

**DRAPER**

# **Advanced Celestial Navigation Systems**

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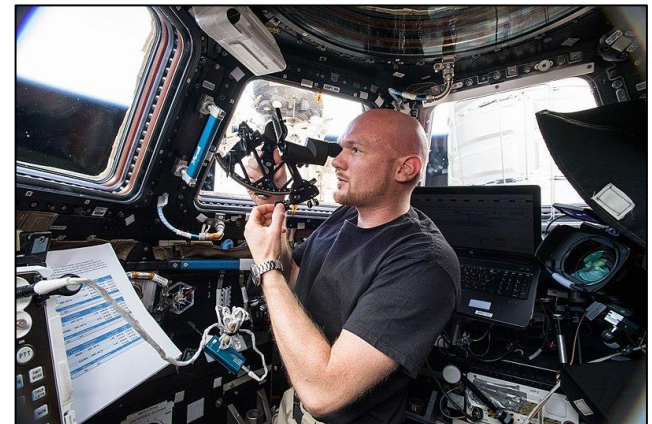
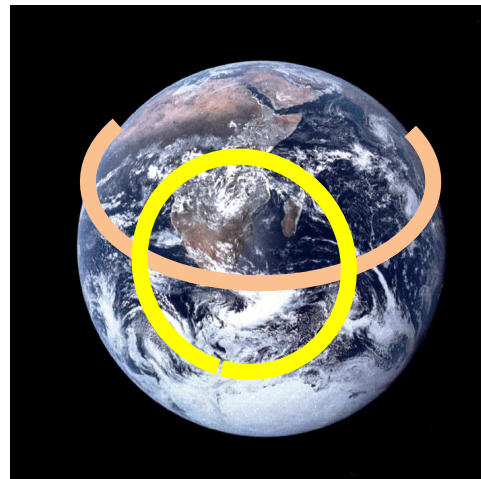
# The Celestial Advantage

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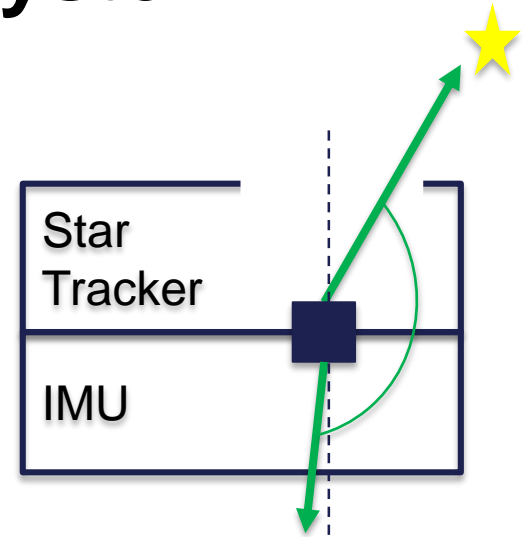
# Celestial Navigation

- **Mariners have used various celestial navigation techniques since ancient times**
  - *Sun, Polaris, the Sextant*
- **Sextant sightings**
  - *In order to determine position with a sextant, one needs 2 stars, local vertical, and a clock.*
  - *Position accuracy reference values:*
    - 1 arcmin ~ 1 nautical mile
    - 1 arcsec ~ 30 meters

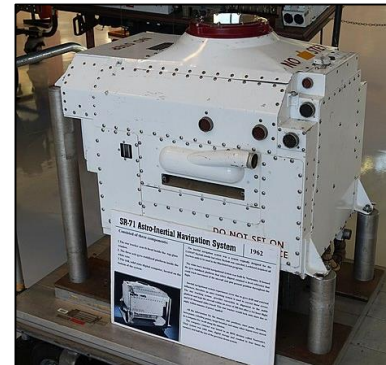


# Automated Sextant – Astro-Inertial Navigation System

- On a dynamic platform, the biggest challenge is determining vertical
  - Requires an IMU
- Mid 20<sup>th</sup> century saw automated astro-navigation systems in aircraft use (e.g. SR-71 ANS)



