National Aeronautics and Space Administration

Micro-arcsecond Astrometry Telescope Instrument on the Lunar Gateway/SmallSat

Principal Investigator: Inseob Hahn (382)
Mike Shao (326), Slava Turyshev (326)
Topical R&TD

Overview

- **Find all the Earth-mass planets within the habitable zones of the nearest Sun-like stars.** Search the 20 nearest FGK stars for all the planets in the habitable zones with sensitivity down to 1-3 Earth masses.
- **Make thousands of observations** during the planned 3 year mission.
- Achieve **2 orders of magnitude** improvement in astrometric precision over ESA's Gaia mission.
- Leverage **the interferometric pixel metrology** techniques in the calibration of silicon optical detectors - enabling ultra-high precision astrometry.
- **Demonstrate** sub-micro-arcsecond differential astrometry in a small satellite platform for the benefit of future exo-Earth imaging missions.

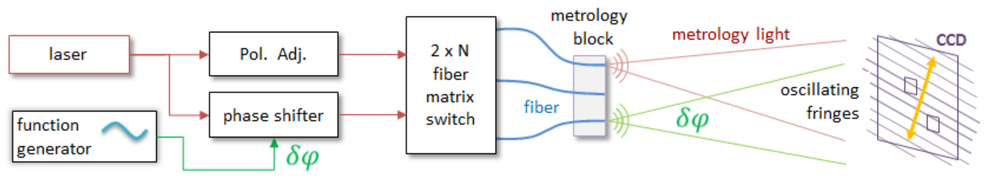
"MASS" (Micro-arcsecond Astrometry Small Satellite) is an astrophysics mission designed to produce the first survey of the habitable zone (HZ) planets in the nearby stellar neighborhood. MASS is based on **differential astrometry** (angle measurements) of a target star relative to a background of reference stars. While both radial-velocity and transit techniques have been successful at finding planets more generally, they have been ineffective at reaching Earth-mass planets in the HZ of nearby Sun-like stars due to the inherent constraints of these methods. Our astrometric approach overcomes these limitations.

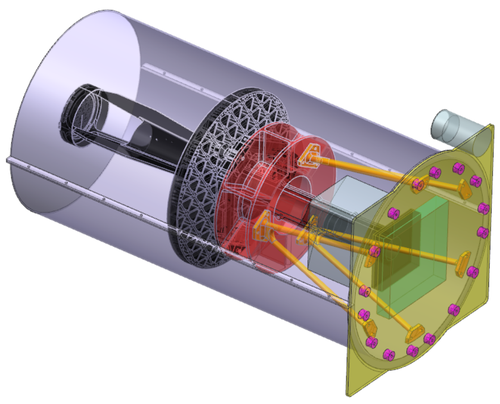
R&TD Objective:

(1) To design conceturally the MASS instrument on the Lunar Gateway/SmallSat, (2) to study the science capabilities/erro budget for the MASS and perform simulation of its expected science impact, and (3) to demonstrate the key laser pixel metrology calibration technique using a large state-of-the-art 150Mpix sCMOS detector.

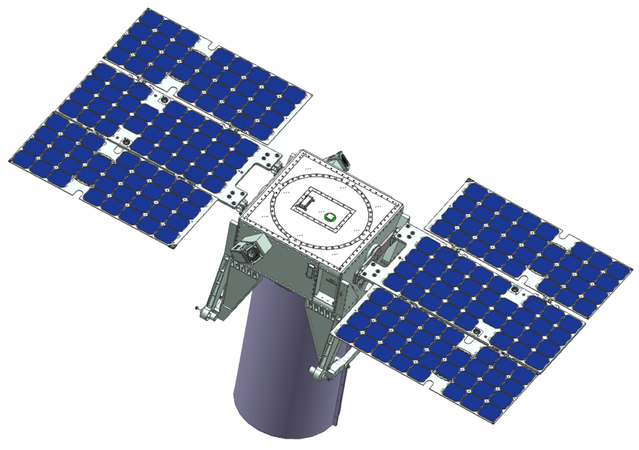
Pixel Metrology

High-precision calibration of focal-plane errors uses moving fringes placed on the detector. Each pixel's location can be derived from the measured phase and amplitude of the fringe at that pixel

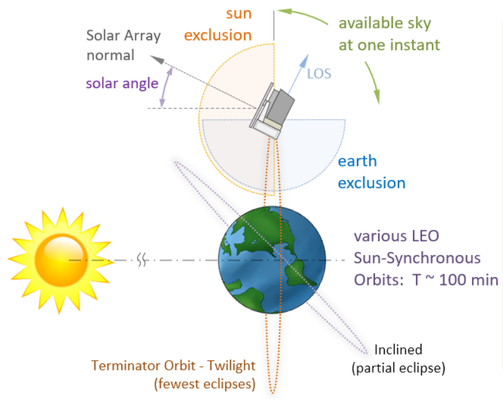


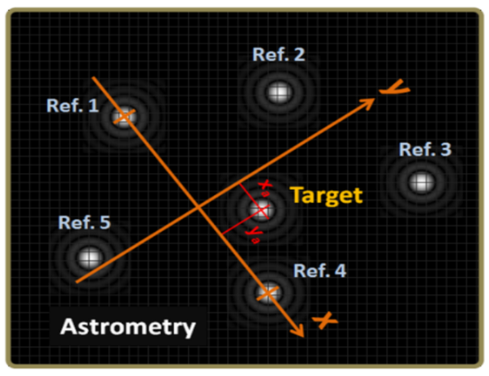


- A commercial, 35 cm aperture, SiC corrected RC telescope
- 6 μas accuracy over 30 min observation
- Detector calibration pre-launch



