

Polar Orbiting Infrared Tracking Receiver (POINTR)

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Abstract—The Satellites Team of the Stanford Student Space Initiative (SSI) has designed and prototyped Polar-Orbiting Infrared Tracking Receiver (POINTR), a 1U cubesat payload to demonstrate optical-communications technology. Because of the narrow beam divergence of optical signals it is crucial to have reliable and accurate Pointing, Acquisition, and Tracking (PAT) abilities on board the spacecraft. POINTR will demonstrate the use of a silicon MEMS fast steering mirror (FSM) for fine pointing in a cubesat optical receiver by tracking a ground laser beacon. To the authors' knowledge this will be the first in-flight demonstration of a MEMS device in a cubesat optical receiver. POINTR is scheduled to launch summer 2018 as a hosted payload onboard a 3U cubesat built by Audacy Corporation.

them with the hands-on project experience to gain those necessary skills [1]. The group consists of four project-based team: Satellites, Rockets, Biology, and Balloons. For the past two years the SSI Satellites team has been working on optical communications projects with the goal of demonstrating a bidirectional inter-satellite link between cubesat spacecraft.

The satellites team has previously demonstrated terrestrial bidirectional optical communications links across 10 kilometers, and is progressing towards a two cubesat demonstration mission.

The Stanford Student Space Initiative has been offered a 1U (10x10x10cm³) secondary payload space on a 3U cubesat being built by Audacy [2]. Audacy is a startup space communications service provider aiming to deploy a constellation of data relay satellites and connected ground stations to provide continuous high-speed data transfer from space to its customers. As part of their initial technology development they are building a 3U cubesat to demonstrate a custom high-speed radio, which will downlink to a new ground station near San Francisco. This 3U cubesat is set to launch on the Spaceflight Industries SSO-A mission aboard a SpaceX Falcon 9 in the summer of 2018.

POINTR is an optical tracking payload designed to acquire and track a beacon laser from the ground. A silicon micro electro mechanical system (MEMS) mirror in the optical path is used as a tip/tilt mirror for fine pointing correction. This mission was chosen as a strong technology demonstration relevant to the requirements of a full bidirectional optical

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1. INTRODUCTION

The Stanford Student Space Initiative is a student-organization at Stanford University whose purpose is to educate the future leaders of the space-industry and provide

inter-satellite link, as well as an opportunity to build technical capability within SSI for future satellite missions.

This paper will present the background and need for this mission, the primary objectives, a mission overview including concept of operations, payload architecture, and finally a discussion of our integration and testing.

2. BACKGROUND AND NEED

Radio communications are currently the primary means of communication for inter-satellite and ground-to-satellite. However with increasing data demands from imaging, communications, and scientific satellites, the speed limitations imposed by radio communications have become a bottleneck for returning science data[3].

Due to the narrower beam divergence and higher bandwidth of optical signals, optical communication allows for more efficient data transmission between two locations than radio communications. This translates into equipment that demands less power and smaller receiver hardware. Transmitting information optically presents an attractive alternative because the savings in size, weight, and power are accompanied by a data rate boost of 20x that of typical radio links [4].

The European Space Agency (ESA) has demonstrated coherent optical links between LEO-LEO satellites at 5.6Gb/s [5], used the developed optical terminal operationally on the Sentinel series of earth observation missions and European Data Relay System (EDRS) satellites LEO-GEO [6], and tested LEO-Ground [7]. The ESA Laser Communications Terminal (LCT) operates at 1.8Gb/s data rates over 42000km LEO-GEO. To achieve this level of performance the terminal is capable of pointing to <400 μ rad and tracking at 16nrad rms [8]. NASA has also had multiple demonstrations including a 50Mb/s downlink testbed on the International Space Station: Optical Payload for Lasercom Science (OPALS) [9], a high data rate optical link to the moon and back Lunar Laser Communications Demonstration (LLCD) [10], and will soon demonstrate a GEO-Ground link with Laser Communications Relay Demo (LCRD) [11]. NASA is also developing long reach deep space optical communications (DSOC) terminals to increase the data rate and scientific data gathering for inner solar system planetary exploration missions [12].

Optical communications has successfully been demonstrated from large satellites, but there is still much work to be done at the cubesat scale. Researchers at MIT have developed NODE, a 0.5U optical downlink payload capable of 50Mb/s [13], and are working on inter-satellite links [14]. The Aerospace Corporation is preparing to demonstrate a pair of 1.5U space-ground optical communications cubesatellites Optical Communications and Sensor Demonstration (OCSD) [15] while a small satellite scale optical terminal was also presented by Applied Technology Associates [16]. There is still a lot of work to be done developing and demonstrating

cubesat scale optical communications systems, especially for inter-satellite links.

At the same time, distributed satellite networks are a rapidly growing area of interest, particularly in the field of cubesats. The development of cubesat-sized optical communications will be exceedingly useful for smallsat projects, accessible to universities and private industry, or for large distributed networks.

