The AeroAstro Fast-Angular-Rate Miniature Star Tracker:

Algorithms and Simulation Results

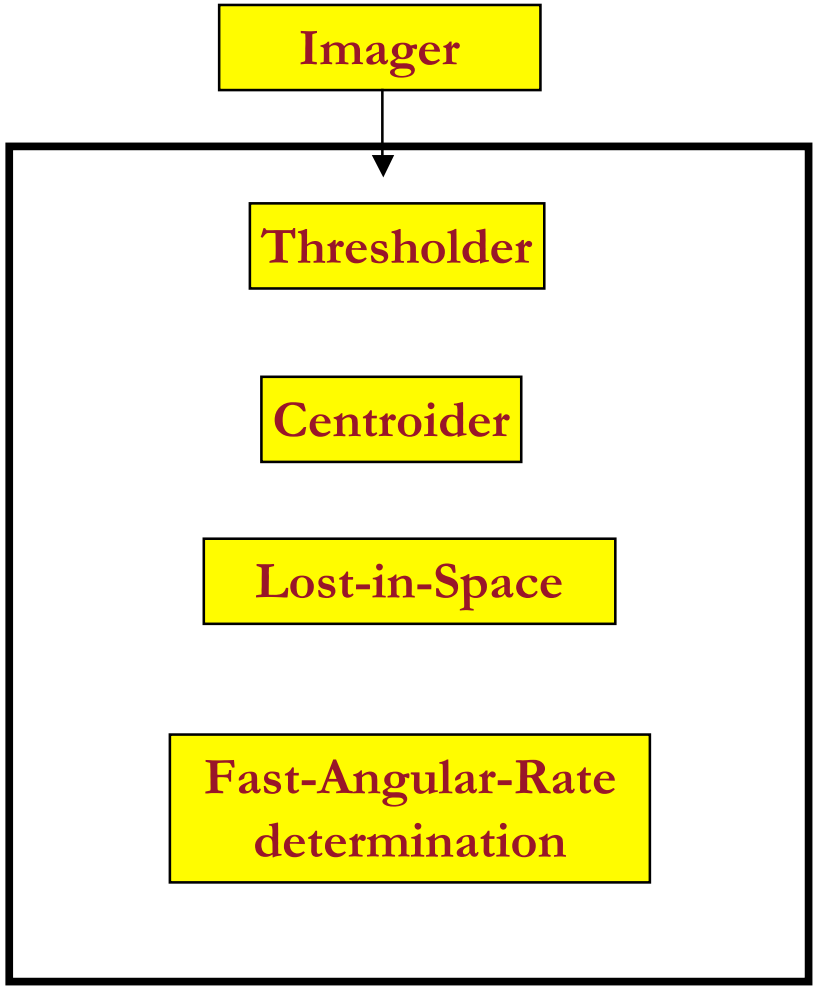
Bill Seng, James Stafford,
Vickie Kennedy, Ray Zenick
AeroAstro
bill.seng@aeroastro.com
703.723.9800 x 158

SSC05-XI-7

AEROASTRO

Block Architecture

- AA Star Tracker - all-optical!

