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The International Celestial Reference System, Maintenance and Future Realizations

Proceedings of IAU General Assembly XXV,
Joint Discussion 16
Sydney, Australia, 22 July 2003

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IAU XXV General Assembly Sydney 13-26 July 2003

Space Astrometry With The Milli-Arcsecond Pathfinder Survey (MAPS): Mission Overview And Science Possibilities

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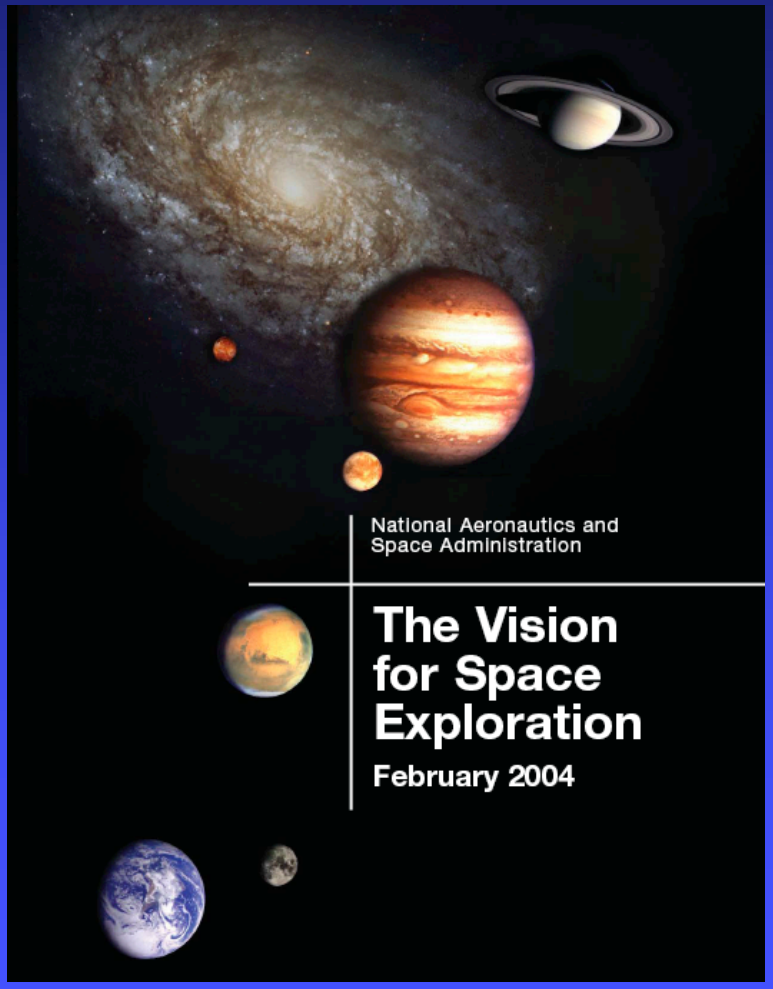
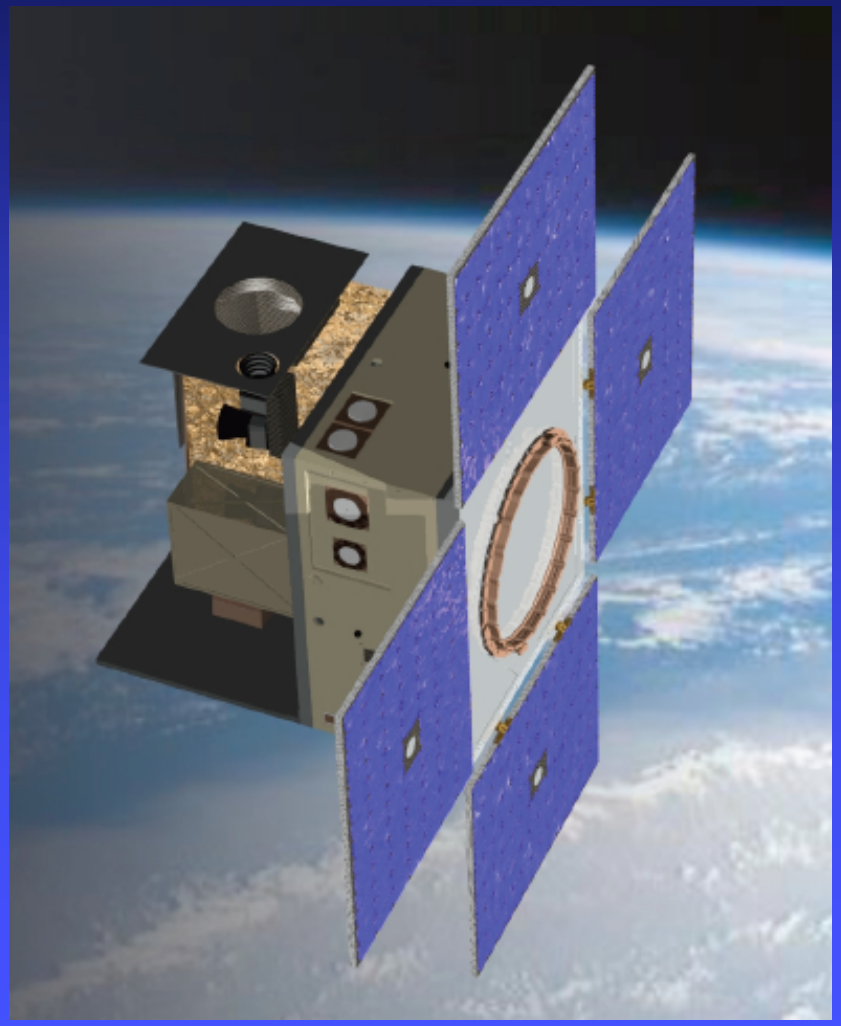
Prospects for **near** future NASA funding for a Space Astrometry Mission?