- 2x 200W solar panels
- 110 kg total mass
- ESPA-Grande compatible
- Propulsion for station-keeping

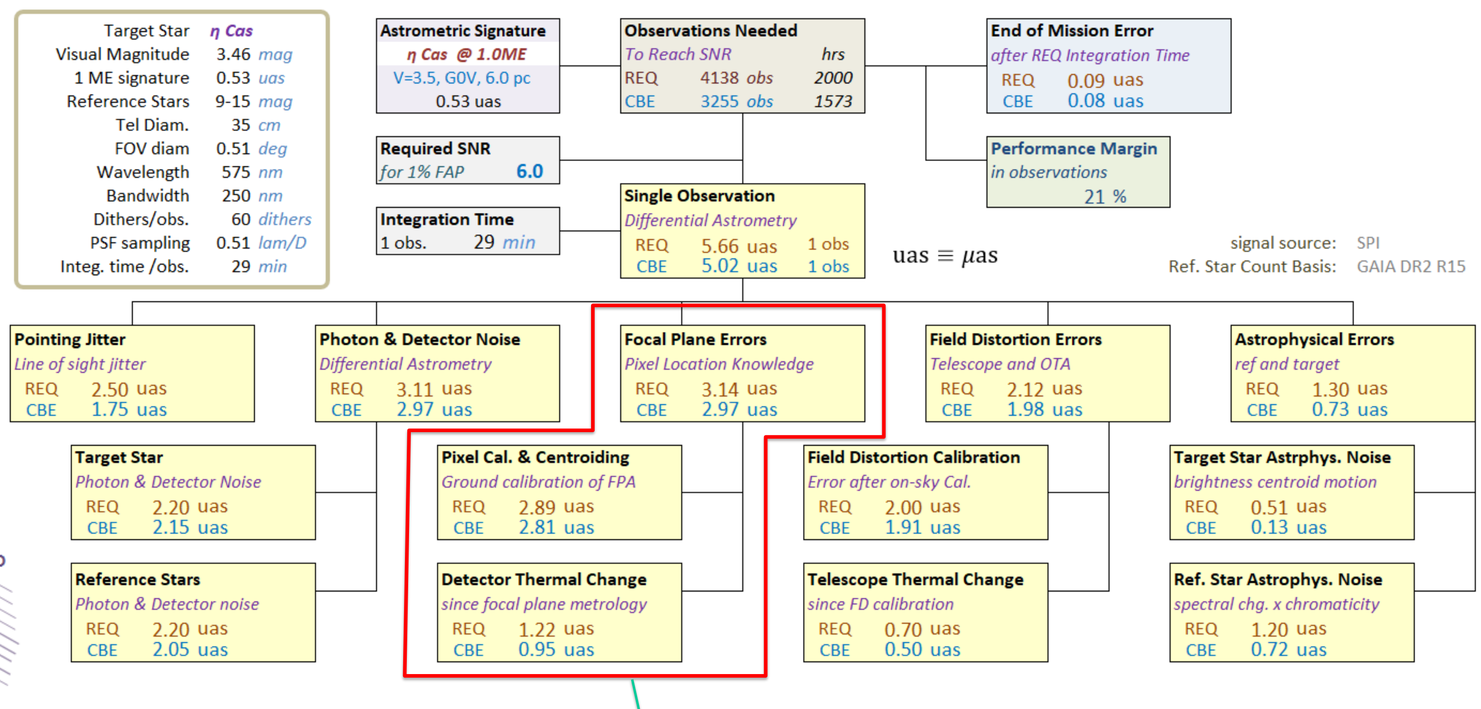


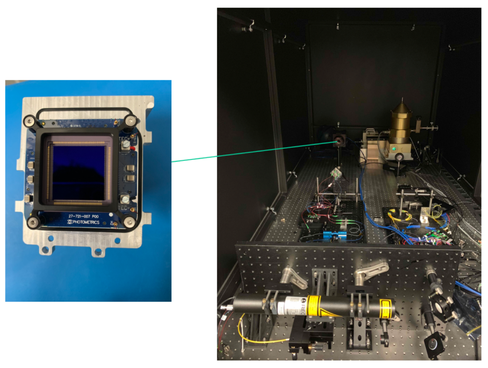


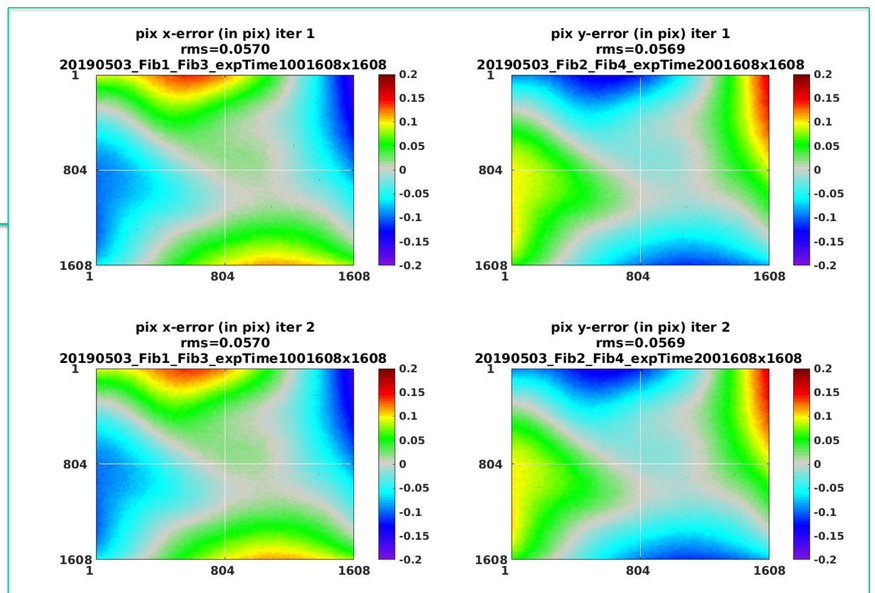
HIP	Name	Depth, ME	V mag	Spect. Type	Dist., pc	signature μas	Ref Stars	hours to SNR=6	cumul. hours
71683	α Cen A	1	0.0	G2V	1.3	2.42	1228	59	59
71681	α Cen B	1	1.4	K1V	1.3	1.71	1228	121	180
2021	β Hyi	1	2.8	G2IV	7.5	0.55	105	957	1136
3821	η Cas	1	3.5	G0V	6.0	0.53	488	1530	2667
77952	β TrA	1	2.8	F1V	12.3	0.44	999	1511	4178
99240	δ Pav	2	3.6	G8IV	6.1	0.99	119	444	4622
22449	π3 Ori	2	3.2	F6V	8.0	0.98	139	543	5164
27072	γ Lep	2	3.6	F6V	9.0	0.84	127	602	5766
746	β Cas	2	2.3	F2III	16.7	0.87	372	703	6469
96100	σ Dra	2	4.7	K0V	5.8	0.79	133	1236	7705
14632	ι Per	2	4.1	G0V	10.5	0.69	231	1377	9081
12777	θ Per	2	4.1	F8V	11.2	0.67	328	1591	10673
19849	40 Eri	2	4.4	K1V	5.0	0.89	77	1652	12325
105858	γ Pav	2	4.2	F9V	9.2	0.72	94	1701	14026
8102	τ Ceti	2	3.5	G8V	3.6	1.31	28	1715	15741
108870	ε Ind	2	4.7	K5V	3.6	0.96	65	1950	17691
1599	ζ Tuc	3	4.2	G0V	8.6	1.10	68	1238	18929
78072	γ Ser	3	3.9	F6V	11.1	1.07	62	1340	20269
57757	β Vir	3	3.6	F9V	10.9	1.14	41	1453	21722
