ASTROBOTIC: PEREGRINE LUNAR LANDER TECHNICAL PROGRAM UPDATE. S. Bhaskaran[1], J.K. Hopkins[1]. [1]Astrobotic Technology Inc., 2515 Liberty Ave. Pittsburgh, PA 15222, sharad.bhaskaran@astrobotic.com, jeff.hopkins@astrobotic.com.

Introduction: This paper describes the latest developments in Astrobotic's lunar lander mission program. Topics addressed here include program updates, technical updates, and a summary of our approach.

Program Update: Since the last update to LEAG in 2016, Astrobotic has added about 90 years of spaceflight expertise to its team, in the areas of program management, systems engineering, propulsion, GNC and C&DH. The nationwide search for top candidates resulted in key staff positions which now form the nucleus of the Mission Team. The team quickly progressed to a Preliminary Design Review (PDR) in November 2016. Participants in the review included 40 NASA experts representing multiple disciplines and 5 NASA centers; 7 Airbus Defense & Space experts in systems engineering, propulsion and mission design, and 2 Aerojet Rocketdyne propulsion experts. The review comprehensively covered all spacecraft subsystems as well as the mission design. Review feedback was positive – participants recognized the subsystem designs had matured significantly although the design had not closed at the system level. A delta PDR is scheduled for August and September 2017 to demonstrate design closure and compliance with all mission requirements. Again, a large contingent of NASA experts is expected along

Figure 1: Astrobotic's Peregrine Lunar Lander along with key mission partners.

with the previous Airbus contingent. Joining in the review will be a launch vehicle representative from United Launch Alliance (ULA), building on the recent announcement of the Astrobotic/ULA partnership.

Following a successful delta PDR, Astrobotic will initiate engineering unit development for component level testing, performance characterization and integrated system testing, and continue refining system design analyses. The schedule moving forward includes key milestones such as a Critical Design Review (CDR), Systems Integration Review (SIR), and Test Readiness Review (TRR). Peregrine will be assembled and integrated at our Pittsburgh facility in a high bay outfitted with a clean room and equipment for component level manufacturing and testing.

Technical Update: A key feature of the ULA partnership is an Atlas V/Centaur launch vehicle offering a higher energy boost to orbit than was previously planned. As a secondary payload aboard Atlas V, Peregrine will benefit from the leftover energy from Centaur's Earth departure burn, which sends Centaur into a hyperbolic disposal orbit. This final burn reduces the delta-V requirement for Peregrine, and decreases the transit time to lunar orbit due to a more favorable direct transfer.

The ULA partnership also includes the development of an expanded payload fairing, increasing Peregrine's axial and lateral growth margins, which increase mass carrying capability and payload volume envelopes. The maximum payload limit on future missions will be achieved with minimal changes to structure, optimization of the performance of the spacecraft's engines, and use of telemetry data from prior missions to optimize spacecraft operations.

Overall, spacecraft design analyses demonstrate all subsystems meet mission requirements with margins of safety consistent with industry standards, and selection of space flight heritage components raised system reliability and increased mission probability of success.

Our Approach: Astrobotic's mission implementation philosophy is derived from government and industry best practices which align with early approaches practiced by the company. Our Guiding Principles consist of strategies which drive tactical implementation across programmatic and technical areas while maintaining an acceptable balance with the company's risk posture. Adherence to these principles enables the team to develop Peregrine as a "Class D", low complexity spacecraft designed with proven spacecraft components, at a fraction of the cost of comparable spacecraft developed by government agencies. We draw on decades of successful spaceflight experience through our partners and suppliers – NASA, Airbus, ULA, Orbital ATK, Honeywell, and the Swedish Space Corporation (SSC) – to design a spacecraft that will have high reliability and high probability of mission success. Repeatability and standardization of payload allocations and interfaces will optimize our payload services offering for future missions.