NASA's science portfolio is in a period of *change and reprioritization.*



Milli-Arcsecond Astrometric Pathfinder Survey (MAPS)

- Milliarcsecond astrometry with (relatively) low-cost microsatellite
- Pathfinder for new astrometric technology and missions, e.g. OBSS
- USNO is primary funding agency
- Intend to seek NASA involvement as junior funding partner (science team funding)

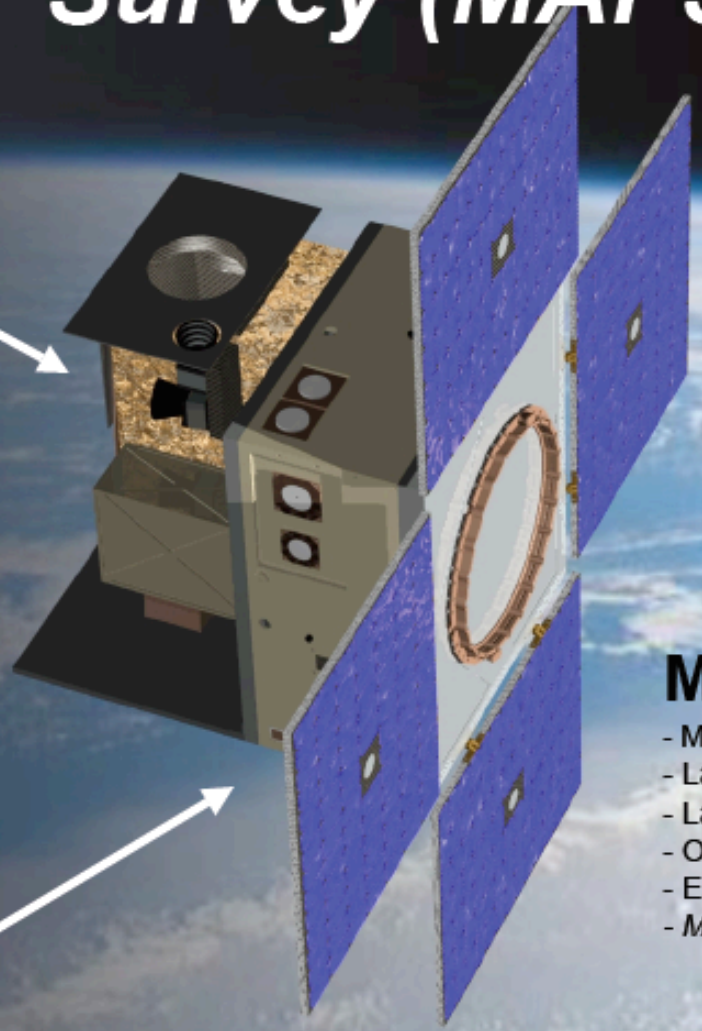


Milli-Arcsecond Astrometric Pathfinder Survey (MAPS)

Instrument

Visible band, bright star, single aperture astrometric telescope

- 15 cm aperture
- Four Mirror Anastigmat
- 8k x 8k CMOS-Hybrid FPA



Orbit

900 km, Sun Synchronous/ terminator

- Allows for continuous scanning maximum parallax bands
- Provides stable thermal and power environment

