MARS MISSION CONCEPTS: SAR AND SOLAR ELECTRIC PROPULSION. Kurt Klaus[1], Stephen Clifford[2], Samuel J. Lawrence[3], David B. Smith[1], Michael Elsperman[1]; [1]The Boeing Company (5301 Bolsa Avenue, Huntington Beach, CA 92647, kurt.k.klaus@boeing.com, david.b.smith8@boeing.com, michael.s.elsperman@boeing.com), [2]The Lunar and Planetary Science Institute (3600 Bay Area Boulevard, Houston, TX 77058, clifford@lpi.usra.edu); [3]School of Earth and Space Exploration (Arizona State University, samuel.lawrence@asu.edu)

Introduction: Our ambitions for space exploration have outpaced our ability to afford frequent visits to targets of interest. Launch costs and development times continue to increase for getting large spacecraft to deep space. This particularly affects workforce development and imperils opportunities for new development starts. A new paradigm for planetary exploration is clearly needed. The time has come to leverage technology advances (including advances in autonomous operation and propulsion technology) to reduce the cost and increase the flight rate of planetary missions, while actively developing a scientific and engineering workforce to achieve national space objectives.(1)

Mission Science at Mars: A Synthetic Aperture (SAR) imaging radar offers an ability to conduct high resolution investigations of the shallow (<10 m depth) subsurface, enabling identification of fine-scale layering within the Martian polar layered deposits (PLD), as well as the identification of pingos, investigations of polygonal terrain, and measurements of the thickness of mantling layers at non-polar latitudes. Similar orbital SAR investigations, conducted over terrestrial desert environments, have resulted in the identification of numerous (and previously undetectable) paleodrainage channels – buried just a few meters beneath the desert throughout eastern Libya, western Egypt and northern Sudan. SAR investigations of the Martian densely-cratered Noachian highlands are expected to yield similar results – effectively peeling away billions of years of eolian mantling, to reveal the full extent and drainage density of the Martian valley networks. In this way, an orbital SAR will help address some of the most recent and oldest evidence of climate change on Mars – providing a unique window into the planet's past.

It would allow systematic near-surface prospecting, which is tremendously useful for human exploration purposes (in particular, the identification of accessible ice deposits and quantification of Martian regolith properties). Previous Mars orbital radars (i.e., MARSIS and SHARAD) operate at much longer wavelengths; thus, our SAR instrument would acquire a unique new dataset. Studies indicate that P-Band is best for the deepest penetration of dry surfaces. Schaber and Breed, 1999, calculated that maximum radar imaging depth for X, C, L and P-band is equal to 0.25 m, 0.52 m, 2.07m and 5.87 m respectively. These values were confirmed by field investigation in Egypt and Arizona.(2)

Depending on mass/power remaining after the SAR, there are several instruments that could also be useful. One that would have a large degree of science return and Exploration utility would be a high resolution stereo imaging system with pixel scales comparable to the MRO HiRise instrument, but utilizing fore-and-aft mounted imaging capability to enable routine collection of stereo observations while obviating the need to roll the spacecraft. Limited color capabilities in this notional high-resolution stereo imaging system would enable the generation of false color imagies, resulting in useful science results, and the stereo data could be reduced into high-resolution Digital Elevation Models uniquely useful for exploration planning and science purposes. Since the SAR and the notional high-resolution stereo imaging system would be huge data volume producers - to maximize the science return we are currently considering the usage of laser communications systems; this notional spacecraft represents one pathway to evaluate the utility of laser communications in planetary exploration while providing useful science return..

Mission Concept and mapping to goals: Using a common space craft reduces mission costs for both single missions that achieve multiple science objectives or for multiple mission campaigns. Solar electric propulsion (SEP) provides the flexibility required for multiple mission objectives. SEP provides the greatest payload advantage albeit at the sacrifice of mission time.

Our concept involves using a SEP enabled space craft (Boeing 702SP) with a highly capable SAR imager that also conducts autonomous rendezvous and docking experiments accomplished from Mars orbit. Our concept of operations is to launch on May 5, 2018 using a launch vehicle with 2000kg launch capacity with a C3 of 7.4. The Heliocentric phase of the mission is 273 days that includes 135 days of coasting. For this mission design, a 100 kg payload is assumed and our launch mass is 1769 kg. We will only consume 243 kg of propellant out of 450 kg that is available on the spacecraft. Removing a propellant tank can give us up to an additional 100 kg of payload with sufficient launch margin. After reaching Mars it takes

145 days to spiral down to a 250 km orbit above the surface of Mars when Mars SAR operations begin. A small payload is dropped off during the spiral operations to be later retrieved using Autonomous Rendezvous and Docking (AR&D) technology demonstrated by the DARPA Orbital Express mission. In terms of the workshop Challenge Area 1, subareas 1 and 3 are addressed; 1.Interrogating the shallow subsurface of Mars from orbit (remote sensing, active, or passive); and 3.Orbital measurements of surface characteristics such as composition and morphology. In terms of Challenge area 2, nearly all are addressed, except for aerocapture. In terms of the mid –term, the single most important challenge is addressed: Lightweight, low-cost concepts for vehicle-to-vehicle detection and orbit determination of objects in Mars orbit (in support of rendezvous and docking/capture). Our spacecraft is designed to use the Boeing Advanced Modular Power System (AMPS) solar array, currently in development, provideing nearly 5 kWe (EOL) for non propulsive science operations. AMPS (currently TRL4) is based on previous DARPA and AFRL solar power and propulsion system technology development programs and continues to mature through Boeing IRaD. It is also a candidate for a planned NASA Technology Demonstration Mission sometime after 2015 according to the NASA Office of the Chief Technologist (OCT).

Preliminary investigation into using the 702SP for a Mars mission shows that there could be sufficient margin left at the end of mission for a Phobos rendezvous. A small number of instruments could be included to enhance the SAR science at Phobos, such as a UV/VIS spectrometer.

Concepts using the SLS. A “free” ride for up to a 20 metric ton payload to Mars has potential for one of the SLS unmanned test flights. Additional point of departure mission concepts using the SLS are

1) Netlander – fly the Netlander mission with 3 or more geophysical monitoring landers
2) ExoMars-MaxC – fly the canceled joint US/ESA mission in a single launch
3) Multiple MER class rovers – Rove to multiple locations on Mars to search for the game changing sample for MSR. The rovers could also characterize soil reactivity for human health and safety concerns.
4) Do a grab and go sample return from Gale Crater assuming that MSL finds something groundbreaking. There is sufficient margin on the SLS to avoid AR&D risk and launch direct back to earth
5) ISRU Demo near the North or South Pole

With the addition of SLS, all the Challenge areas identified in the workshop are addressed**.**

Summary/Conclusions: A robust and compelling Mars mission can be designed to meet the 2018 Mars launch window opportunity. Using advanced in-space power and propulsion technologies like High Power Solar Electric Propulsion provides enormous mission flexibility to execute the baseline science mission and conduct necessary Mars Sample Return Technology Demonstrations in Mars orbit on the same mission. An observation spacecraft platform like the high power (~5Kw on station) 702SP at Mars also enables the use of a SAR instrument to reveal new insights and understanding of the Mars regolith for both science and future manned exploration and utilization. Leveraging the NASA investment in SLS by integrating this mission on a 2018 SLS test flight would provide the ability to greatly expand the scientific scope and return while demonstrating beneficial synergy between the NASA Human and robotic exploration program investments.

References: [1] Klaus K. et al. (2012) LPSC 43. Abstract #1441. [2] Schaber G.C. and Breed C.S.. (1999) *REMOTE SENS. ENVIRON., 69,87–104*