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NEAR-EARTH OBJECT (NEO) SURVEYOR DEVELOPMENT: CHALLENGES AND OPPORTUNITIES IN SUPPORT OF PLANETARY DEFENSE

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Abstract

The Near-Earth Object (NEO) Surveyor mission is a key element in our future planetary defense portfolio, which will survey our solar system in the infrared to discover and characterize asteroids and comets.

The mission is designed to detect, track, and characterize small bodies throughout our solar system. By United States Congress mandate, NASA must discover more than 90% of all asteroids and comets that are larger than 140 meters in diameter and could potentially impact Earth. NEO Surveyor will provide critical decision support for stakeholders who must assess the risks of NEO impacts to Earth and identify potential mitigation strategies.

By using two infrared imaging channels, NEO Surveyor will be able to detect NEOs that ground-based telescopes or space-based visible instrumentation are unable to detect due to the objects' darkness and the limitations of ground-based surveyal. These objects can "sneak through" our existing detection methods and are large enough to cause major regional damage if one were to impact Earth. NEO Surveyor is the first space-based observatory specifically designed for detecting NEOs.
The Space Dynamics Laboratory (SDL), under the leadership of the Jet Propulsion Laboratory and in partnership with other organizations, is playing a critical role in subsystem development, systems engineering, and observatory-level assembly, integration, and test. This presentation will review challenges, lessons learned, and critical accomplishments in the preparation for launch of NEO Surveyor.

Keywords: NEOs, mission, planetary defense

1. Mission Introduction

The Near-Earth Object (NEO) Surveyor mission is a key element in our future planetary defense portfolio, which will provide a complete survey of our solar system in the infrared.

The mission is designed to detect, track, and characterize small bodies throughout our solar system that come within 30 million miles of Earth’s orbit over a five-year survey. These bodies are known as near-Earth objects (NEOs). By United States Congress mandate (2005 George E. Brown law), NASA must discover more than 90% of all asteroids and comets that are larger than 140 meters in diameter and could potentially impact Earth. NEO Surveyor will provide critical decision support for stakeholders who must assess the risks of NEO impacts to Earth and identify potential mitigation strategies. Mitigation of such risks is only possible when we have years to decades before an impact. Only roughly 40% of projected NEOs have been discovered to date, and existing ground-based surveys are decades away from reaching a high level of completeness that NEO Surveyor will complete over its five-year mission.

2. Instrument Overview

The NEO Surveyor instrument is being developed under the leadership of the Jet Propulsion Laboratory (JPL) with several partnering organizations including SDL. NEO Surveyor consists of a single scientific instrument: a 50-centimeter (nearly 20-inch) diameter telescope that operates in two infrared wavelengths, 4–5.2 μm (MWIR) and 6–10 μm (LWIR), imaging simultaneously with a wide field of view (approximately 2 degrees by 7 degrees). By using two infrared imaging channels, NEO Surveyor can make accurate measurements of NEO sizes and collect valuable information about their composition, shapes, rotational states, and orbits. The telescope will be capable of detecting both bright and dark asteroids, which are the most difficult type to find by existing ground- and space-based observatories. NEO Surveyor is passively cooled and will orbit the L1 Lagrange point.

The telescope is an all-aluminum off-axis three-mirror anastigmat, which focuses the scene through the Camera Enclosure Assembly (CEA). The CEA houses a dichroic beamsplitter and two filters to split the infrared light into two channels, NC1 and NC2. The focal plane modules (FPMs) for each channel are housed in the CEA. Baffles provide stray light rejection from Earth and the Moon.

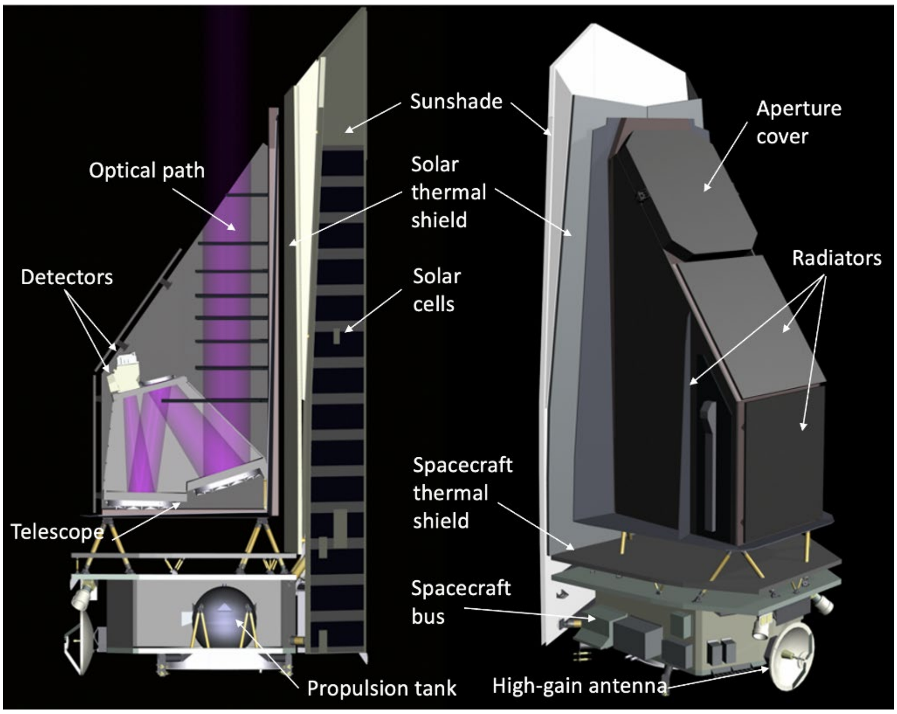


Figure 1. NEO Surveyor instrument. Credit: Jet Propulsion Laboratory

3. Space Dynamics Laboratory Contributions

The Space Dynamics Laboratory (SDL) is proud to partner with Survey Director Amy Mainzer and JPL to execute the NEO Surveyor instrument development, build, and test. SDL is responsible for the design, build, test, and verification of the following instrument subsystems: Camera Enclosure Assembly (CEA), Focal Plane Electronics (FPE), Focal Plane Module (FPM), Central Electronics Unit (CEU), and supporting harnessing. SDL has completed critical design reviews of all subsystems for which it is responsible. SDL is also responsible for environmental testing of the Optical Telescope Assembly (OTA), instrument calibration, and instrument environmental testing.