Mission Overview

- Mission life: 2 years (min), 3 years (goal)
- Launch: CY10
- Launch vehicle: TBD/STP launch possible
- Operations: AFSCN (2—3 years)
- Estimated cost: ~$75M (excluding LV)
- *MAPS is currently in the Concept Study phase*

Bus

Avionics, GN&C, Power, Comm and Thermal Subsystems

1 milliarcsecond astrometry for the brightest 10 million stars

MAPS SCIENCE MEASUREMENT GOALS

Coverage

- 95% complete coverage for magnitude range 3—14 (req.), 2—16 (goal)

- > 40 million stars

Astrometry

- 5 milliarcsec (mas) single measurement precision

- 40—60 observations per star

- 1 mas/1 mas per year/1 mas (pos./pm/par) mission accuracy for 3—10^m (req)

- 0.5 mas/0.5 mas per year/0.5 mas mission accuracy for 2—12^m (goal)

- 0.1 mas per year proper motion for MAPS—Hipparcos stars

Photometry

- ~ 10 mmag (~1%) single measurement photometric precision

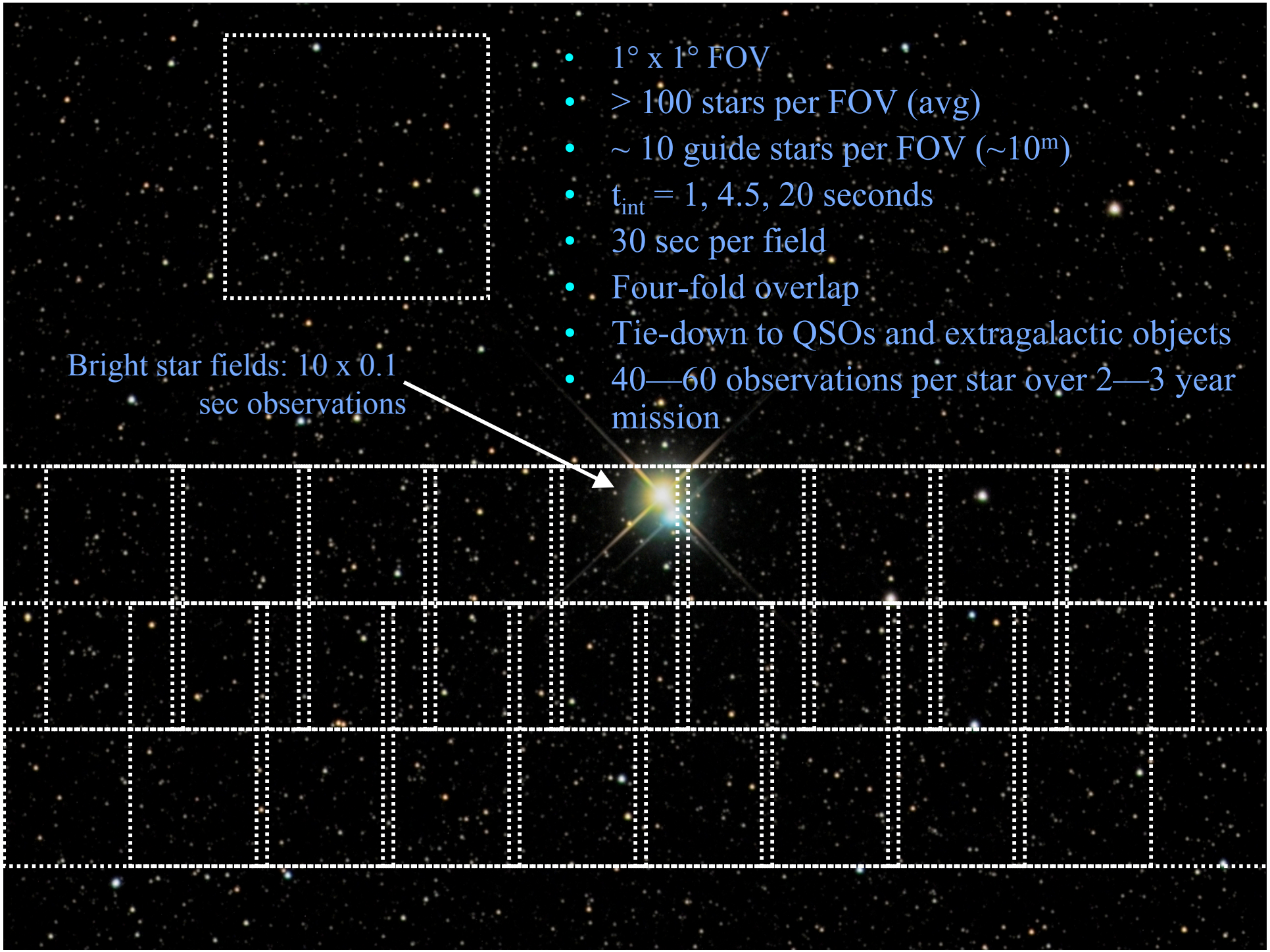
The MAPS limiting magnitude for standard observations will be between 14—16^m. Observations to 17^m will be possible in deep exposure mode