3. MISSION OVERVIEW

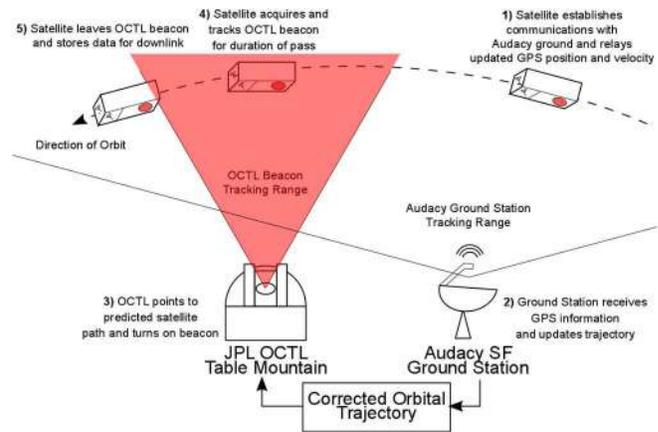


Figure 1: POINTR Mission Concept. The optical terminal hosted on a 3U cubesat points to the ground beacon laser using coarse body pointing as it passes overhead. The laser illuminates the satellite and any remaining pointing error is corrected by the optics.

POINTR is an in-flight demonstration of an optical receiver pointing, acquisition and tracking (PAT) system. The optical receiver payload will be hosted on Audacy's 3U cubesat and will be pointed to the ground to acquire and track a beacon laser sent from a suitable ground facility, currently proposed as NASA JPL's Optical Communications Telescope Lab (OCTL) facility. This mission will demonstrate many of the operational and technical requirements related to two satellites establishing an optical communications link with each other, including mission planning, orbit determination, command and execution of a pointing maneuver, acquisition of an incoming optical signal and tracking of the optical signal.

Mission Goals

The primary mission goal is to maximize the Audacy payload opportunity as a means to build experience and demonstrate technology in preparation for a two cubesat optical communications mission.

The mission technical goals include: demonstrating a subset of technology for full bidirectional optical communications mission within the constraints placed by Audacy's primary mission; increasing the chance of bidirectional optical communications mission success; developing experience within SSI designing, building, and testing space hardware; and contribute to the cubesat and satellite optical communications technical fields.

Mission Objectives

The first mission objective is to demonstrate a cubesat optical pointing, acquisition, and tracking (PAT) by tracking a ground beacon laser from orbit. This technology will be directly applicable to tracking another spacecraft when establishing a bidirectional inter-satellite link.

The second major objective is to validate the use of a MEMS mirror fine pointing system in flight. MEMS devices are attractive for cubesat scale optical systems due to small size, low power consumption, large angle-diameter product and high bandwidth. The MEMS device chosen for POINTR is discussed in Section 5.

Furthermore, our last objective is to measure the thermal and vibrational environment seen by an optical payload aboard a 3U cube satellite in a 550km sun-synchronous orbit. This data is valuable to the planning and design of future optical cubesat missions from SSI or others.

Mission Success

POINTR will be considered a success if it is able to acquire the ground beacon laser and maintain it centered on the tracking sensor for the remainder of the orbital pass. The mission will also be successful if POINTR is able to characterize the MEMS mirror performance in orbit, confirming it survived launch and the LEO environment.

Concept of Operations

The basic concept of operations can be seen in Figure 1. As the Audacity cubesat passes over the ground terminal it will downlink its most recent set of updated GPS measurements which will be used to update the orbital propagation model. This information will then be passed to the ground station to update the pointing target. The ground station will fire the beacon laser at the predicted orbit and track until approximately 25° above the horizon. POINTR will be oriented to the ground station using the satellite body steering. The optical system will have a wide enough field of view to see the beacon within the expected coarse-pointing error. The optical system will then attempt to remove the pointing error and record the residual tracking error. Measurement data will be stored until the next available pass and downlinked over radio.

SSI is working with NASA JPL to partner in using the OCTL telescope beacon laser, which was previously used for the OPALS demonstration [17]. POINTR and its host satellite will be placed into a sun-synchronous orbit, with a descending node at 10:30AM local time. Simulations show the satellite remains in view of the OCTL ground terminal for typically 4.5 minutes continuously. These passes can occur up to twice a day. Many passes over JPL's ground station coincide with passes over Audacity's ground station just north near SF, allowing the rapid update of orbital position and velocity. It may be possible to have concurrent RF and optical links established, but further analysis is required and such

simultaneous links are not within the nominal mission profile. During the testing phase, the spacecraft will alternate between contacts with the Audacity RF ground station and optical test attempts. The total measurement campaign is expected to last one week.

