-limb sightings and offers a cheap, simple, robust backup navigation source for exploration missions independent from the ground. Sextant sightings from spacecraft were first exercised in Gemini and flew as the lost-communication backup for all Apollo missions. This study characterized error sources of navigation-grade sextants for feasibility of taking star and planetary limb sightings from inside a spacecraft. A series of similar studies was performed in the early/mid-1960s in preparation for Apollo missions. This study modernized and updated those findings in addition to showing feasibility using Linear Covariance analysis techniques.

The human eyeball is a remarkable piece of optical equipment and provides many advantages over camera-based systems, including dynamic range and detail resolution. This technique utilizes those advantages and provides important autonomy to the crew in the event of lost communication with the ground. It can also provide confidence and verification of low-TRL automated onboard systems. The technique is extremely flexible and is not dependent on any particular vehicle type. The investigation involved procuring navigation-grade sextants and characterizing their performance under a variety of conditions encountered in exploration missions. The JSC optical sensor lab and Orion mockup were the primary testing locations. For the accuracy assessment, a group of test subjects took sextant readings on calibrated targets while instrument/operator precision was measured. The study demonstrated repeatability of star/planet-limb sightings with bias and standard deviation around 10 arcseconds, then used high-fidelity simulations to verify those accuracy levels met the needs for targeting mid-course maneuvers in preparation for Earth reentry.

## INNOVATION

This technique has the potential to deliver significant risk mitigation, validation, and backup to more complex low-

TRL automated systems under development involving cameras. It increases system reliability and improves safety and mission risks

## OUTCOME

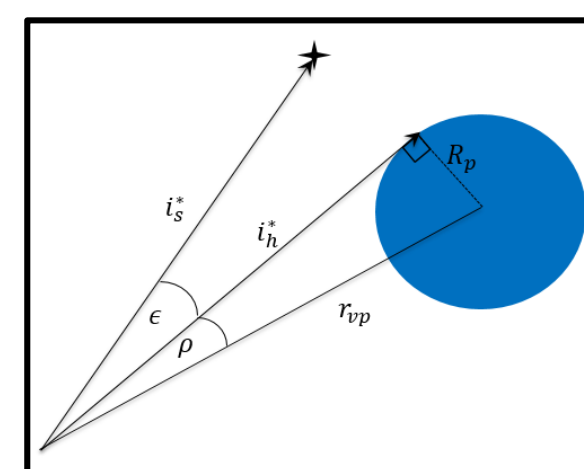
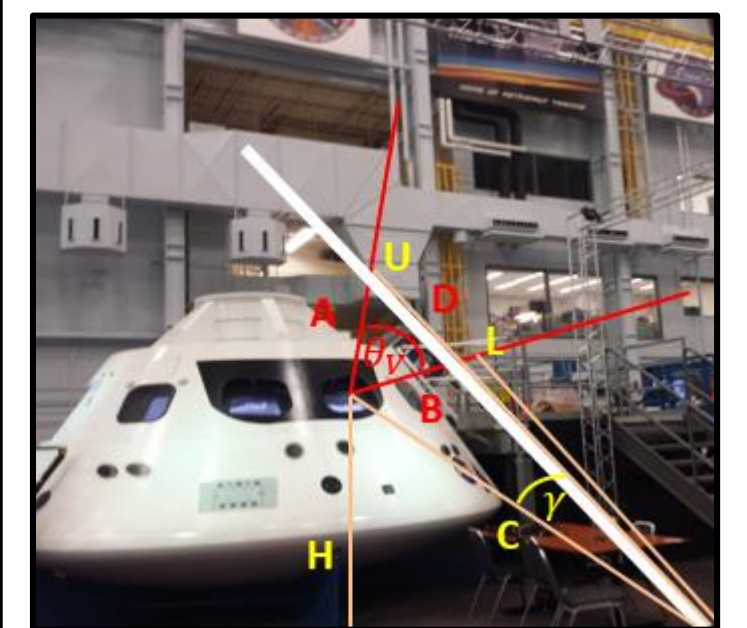
- Laboratory tests characterized accuracy
- Field-of-view was evaluated in Orion mockup
- Linear Covariance analysis showed feasibility

## INFUSION SPACE / EARTH

This technology is applicable as an autonomous backup or confirming navigation source for any future human spaceflight mission.



*Effective Field-of-View  
Testing in Orion Mockup*



*Star/Limb  
Sighting  
Concept*



*Laboratory  
Accuracy  
Tests*

## PAPERS / PRESENTATIONS

The results of the test campaign were presented at the Orion Critical Design Review and accepted as a feasible technical Risk-Mitigation strategy for camera-based automated systems.

## FUTURE WORK

The next steps include optimizing the instrument for mass and volume, developing crew training techniques, developing procedures and star charts for crew use, calibration exercises using actual cockpit glass, and developing a stowage plan for launch and entry.