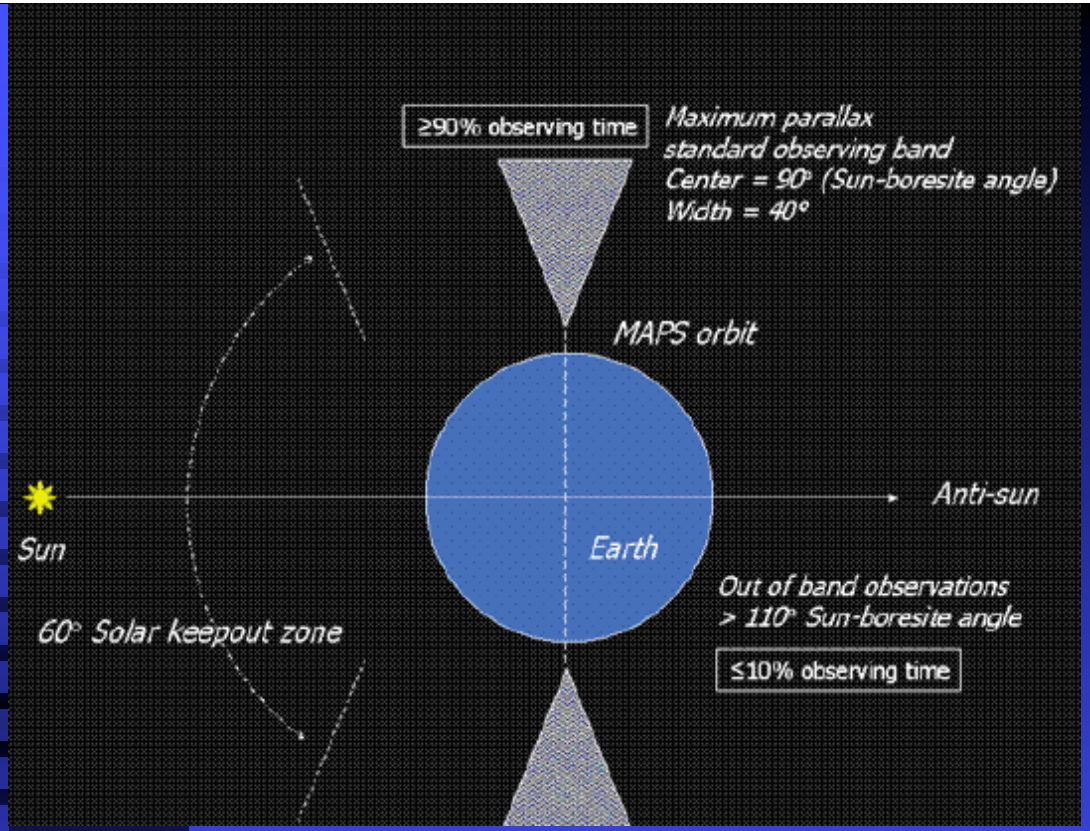
Star Counts

m_v	Stars per square degree, galactic plane	Stars per square degree, galactic pole	Stars per square degree, avg. over sky	Total stars in sky (M)
9	6.0	1.4	2.9	0.1
10	18.0	3.5	8.0	0.3
11	54.0	9.1	22.0	0.9
12	150.0	21.0	59.0	2.4
13	400.0	49.0	150.0	6.1
14	1050.0	100.0	370.0	15.0
15	2600.0	190.0	880.0	36.0
16	6000.0	350.0	2000.0	82.0
17	14000.0	600.0	4400.0	180.0

