The ExoplanetSat Mission to Detect Transiting Exoplanets with a CubeSat Space Telescope

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ABSTRACT

We present a CubeSat mission for the discovery of exoplanets down to 1 Earth radius around the nearest and brightest Sun-like stars. The spacecraft prototype―termed ExoplanetSat―is a 3U space telescope designed to monitor a single target from low Earth orbit. The optical payload will precisely measure stellar brightness, seeking the characteristic dip in intensity that indicates a transiting exoplanet. Once ExoplanetSat identifies a candidate exoplanet, larger assets can be used to conduct follow-up observations to characterize the atmospheric constituents. The prototype will serve as the basis of an eventual fleet of nanosatellites, each independently monitoring a single bright, nearby star. Given the spacecraft's low mass and sub-pixel sensitivity variations in the science detector, image jitter and its resultant photometric noise is a primary concern. The attitude determination and control subsystem (ADCS) mitigates this using a two-stage pointing control architecture that combines 3-axis reaction wheels for arcminute-level coarse pointing with a piezoelectric translation stage at the focal plane for fine image stabilization to the arcsecond level. The ExoplanetSat optical design combines star camera and science functions into a single device that fits into the 3U form factor. This paper presents the ExoplanetSat science case, mission overview, concept of operations, and spacecraft configuration.

INTRODUCTION

The field of exoplanets—i.e. planets orbiting stars other than the Sun—is relatively young, with the first discovery of an exoplanet around a Sun-like occurring in 1995.[1] Since then, over 500 planets outside our solar system have been discovered. An additional 1,200+ exoplanet candidates have been recently identified by the Kepler mission.[2]

The existence of planets in other planetary systems elicits natural questions about the possibility of life in these locations. However, current technology makes the discovery and characterization of such habitable worlds challenging in the near term and many large-scale exoplanet missions such as the Space Interferometry Mission (SIM) and Terrestrial Planet Finder (TPF) have been canceled due to financial and technical reasons.

The ExoplanetSat project, described in this paper, pursues a new approach in the field of exoplanets, one that is compatible with the current constrained fiscal environment. Instead of relying on a single flagship observatory, we seek to leverage the CubeSat form factor to create a distributed observing architecture. This allows us to carry out a meaningful exoplanet search for lower cost and on reduced development time scales.

ExoplanetSat is a 3U (10 x 10 x 34 cm) CubeSat space telescope designed to detect Earth-sized exoplanets around the nearest and brightest Sun-like stars. It is currently under development by a joint Massachusetts Institute of Technology (MIT) and Draper Laboratory team, with an intended launch date in 2013 under NASA's ELaNa program. ExoplanetSat will perform ultra-precise photometry on one target star at time to the level of tens of parts per million (ppm). By detecting the characteristic intensity dip of a transit event, ExoplanetSat will identify bright stars harboring Earth-size exoplanets. These exoplanets will become high priority targets for follow-up observation to determine atmospheric constituent gases and the potential for habitability. ExoplanetSat will eventually evolve into a "fleet" of nanosatellites, each monitoring a star for transit events.

This paper is intended to provide an overview of our science objectives, mission concept, long term fleet architecture, general spacecraft design, and technical challenges. It is an update of a previous publication describing the overall system[4] and complements prior in-depth publications on the attitude determination and control subsystem[5,6].

SCIENCE

The "holy grail" of exoplanet research, as yet to be achieved, is the discovery of a true Earth analog—i.e. an Earth-sized planet orbiting in the habitable zone of a Sun-like star. The habitable zone is most often defined as the orbital band in which liquid water can exist on the surface of a planet. In our own solar system, for example, the habitable zone extends from approximately 0.95 to 1.37 AU.[7] The discovery of an Earth analog is scientifically interesting because such a planet could potentially harbor life.

The objective of ExoplanetSat is to detect Earth-sized planets in the habitable zones of the nearest and brightest Sun-like stars. After detection, the catalog of transiting exoplanets would be released to more capable observatories (e.g. Hubble Space Telescope, James Webb Space Telescope) for further characterization.

Of the five main methods for detecting exoplanets—radial velocity measurements, timing measurements, gravitational microlensing, transit photometry, and direct imaging—only the transit method and direct imaging can detect photons from the exoplanet itself. This permits the study of exoplanet atmospheres, which is critical for confirming habitable conditions or detecting biosignature gases. Direct detection requires a measurement (in this case, planet/star contrast ratio) of 1 part in 10 billion. On the other hand, a transit detection of an Earth-sized planet around a Sun-sized star requires a measurement of approximately 1 part in 10,000 (i.e. 100 ppm). With direct detection beyond the limits of technology immediately available, we view the transit method as the best means of discovering an Earth analog in the near term.