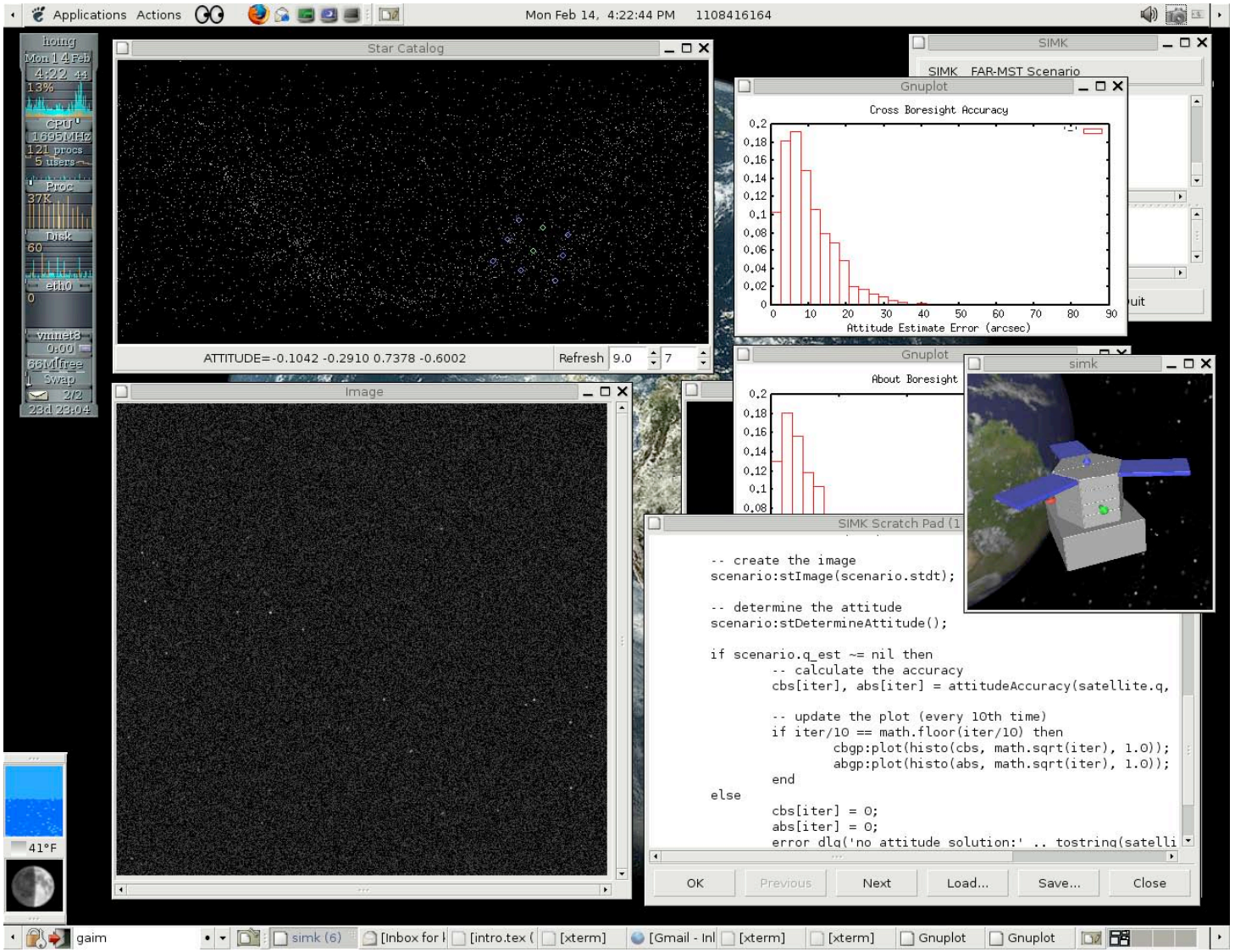


AEROASTRO

Simulation Environment

- **Simulate major Star Tracker components**
  - CMOS imager
  - Camera model
  - Star Catalog
  - Lost-In-Space algorithms
  - Fast-Angular-Rate algorithms
- **Simulates spacecraft dynamics affecting view**
  - Attitude/Pointing
  - Flight path
- **Neglect**
  - Spectral nature of optics, stars

Simulation Environment (cont'd)