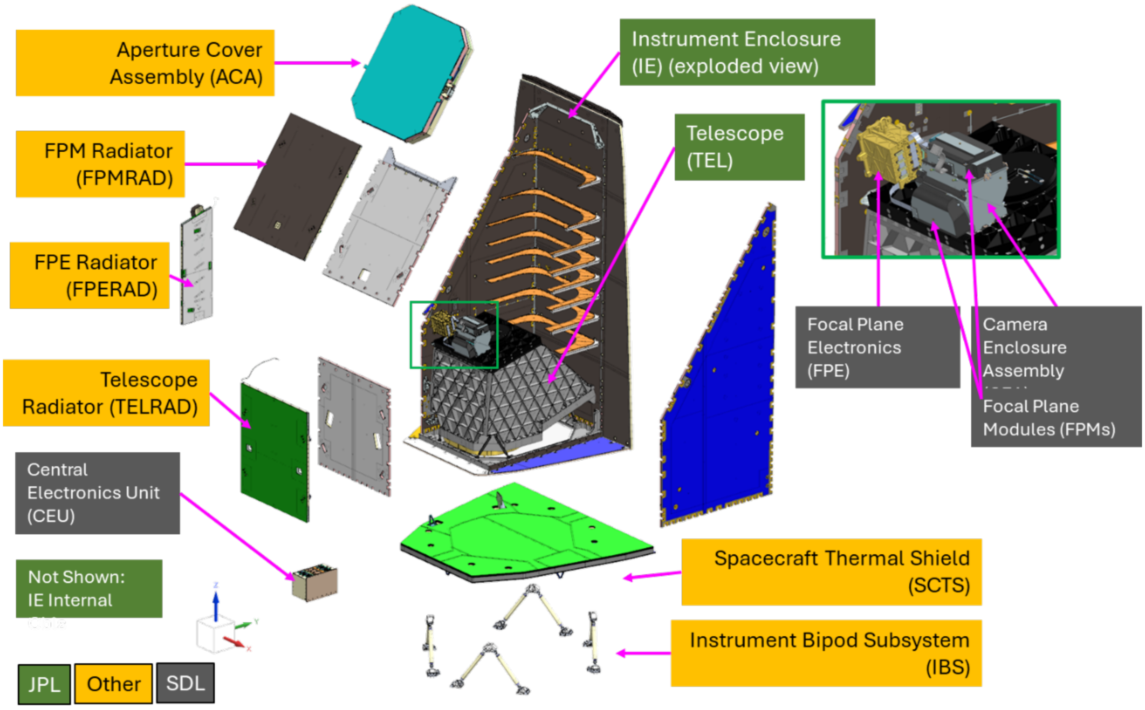


Figure 2. Organization responsibilities

4. NEO Surveyor Subsystem Progress

4.1 Focal Plane Module

There are two FPMs in the NEO Surveyor Instrument, NC1 (MWIR) and NC2 (LWIR). The FPM subassemblies are installed on the CEA. Each FPM contains four 2k x 2k HgCdTe (H2RG) sensor chip assemblies (SCAs) from Teledyne Imaging Sensors (TIS) in a 4 x 1 mosaic configuration, with flexible harnesses connecting them to SIDECAR Electronics (SCEs) housed within the FPE subassembly. SDL assumed design cognizance of the FPM design at the Critical Design Review phase and has carried the design through the build and test of a qualification unit and initiation of flight subsystem assembly. SDL has developed custom test software utilized in the real-time assessment of detector performance, which has been proven invaluable in characterizing intricacies of these SCAs critical to the success of the mission.

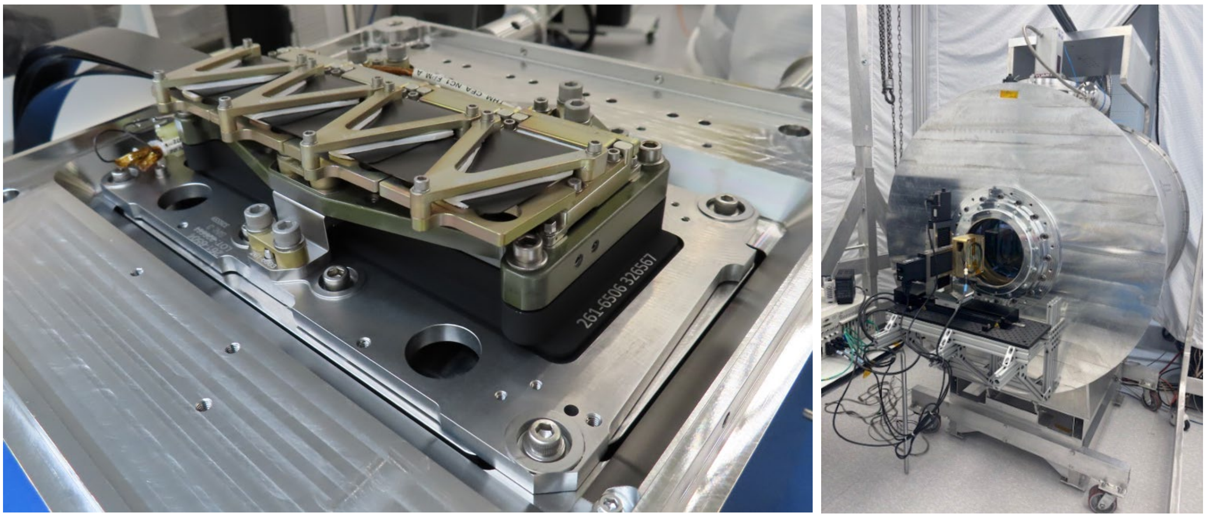


Figure 3. Qualification FPM undergoing coplanarity testing

SDL has completed extensive efforts in the design of ground support equipment, cleanroom facilities, and handling protocols to ensure the safety of the H2RG detectors. The yield of the detector growth and assembly process has been low, particularly in the NC2 channel. The NEO Surveyor team has completed exhaustive testing and downselection of the available SCAs to enable the best possible science data collection for the NEO Surveyor mission.