The Transit Method and Follow-up Observation

The transit method works by carefully monitoring the intensity of a target star. When an exoplanet crosses the line of sight between the telescope and star, a characteristic drop in brightness occurs that is proportional to the area ratio of the star and planet. The transit depth therefore constrains the planet radius (given knowledge of the star radius) and the transit duration constrains the orbit period (and therefore the planet semi-major axis).

Given the proper instrumentation, transits can also yield information about exoplanet atmospheres, as indicated in Figure 1. During the primary eclipse, star light is transmitted through the exoplanet atmosphere. By observing the star before and during a transit, it is possible to identify the exoplanet atmosphere's underlying chemical composition.[8,9]

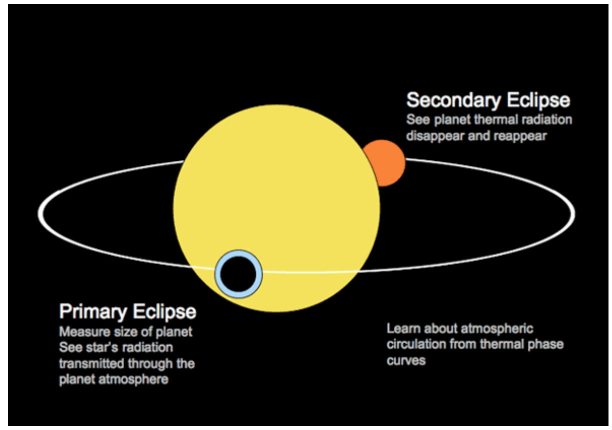

Figure 1: The transit method for detecting and characterizing exoplanets.

ExoplanetSat's focus on nearby, bright stars is motivated by a desire to enable follow-up observations of the type described above. Spectroscopic measurements, for example, are only possible with sufficient photon flux. The ExoplanetSat mission aim is therefore to build a map that charts the location of Earth-sized exoplanets for follow-up observation and characterization using the necessary instrumentation.

Science Requirements

The primary performance metric for ExoplanetSat is photometric precision, a requirement which can be directly derived from the desired planet detection size. Based on projected area ratios, an Earth-Sun transit will result in an 84 ppm reduction in brightness. We seek a 7σ detection certainty, thus the fractional photometric noise must be below 84/7 = 12 ppm over time periods corresponding to half the duration of a central transit. For an Earth-Sun analog system, this is 13 hours / 2 = 6.5 hours. ExoplanetSat will seek transits down to 3 hours in duration, enabling the mission to identify transit events for short-period exoplanets.

Figure 2 shows an upper bound on achievable photometric performance over 1.5 hour periods considering only photon (shot) noise for a given aperture size. The plot does not consider other noise sources such as dark current noise, read noise, jitter noise, etc. The 3U ExoplanetSat has an effective aperture diameter of 6 cm, while an expansion to larger spacecraft buses permits larger apertures and a corresponding improvement in sensitivity. For example, considering only shot noise, the limiting magnitude for an Earth transit over 1.5 hours is V=4 for a 6 cm aperture, V=5.5 for a 12 cm aperture, and V=7.5 with a 30 cm aperture.

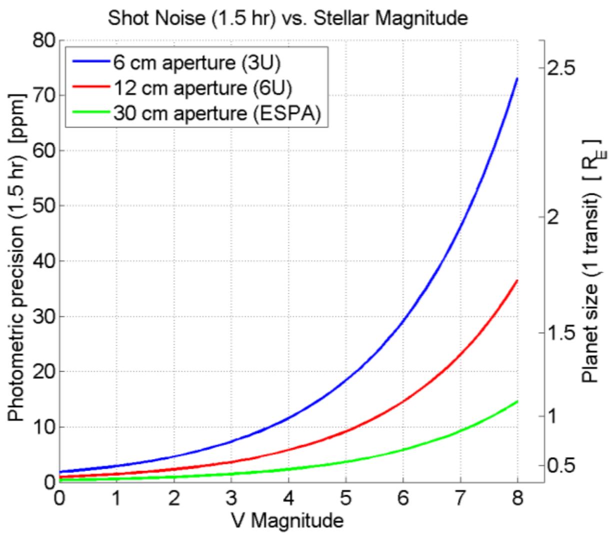

Figure 2: 1.5 hr-to-1.5 hr photometric precision due to shot noise as a function of stellar magnitude. The right vertical axis shows detectable planet size (in units of Earth radius) in a single transit.