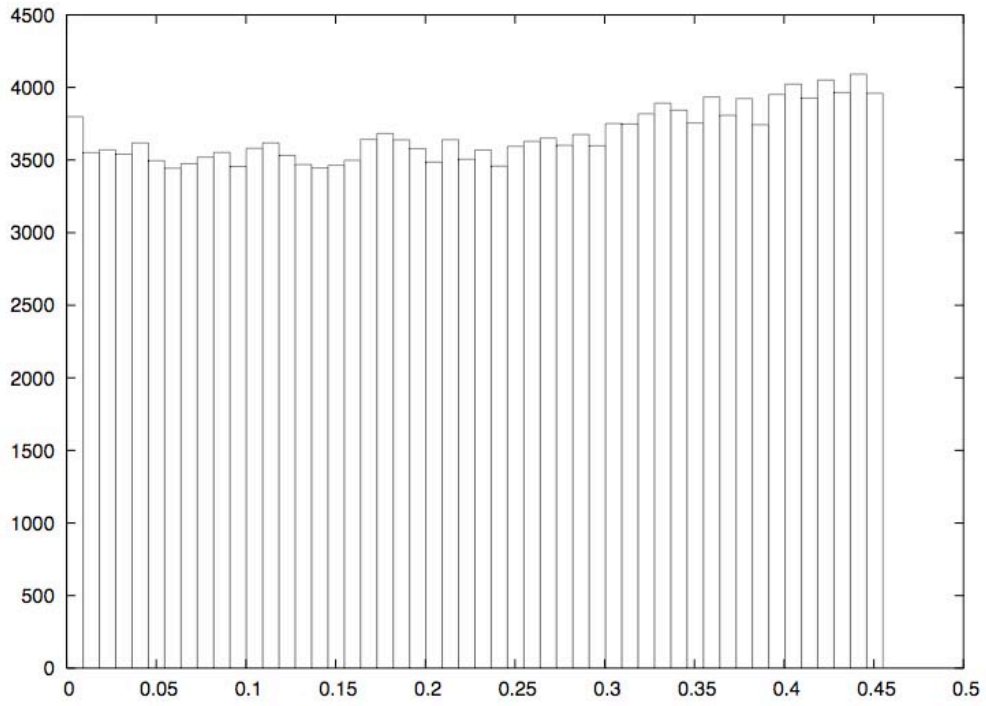
Lost-In-Space Algorithm (LIS)

- **Choice:**
  - Inter-star, angular separation
  - Grid-based
  - Neural-networks based
- **We chose:**
  - Inter-star, angular separation (more mature alg's)
  - Specific implementation: Pyramid (Junkins, Mortari)
- **Problem:**
  - How do you search the star catalog efficiently?
- **Answer:**
  - Hash tables (k-vector approach)

LIS (cont'd)

❖**Hash tables work because…**

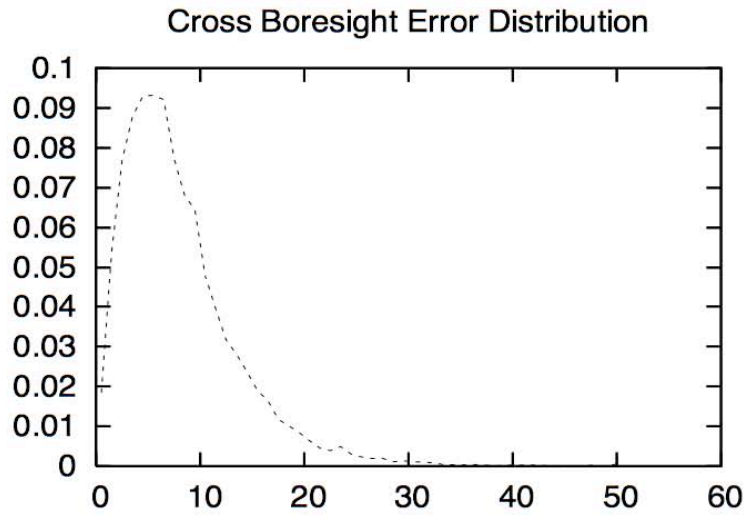
- Distribution of angular separation of stars is relatively flat