64924	61 Vir	3	4.7	G7V	8.5	0.97	121	1661	23383
15510	e Eri	3	4.3	G6V	6.1	1.28	51	1961	25344
64394	β Com	3	4.2	G0V	9.2	1.06	31	3419	28763

One possible MASS target list, sorted by the number of hours needed to reach the targeted sensitivity depth, in Earth masses ($M_\oplus$), in the habitable zone.

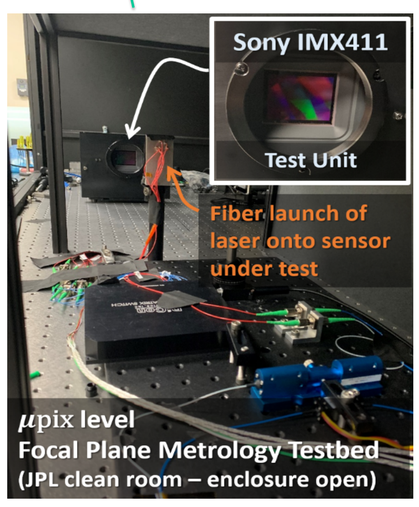
The astrometric error budget for the MASS mission.







Results of pixel error determination of the Photometrics camera (1608x1608). The color bar is indicating the pixel irregularity in pixel unit.



150Mpix detector (MASS detector) is set up for the pixel error determination

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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Publications:

(1) M. Shao, S. Turyshev1, I. Hahn, G. Vasisht, E. Bendek, D. Fisher, B. McArthur, and M. Muterspaugh, "Microarcsecond Small Satellite (MASS) ROSES 2018 Astrophysics Science SmallSat Studies Final report," submitted (2019).
(2) B. Netami et.al. "Micro-arcsecond Astrometry Small Satellite," submitted to 2019 Astrophyiscs Explorers Mission of Opportunity.

Contact Information: Inseob.Hahn@jpl.nasa.gov

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