4.2 Camera Enclosure Assembly

The CEA design has rapidly matured over the past two years, moving from preliminary design and prototype hardware to culminating in a successful environmental test campaign in early 2025. The flight CEA has been thoroughly tested and is now being delivered for instrument integration.

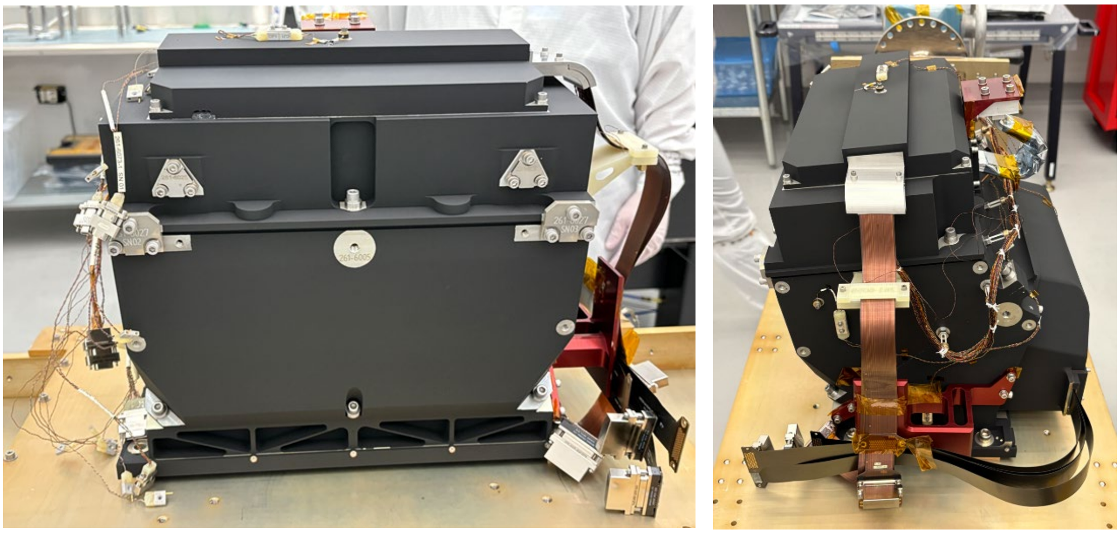


Figure 4. Flight CEA assembly

One of the largest challenges overcome was the fabrication of the germanium beamsplitter used to split incoming light into the MWIR and LWIR channels.

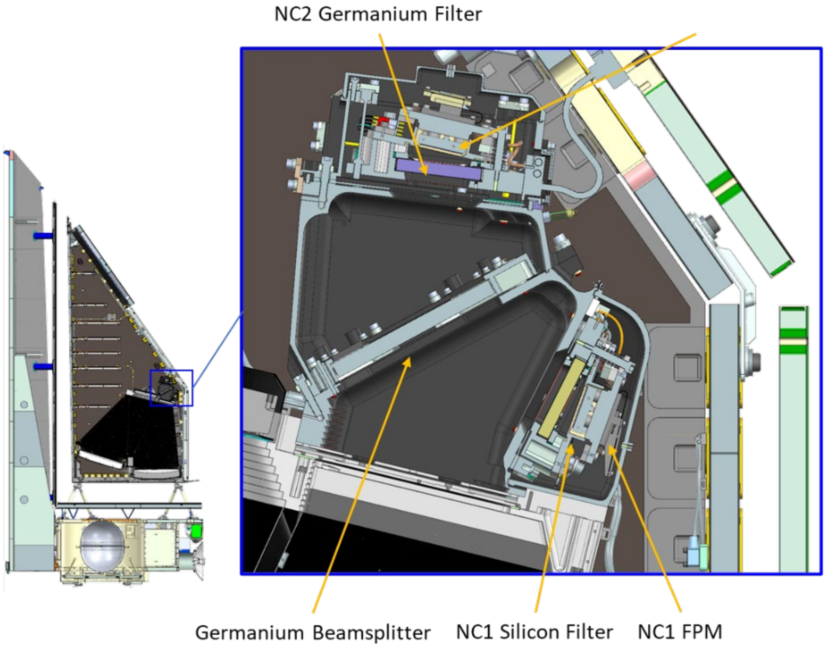


Figure 5. CEA cross section

The beamsplitter fabrication was challenging due to the material used and geometry of the part. The optic is made from monocrystalline germanium (Ge) due to its high bulk transmission in the long wave infrared. This brittle crystal has limited sources in the sizes needed for NEO Surveyor, and while it is a hard material, it is more fragile than other crystals typically used in infrared applications like silicon.

The parts were sourced from two lots of Ge, with a limited number of candidate parts and a variety of witness coupons that went through material testing to qualify the strength and optical properties of the eventual flight part. The strength coupons were fabricated using similar methods to the flight part and were tested to failure to establish robust allowables for the flight lot of Ge. This was critical so that survival against the launch vibrational performance could be assessed.

The size of the part and the density of Ge along with the need to survive launch loads drove the design to a four-point mount, which overconstrains the part and can lead to significant mounting and cryogenic distortion. To combat this potential warping, SDL developed a mounting and bonding process to minimize distortions during assembly into a frame and created a flexured three-pad interface between the frame and its fixture to minimize stresses imparted to the optical element. The pads on both sides of the interface were lapped into a single plane to further ensure that mounting stresses were reduced.