The goal of ExoplanetSat is to achieve nearly shot noise-limited photometry over 1.5 hours for $0<V<6$. Earth-sized transits will be detectable for fainter stars by binning multiple observations to obtain 7σ certainty. The mission will target Sol-comparable stars of the G and K spectral type. Our preliminary target star list consists of Alpha Centauri, the nearest Sun-like star, along with other Sun-like stars with super-Earths discovered through radial velocity measurements. It is unknown whether planets around the latter stars transit. Note that Alpha Centauri is a binary star system that will not be resolved into its two separate stars by our optics. Detailed simulations support the possibility of planet formation around Alpha Centauri B out to 1.5 AU.[10]

Related Missions

There are several current and planned photometry missions that are similar to ExoplanetSat, however none of them use the CubeSat form factor. This section describes these other efforts briefly and identifies the scientific or technical aspects of the ExoplanetSat mission that distinguishes it from them.

NASA's Kepler mission was launched in March 2009 and has been continuously monitoring a field of 150,000 stars in an effort to detect transiting exoplanets down to Earth-sized.[11] The requirement on Kepler's photometric noise is 20 ppm over 6.5 hours for a V=12 star.[12] This mission has been enormously successful and has reported its first planet discoveries[13]. The Kepler mission, however, was designed to conduct a statistical census of the frequency of Earths in the Galaxy, not necessarily to permit detailed follow-up observation. Most of the target stars in the Kepler field are in fact too faint to allow follow-up studies. By focusing on a brighter set of target stars, ExoplanetSat will enable subsequent characterization of any exoplanets detected.

Microvariability and Oscillations of Stars (MOST) is a Canadian small satellite mission to conduct astroseismology measurements on stars down to V=5.5.[14] Launched in June 2003, the spacecraft is the size of a suitcase (65 x 65 x 30 cm^3) and has a mass of 54 kg. The payload consists of a 150 mm aperture telescope and CCD for photometry with a signal-to-noise ratio (SNR) of 8300 (120 ppm) for a minute long exposure. MOST has shown meaningful science return and has, for example, been used to measure timings for transiting exoplanets in order to infer the presence of other planets.[15,16]

The BRIght Target Explorer (BRITE) nanosatellite constellation under development by researchers in Canada and Austria is a photometry mission to measure the stellar variability of the brightest stars.[17] The mission will achieve 20 ppm differential photometry on timescales of one month for stars down to V=3.5. Aside from different target star spectral types (O, B for BRITE and G, K for ExoplanetSat) and different science (stellar evolution for BRITE, exoplanets for ExoplanetSat), the two missions differ in several technological areas. The BRITE spacecraft bus is larger than that of a CubeSat (measuring 20 x 20 x 20 cm^3) and their science telescope aperture (30 mm diameter) is smaller than that of ExoplanetSat's (60 mm diameter). The BRITE star camera and science optics are separate, while on ExoplanetSat they are combined. Finally, the attitude determination and control subsystems between the two spacecraft differ in terms of architecture (reaction wheels for BRITE, reaction wheels plus piezo stage for ExoplanetSat) and pointing precision (1.5 arcminute for BRITE, 10 arcseconds for ExoplanetSat as described below).

In summary, ExoplanetSat is a unique CubeSat mission to conduct transit searches for exoplanets. The science is enabled by several engineering approaches, described in the System Design section below. Key innovations include combining the science and star camera optics, a compact modular payload design, and the use of a two-stage control architecture.

MISSION ARCHITECTURE AND LONG TERM VISION

As discussed above, ExoplanetSat's targeting of relatively bright stars is intended to enable follow-up observations. Because the brightest stars are distributed randomly over the sky, it is infeasible that a single telescope could monitor all of the targets simultaneously. Multiple telescopes are required, each monitoring a single star. This in turn requires that each spacecraft is relatively low cost both to produce and launch, something that is achieved by using the CubeSat standard. The CubeSat form factor is therefore a key enabler of the ExoplanetSat mission architecture.

We envision a staged approach to the ExoplanetSat fleet. This begins with a single 3U prototype (Phase 1) and evolves into larger and more numerous spacecraft (Phases 2, 3) as described below.