MAPS Science

- ***Planets:***
  - Are there long-period Brown Dwarf or giant planets around nearby stars (e.g., Barnard's star, Kapteyn's star)?
- ***Black Holes:***
  - Detection of long-period, low-mass binary black holes in distant accelerating Hipparcos binaries
- ***Galactic Cannibalism:***
  - Search for recent Galactic mergers: detection of co-moving groups of bright giants and halo stars on retrograde or high-inclination orbits
- ***Open Cluster Dynamics:***
  - Internal dynamics of nearby open clusters with ages 10 to 700 Myr (Hyades, Pleiades, Coma Berenices, α Persei, IC 2602, η Chamaeleontis, Praesepe): Determination of velocity dispersion, expansion or contraction, rotation, condition of energy equipartition, mass segregation, spread of ages, star formation history
- ***Star Formation Dynamics:***
  - Dynamics of pre-main-sequence stars in the nearest star-forming regions (Taurus-Auriga, Orion and Ophiuchus), including the dispersed population of weak-lined T Tauri stars: What is the main formation mechanism: fragmentation or collision of molecular clouds?
- ***Stellar Origins:***
  - The origin of nearby young stars: Are the sparse moving groups (TWA, β Pic, Horologium) real, and where and when did they form?
- ***Cosmic Distance Scale:***
  - Distance to the Pleiades and other clusters as cosmic distance scale calibrators: Fixing the distance scale ladder after Hipparcos

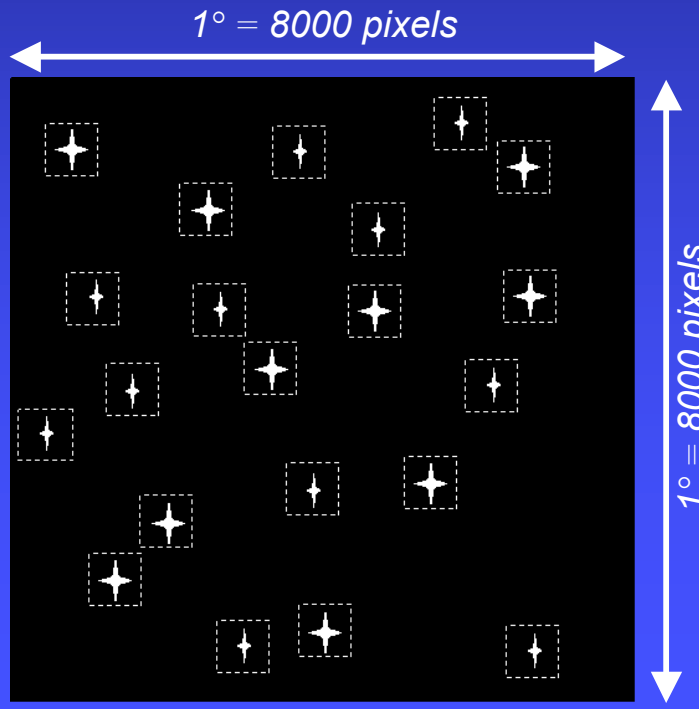

• 1° x 1° FOV
• > 100 stars per FOV (avg)
• ~ 10 guide stars per FOV (~10m)
• tint = 1, 4.5, 20 seconds
• 30 sec per field
• Four-fold overlap
• Tie-down to QSOs and extragalactic objects
• 40—60 observations per star over 2—3 year mission
Bright star fields: 10 x 0.1 sec observations