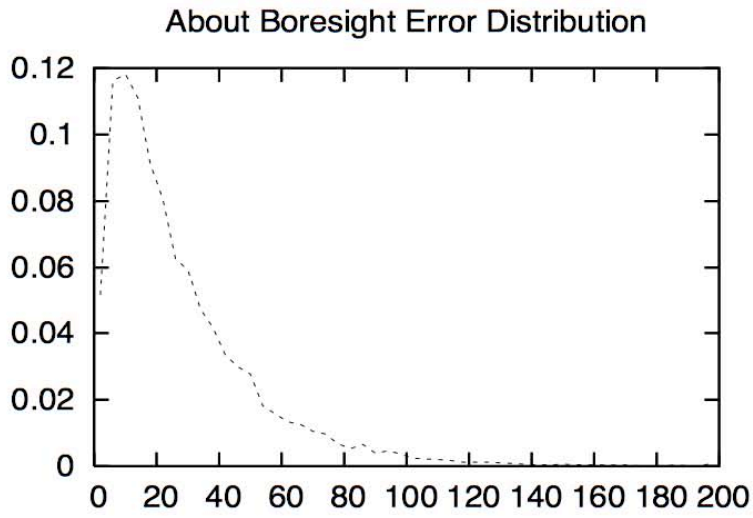


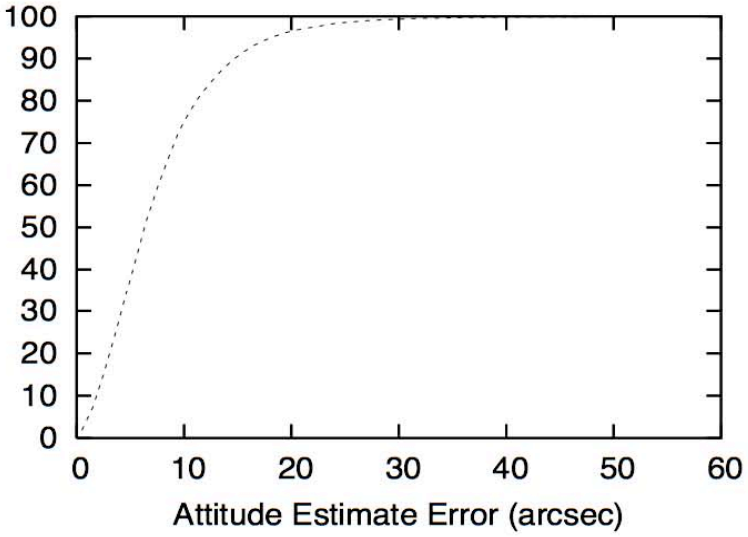
$Sin^2(\theta)$

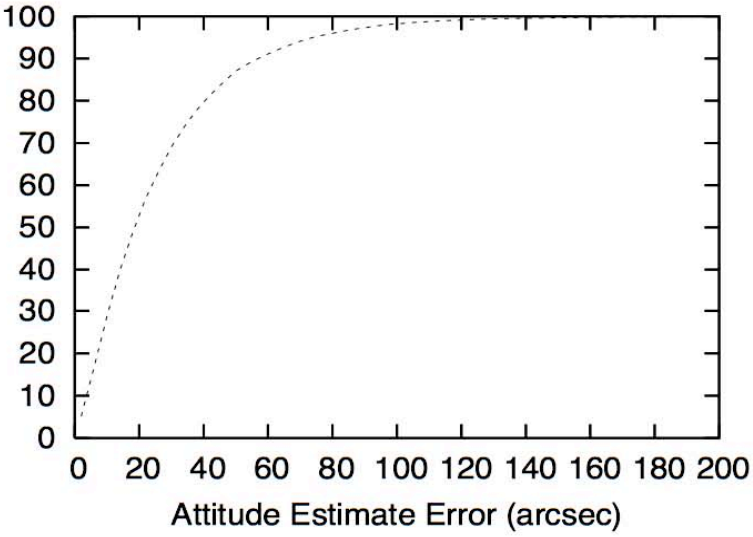
AEROASTRO

LIS Performance







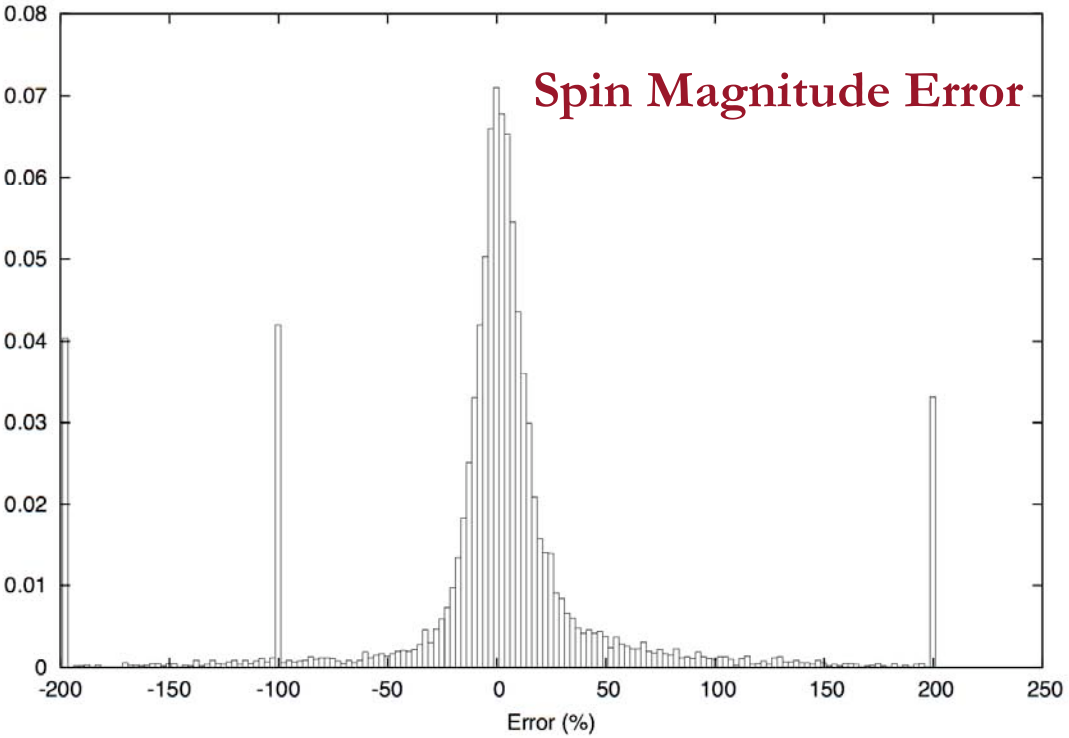


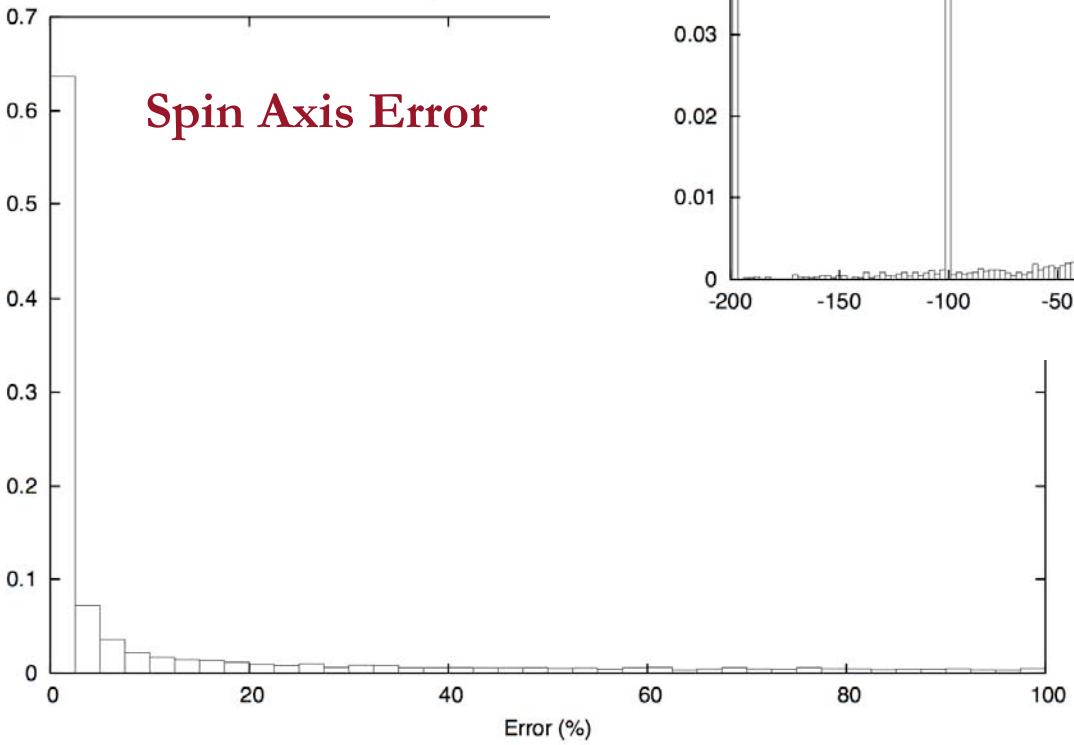
AEROASTRO

FAR-MST Algorithm

- **Estimate apparent star motion in the focal plane at several points**
  - Magnitude
  - Direction
- **How? - Use star streaks!**
  - Gaussian steerable filter
    - Detect, get orientation
  - Determine direction of rotation (sign issue..)
  - Use sequence of images
    - Sign of direction
    - Speed
- **Know spin axis = know spacecraft attitude**