Phase 1

The first phase—currently underway—encompasses the design, integration, launch, and verification of a single 3U ExoplanetSat prototype. This first spacecraft will target Alpha Centauri to search for undiscovered exoplanets and will target stars with known super-Earths (discovered by radial velocity surveys) to determine whether or not they transit.

Phase 2

The second phase is an initial expansion from a single ExoplanetSat to multiple 3U and possibly 6U (12 cm aperture) spacecraft. The aim of Phase 2 is to observe 20 of the brightest stars for Earth-sized transits with improved temporal coverage. ExoplanetSat's position in low-Earth orbit (LEO) causes a cut-off in science data during orbital day, therefore multiple spacecraft spaced evenly in an orbital ring can provide continuous coverage of a star. The addition of 6U spacecraft would allow studies of fainter stars.

Phase 3

The final phase constitutes a full planet detection survey. The aim is 95% confidence of 3+ planet detections by observing 250+ bright stars down to V=8.[3] This would require a further expansion of the fleet and possible the use of larger satellites, such as buses compatible with the EELV secondary payload adapter (EPSA) ring interface.

SYSTEM DESIGN

ExoplanetSat is a 3U CubeSat (10 x 10 x 34 cm^3) shown in Figure 3. Electrical power is supplied by a set of deployed solar panels that are removed for clarity.

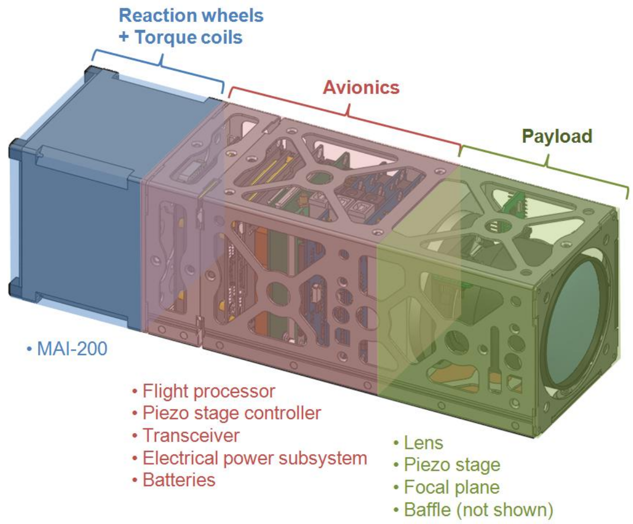

Figure 3: ExoplanetSat layout showing three modules: reaction wheels, avionics, and payload.

The spacecraft itself is composed of three similarly sized "modules" each with a different function. The aft end of the spacecraft houses a commercially available reaction wheel and torque coil unit that provides coarse attitude control. The other end houses the payload, which consists of the lens, hybrid focal plane containing multiple imagers, and two-axis piezoelectric nano-positioning stage. The piezo stage is used for fine image stabiliation, translating the focal plane in two axes to cancel residual pointing errors that the reaction wheels are unable to correct. Between the reaction wheels and payload is the avionics module housing the batteries, charging and power distribution board, modem, and single board computer. Additional details of these various elements are given in the sections below.

Concept of Operations

The concept of operations for ExoplanetSat is shown in Figure 4. Intended mission lifetime is two years and the ideal orbit is circular at 650 km altitude with as low inclination as possible. This altitude avoids excessive orbital decay due to atmospheric drag, yet is low enough to mitigate radiation exposure. Low inclination is advantageous because it avoids radiation in the South Atlantic Anomaly (SAA) and at the poles. This particular combination of altitude and inclination is less common than others, therefore the mission is evaluating the feasibility of operating in more highly inclined orbits (with the drawback of increased radiation dosage) and/or lower altitudes (with the drawback of increased aerodynamic drag and decreased mission lifetime).

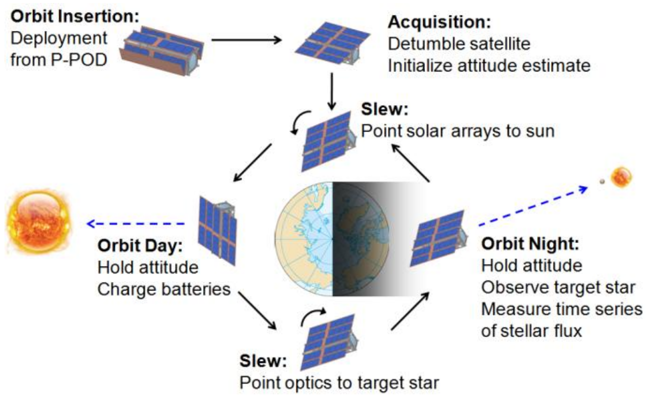

Figure 4: ExoplanetSat concept of operations.

