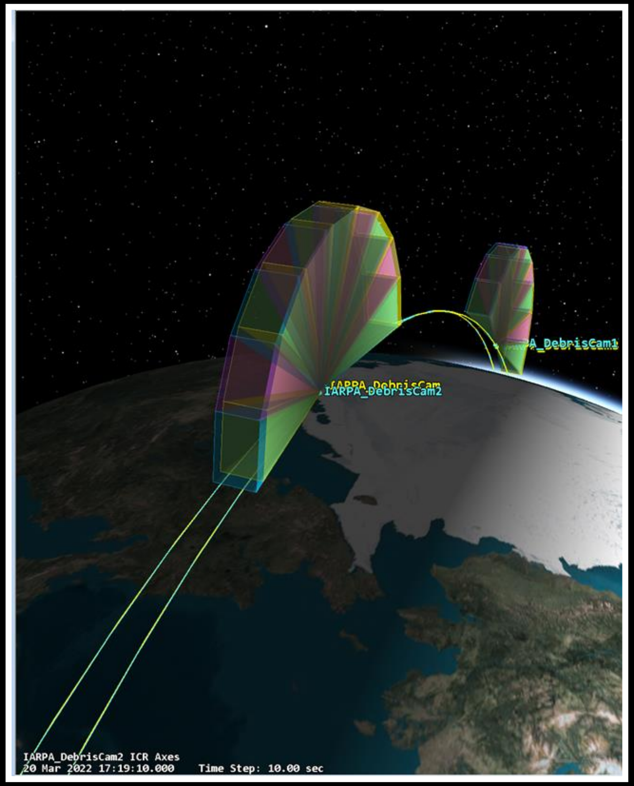
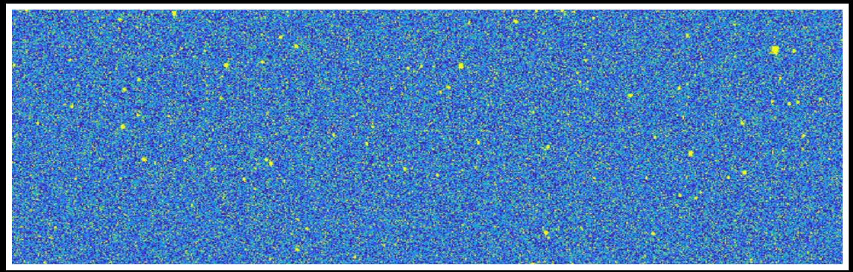
Space-based Optical Detection of mm-Scale Space Debris

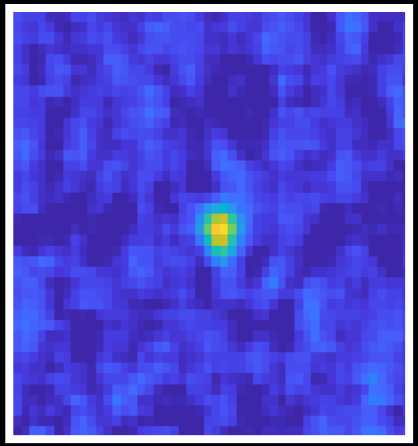
Peter Zimmer

Research Scientist
J.T. McGraw and Associates, LLC (JTMA)
zimm@lodestar.org





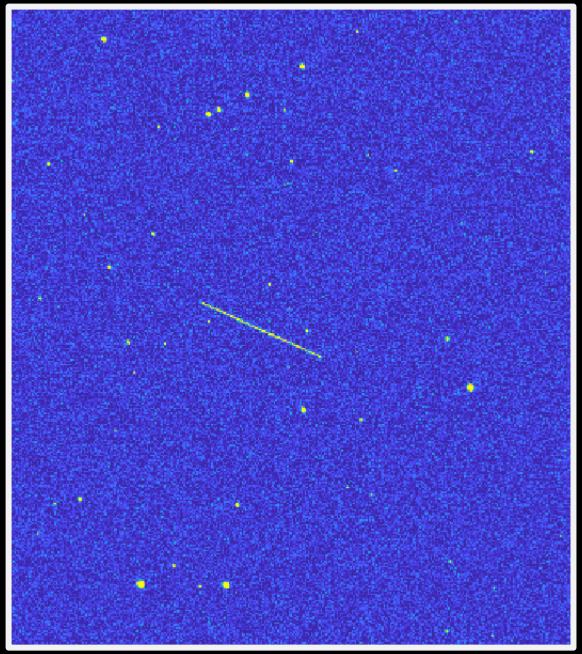
Limits of Ground-based Optical Detection



- With ground-based telescopes:
  - Debris to ~4cm diameter with small telescopes (0.35m)
- Limited by:
  - Range - can’t get closer than ~400km
  - Atmosphere – increased background noise, clouds, scatter and absorption
  - Terminator illumination:
    - Short duration window
    - Many Sun-sync objects never viewable

