THE JOINT MILLI-ARCSECOND PATHFINDER SURVEY (JMAPS): INTRODUCTION AND SCIENCE POSSIBILITIES

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ABSTRACT. JMAPS is a small, space-based, all-sky visible wavelength astrometric and photometric survey mission for 0^{th} through 14^{th} V-band magnitude stars with a 2012 launch. The primary objective of the JMAPS mission is the generation of an astrometric star catalog with better than 1 milliarcsecond positional accuracy and photometry to the 1% accuracy level or better at 1^{st} to 12^{th} mag. A 1-mas all-sky survey will have a significant impact on our current understanding of galactic and stellar astrophysics. JMAPS will improve our understanding of the origins of nearby young stars, provide insight into the dynamics of star formation regions and associations, investigate the dynamics and membership of nearby open clusters, and discover the smallest brown dwarfs at distances up to 5 pc after a 2-year mission, and Jupiter-like planets out to 3 pc after 4 years.

1. INTRODUCTION

Over the last 10 years the U.S. Naval Observatory (USNO) has been involved in a number of space astrometry missions. The Full-sky Astrometric Mapping Explorer (FAME) (Johnston 2003) was a NASA-funded mission that was cancelled after the Preliminary Design Review (PDR) due to budget considerations. A concept study for the Origins Billions Star Survey (OBSS) mission (Johnston et al. 2006) was funded by NASA, but subsequent funding for mission development was not provided. USNO has been directly involved in the SIM PlanetQuest mission (Unwin et al. 2008). Although significant technology development has occurred for SIM PlanetQuest, at present the mission does not have a viable launch date.

All of the space astrometry missions discussed above, along with several other concepts, are (or were) proposed for NASA funding. During 2004, changing budget priorities within NASA prompted the USNO to explore alternative mission designs and funding sources. The result of this exploration is the Joint Milli-Arcsecond Pathfinder Survey (JMAPS).

2. JMAPS OVERVIEW

JMAPS is a small single aperture spacecraft, funded by the US government for launch in 2012. The principal objective of the JMAPS mission is to produce an all-sky visible wavelength astrometric and photometric catalog for 0^{th} through 14^{th} V-band magnitude stars. The accuracy objective of the JMAPS mission is to generate an astrometric star catalog with better than 1 milliarcsecond positional accuracy and photometry to the 1% accuracy level, or better, for stars in a 1^{st} to 12^{th} mag range. The final JMAPS catalog will be delivered in 2016. Astrometric positions will be reported in ICRS coordinates, tied to the ICRF though direct observations of the visible wavelength counterparts of radio wavelength ICRF sources. An artist's conception of JMAPS in orbit is depicted in Figure 1.

3. SPACECRAFT OVERVIEW

The current JMAPS spacecraft concept is shown in Figure 2. JMAPS is a single payload spacecraft consisting of a customized spacecraft bus (bottom), with solar panels, and an instrument deck (top). The solar panels fold against the bus in a stowed and locked position during launch and are deployed on-orbit. In addition to housing the power subsystem, the spacecraft bus contains communications, thermal control, avionics, reaction wheel, and inertial measurement unit subsystems. The Attitude

Determination and Control System (ADCS) is split between the bus and instrument deck. While the spacecraft is slewing, the star tracker located on the instrument deck determines spacecraft attitude to approximately 1 arcsecond. During standard observations the ADCS system holds spacecraft pointing stability to a 50 mas specification. This is accomplished by using the primary instrument to generate boresight pointing quaternions at a 5 Hz rate as derived from observations of a handful of reference stars on the primary focal plane. The total mass of the spacecraft, including contingency, is about 180 kg and the spacecraft occupies a volume of 96.5 cm (h) x 71 cm x 61 cm.