In addition to mounting concerns, the beamsplitter geometry presented challenges to the fabrication process. The part was designed to minimize mass in an octagonal form factor. The edges of the part were polished using a process developed between SDL and Optimax to minimize the risk of defects, which could propagate into part failure due to thermal or vibrational stresses. The plate beamsplitter is mounted at a 35° angle, which induces aberration in the transmitted path. To correct for this aberration, a tightly toleranced wedge was imparted, and an off-axis freeform surface was generated on the rear surface. This required precision diamond turning and magnetoresonance fluid (MRF) polishing processes iteratively applied to achieve the required optical performance. Through the assembly, integration, and test (AI&T) process, the part was shown to survive flight qualification temperatures and vibrational environments while overachieving on optical performance requirements.

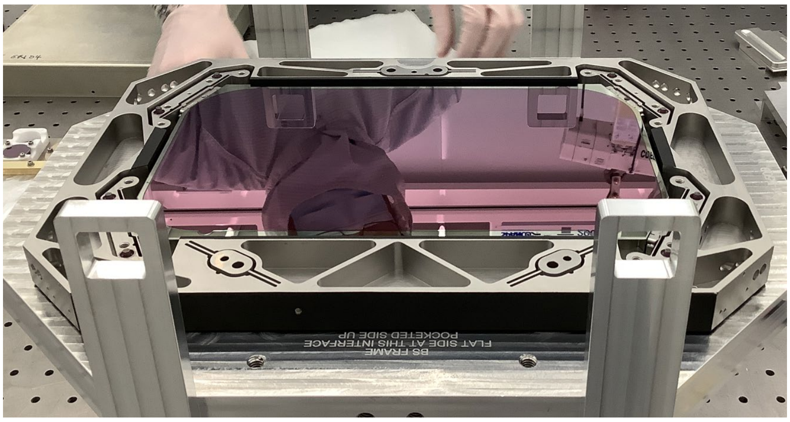


Figure 6. Flight spare beamsplitter frame assembly, prior to removal from bonding fixture

4.3 Focal Plane Electronics

The FPE subassembly consists of quantity eight SCEs to interface with the FPM detectors and associated flex harnesses. The flight FPE subassembly is presently in the initial stages of manufacturing prior to environmental test.

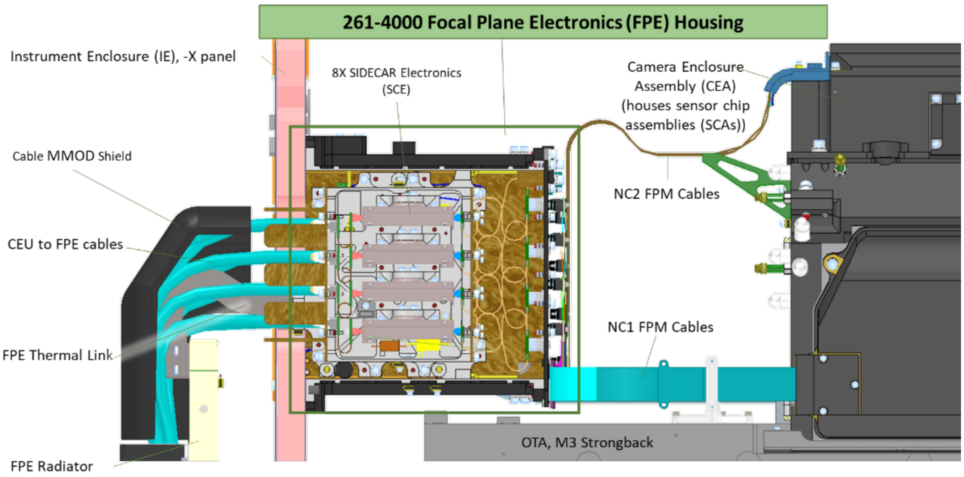


Figure 7. Focal Plane Electronics overview

4.4 Central Electronics Unit

The NEO Surveyor CEU controls the state or mode of the NEO Surveyor instrument (standby, decontamination, or survey) and both packages and transmits data received from the FPE to the spacecraft. The CEU also collects and controls the detector image data originating from the FPM. The CEU consists of eight cards per side on a common backplane. There is a redundant A and B side.

