John Dankanich (00:15):

Hello, I'm John Dankanich, and I will be discussing the technology needs for in-space transportation capability, as well as some of the specific needs for cryogenic fluid management. The in-space transportation system area has relationships with a large number of technology areas and strategic technology plans. It includes everything from the mission design and analysis tools that define the hardware technology needs, to the new materials and manufacturing processes required to enable many of the systems to operate under extreme environments. Both induced environments, which itself range from cryogenic to internal thruster and nuclear fuel system peak temperatures and the operational environment such as deep space cold.

The capability area is often one of the largest drivers for overall campaign architectures with potential for high return on investment due to the gear ratios on Delta V intensive missions and the exponential mass impact of rocket equation performance. In addition to the numerous strategic technology plans, I always welcome the community to study the architecture trades that have been documented. When industry partners are looking to solve one of our in-space transportation challenges, the ability to quantify the key performance parameter improvement for a reference mission is the most direct way to convey the technology benefit and prioritization of resources and communicate direct return investment.

The focus strategic technology plans feeding the in-space transportation are intuitively the advanced propulsion plan, in addition to the cryogenic fluid management plan necessary for operational cryogenic propulsion systems. However, [inaudible 00:01:42] capture defines common interfaces in operations for propellant transfer, in-situ resource utilization generates the propellant for the propulsion systems, power is required for the electric propulsion efficacy as we scale up, and materials in advanced manufacturing is pervasive across all our elements, often enabling both the performance as well as the cost and cycle times we need.

Finally in space transportation ranges from micro-newton electrospray systems to large scale methane systems, and the technologies range from conventional combustion propulsion to those like solar sales, including the ones under investigation for solar cruiser for heliophysics missions, large scale electric propulsion or nuclear thermal propulsion for Mars transportation, it also includes lower maturity systems such as the rotating detonation engines for a leap and performance, and modeling efforts such as plume service interaction for sustainable lunar landing sites.

All of these elements benefit from small business and commercial innovative solutions, including deployable boom technologies, thruster designs, and maturation active cryo-coolers, and so on.

The STMD framework is based on the thrust of go, live, land, and explore. We are making the investments today necessary to enable the human exploration of Mars with acceptable round trip crew times, the efficient delivery of cargo and prepositioning assets, but also fostering economic growth in the commercialization of cislunar space.

Go is the obvious framework thrust area for in-space transportation. This includes the high level goals for crude round-trip Mars missions under 750 days, the continued emphasis on cost reduction for payload delivery to the moon, Mars, and beyond, the continued reduction in both launch and in-space repulsion elements, also the eventual transition to maximize our leverage of in-space and in-situ resource utilization for propellant production.

We are currently making investments in advanced metal and composite manufacturing to bring down both the cost and cycle times of new system production, transitioning elements of our in-space fleet to non-toxic propellants, and maturing the cryogenic fluid management system which is the foundation of future transportation architectures that include long-term storage and refueling of cryogenics such as methane, oxygen, and hydrogen.

Beyond just the Go strategic thrust area, in-space transportation touches all the elements of the framework. Surface power is required for the energy intensive ISRU. ISRU is initially focused on lunar ice to water. This requires us to demonstrate systems for collecting a purifying water on the lunar surface. The systems and processes must be capable of scaling to tens of metric tons per month, operating with little to no involvement. For this capability, we expect proposed content that might include innovative new concepts for early stage development, promising technology concepts for maturation, and technology ready for demonstrations in relevant environments. ISRU is a path for enabling human and robotic activities to extend and expand, of becoming more affordable, initially less dependent on support from the Earth and ultimately independent.

Again, after we have water, then we're going to focus on our water to cryogenic propellant, and here we will need to demonstrate systems for converting and liquefying hydrogen and oxygen from water, again capable of scaling for tens of metrics of tons per month. For this capability we expect to see proposed content that might include innovative new concepts for early stage innovation against some promising technology for maturation and technology ready for demonstrations in relevant environments.

This could be either on Earth, in space, including ISS or Gateway or some of the early lunar payloads. Efforts might employ partnerships or complement the work that's being done by industry. We need to be able to then store, transfer, engage the cryogenic systems. This includes cislunar aggregation of propulsion elements on our way to Mars, and the orbit servicing and rendezvous capabilities with fluid transfer.