Figure 1: JMAPS in orbit

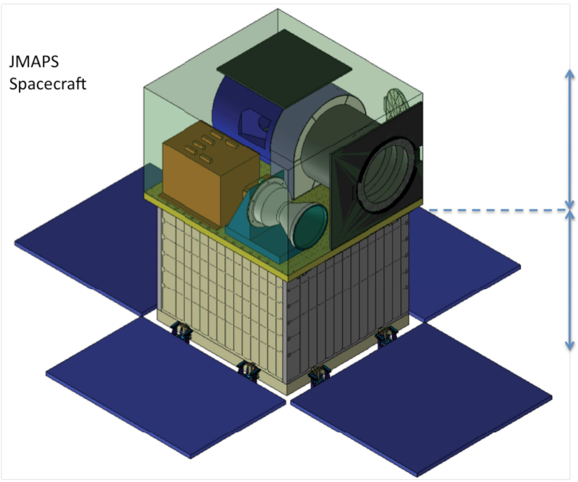

Figure 2: JMAPS Spacecraft

4. INSTRUMENT OVERVIEW

A depiction of the layout of the JMAPS instrument deck components is shown in Figure 3. The Optical Telescope Assembly (OTA) is the largest structure on the instrument deck, consisting of a single aperture, 19 cm diameter, f/20 telescope. The nominal point spread function (PSF) is 0.87 arcseconds full width half maximum (FWHM). The J-MAPS field of view is 1.24° x 1.24°. The OTA supports a JMAPS astrometric bandpass of 700-900 nm; spectroscopic observations will be conduced within a wider 450-900 nm band. During normal observations, a sun shield (not shown in Fig. 3) will protect the OTA from direct exposure to solar heating.

Tucked under the OTA (not seen in Fig. 3) is the Focal Plane Assembly (FPA). The JMAPS FPA consists of a 2 × 2 mosaic of Teledyne Imaging Sensor (TIS) H4RG-10 detectors, as shown in Figure 4. The H4RG-10 is a 10 micron pitch, 4192 × 4192 pixel CMOS-Hybrid detector. CMOS-Hybrid technology combines many of the best characteristics of CCD and CMOS technology. The nominal pixel subtense is 0.55 arcseconds, providing a sampling of approximately 1.6 pixels per PSF FWHM. USNO has sky-tested the first generation H4RG-10 detector (the A1) (Dorland et al. 2007). USNO will receive and sky-test the second generation detector (A2) in 2009. It is anticipated JMAPS flight devices will result from the third generation of the H4RG-10 detector.

Major components of the instrument deck also shown in Fig. 3 are the Instrument Electronics Box (IEB), which houses the primary on-board electronics for both the instrument and bus, the Terma star tracker, and thermal radiators. Combined with a thermoelectric cooler (TEC), the radiators will help maintain the JMAPS FPA at a temperature of 193K, with a stability of 10mK.