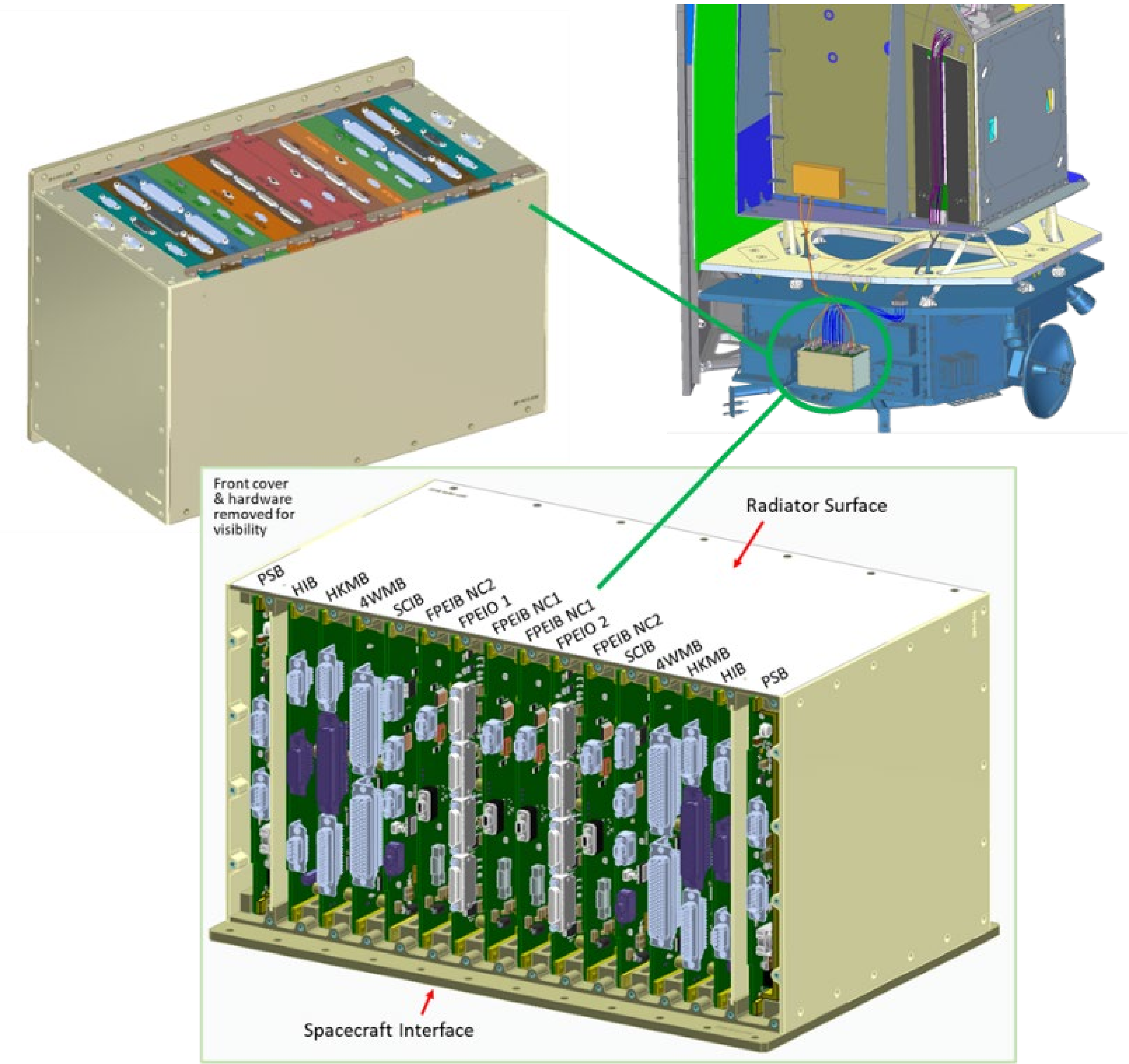


Figure 8. CEU overview

The CEU development has overcome long lead procurement challenges and successfully completed prototype development and environmental testing of engineering hardware (thermal vacuum [TVAC], vibration, and electromagnetic interference [EMI]).

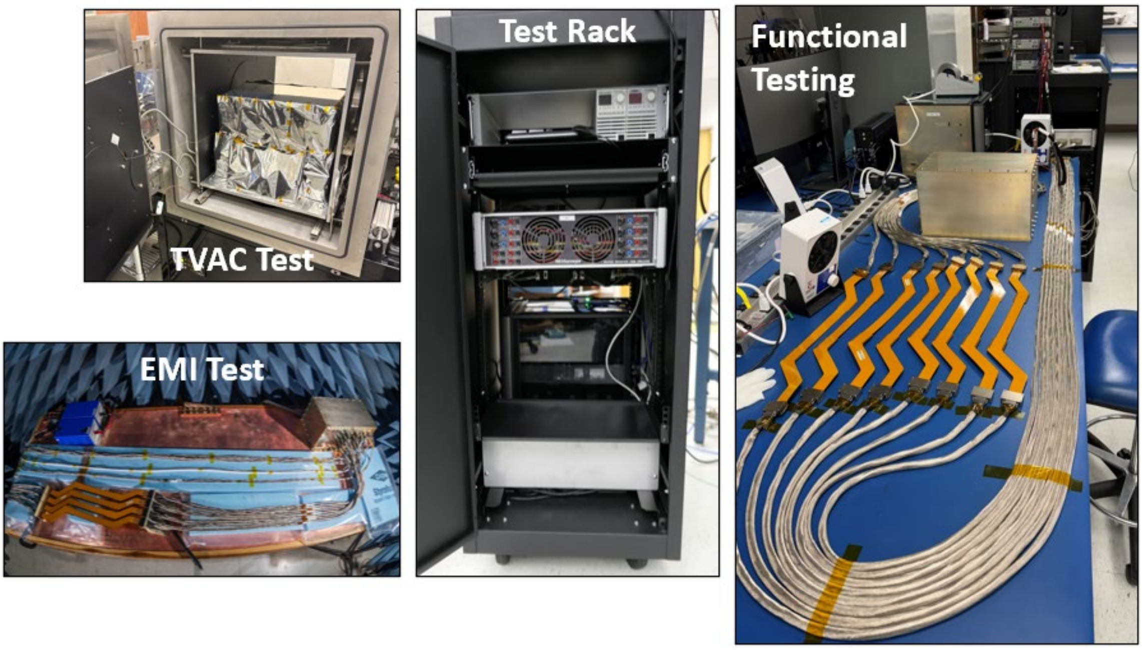
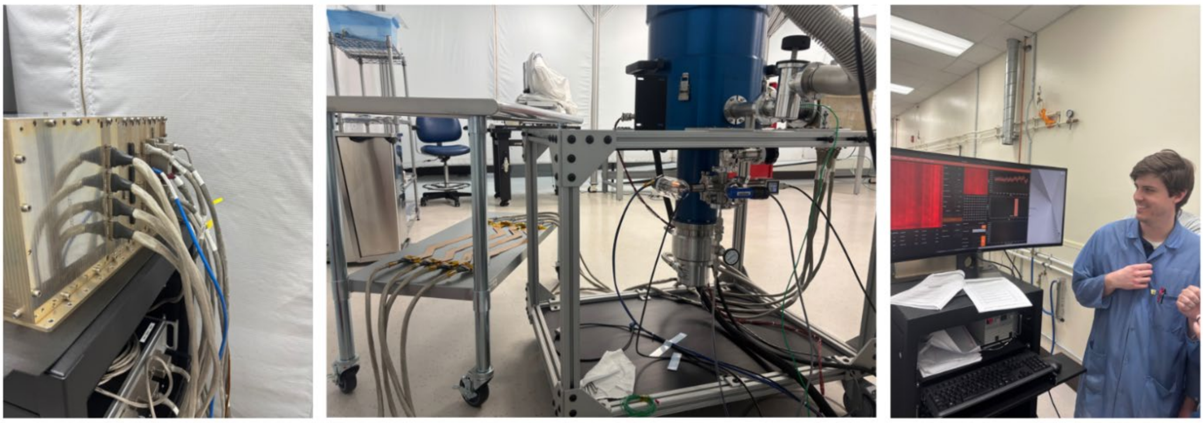


Figure 9. Successful CEU environmental testing

Recently, the prototype CEU was successfully paired with the qualification FPM for the first time in an end-to-end test to demonstrate core functionality, including detector image acquisition. Images were successfully collected on the very first attempt, evidence of a robust engineering development process being employed by the team. The flight CEU is presently in the final stages of assembly and moving forward with the flight acceptance environmental test campaign.