On-orbit operations begin after ejection from the P-POD. The solar array deploys and the satellite enters a de-tumble sequence where angular rates are nulled using magnetometer inputs. Coarse sun sensors are then used orient the spacecraft such that the solar array points toward the sun. Once power is stable, ExoplanetSat uses the star camera function of the optical payload to initialize its attitude estimate using a lost-in-space star matching algorithm during orbital night. ExoplanetSat uses the magnetometer and sun sensors for attitude determination during orbital day.

During nominal operations, ExoplanetSat will observe a target star during orbital night and will re-orient itself during orbital day to recharge the batteries and communicate with ground stations. There is time allocated to slew and settle between each day/night transition. For more details on the control modes, see Pong et al. (2011).[5]

Because of the optical exclusion cone of the payload and the orbital geometry of the Sun and Moon, lower declination target stars may not be visible the entire year. In these cases, ExoplanetSat will switch targets to one with more favorable viewing conditions when the original target is no long visible. Therefore while ExoplanetSat will only observe one star at a time, the spacecraft may target multiple stars during a given year on orbit.

Payload

The ExoplanetSat payload is really two instruments in one: a photometer for measuring star intensity and a high-precision star camera for attitude determination and control. The payload is shown conceptually in Figure 5 and consists primarily of a lens, piezoelectric nano-positioning stage, and a dual-imager focal plane array. The optic is a commercial off-the-shelf (COTS) photography lens, modified to survive the launch and space environments. The selected lens, based on the Zeiss Planar T 1.4/85, offers a balance between large aperture size, physical compactness, and wide field of view. See Smith et al. (2010)[4] for the characteristics of other lenses considered for the mission.

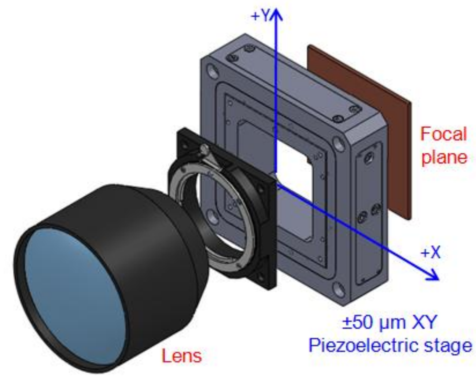

Figure 5: ExoplanetSat payload module.

The lens projects a 43 mm diameter image circlet onto a focal plane that houses two CMOS detectors, one for the science and star camera functionality (the larger) and one for fine star tracking (the smaller). The larger detector is used in a rapid-cadence mode as a star camera to provide attitude knowledge to the ADCS. During science operations, a subsection the same imager is used with longer integration times to collect photometric measurements of the target star, along with several other bright stars for comparison.

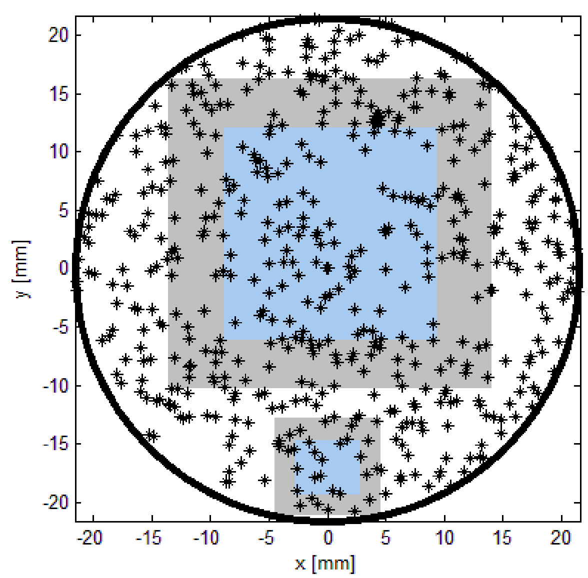

Figure 6: Notional ExoplanetSat focal plane array with Cancri 55 star field (V<8) superimposed. The black circle is the lens image spot, the two blue areas are the imaging areas of the star camera/science detector (larger) and fine star tracker detector (smaller).