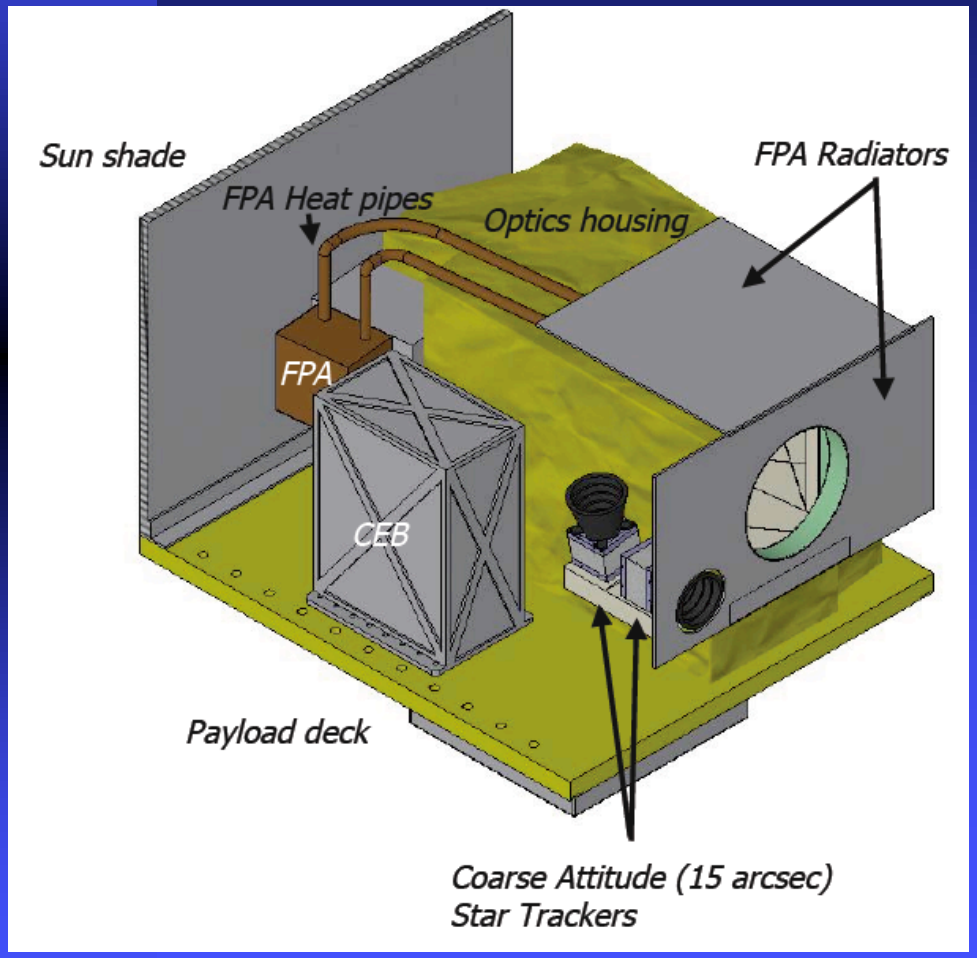
Mission Observing Concept:

- Step-stare observing cadence
- 1° x 1° field of view
- 90% of observing time spent in "max parallax"
band (90° ± 20° Sun—instrument angle)
- 60° Sun exclusion angle
- 900 km SSO/Terminator orbit

Science observations read out entire FPA; data are then processed on-board to extract regions around every star. Only these window data are returned to the ground.