PT CEU

PT CEU Cabling to Dewar

First Detector image acquired through CEU

Figure 10. Successful FPM-CEU end-to-end engineering testing

5. NEOS Assembly Integration and Test Progress

5.1 Optical Telescope Assembly Testing

SDL is executing the TVAC environmental testing of the OTA. SDL is leveraging existing TVAC resources (the THOR chamber) used on past missions such as the Atmospheric Waves Experiment (AWE) to execute this testing in the spring of 2025. SDL has also implemented the use of a high-precision, vacuum-rated hexapod as a pointing mechanism for the OTA during test. Custom thermal straps and busbars were also designed and built onsite to achieve the desired OTA test temperature of 45 K.

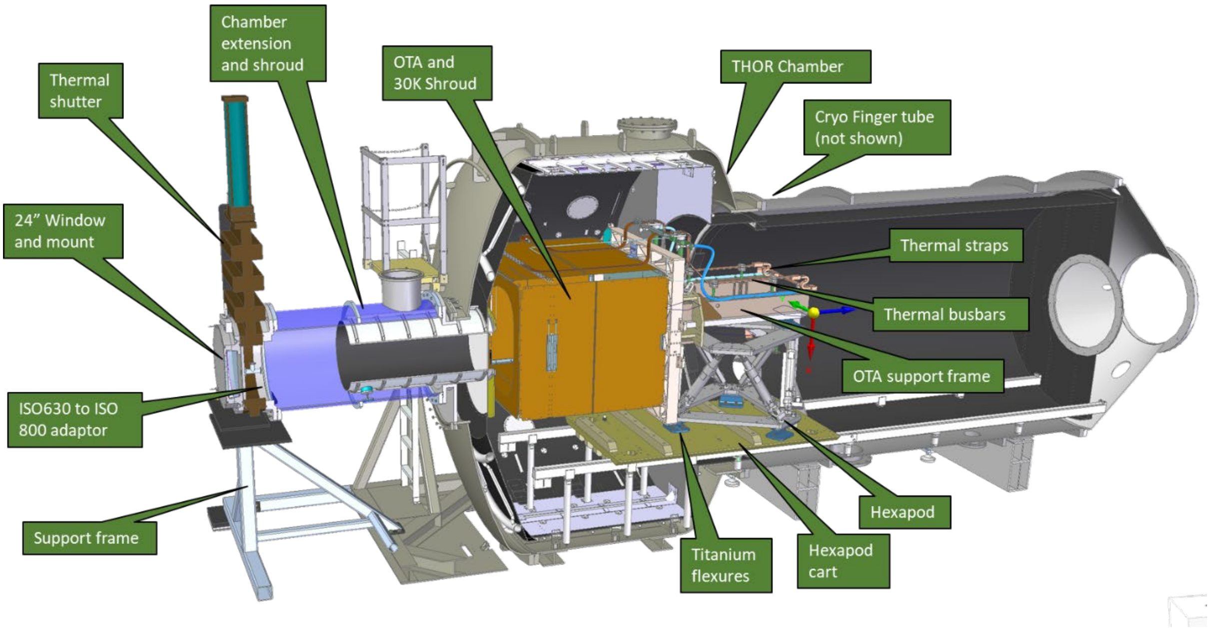


Figure 11. OTA TVAC testing is in progress at SDL

5.2 Instrument Calibration and Environmental Testing

SDL has the responsibility to complete instrument-level testing, including calibration. This is the largest instrument SDL will have tested, resulting in the need for significant facility expansions and improvements.