Link Budget

Transmitter (JPL OCTL)		
Wavelength	976	nm
Avg Power Out	4	W
Beam Div	500	urad
Channel		
Distance	1000	km
Atmospheric Loss	3	dB
Power at Receiver Plane	2.5	uW/m ²
Receiver		
Receiver Aperture Diameter	50	mm
Receiver Loss	3	dB
Collected Power at Detector	10	nW
Worst Case Background	10	uW

An optical link budget was calculated using numbers reported from OCTL and an estimate of how large an aperture could be fit on the 10x10cm 1U face. Even with a high transmission power and tight beam divergence the long propagation distance and small receiver aperture result in very low received optical power, on the order of 10nW. This low light level is even more problematic when it must be distinguished from a background level 100-1000 times brighter [18]. POINTR was designed around the expected worst case of needing to detect a 10nW signal against a 10uW background. The background intensity was estimated as the maximum amount of reflected light in a 10nm bandwidth centered on the laser beacon wavelength (976nm). This was limited by using a commercially available band-pass filter.

4. PAYLOAD ARCHITECTURE

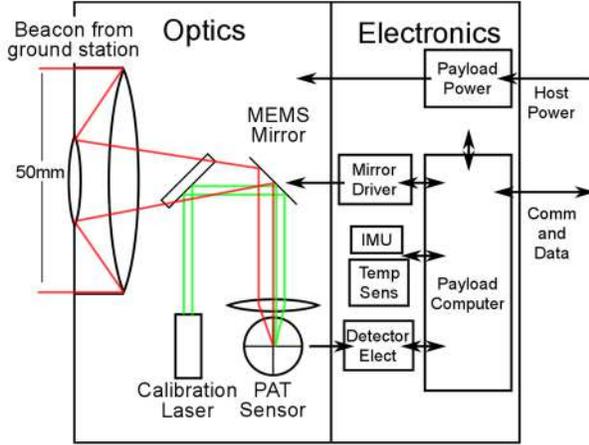


Figure 2: POINTR System Block Diagram.

The POINTR payload consists of an optical receiver, detection electronics, and payload processing. The system features and arrangement can be seen in Figure 2 and are each explained in the following sections. The payload will also include a calibration laser to measure the changes in the mirror open loop steering performance while in orbit.

Optical System

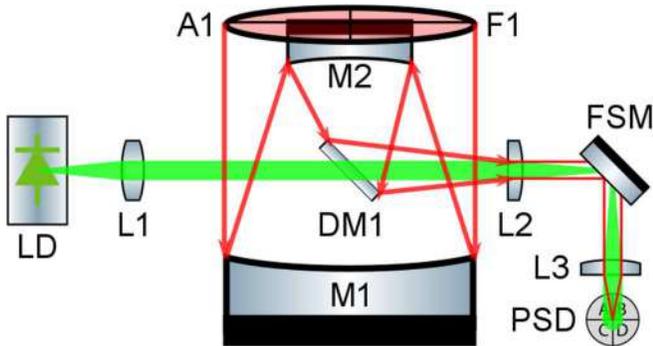


Figure 3: POINTR optical elements and beam paths.

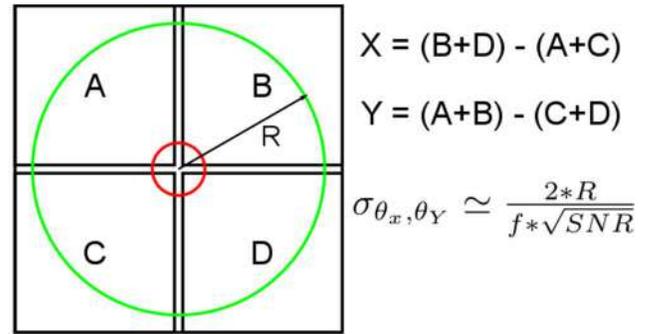
The basic optical design and beam path is shown in Figure 3. Light from the NASA JPL 976 nm laser beacon is shown in red. Light from an internal calibration laser is shown in green. 976 nm beacon light enters through main aperture A1 which is 50 mm in diameter. Covering A1 is the ~10nm optical bandpass filter F1 which rejects background light reflecting off the earth. Light bounces off primary mirror M1, and secondary mirror M2 which make up a ~F/4 Cassegrain telescope. The beam is again folded by bouncing off dichroic mirror DM1 which reflects 976 nm and passes the 650nm calibration laser. The beam hits the “eyepiece” lens L2 which collimates the beacon laser to hit the Fine Steering Mirror (FSM) which is a Mirrorcle [19] MEMS device. The steering mirror tilts in X,Y to steer the beam onto lens L3 which focuses the beam onto the Position Sensitive Detector (PSD), which is a quadcell photodiode.

The second optical path is the 650nm laser light from the calibration laser diode (LD), which is collimated by lens L1 and sent along the same beam path as the beacon light by combining through the dichroic mirror DM1. The internal calibration laser hits L2 where it is focused onto the FSM, then is adjusted by L3 to form a large spot on the PSD. Since the calibration laser has much more power than the beacon light collected, it can make a much bigger spot on the PSD and still have the same measurement sensitivity. This is useful to characterize the mirror over a wider range of angles.