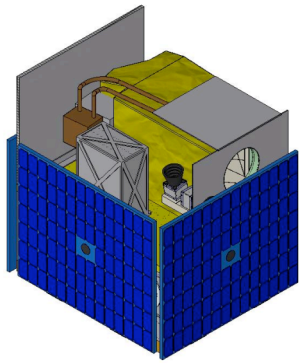
Concept Study Instrument

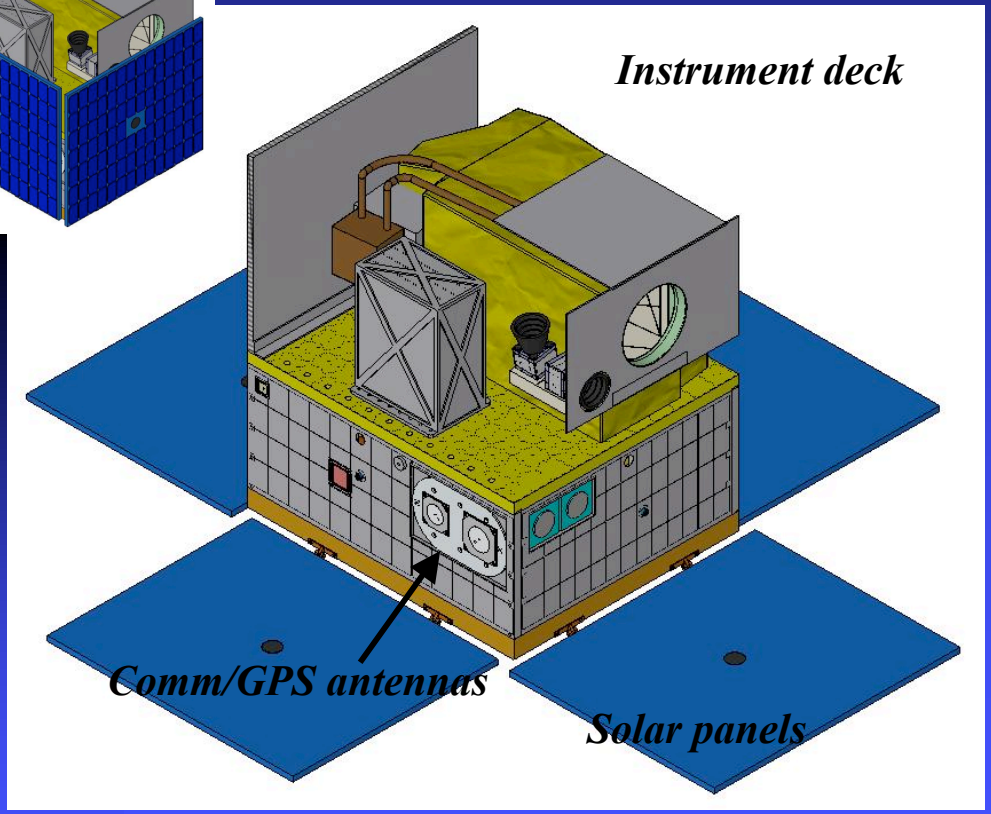


- 15 cm, off-axis FMA telescope
- Broadband (525-775 nm) operation
- Optional Multi-color photometry
  - Broadband + 2 standard photometric bands (e.g., B + I)
  - Necessitates instrument modifications
- 8k x 8k active pixel sensor (APS) detector
  - CMOS-Hybrid or similar technology
  - 500 mas pixels
- Camera Electronics Box (CEB):
  - Clocks, biases, ADC, mass memory, data processing, FPA temp control
- Mass = 30 kg (w/margin)
- Power = 100 W (w/margin)
  - < 100 mW dissipated on the FPA
- Temp. control
  - FPA = 193 ± 0.1 K
  - All else = ambient (≈273 K)
- Attitude determination
  - Coarse (15 arcsec): 2 x star trackers
  - Fine (<50 mas): primary instrument

Concept Study Bus

Stowed configuration





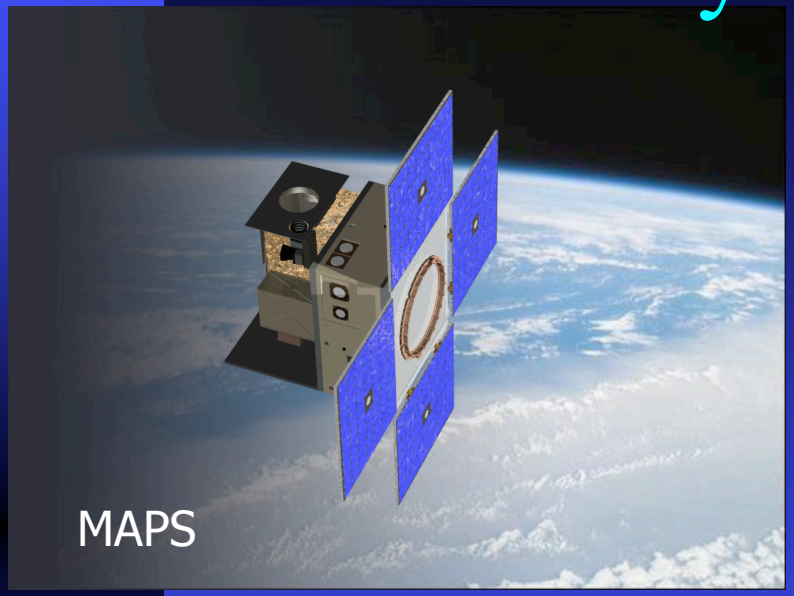
Deployed configuration

- Major subsystems
  - Avionics
  - GN&C
    - Reaction wheels, torque wheels
    - IMU, magnetometer
    - Star trackers
  - Power
    - Solar panels, battery
  - Comm
    - S-band: 2 kbps up, 2 Mbps down
    - X-band: 20 Mbps down
  - Thermal
    - Bus walls
- Mass
  - 84 kg (bus), 115 kg (total)
- Power
  - 66 W (bus), 169 W (total)

On-orbit tech. demo. and performance assessment

- New and innovative technology will be flown for first time
  - Detectors, electronics, GPS, et al.
- Significant risk reduction for future missions
  - e.g., detector ROIC is RSC SIDECAR ASIC/same as JWST, but flies years before
- Instrument is demonstration of 10 mas star tracker