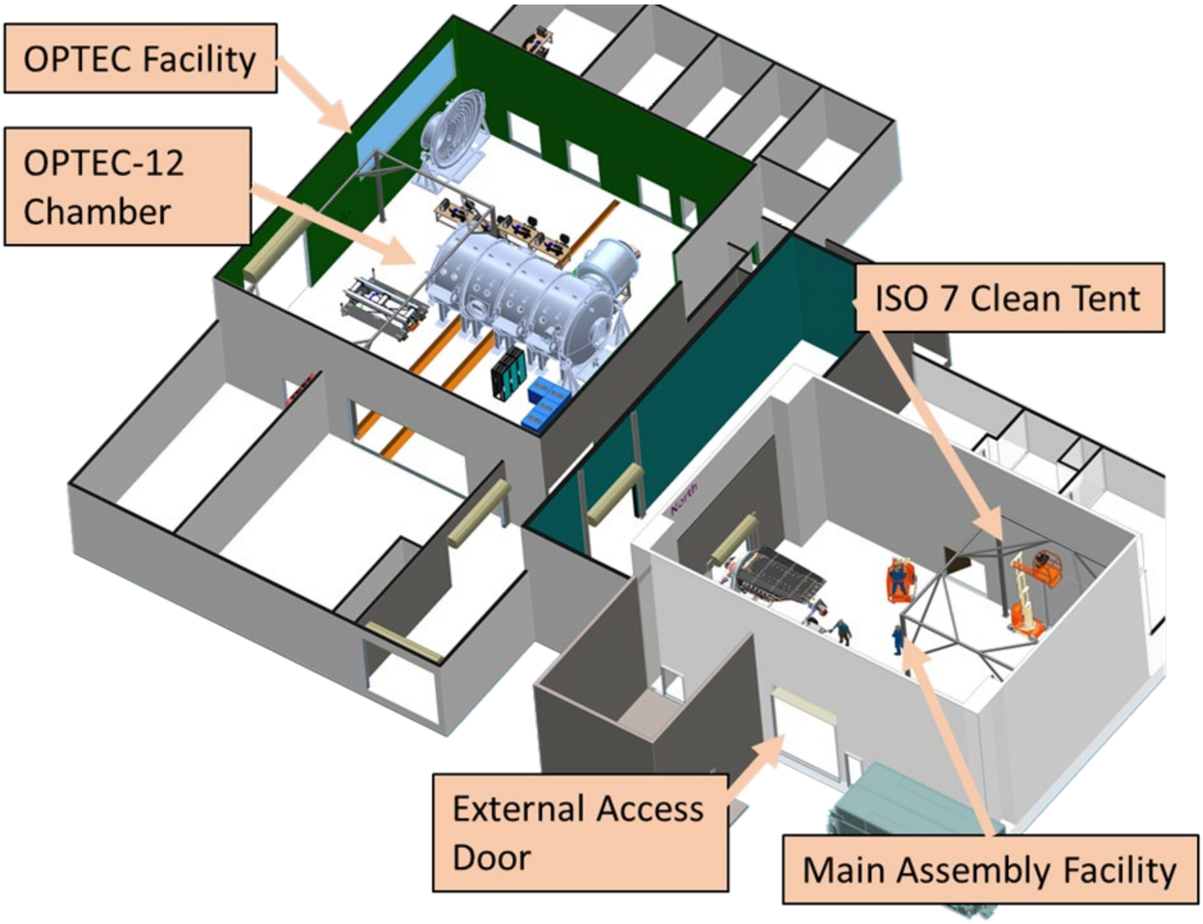


Figure 12. NEO Surveyor instrument AI&T facility planning

While SDL does have a large vibration table capable of supporting the NEO Surveyor instrument in a building adjacent to the main assembly facility, an entirely new TVAC and calibration test facility is in the process of being commissioned to support this effort. The calibration equipment, which needs to be held in vacuum, will be installed in the Multifunction Infrared Calibrator (MIC) 6 chamber, which was designed and built by SDL based on the MIC-5 chamber utilized in several past calibration programs. The instrument will be installed in the larger OPTEC-12 chamber. MIC-6 is designed to accommodate NEO Surveyor's 50 cm diameter entrance pupil, enabling accurate focus testing and characterization. The on-orbit focus of the fixed-focus NEO Surveyor instrument will be set by SDL using MIC-6 and heritage from past programs, including the Wide-field Infrared Survey Explorer (WISE).

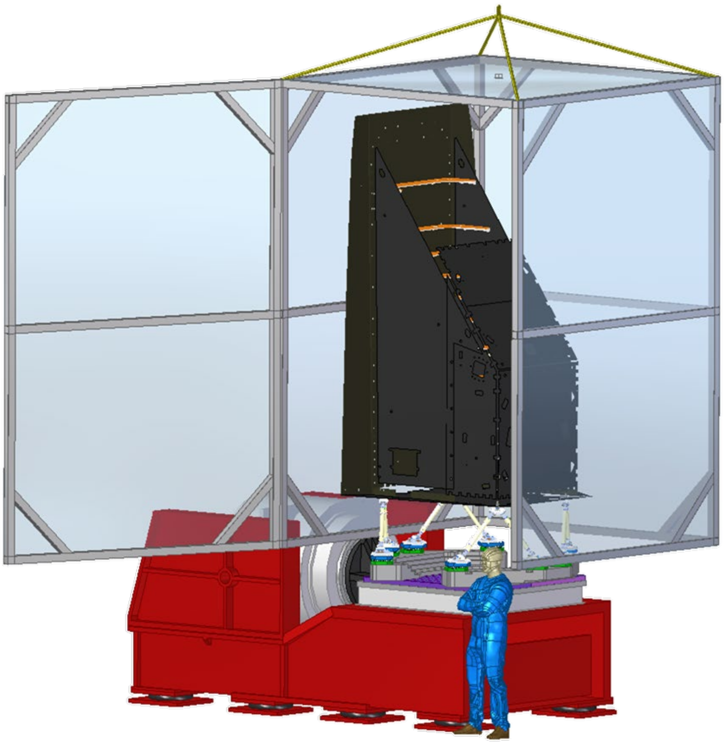


Figure 13. NEO Surveyor instrument vibration test design

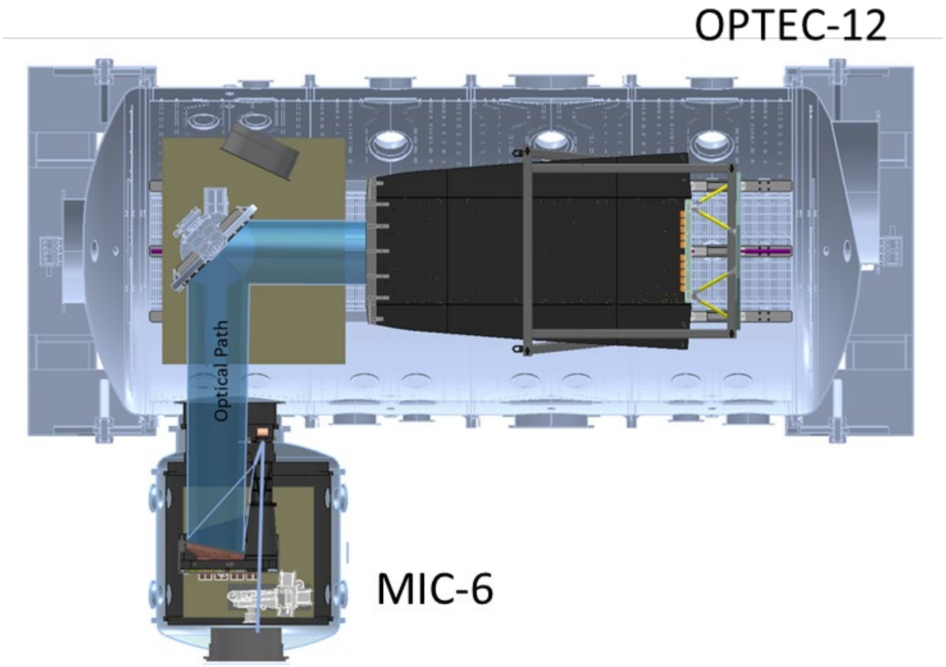


Figure 14. NEO Surveyor instrument calibration and TVAC test design

Figure 15. New TVAC chamber in commissioning process at SDL to support NEO Surveyor

In addition to physical infrastructure, SDL is preparing all of the support equipment needed to successfully integrate the comprehensive calibration and performance testing effort. SDL is also formulating the digital infrastructure to ensure rapid data sharing between SDL, JPL, and partnering organizations required by NEO Surveyor to ensure mission success.