MEMS Fast Steering Mirror

To realize the fine pointing requirement of the optical receiver we used a 4.2mm gold plated MEMS mirror from Mirrorcle technologies [20]. The mirror is capable of steering $\pm 5^\circ$ in X and Y axis from DC-180Hz. These devices are very small (2x2 cm) and low power consumption, but place a limit on the receiver field of view due to the small mirror diameter. Shrinking the beam diameter to fit on the small mirror requires large magnification which multiplies the angle of arrival by the same amount. For a 50 mm receiver aperture resized to a 3mm beam this is ~20x magnification. A 1° error satellite pointing error is then magnified to 20° . With $\pm 10^\circ$ of optical beam steering the tracking field of view is limited to 0.5° . The mirror is placed at the exit pupil of the telescope to maximize the amount of light collected and steered.

Quad Cell Photodetector



- Small spot: higher sensitivity, lower FOV
- Large spot: lower sensitivity, larger FOV

Figure 4: Quadcell photodetector used to measure beam displacement.

A quad cell photodetector serves as a four pixel camera to measure the beam displacement in X and Y. By using the outputs of the four photodetectors and the geometry of the optical receiver (lens focal length) the angle of arrival of the incoming light can be determined. This information will be used as input to a control loop running on the payload avionics to control the MEMS steering mirror angle and correct the incoming laser beacon angle of arrival, keeping the spot on the center of the detector.

With the expected 10nW of signal and a spot size of 250 μm the angular measurement performance is 50 μrad 1 sigma for our chosen detector and optical layout.

A large active area (5 mmØ) quadcell was chosen to ease detection and maximize the receiver field of view (FOV). With this size detector POINTR has an acquisition FOV of nearly 2°, larger than the stated body pointing accuracy provided by the host satellite.

Calibration Laser

In order to test the optical receiver calibration and measure the MEMS steering mirror performance while not tracking a ground beacon, the optical receiver will include an internal calibration laser at 650nm. This laser will be aligned to share the beam path with the ground beacon laser using a dichroic mirror. By serving as a fixed reference the internal laser will allow the alignment of the internal optics (after the telescope) to be checked and the performance of the MEMS steering mirror to be characterized over time while in orbit. The calibration beam measurement performance goal is 10 µrad rms, but will need to be verified on the prototype.

Optical Path Simulation

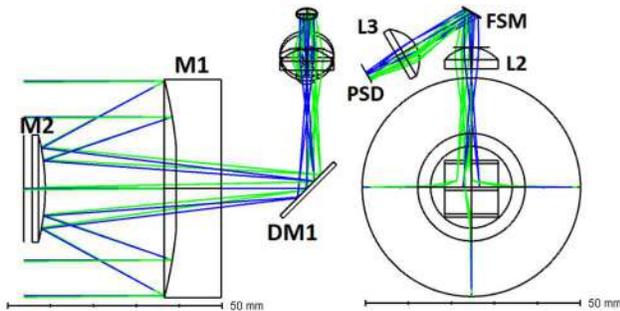


Figure 5: Receiver optical design simulation in Zemax Opticstudio 16.

The proposed optical path was simulated in Zemax Opticstudio using commercial off the shelf optics from the Edmund Optics catalog. After several iterations a design was found that met the required FOV, produced a 3mm collimated beam on the MEMS mirror, concentrated 95% of the encircled energy inside 300µm on the quadcell, fit inside the available payload volume, and only used off the shelf optical elements within the project budget. Figure 5 shows the optical element layout and beam path for an on-axis beam(blue) and a beam tilted by 0.5° in X and Y(green). Both beams are successfully directed to the MEMS mirror and onto the quadcell detector. The calibration laser path is not shown in this diagram but is combined through DM1 from the bottom of the side view.

Receiver Optoelectronics

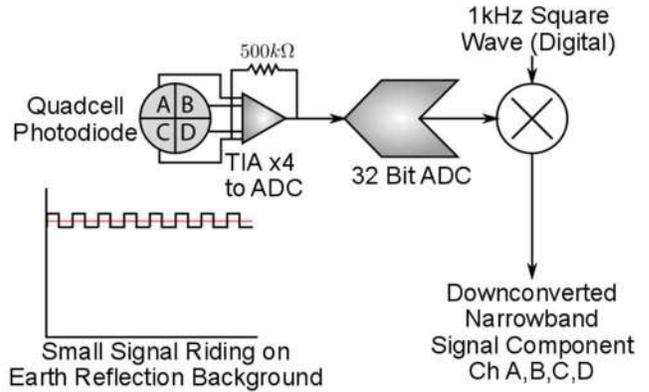


Figure 6: The assembled payload computer printed circuit board, with test interface module attached.

The optical detection electronics have to be very sensitive and low noise to see 10 nW against 10 µW of background. POINTR uses a very high gain (500 kohm) low noise ($\frac{\mu V}{\sqrt{Hz}}$) transimpedance amplifier on each quadcell pixel fed into a 32-bit digital oversampling analog-to-digital converter (ADC). The advantage of feeding the analog signal directly into a precision ADC without signal conditioning or automatic gain control is a simpler analog front end and flexibility in digital signal processing. This approach limits the gain to the saturation level of the background light.