- Moving to space-based platforms largely eliminates these

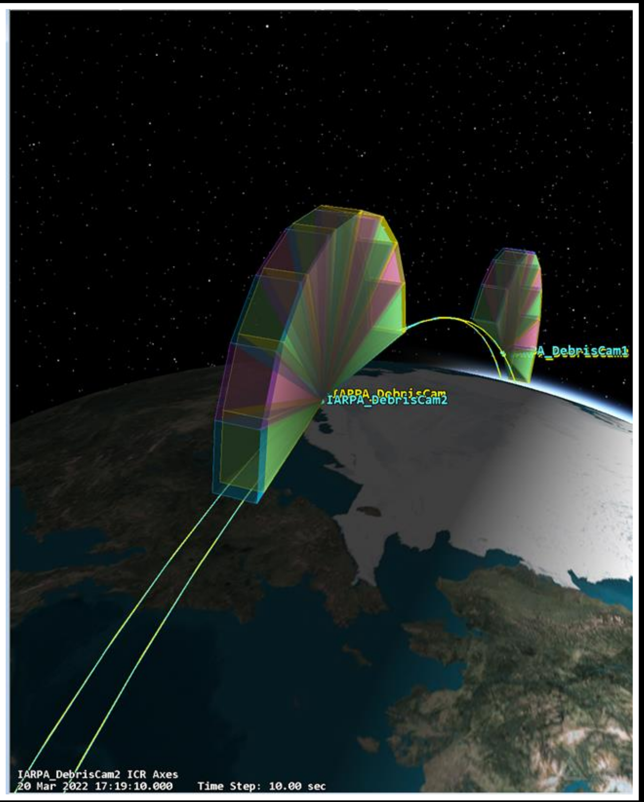
How Space-based Sensing Helps



- Sensors can be closer to debris
- Sensors can ride the terminator for constant illumination
- Sky background up to 100x fainter
- No atmospheric transmission losses

- But:
  - Smaller optics
  - SWAP-C and radiation environment
  - Limited detector options

SINTRA and Space-based Optics



- Optical detection probes different, complementary physics
- Detector development:
  - Detector noise drives fundamental limits
  - With state-of-the-art CMOS, a LEO small-sat could measure
    1.5 cm debris at 250 km standoff
  - With next-generation photon-counting arrays (e.g., QIS GigaJOT):
    < 5 mm debris at 250 km standoff
  - Current sensors need to be larger and space-qualified
- On-Orbit Compute:
  - Large data volumes that need to be searched for debris
  - GPUs well-suited to the task, but power hungry and unproven in space
- Parallax range for robust initial orbit determination

What JTMA brings to SINTRA

- Proven technology and IP for LEO debris detection and measurement
  - Optical design
  - Detector optimization and operation
  - Algorithm development

- Extensive experience in Space Domain Awareness (SDA)

- 15 active automated SDA optical systems operating around the world

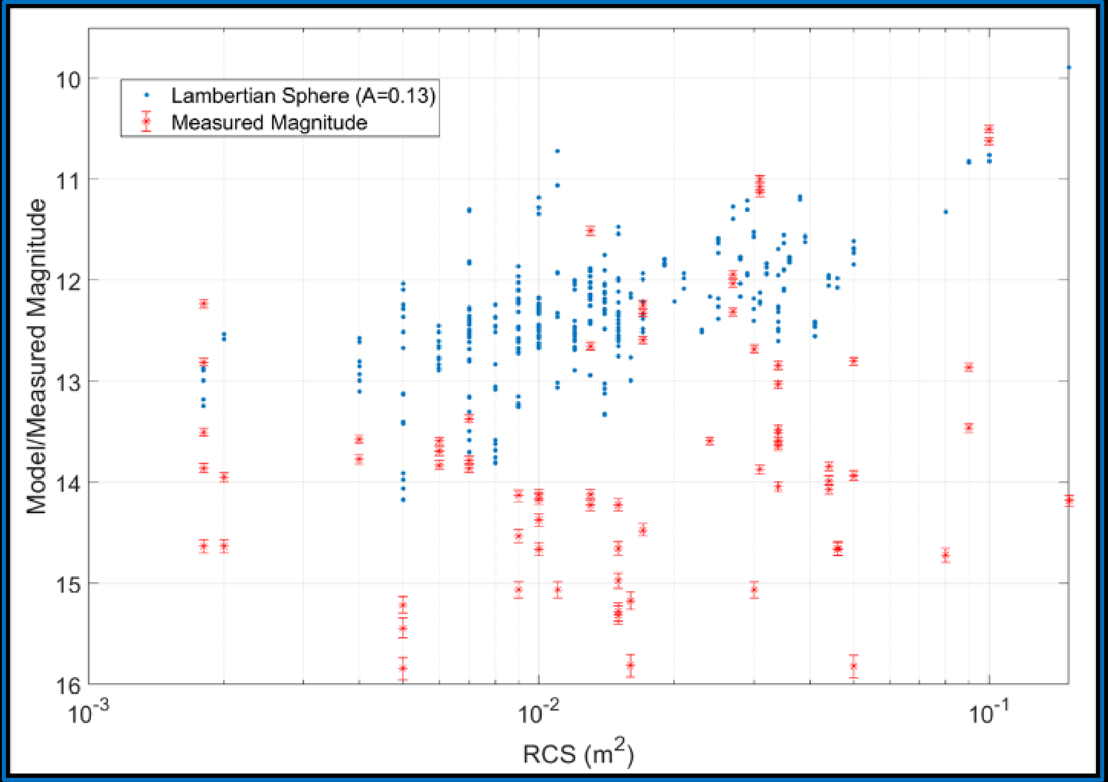


Figure 2 – Fengyun 1C debris measured with JTMA image stacking, showing measured magnitude vs radar cross section.