The fine star tracker imager, shown in Figure 6 below the science/star camera imager, has smaller pixels and is used to achieve greater pointing precision during science observations. Centroid locations of a group of guide stars from the star tracker imager is used to drive the piezoelectric stage, which translates +/-50 µm along either axis to keep the target star located over the same fraction of a pixel on the science imager. This is necessary because of intrapixel and interpixel quantum efficiency variations that would cause additional photometric noise—i.e. "jitter noise"—when combined with dynamic pointing errors. Detailed jitter simulations show that nearly shot noise-limited photometry requires 10 arcsecond (3σ) or better pointing precision. The two-stage pointing control approach is essential to our ability to use a nanosatellite bus for ultra-precise photometry.

Table 1 summarizes key parameters of the payload. Several candidates for the fine guiding imager are currently under evaluation.

Table 1: Payload parameters.

	Parameter	Value
Lens	COTS model equivalent	Zeiss Planar T 1.4/85
	Focal length	85 mm
	F-number	1.4
	FOV	28.6 deg. (full cone)
	Elements	6
Science/Star Camera Imager	Format	1024 x 1024
	Pixel size	18 µm
	FOV (diagonal)	17.3 (full cone)
	Well capacity	100,000 e-
	Quantum efficiency x fill factor	0.45
	Plate scale	43.7 arcseconds/pixel

The primary science data product for ExoplanetSat is time-indexed windowed "postage-stamp" frames of the target star, comparison stars, and relatively empty portions of the sky for background signal estimation. The optimum integration time is a function of target star brightness and image size (the nominal PSF size is defocused to 5 pixels full-width half maximum). The maximum integration time will be on the order of 30 seconds. Once received on the ground, the time-indexed images will undergo a data processing pipeline not unlike that of the Kepler mission to remove systematic noise and produce light curves for transit identification.[18]

Attitude Determination and Control

One main drawback of small satellites for precision science is that their low inertia makes instruments susceptible to pointing jitter-induced errors, such as the "jitter noise" contribution discussed above. ExoplanetSat solves this by adopting a two-stage control architecture that separates coarse pointing control and fine pointing control into two actuators. This paper summarizes the fine guiding mode that is necessary for precise photometry during science operations. For a thorough discussion of the other modes, along with additional details of the ADCS, see Pong et al. (2011).[5]

Three-axis coarse pointing control down to approximately 60 arcseconds (3σ) is provided by a set of orthogonally-mounted reaction wheels. These are contained, along with a set of orthogonal electromagnetic torque coils, inside the MAI-200 unit, manufactured by Maryland Aerospace, Inc. ExoplanetSat operates in a momentum biased mode and uses the torque coils to periodically de-saturate the reaction wheels. Fine image stabilization at the arcsecond level is achieved by actuating the two-axis piezo stage in the manner outlined above. The star tracker CMOS—with its relatively small pixel pitch—tracks centroid movements on a group of guide stars. These motions are then feed back as part of an inner control loop that moves the piezo stage to compensate for image jitter on the detector that the reaction wheels cannot control.

The primary image stabilization sensor for fine star tracking is the smaller, fine-pitch CMOS. Attitude determination is accomplished using the larger star camera imager and star matching algorithms. The ADCS sensor suite also includes a magnetometer and coarse sun sensors, which are used together for attitude determination during orbit day. The magnetometer is also used for de-tumble and the coarse sun sensors are used to acquire the sun after deployment.

The ADCS has been the subject of a large portion of the hardware testing completed to date on the project. Many of the results are summarized by Pong et al. (2011)[5], including detailed characterization of the MAI-200 reaction wheel imbalances and guide detector centroid performance under flight-like imaging conditions. Figure 7 shows a fine pointing hardware in the loop test bed assembled at MIT (a light-tight box has been removed for clarity).

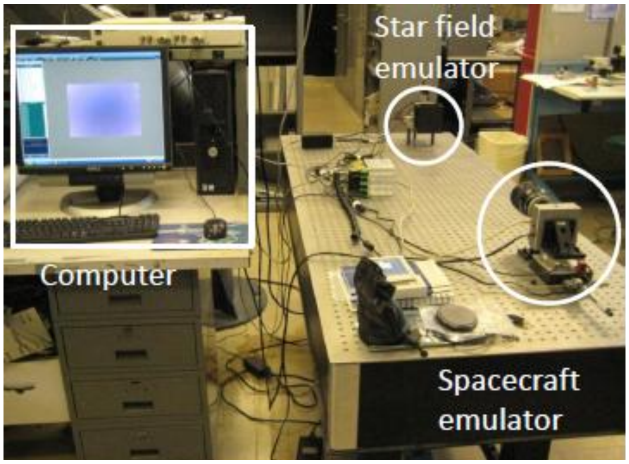

Figure 7: Fine image stabilization hardware-in-the-loop (HWIL) test bed.