The challenge in detecting a small signal against a bright background is addressed by modulating the beacon signal at 1 kHz and implementing an incoherent detector in DSP post-detection. The digitized signal is “mixed” with a sinusoid at 1 kHz to extract and narrowband filter the modulated component of the input while rejecting the background light. This process is discussed further in the software section below.

Avionics and Software

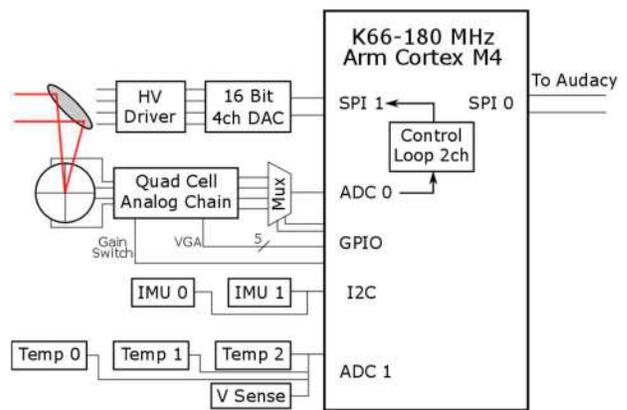


Figure 7: High-level block diagram of the payload computer.

The payload is electronically controlled by an onboard payload computer built around an Arm M4 microcontroller operating at 180MHz. This computer handles all

communication between the payload and the host flight computer as well as execution of tasks both scheduled and commanded by the host flight computer. The payload is powered by electronically switchable power supplies contained within and controlled by the host satellite. The electronics consists of a payload power system to distribute power from the satellite bus to the rest of the electronics, as well as generate and provide the correct drive voltages for the steering mirror and detectors.

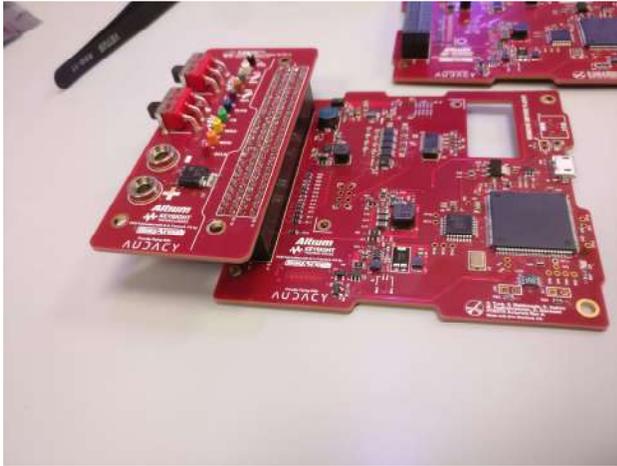


Figure 8: The assembled payload computer printed circuit board, with test interface module attached.

Software also implements the incoherent detector processing as well as the control loop that adjusts the MEMS mirror to correct the input pointing error. As described earlier, to distinguish the beacon from background light, a constant tone will be transmitted from the beacon laser. The payload computer will use the Goertzel algorithm [21] to efficiently evaluate the amount of light received at the beacon frequency for each cell of the detector. These values are used by the controller to actuate the mirror. The control loop is currently a PID controller operating separately on the X- and Y-axis, but more optimal control systems are being considered.

In addition to the measurement and control loop processing the mission software communicates with the host flight computer and transfer data for storage and radio downlink. A specialized protocol is used to interface the payload with the host satellite computer and to pass data to it for transmission to the ground through Audacy's general-purpose data downlink infrastructure.

Structures

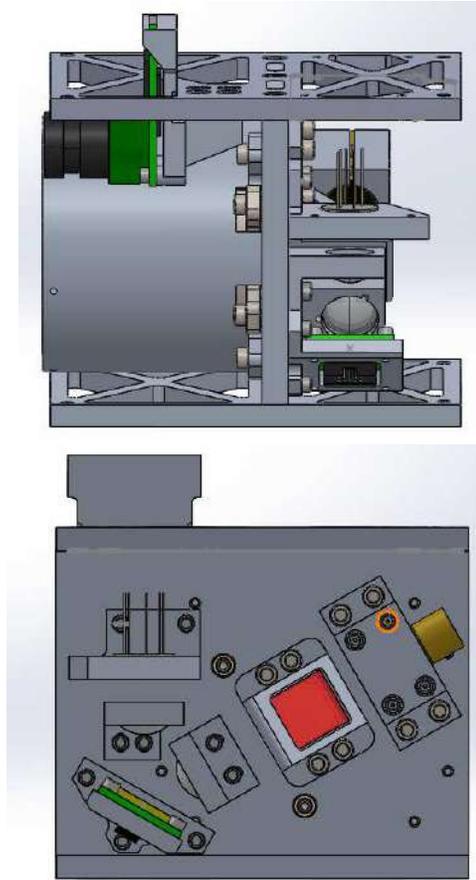


Figure 9: POINTR mechanical CAD side and rear view.