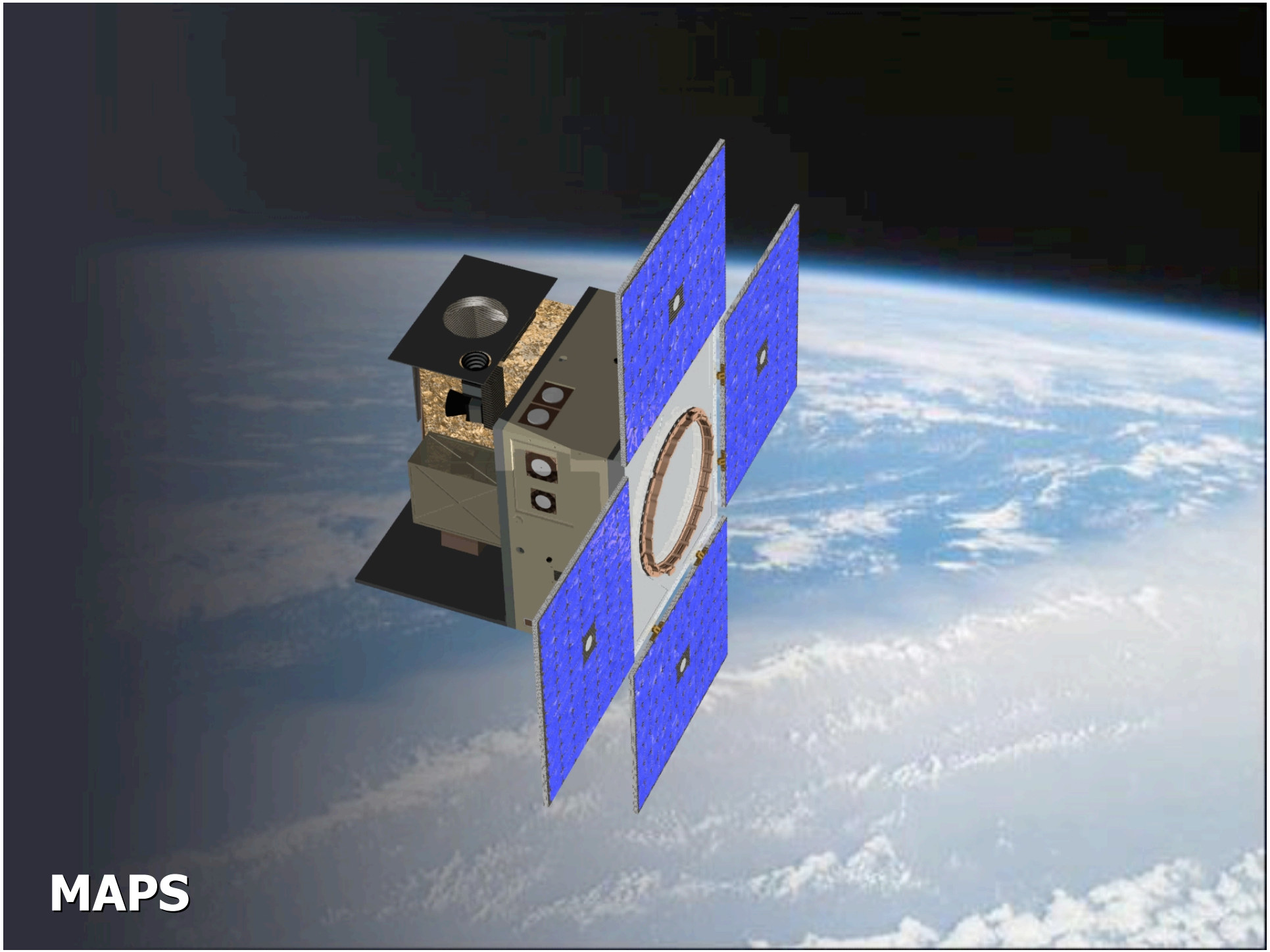
MAPS Summary and Status



- Astrometric Survey
  - 1 mas astrometry (star positions, motions) 15x more accurate than *best* current catalogs
  - New catalogs good for decades (combine with Hipparcos)
- Technology Demonstration
  - For Example: *In situ* demonstration of large format CMOS-Hybrid
  - Prototype 10 mas class star tracker

- Instrument
  - 15 cm aperture, WFE < λ/20 optics
  - 8k x 8k CMOS-Hybrid Detector
  - 500 milliarcsecond (mas) pixel FOV
  - 1.1° x 1.1° FOV
  - Dynamic range $m_v \approx$ 2—15.5
  - Prototype <10 mas-class rad hard star tracker
- Microsat bus (~100 kg)
- LEO SS Orbit (900 km baseline)
- Step-stare observing cadence

- Completed pre-Phase A Concept Study
  - $75M estimate (excluding launch costs)
  - ~30 mos. development estimate
- Seeking Authority to Proceed into Phase A
- Work Concentrating on high risk items
  - 4K x 4K RSC detector procured, camera being built, to be delivered this fall, astrometric capabilities evaluated this winter.
- Development phase
  - FY07—FY09
- Operations
  - FY10—12
  - Catalog releases beginning in FY11—15


MAPS