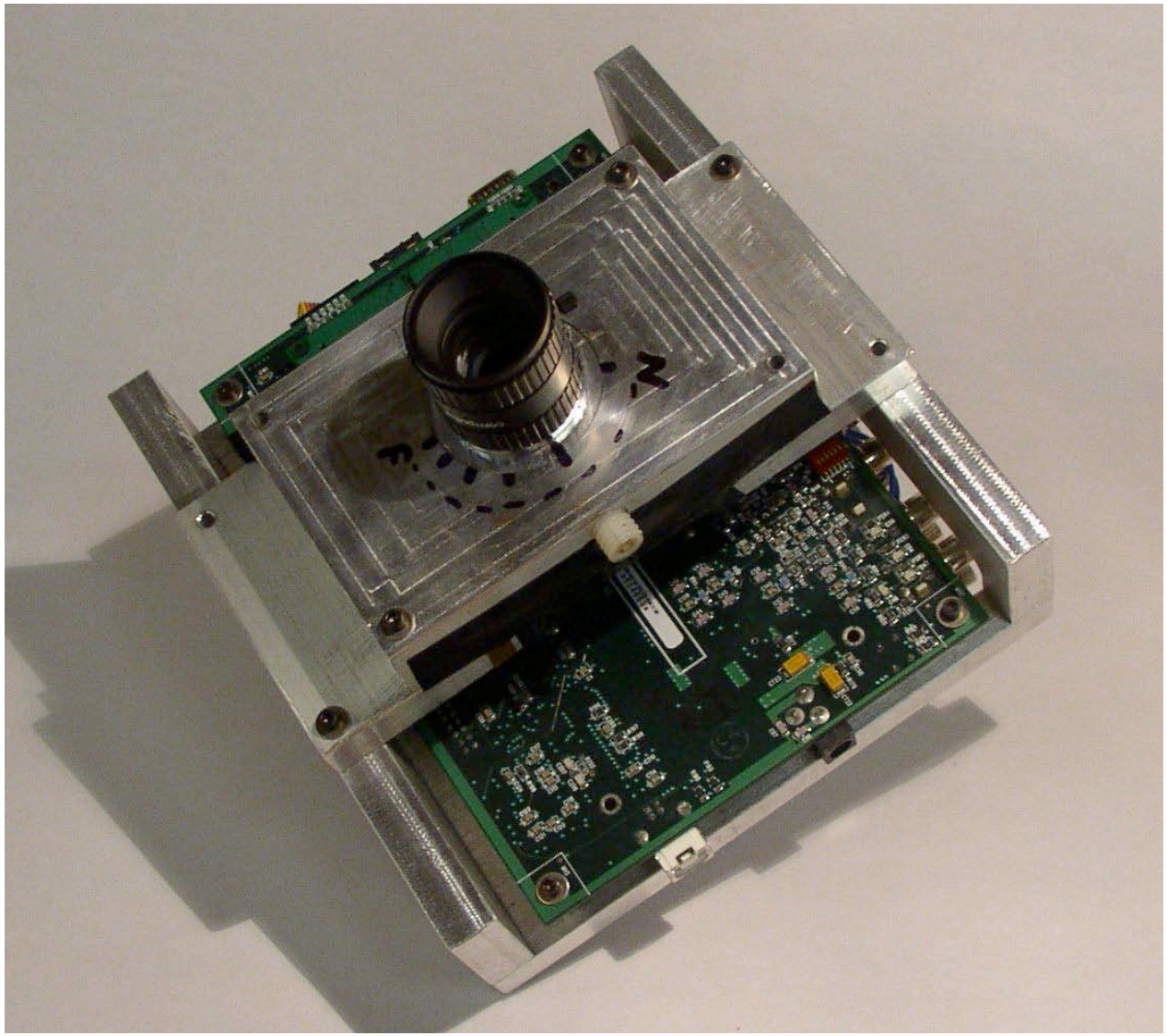
FAR-MST Performance





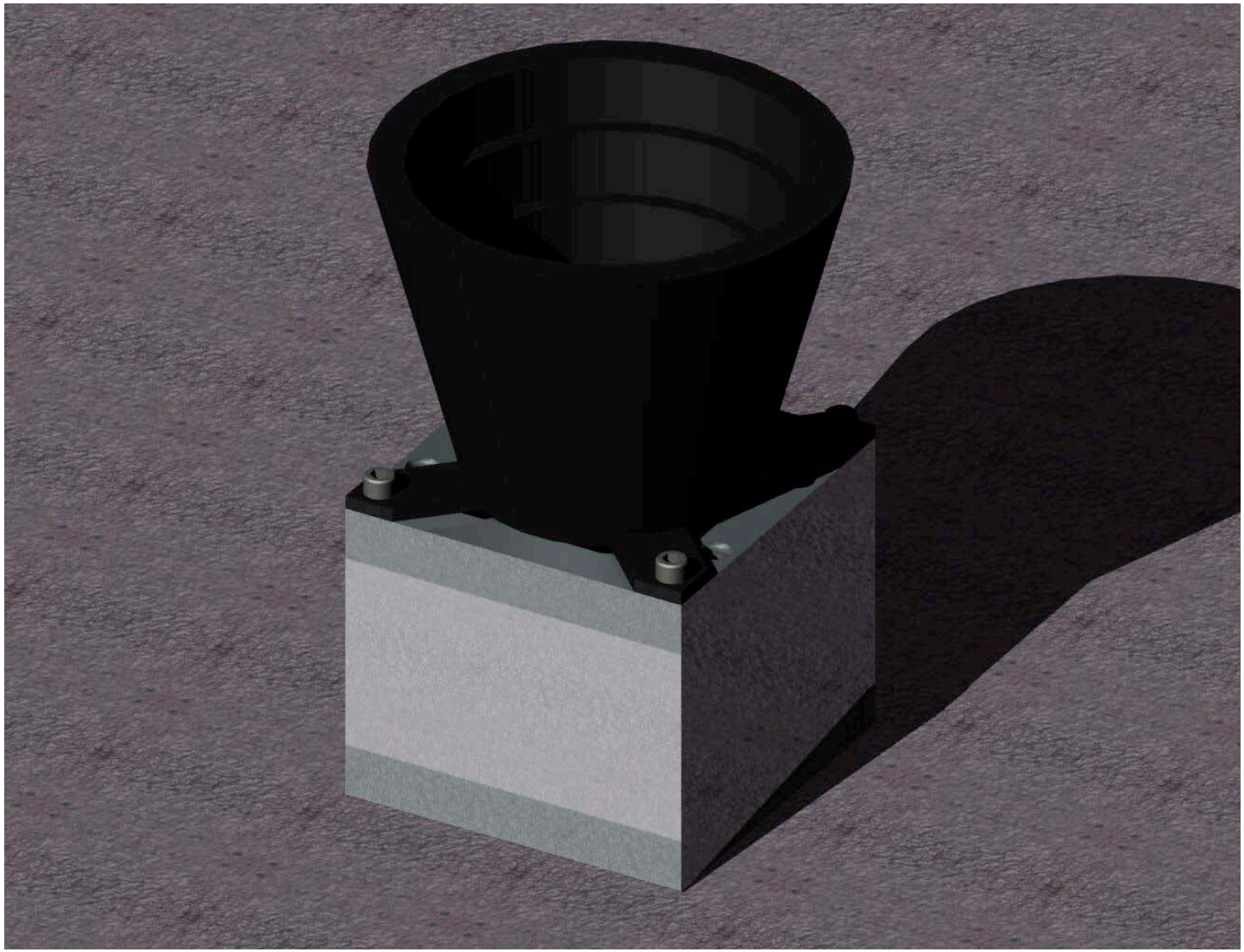
AeroAstro

Current Hardware



AeroAstro

Future Hardware



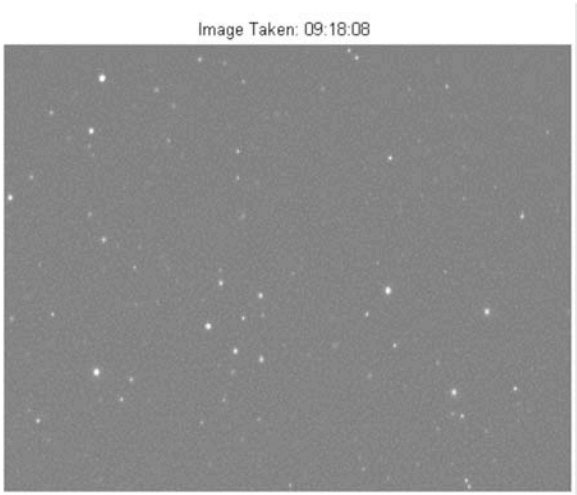
AeroAstro

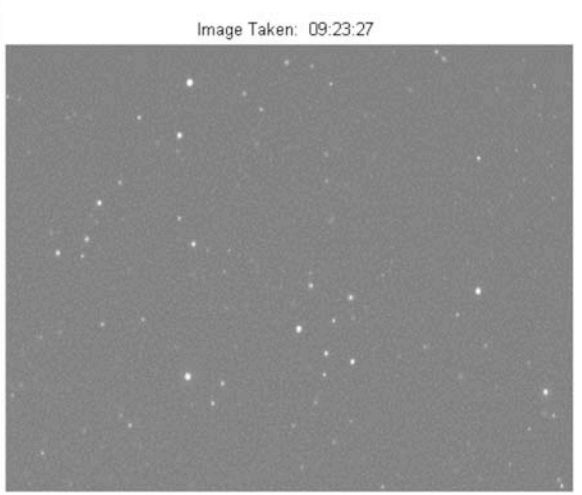
FAR-MST specs

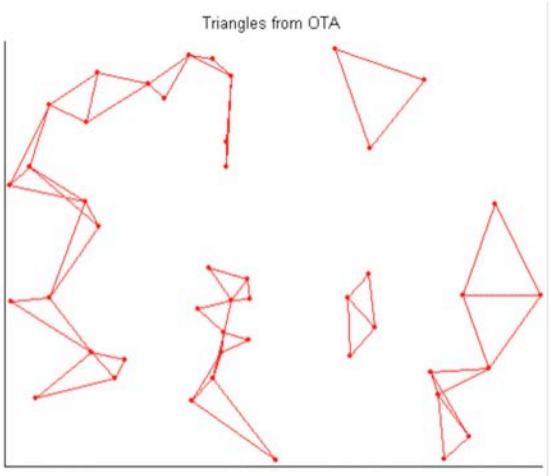
- **Mass: < 1 kg,**