The mechanical structure was built up around the optical path to house the optical elements in their correct positions and provide a mounting point for the avionics. Figure 9 shows the side and rear views of the frame / optical bench assembly which implements the optical path from Figure 5.

The payload structures were confined to a mass budget of 0.6 kg. All structural components were designed by SSI members, including the custom camera mount for an earth-facing observation camera that is part of Audacy's mission demonstration. Structural CAD models were used to ensure designs complied with this requirement, as well as to verify the fit of all non-structure components and calculate the necessary wire harness bend radiuses.

The optical mounts were optimized for simplicity and ruggedness, with the optical elements potted and secured with low-outgassing epoxy. The only adjustable mount is for the telescope primary mirror, which has three fine adjustment screws on its base (two are visible beside the DM1 mount in Figure 9). These screws allow a small amount of tip/tilt and separation adjustment to fine tune the system focus.

Extensive simulations were used to verify the launch survivability of the components. All parts were simulated to 20Gs of static load and modal analysis was used to verify that

all structures have their lowest resonant frequency at least an order of magnitude above 100Hz.

5. INTEGRATION AND TESTING

Testing of the payload functionality and confirming it meets all performance requirements for the proposed mission will be done at Stanford. This testing will take place incrementally and continuously as systems are developed, with a final set of major tests when each subsystem is completed and integrated together to form a complete payload.

Flatsat / Optical Bench Tracking Experiment

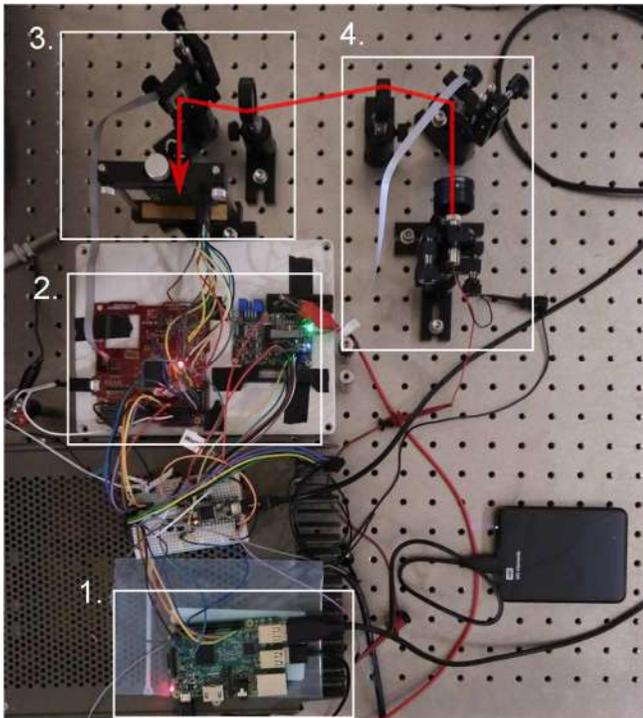


Figure 10: POINTR optical bench test setup. 1. Raspberry Pi emulating the Audacy flight computer. 2. POINTR avionics prototype board. 3. POINTR optoelectronics including quadcell, TIA, ADC and MEMS. 4. Antagonist MEMS mirror driving input disturbance.

A flatsat testbed was built on the optical bench to perform hardware in the loop testing of our tracking control loop. Figure 10 shows the bench top layout. A prototype version of the flight avionics board(2) is run as a slave device by a Raspberry Pi(1), with the detection electronics and MEMS mirror connected(3). A second independently driven MEMS mirror(4) acts as “antagonist” driving the laser randomly over the receiver aperture. The avionics hardware can then use the quadcell output to counteract the antagonist mirror with its own MEMS.

This test bench allows full hardware in the loop testing of the signal processing software, mirror control loop, and measurement data logging, as well as testing packet-based communications interface with the Audacy host flight computer. The entire setup is run as a slave off of the

Raspberry Pi, connected over WiFi, enabling software team members to remotely run testing.

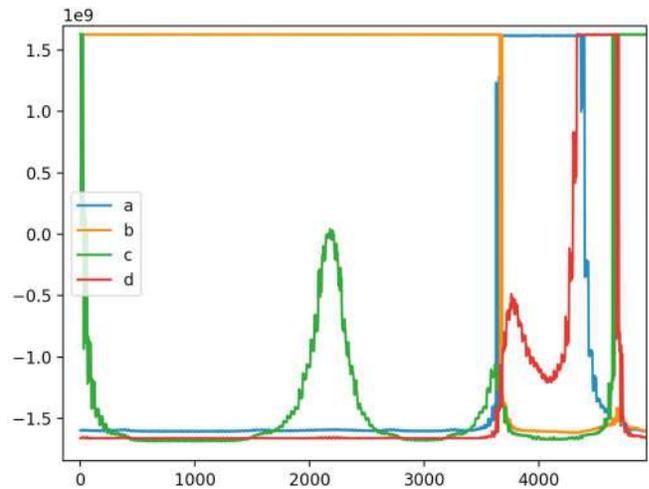


Figure 11: Plot of quad cell voltage per axis versus sample number, with samples taken at 4kHz. The above plot shows the result of a rotation test, using the antagonist MEMS mirror to steer the laser. Voltage is scaled to a 32-bit signed integer, with MIN_INT corresponding to 0V and MAX_INT corresponding to 5V.