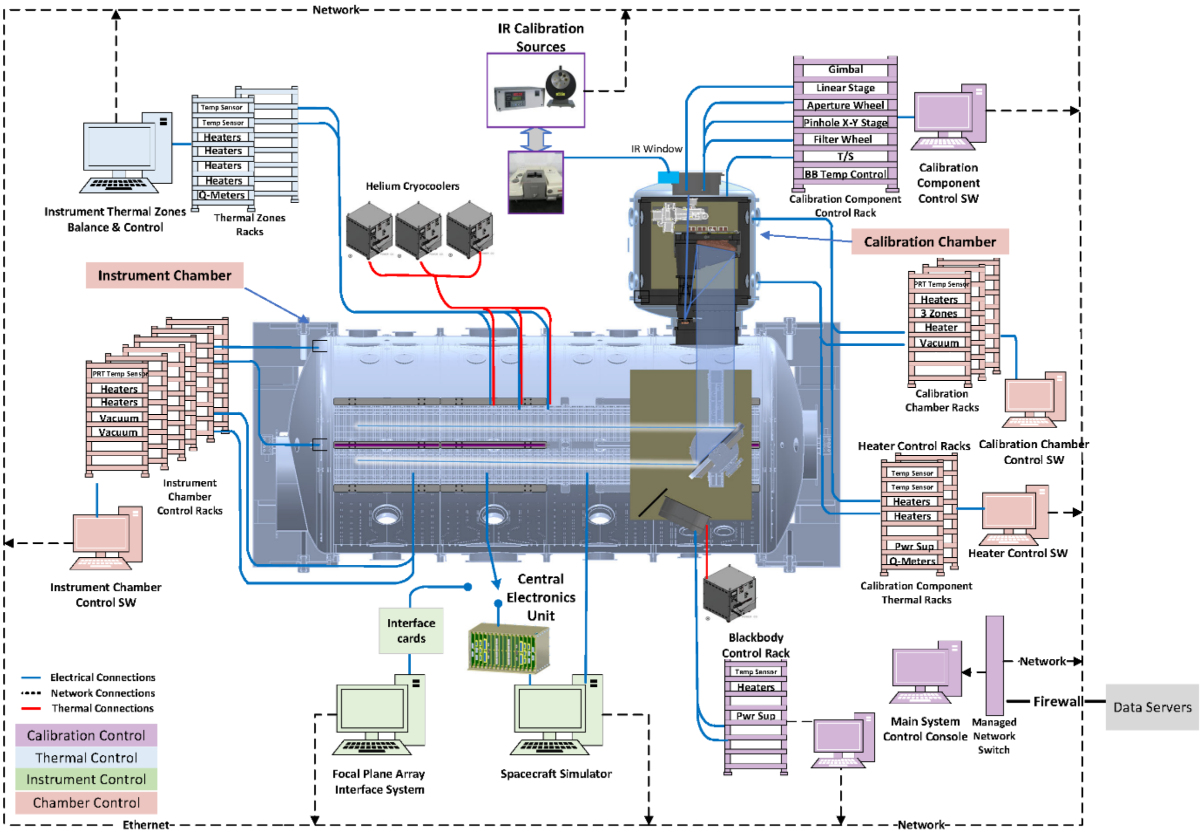


Figure 16. Ground support equipment overview in support of NEO Surveyor instrument testing

6. Performance Systems Engineering and Integrated Modeling

SDL plays a key role under the JPL-led project systems engineering team, which manages a suite of interdisciplinary models to produce regularly updated estimates of key performance parameters. On behalf of JPL, SDL maintains the observatory-level radiometric sensitivity budget and analysis, which produce driving metrics that guide engineering decisions and feed directly into survey completeness estimates.

The radiometric sensitivity model calculates how dim of an object can be observed in the survey. The model calculates a noise equivalent spectral irradiance by combining a wide range of parameters across the observatory, including optical system metrics, detector metrics, zodiacal background estimates, stray light from celestial sources, on-orbit calibration errors, and other terms.

In addition to the radiometric sensitivity budget and analysis, SDL maintains stray light modeling, in-band and out-of-band optical transmission budgets, image quality modeling, a well depth budget, and other optical systems engineering analysis efforts, incorporating as-built information to converge the estimates. As part of the project systems engineering and instrument systems engineering teams, SDL works with NEO Surveyor partner organizations to derive and refine requirements at various levels of assembly, provide technical expertise for the closure of requirements at various levels of assembly, and deliver important parameters to NEO Surveyor partners, including the science team.

SDL will provide instrument-level radiometric calibration and testing, as well as stray light testing, in line with this performance systems engineering role.

7. Conclusion

The NEO Surveyor mission is a fundamental contributor to planetary defense efforts moving forward in the detection of NEOs that could have devastating regional impacts on our planet. SDL, in partnership with multiple organizations under the direction of JPL, has made great strides in bringing the design from concept to reality over the past years. SDL has executed on planned hardware development and is now rapidly preparing resources to ensure the success of instrument assembly, integration, and test.

Acknowledgements

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The author would like to acknowledge the contributions of all co-authors, as well as all partner organizations. This mission is a great example of teamwork, collaboration, communication, and successful execution by all partners involved.

More information can be found at the following:
https://www.sdl.usu.edu/science/
https://www.jpl.nasa.gov/missions/near-earth-object-surveyor/