- **Power: < 3 W**
- **Functions:**
  - LIS
  - Angular rates to 15 degrees/sec
- **Accuracy ~ 75 arcsec**
- **Size : 15 x 8 x 8 cm**
- **Price < $ 100K**
- **Interface**
  - USB
  - RS-422

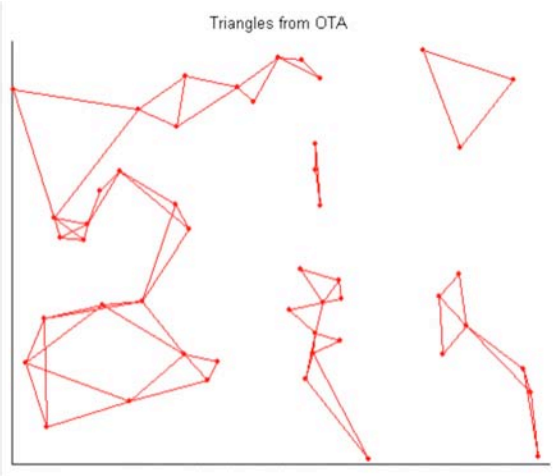
Real Star images

- Picture sequence taken 319 sec apart
- Quaternions generated, earth's rotation found to be 1.335 deg = 319.6 sec









AEROASTRO

CMOS image

AEROASTRO

Conclusions

- **Simulations show algorithms accurate**
  - Better than the ~75 arcsec quoted
- **All-optical system can provide**
  - LIS
  - Fast-Angular-Rate Measurements
- **Camera parameters currently being optimized**
- **Flight-ready prototype**
  - 12-14 months