The above plot show the response of the laser steering test, with no beacon frequency and the antagonist MEMS mirror steering the laser across the quad cell. With no attenuation, the laser saturates the detector when directly on the cell. The mirror pattern sweeps in a 1Hz pattern, and 1 second (4000 samples) of data are shown here. We can modulate the laser to test the modulated signal interference and are gathering this data now.

3D Printed Prototype

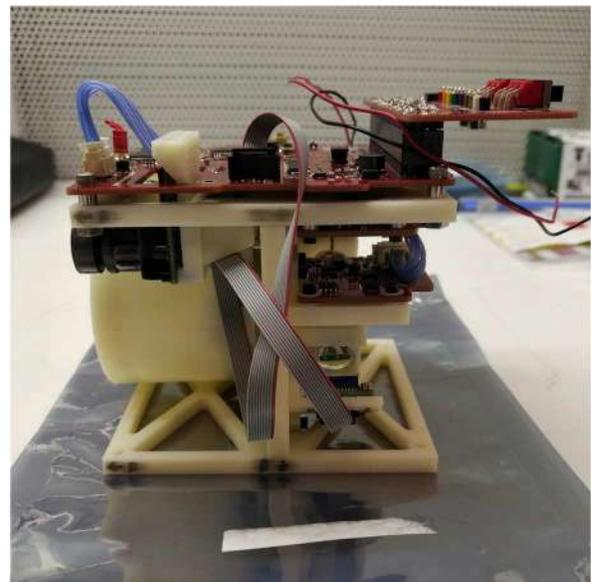


Figure 12: Test integration of hardware components using a 3D-printed frame.

SSI constructed several 3D printed prototypes of our mechanical assembly to test the fit, integration and

alignment of our design. Figure 12 shows a picture of a nearly fully integrated model of our payload. This prototype includes working versions of our flight avionics, optoelectronics, and a full set of optics, and is currently being used to test alignment and performance of our design. Lessons learned from this prototype will be incorporated into the final design and sent for rapid manufacturing.

Environmental Testing

SSI is looking to partner with a local environmental testing provider to perform our own qualification of the payload hardware, especially for the survivability of the MEMS steering mirror devices. This testing will involve thermal and vacuum testing to comply with the Falcon 9's Payload User's Guide [22], as well as Shock and Vibration Testing under parameters set by NASA's Goddard Space Flight Center. POINTR will undergo protoflight environmental testing once integrated with the rest of the Audacy satellite.

Complete Satellite Verification Testing

SSI will work closely with Audacy to perform a series of tests with the payload integrated to ensure correct and expected behavior of POINTR in their system, and that there is no negative impact on their satellite operations. These tests will include power draw, startup and shutdown modes, communications, measurement and data transfer.

6. MISSION PARTNERS

Audacy

Audacy determines the mission design and satellite hardware to best realize their radio demonstration objectives, as well as the design and integration timeline. SSI will work around the capabilities of their 3U cubesat. This may impose limits on optical testing to pass that Audacy will not be demonstrating their radio. SSI is also dependent on Audacy for ground segment support, providing ephemeris data, and communications to/from the satellite

Spaceflight Industries

Spaceflight Industries is the owner of the launch that will take Audacy's cubesat to orbit, and sets a series of launch requirements that must be met by all hosted payloads. SSI will have to ensure our payload adheres to all of these requirements set by Spaceflight for Audacy's satellite, as well as any requirements specific to our use of optical components. SSI must produce the appropriate documentation to ensure compliance with Spaceflight as well as any information for Audacy's documentation.

NASA JPL

SSI is coordinating with NASA JPL for the use of their OCTL telescope in Table Mountain CA. OCTL was used as a ground station for both OPALS optical communications demonstration from the ISS, and the LLCDC optical communications demonstration from the moon. It contains

the required pointing and tracking hardware, beacon laser, and support hardware to serve as the ground segment for our beacon tracking test. JPL also provides a wealth of experience in satellite optical communications and mission planning that SSI has found greatly beneficial.

7. SUMMARY

The Stanford Student Space Initiative's Satellites Team has built an optical tracking receiver payload, POINTR, to demonstrate pointing, acquisition and tracking (PAT) from a cubesat platform using a silicon MEMS mirror. This demonstration will help enable the success of a future mission of optical inter-satellite communications between cubesats. We hope POINTR will meaningfully contribute to the field of an optical communication as a flight-verified compact, low SWaP PAT system.

