LUNAR INFRASTRUCTURE FOR LANDING AND LAUNCH RISK MITIGATION. J. G. Mantovani[1], R. P. Mueller[2], J. M. Schuler[3], N. J. Gelino[4], and L. Sibille[5], [1]NASA Kennedy Space Center, UB-R1, Kennedy Space Center, FL 32899, james.g.mantovani@nasa.gov, [2,3] NASA KSC, UB-R1-A, Kennedy Space Center, FL 32899, rob.mueller@nasa.gov and jason.m.schuler@nasa.gov, [4]NASA KSC, NE-L-6, Kennedy Space Center, FL 32899, nathan.j.gelino@nasa.gov, [5]SURA, LASSO-013, Kennedy Space Center, FL 32899, laurent.sibille-1@nasa.gov.

Introduction: To prepare for human exploration missions to Mars, NASA is planning to demonstrate surface operations initially on the Moon. These operations may include

- Teleoperation of surface assets from orbit (Gateway)
- Sample return from the lunar surface
- Surface power technology demonstrations
- Communications delay and autonomous operations
- Establishing deep space logistics supply chains
- In-Situ Resource (ISRU) demonstration missions

Current plans envision a Transfer Vehicle Element will transport the Descent/Ascent Elements from Earth or Gateway to low lunar orbit for subsequent deployment to the surface. The Ascent Element will return to Gateway from the lunar surface.

During descent and landing, a lunar lander's rocket exhaust plume will interact with surface regolith causing cratering and the generation of a stream of high-speed, abrasive particles. Depending on their speed and trajectory, the ejecta may damage both nearby and distant surface assets, including the historic Apollo sites. The speed of the ejecta particles may even be sufficiently large to inject them into lunar orbit where they would potentially risk orbiting assets. The subsequent ascent from the lunar surface, e.g., using the Ascent Element to return lunar samples to Earth or an orbital Gateway platform, may also produce plume surface interactions that result in an ejecta stream. In this presentation, we will review damage mitigation technologies for the Moon, such as landing pads, berms and/or blast deflection walls.

Rocket launches on Earth have sometimes resulted in damage to the launch pad facility and nearby assets. For example, during the STS-124 launch in 2008, approximately 3,500 fire-resistant bricks were dislodged from the flame trench wall (see Fig. 1).

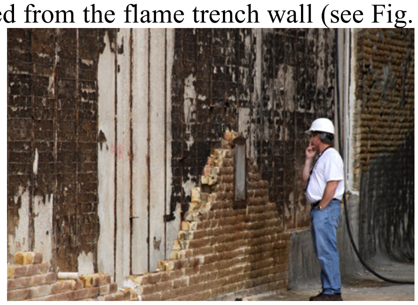

Figure 1. KSC worker inspects damage to flame trench wall at Launch Pad 39A in 2008.

During the descent and landing of a lander vehicle, the descent engines will generate hot exhaust gases resulting in a high speed gas flow that will erode surface regolith and cause cratering. In the vacuum of space, granular regolith ejecta will be propelled at high speed by the gas flow and potentially travel great distances in all directions from the landing site without any atmosphere to slow them down unless they happen to impact an obstacle on the surface (see Fig. 2).

Fig 2. Apollo lander on Moon (left), and JSC Morpheus vehicle landing on lunar hazard field at KSC (right).

Approach: We will review concepts and technology development related to lunar landing and launch (L&L) infrastructure that have been developed in the past 10 years at NASA and by NASA contractors. These concepts range from excavating, grading and stabilizing the regolith surface, to robotically assembling interlocked in-situ sintered regolith pavers into a pad, to insulation material blankets that are rolled out on the surface, to using locally mined rocks in a gravel bed type of structure, and more. Other infrastructure required will be a way of deflecting or stopping the blast ejecta, which is predicted to attain velocities as high as 2,000 m/s, if loose regolith or dust is entrained in the rocket exhaust jet. Concepts will be presented such as building berms around the perimeter of the L&L pad, inflatable blast deflection structures, deployable fence mechanisms, in-situ basalt glass fiber structures and 3D printed blast deflection walls.

Other L&L infrastructure that will be required will also be discussed in the context of functions that are known to be needed by a reusable lunar lander. Examples are lighting systems, landing navigation aids such as beacons and visual target markings, communications systems, and flight corridors.

This presentation aims to inform the ISRU community as to what will be required to mitigate L&L risks in a lunar human campaign where repeated landings occur at the same destination on the Moon. Potential solutions will also be presented to stimulate discussion and potential new mitigation ideas [1].

References:

[1] Mueller R. P., and King R. H. (2008) "Trade study of excavation tools and equipment for lunar outpost development and ISRU." *STAIF 2008, AIP Conference Proceedings* ***969***, 237-244.