1 arcsecond angle error results in a 30-meter position error

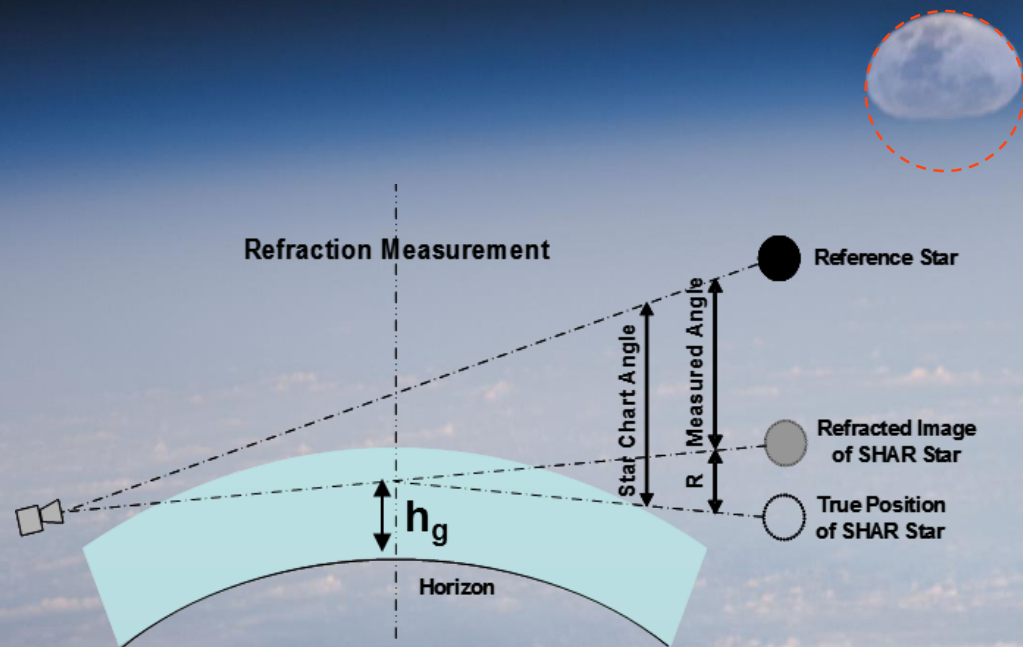




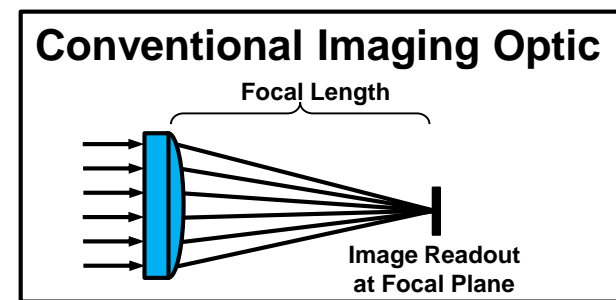
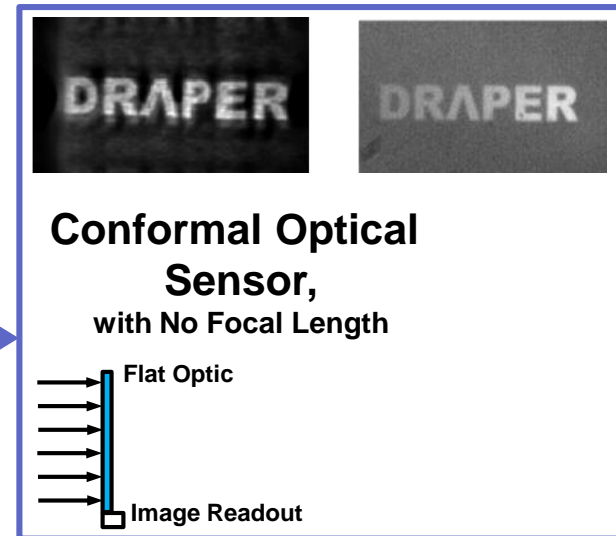
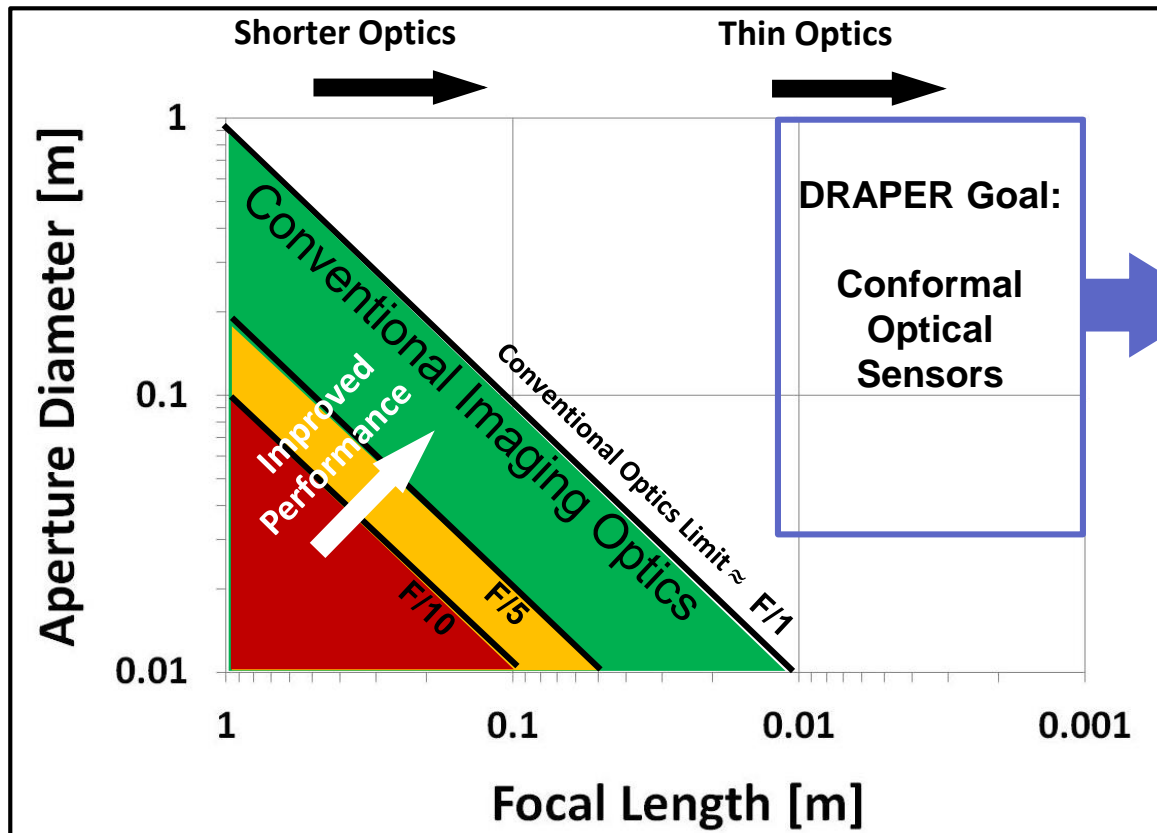
# Advanced Algorithm Development

## STELLAR HORIZON ATMOSPHERIC REFRACTION

- No local vertical required
- Accuracy depends on knowledge of atmospheric density profile
- Developed and published by DRAPER



# Advanced Hardware Development



**DRAPER Goal: Conformal Optical Imaging Sensors**

# Summary

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- **Long history of Celestial Navigation**
- **Robust techniques**
- **Automated sextants integrated into astro-inertial navigation systems**
- **Advanced technologies developed in past decades**