Then we're going to do it all again with Mars with ISRU to generate methane and become even more sustainable on our architectures. Eventually, we're going to need to utilize reusable cryogenic propulsion systems. We're looking to demonstrate technologies here that will enable a reusable, integrated cryogenic propulsion system with a lifetime of at least 25 cycles without servicing. This will be for use for in-space transfer and also the landing vehicles.

For this capability, we'll be looking for content that might include partnership or efforts that complement work being done by industry, in particular development of components or subsystems or cooperative testing and demonstration activities for orbit transfer or Lander propulsion systems.

The aggregation over 100 technologies are needed to field the transportation elements for both the near-term and far-term future. We cannot be successful without the participation innovators and commercial partners.

In addition to the human exploration transportation systems, we still require continued advancement and maturation in systems for science-focused missions.

We are currently in the process of updating the next decadal survey, but the existing technology needs are clearly identified, and reference missions can be found in the decadal survey guiding documents for all divisions of the science mission directorate. We will need systems for lower temperature operation, aero capture and so on to enable outer planet and outer planet moon orbit insertion and landing.

Small spacecraft are also continued growth area for enabling meaningful science return with modest budgets. There were funded studies recently that highlighted propulsion gaps for the high Delta V emissions using small spacecraft. We're actually already preparing to launch inter planetary small sets in multiple of the small innovative missions for planetary exploration, or simplex required new technologies with two missions dependent on small business transportation system products.

There are still significant gaps for geocentric and small SAT transportation systems. Most people are familiar with the Starlink systems where they leverage electropropulsion to cost effectively establish large constellations of spacecraft. There are viable commercial Leo missions and a growing number of Earth observation constellations currently under consideration.

These still need reliable and high performance propulsion solutions, usually suitable for secondary payloads and viable for development and commercialization through small businesses. Many of these needs are captured under the small spacecraft or the advanced propulsion strategic technology plans.

Specifically for the cryogenic fluid management strategic technology plan, the CFM technology gaps are throughout the system and at various ranges of technology readiness level, from modest through ready for flight demonstration. They are generalized as technologies for long duration storage, fluid transfer, propelling, engaging liquefaction cross-cutting elements and the analytical tools for system performance analysis and optimization.

The CFM strategy is focused on ground system development, many through SBIRs and partnerships such as tipping points for near-term demonstration. We will benefit from progress made through the human landing system development and the flight, and then we'll perform large scale demonstrations and feed those lessons learned into both sustainable lunar architectures and also viable Mars transportation solutions.

In the very near-term, we'll be leveraging HLS investments for cryogenic capabilities. This will be for both locks hydrogen, and also locks methane systems. However, we will still have CFM technology gaps after the first HLS missions. This presentation is available for you guys to look through and we'll note many of technology challenges. Some of the elements are fluid specific.

For example, the liquid hydrogen system may be at different technology readiness level than the liquid methane. The same is true for the difficulty to mature the systems, as example elements such as the liquid acquisition devices or LADS are more challenging for the liquid hydrogen due to the viscosity and surface tension properties. We also don't need efficient 20K coolers except for the methane.

CFM is needed to support a system, and this is what we need to keep in mind with multiple components, but also to field multiple capabilities. For example, we're going to need to show that we can store cryogenic propellants before we can move on to demonstrating propellant transfer. We're also going to want to be able to gauge the propellant levels before and after this process.

Across the multiple technology needs and the applications for CFM, we have a strong track record record of leveraging small business and commercial investments to mature the many elements. We will continue to leverage SBIRs and partnerships for risk reduction as we move forward.

The technologies proposed to NASA should target the appropriate opportunity and program based on the TRL and the need date of the system. In other words, we won't likely be making SBIR or early stage innovation investments on low TRL technologies required for the 2024 manifested missions.

However, a small business developing a system that might transition to a flight opportunity investment, advances our knowledge and our matures components for sustainable cryogenic systems would be well aligned with expectations on maturation and investment phasing.

So in summary, in-space transportation has a wide range of interdisciplinary needs to enable our future architectures. As you identify innovations to solve our challenges, please leverage reference missions and quantify the key performance parameters, your ideas improve upon the existing solution. Both in the past and in the future, we will heavily rely on small business and commercial partnerships.

NASA missions require new and innovative solutions to meet our known programs of record, and I look forward to working together and achieving our goals. Thank you.