On one end of the optical bench is a flight-equivalent lens, plus a fine guidance detector mounted to a two-axis piezo stage. This constitutes the "spacecraft emulator." On the other end of the bench sits a perforated back-lit screen mounted to a second two-axis stage. This screen constitutes the "star field emulator" and re-creates a sky image on the guidance detector. Coarse pointing errors are pre-computed using measured MAI-200 reaction wheel imbalance data. These motion trajectories are injected into the star field emulator stage, mechanically simulating expected motion of the spacecraft as viewed through the lens. The spacecraft emulator then closes a loop using only centroids from the fine guidance sensor—no *a priori* knowledge of the injected motion trajectory is used. The centroid trajectories without and with piezo stage motion compensation are shown in Figure 8. The test provided a successful proof-of-concept demonstration of the fine pointing loop. Pointing errors with the piezo stage were 2.3 arcseconds (3σ).

Avionics

On-board data handling and attitude control processing will be accomplished by a modified off-the-shelf single board computer from Andrews Space, Inc. The architecture consists of a radiation tolerant field-programmable gate array (FPGA) with embedded processor running a real-time operating system. Importantly, the board features two parallel camera ports to be used for interfacing with the dual imager focal plane array.

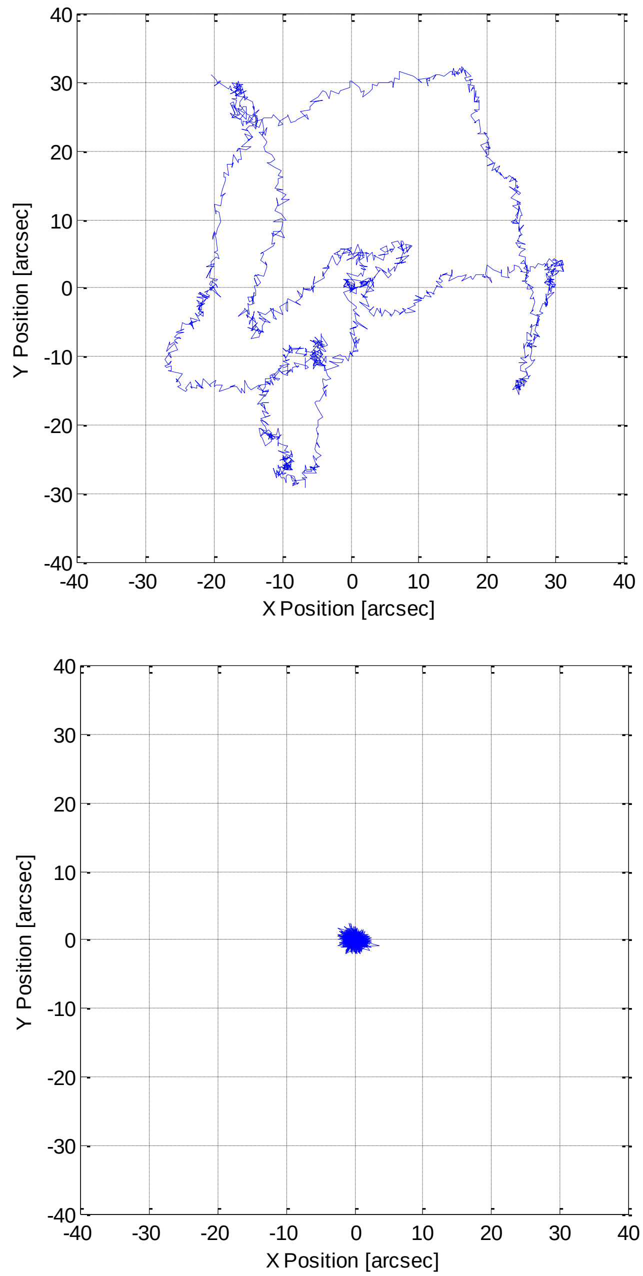

Figure 8: HWIL test bed results showing centroid trajectories without activating the piezo electric stage (above) and after (below).

Power

Electrical power will be supplied by a deployable solar array consisting of Spectrolab UTJ (28.3% efficient). The array geometry, panel count, and cell count are currently being traded with respect to the impact on overall complexity, power delivery, mass, and ADCS—both in terms of flexible dynamics and aerodynamic drag. The mission requires an end-of-life power generating capacity of 35 W.