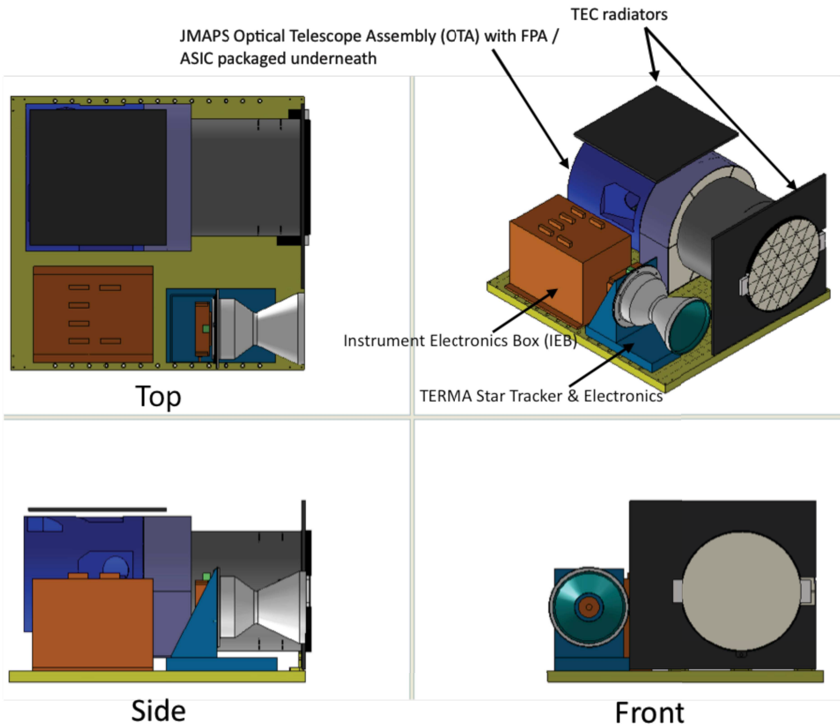

Figure 3: JMAPS Instrument—Conceptual design of the payload deck

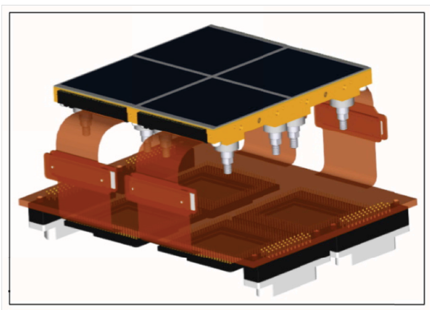

Figure 4: JMAPS FPA 4K 2 × 2 Mosaic Concept

5. JMAPS CONOPS

JMAPS will be launched into a 900 km sun-synchronous terminator orbit and operate in a step-stare mode, typically sweeping out swaths of the sky at approximately a 90° angle to the Earth-Sun line (regions of maximum parallax signal). Windowed FPA integration times of 1, 4.5 and 20 seconds will be used for the majority of stars. Shorter integration times (0.01 or 0.2 seconds) will be used for the brightest stars. In order to link the JMAPS reference frame to the ICRF, the optical counterparts of radio wavelength ICRF quasars will be directly observed by JMAPS by employing integration times of 500 seconds.

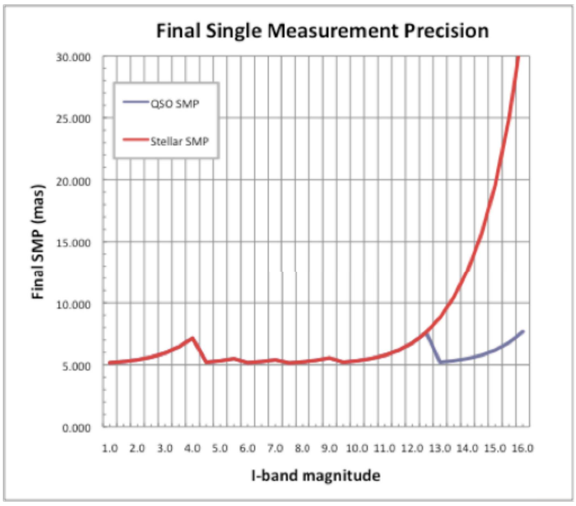

Figure 5: JMAPS **single measurement** precision predictions as a function of stellar I-band magnitude

6. JMAPS SCIENCE POSSIBILITIES

The predicted JMAPS single measurement precision (SMP) is shown in Figure 5. The sawtooth nature of the SMP plot is attributed to the various integrations times utilized for stars of different magnitudes (see §5). The objective of achieving 1 mas stellar astrometric accuracies is achieved through a global reduction of multiple (40–60) observations obtained throughout the 2–3 year mission lifetime. A 1-mas all-sky survey will have a significant impact on our current understanding of galactic and stellar astrophysics. JMAPS will improve our understanding of the origins of nearby young stars, provide insight into the dynamics of star formation regions and associations, investigate the dynamics and membership of nearby open clusters, and discover the smallest brown dwarfs at distances up to 5 pc after a 2-year mission, and Jupiter-like planets out to 3 pc after 4 years. JMAPS will provide critical milliarcsecond-level parallaxes of tens of millions of stars in the difficult 8–14^{th} magnitude range, which when combined with stellar spectroscopy and relative radii determined from exoplanet transit surveys, allows a determination of stellar radii and exoplanet densities. In addition, the 20-year baseline between the groundbreaking Hipparcos mission and the J-MAPS mission allows a combination of the JMAPS and Hipparcos catalogs to produce common proper motions on the order of 50–100 microarcseconds per year.

7. REFERENCES

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