

**A NOTIONAL TUG CONCEPT SERVES AS A “STALKING HORSE” TO FACILITATE EXCAVATOR DEVELOPMENT.** Lee Johnson and Scot Szatkowski, sysRAND Corporation, 17011 Lincoln Avenue, Unit 130, Parker CO 80134, [L.Johnson@sysRAND.net](mailto:L.Johnson@sysRAND.net), [S.Szatkowski@sysRAND.net](mailto:S.Szatkowski@sysRAND.net).

For sixty years, manned space exploration has placed human beings in the ultimate “hostile work environment.” Manned space flight is an inevitable cultural imperative; the next question is how best to economically equip astronauts on their missions, not only in terms of safety, but also efficiency.

Local availability of resources enhances the safety, robustness, affordability, and endurance of manned presence in space. In-Situ Resource Utilization (ISRU) has much to offer to long-endurance missions that employ fixed bases of operations and rely heavily on automation; ISRU will inevitably be validated through a progression of mission successes. In the Lunar context, ISRU applications will typically begin with mining regolith (dirt). Surface Mining will involve the process of gleaning regolith from the Lunar surface and delivering it in bulk to ore processing plants. Civil Engineering has two principal components: geotechnical engineering, *i.e.*, working with dirt, along with structural engineering, constructing things that don’t necessarily involve dirt. A number of Terrestrial tools and “dirt” applications influence and inform corresponding Lunar applications and, by extension, formulations of Mars ISRU missions.

sysRAND is developing a planetary surface excavator with a nominal production capacity of one metric ton per hour of Lunar regolith. The excavator is versatile and is intended to capture volatiles from the start. The excavator, discharge chute, and hopper ensemble is expected to be interchangeable with other ISRU tools and appears to be the most complex of the many conventional surface tools that were surveyed. As a lead example of mining and civil engineering equipment, the excavator design team has been careful to avoid excluding other types of equipment, consistent with the collaborative culture of the company.

Identified applications include landing pad preparation, habitat and facility emplacement, utility functions, rock mitigation, mining ore, and installing structures. There are many possible constructions, such as berms, sub-surface emplacement, narrow trenches, pits, and ramps, to name just a few.

In addition to the basic tools that are necessary for harvesting lunar material as a readily – and remotely available – resource for manned space flight, a mobile platform will be necessary upon which to mount these tools. Such a platform would be the primary source of support and mobility for the excavator/tool system

itself. The platform that we propose as a placeholder is the “TUG.”

Some of the useful platform features to be incorporated into the TUG are modularity, robust power, autonomy, robotic arms, towed implement attachments, pushed implement attachments, and remote teleoperation. With these elements as a starting point, sysRAND has further characterized this mobility platform to employ turrets instead of robotic arms to provide enhanced leverage and reduced power demands for most industrial applications. The TUG model is based on a mobile deck or bench with powered forward, mid, and aft mounting hardpoints. The TUG model also features couplings fore and aft that are reminiscent of railroad couplings, for all the same reasons. The platform is unmanned, providing no riding accommodations for crew except for handholds / tiedowns that could be used in an emergency. Crew-friendly features could include oxygen, water, voice control and hard cable control options. The platform model thus anticipates interoperability with EVA crewmembers.

The TUG derives its name from its similarity to other terrestrial workhorse vehicles. The moniker characterizes the platform somewhat, most notably insofar as the vehicle is *not* a rover. The TUG’s ISRU mission is unlike any other in the NASA portfolio of mobility platforms and the name is a recognition of the features and operations that distinguish the TUG from the rest.