ExoplanetSat will use Clyde Space lithium polymer batteries for energy storage. To maintain a depth of discharge of 20%, the battery stack has 70 Whr of capacity. Battery charge regulation and power point tracking is accomplished by a version of the Clyde Space FleXible electrical power subsystem (EPS) board modified for higher current loads on the 3.3V and 5V buses. The EPS will also feature a custom 12V regulator to power the piezo stage and MAI-200.

Communications

Photometry favors minimal onboard processing so that light curves can be de-trended and stitched together on the ground. Transit events may need to be phase wrapped and binned in order to achieve the desired 7σ detection threshold. ExoplanetSat will store data onboard and transmit when in view of a ground station. The baseline communication system is still being finalized, however a likely outcome the use of an S-band transceiver with one or more patch antennas. MIT owns three equatorial ground stations used for the High Energy Transient Explorer (HETE-2) that are available to the ExoplanetSat mission.

The requirement of minimal onboard processing still allows some steps to be taken to reduce data storage and downlink requirements. As mentioned previously, ExoplanetSat will store only windowed portions of the detector around stars of interest. Within limits, these single integration-long (e.g. 30 second) "postage stamps" can be co-added to form longer cadence data (e.g. 5 minute samples) to achieve reasonable downlink data volumes.

Structure and Thermal Control

The avionics portion of the spacecraft (the red region in Figure 3) resembles a standard CubeSat stack of PC-104 printed circuit boards communicating through a common header. Standoffs and brackets affix the avionics stack to a skeletonized chassis wall that also serves as the mounting point for solar panels and the MAI-200. The payload module (Figure 3, green region) is a separate structural element that mates with the combined avionics/reaction wheel "bus" module. The payload module contains additional fixtures for mounting the piezo electric stage and lens, both of which are fairly massive. Furthermore, the payload module contains sensitive optically-toleranced components. The ability to mate and de-mate the payload allows for camera integration and testing to occur independently of the bus. Once the payload and bus modules have been separately integrated and tested, the spacecraft will be assembled for system-level verification. This modularity also allows the flight payload module to be tested with an engineering bus module prior to spacecraft integration and vice versa.

The baseline thermal control scheme is passive, making judicious use of coatings, multi-layer insulation, and radiating surfaces to dissipate heat away from the imagers. Thermal control was an important driver for the selection of a CMOS imager for science over a CCD, which typically has greater sensitivity to thermal variations and higher dark current at the expected focal plane temperatures in LEO.

FUTURE WORK

In January 2011, ExoplanetSat was shortlisted for launch as a secondary payload under NASA's CubeSat Launch Initiative / ELaNa program. Our current orbital constraints (low inclination, 650 km altitude) preclude manifesting in the short term, so the project is currently evaluating other orbits to determine an acceptable range. Our development schedule supports a launch in the late 2012, early 2013 time frame.

Near-term work includes an expansion of the fine image stabilization HWIL test bed into a new facility that incorporates the MAI-200. This two-stage control HWIL test bed mounts the spacecraft emulator (including the reaction wheels) atop a spherical air bearing to allow demonstration of the reaction wheels and piezo stage working together. See Pong et al. (2011)[5] for additional details.

Development work on the payload and bus models will proceed in parallel over the coming months. An engineering version of the payload is currently being fabricated, and once complete it will be used for night sky testing of the optics, detector, interface electronics, and star matching algorithms using actual stars as a sensor input.

The science team will continue to refine the target list by identifying suitable non-variable stars and nearby bright companions to use as photometric references. Simulations of target star visibility as a function of ExoplanetSat orbital parameters have been developed and will be applied to each of the target star candidates to determine optimal scheduling of the observation campaign.

CONCLUSION

ExoplanetSat aims to achieve photometric precision down to tens of ppm over 1.5 hours for V=6. This will enable the detection of transiting Earth-sized planets around the nearest and brightest Sun-like stars. Jitter noise is mitigated through the use of a two-stage control system that combines reaction wheels and a nano-positioning translation stage. Furthermore, by combining the star camera, science, and fine star tracking functions into a single instrument, ExoplanetSat can conform to CubeSat volume requirements. The mission seeks to leverage existing nanosatellite launch opportunities and eventually expand into a fleet of satellites capable of conducting a comprehensive transit survey. This modular, extensible approach also allows for the insertion of increasingly capable technology as it becomes available.

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