ACKNOWLEDGEMENTS

The authors would like to first thank the many members of SSI who have contributed to the POINTR development effort. We would like to thank Meera Radhakrishnan, Eldrick Millares, Sandip Roy, Dunia Hakim, Gabi Palavecino, and Stephen Spears for technical and administrative contributions to SSI's satellites' optical communications work. We would also like to thank Elizabeth Hillstrom, Ian Gomez, Sasha Maldonado, and John Dean for their work as co-presidents of SSI and the considerable undertaking they have had in keeping the organization functioning and successful.

We would like to thank Altium Ltd, Keysight Technologies and Zemax for their considerable donations of electronic design automation software and test equipment. We would also like to thank Bay Area Circuits for their support in the manufacture of the boards used in POINTR's avionics.

We would like to thank Professor Simone D'Amico for his administrative support of the project and the effort and guidance helping plan for and minimize the risks involved in this mission.

We would like to thank Matt Malfa, Chien-Chung Chen, Lawrence Leung, Professor Joseph Khan, and others for participating in design reviews throughout the course of POINTR's development.

We would finally like to thank Sam Avery, Ellaine Talle, and their coworkers at the Audacy Corporation for offering us a spot aboard their first spacecraft and working with us to make this mission a reality.

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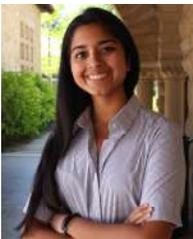
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BIOGRAPHY



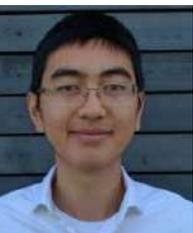
Michael Taylor received a B.Eng.(2012) and M.A.Sc.(2014) in Electrical Engineering from McMaster University in Hamilton, Ontario. He is currently working towards a PhD at Stanford University, researching precision time and frequency transfer to satellites over optical links. He has been involved with the SSI Satellites team for over two years and served as the optical system design lead and lead systems engineer for POINTR. Upon completion of his PhD he hopes to try working for a living, for a change, designing satellite optical communications systems.



Anjali Roychowdhury is a sophomore pursuing a Bachelor's Degree in Mechanical Engineering. She has been involved with SSI's satellites team since her freshman year, and is now Co-Lead of the team. She designed and developed a significant portion of the structural and systems design. She also developed the thermal model used to build the satellite to the proper requirements. She plans to pursue aerospace engineering upon graduation.



Sasha Maldonado is an undergraduate studying electrical engineering at Stanford University. He has been involved with the SSI Satellites team for over three years and has led avionics development for the POINTR mission. He plans to continue working on avionics systems in the satellite industry.



Orien Zeng is an undergraduate studying computer science at Stanford University. He has been involved with the satellites team for two years. For the POINTR mission, he designed and implemented the flight computer's state machine and interface, and is currently leading the implementation of remote testing and signals detection projects. Orien's academic interests include automation and controls and he is also involved in the balloons controller team in the Stanford Student Space Initiative.



Shi Tuck is a sophomore at Stanford University, majoring in Electrical Engineering. She is one of the Satellite's Team Co-Leads, and is extremely proud of her contributions towards the design and assembly of POINTR's main flight computer.



Michal Adamkiewicz is sophomore studying Electrical Engineering at Stanford University, wanting to focus in mechatronics. He has been involved with the Stanford Student Space Initiative since the beginning of his freshmen year, first on the balloons team and since spring quarter worked on the structure of POINTR as part of the satellites team. He is also an active member of Stanford's Robotics Club.



Sandip Roy is an undergraduate studying a Physics at Stanford University. He first joined the SSI Satellites team at the start of his freshman year and has helped lead the structural development of the POINTR mission. His current academic interests are in computational and theoretical physics and engineering and he hopes to continue doing research related to those fields in future with SSI and beyond.



Jake Hillard is an undergrad pursuing a bachelor's degree in Electrical Engineering. He has been involved with the Satellites Team for three years, and was team Co-Lead for over a year. He led the team's efforts on opto-electronics.



Meera Radhakrishnan is currently a junior at Stanford University pursuing a B.S. in Electrical Engineering. She has been a member of the Stanford Student Space Initiative Satellites team since the start of her sophomore year in September 2016 and has contributed to the development and testing of POINTR's avionics and opto-electronics. Beginning in September 2017, she is currently a co-lead for the Satellites avionics sub-team.



Simone D'Amico is SSI Satellites' Faculty Advisor and an Assistant Professor of Aeronautics and Astronautics at Stanford University. He is founder and director of the Stanford's Space Rendezvous Lab (SLAB). He is a Terman Faculty Fellow of the School of Engineering.

He holds a Ph.D. in aerospace engineering from the Technical University of Delft and received his B.S. and M.S. degrees from Politecnico di Milano. He worked as researcher at the German Aerospace Center (DLR) from 2003-2013 in space flight dynamics, autonomous satellite navigation and control, spacecraft formation-flying, and on-orbit servicing.

