Ron Litchford (00:00):

And Welcome To The 2020 Innovation opportunity conference and greetings from the NASA Space Technology Mission Directorate. This forum has been specifically formulated for you, the nation's innovation community. Our goal is to inform you of NASA's future agenda for space and to engage you in solving the many technology development challenges that must be overcome in years ahead. In order to more effectively and efficiently convey these challenges and development needs, we have generated a collection of strategic technology plans partitioned by primary discipline areas. My name is Ron Litchford. I'm the agency's Principal Technologist for Propulsion and I would like to spend a few minutes briefly introducing you to the Advanced Propulsion Strategic Technology plan. So let's get started with a little background perspective.

The guiding principles that underline our data driven technology and investment portfolio are embodied within the STMD strategic framework and shown on the right of this slide. This strategic framework is partitioned into four primary thrusts, go, land, live, explore. Within each of these thrust areas, there is a set of strategic technology plans corresponding to the technology discipline areas of relevance. The advanced propulsion strategic technology plan, for example, is primarily aligned with the go thrust as an enable for rapid, safe and efficient space transportation. For each thrust NASA leadership has established a hierarchy of outcomes and capabilities that align with the strategic priorities of the agency's stakeholders. These outcomes and capabilities are subsequently linked to the critical technology challenges and gaps corresponding with the desired space architecture objectives. The purpose of the disciplinary of strategic technology plans is to guide the formulation of program content that will result in the closure of these key technology gaps.

The strategic framework fundamentally consists of a long term vision for the go thrust as shown on this slide. It is a [inaudible 00:02:12] like projection for future outcomes and capabilities. The multi-decade vision statement incorporates more information than we can cover in this brief introduction, I would urge you to review it in detail at your leisure on your own. The key point to note is that our strategic technology plans are the essential mechanism for relating these outcomes and capabilities to architecture technology gaps with direct impact on programmatic content.

Now, the content of the Advanced Propulsion Strategic Technology plan is shown on the top left of this slide. It includes the definition and scope of the technology domain, indication of the architecture drivers from which we derive the technology gaps and challenges and our quantifiable capability outcomes that we need to achieve. Based on these technology gaps and challenges and outcomes, we have the formulated structured technology maturation plans, which are intended to serve as a guide for closing the gaps. In addition, we also include some suggested research and technology investments in transformational technologies. Now, our transformational push technology strategy is not meant to directly address near term architectures, but it's intended to provide some sustained investment funding so that to pursue transformational technologies that could provide a radical transformative change in how we conduct space transportation in the future.

And in addition, the strategic technology plan will include some content on industry and DOD and OGA data to provide data on the current activities across the nation in the industry and the private sector and within the government. The idea is here to more better understand and coordinate our activities in relation to the activities in other organizations so that we can more effectively manage our resources and outlays. Another point to take remember is that when looking at these plans is that space propulsion technology is also included in plans beyond Advanced Propulsion plan. For instance, there are portions of the Cryogenic Fluid Management plan and the advanced Material Structures and Manufacturing plan, as well as the Small Spacecraft Technology plan, which incorporate some aspects of propulsion, which may be of relevant interest to you. So I would urge you to consult those plans in addition to the Advanced Propulsion plan.

This next slide conveys the definition and scope of the advanced propulsion domain, the icon on the X, basically it represents first of all, the space transportation triad. So propulsion technologies must support the entire spectrum of transportation systems, including launch in space and land and ascent on planetary bodies. So essentially the transportation triad represents all of the space transportation systems, which propulsion technology must address. If you look at the icon, you'll also see that there's a circle representing the different architectures, which the transportation systems must support. So traditionally NASA has focused on science and exploration. Now currently, we are moving toward a agenda where commerce is becoming an indelible part of our plans in the future. And I would also ask you to recognize that space security is something that's growing in importance and there are many dual use applications where propulsion technology that are useful for science and exploration will have implications for space security architectures as well. So all of these architectures need to be considered as we're addressing advanced propulsion technologies.

And the icons on the right hand side are just meant to represent the propulsion technology taxonomy that's being utilized in this technology plan. I think you'll recognize most of these from your past experience. They're very conventional. We have chemical propulsion, solar electric propulsion, nuclear electric propulsion, nuclear thermal propulsion, propellant-less propulsion. And we have a category which we call advanced energetic propulsion, which is essentially intended to capture advanced nuclear systems beyond NEP and NTP. In addition, propulsion systems rely on a number of supporting technologies. So there are crosscutting support technologies that are really important in terms of propulsion technology. And they're indicated in the bottom right icon collection, and those are cryogenic fluid management, advanced materials, structures and manufacturing, and power and distribution.

The next slide represents the space flight domains that we are considering in terms of science, exploration, commerce, and security. Now in the near term, the focus is primarily on cis-lunar development for CLPS Artemis programs in particular. And if you look at this slide, you'll see a number of mission applications and commercial applications and security applications that people have in mind in the cis-lunar environment. And largely these can be supported with modest [Delta V 00:07:44] requirements. So chemical propulsion and solar electric propulsion can largely support the cis-lunar development activities.

As we move out toward Mars, however, in the meso-solar regime, where we're talking about humans on Mars, search for life, sample return from planetary bodies, more in depth outer planetary science and resource mapping, we find ourselves being a real need to move toward nuclear systems. So the strategic [inaudible 00:08:11] plan for advance propulsion large part of it is address at future nuclear systems such as nuclear thermal propulsion, nuclear electrical propulsion, which will begin to provide us the littoral and blue water mobility type analog transportation capability. We will need to support that agenda. As you move out further toward extra-solar, the really far outer solar system and the stellar, the distances become so large and the Delta V requirements become so large that we're really forced to consider advanced energetic propulsion processes and concepts beyond NEP and NTP. So that forms a part of our transformational push technology strategy.

So the next few charts talk about architecture drivers. And the first one I'm showing here is for the lunar phase, the different drivers that we are supporting. One is the propulsion power element, which is the first gateway element. We're working diligently on solar electrical propulsion for that element. This is followed by the commercial lunar payload services, vehicle systems. There is a number of systems that are being developed and there's missions that have been selected for the lunar payload delivery. There are a number of technologies that are needed to enable those CLPS vehicles and STMD is working on developing those technologies to support those CLPS systems.

And for human, for the Artemis program, the transportation systems are essentially under a crew and cargo surfaces, similar to CLPS. And this is all under the HLS program. You'll probably recognize that there have been a number of architecture development selections, including SpaceX with its Starship locksmith aim through to Origin national team for transfer, lander and ascent using cryogenic propulsion and storable propulsion technologies, as well as Dynetics, which is utilizing the locksmith and cryogenic variety of propulsion technologies, including their ALPACA concept. So those are the drivers for the lunar phase.

The next chart talks about the Mars phase drivers. Essentially for Mars transport for crewed Mars transport, there are two primary options under consideration. One is the nuclear propulsion chemical propulsion hybrid, which is our current reference configuration is shown on this slide. And the nuclear thermal propulsion is an alternate configuration, which we are considering as an option. Both of these systems are capable of doing fast opposition class capability. In addition to the in space transport systems, we are looking at Mars EDL technologies for lander delivery and cryogenic propulsion technologies for the various landers and assist stages, which will be needed to support a human Mars expedition.

The next chart talks about the science, commerce and security architecture drivers. There are six total here. And they're essentially concentrated on enhanced spacecraft and platform mobility. We don't have time within this brief introduction to go into those in detail, but I would ask you to read those at your leisure and become more familiar with them because I think these are going to be the primary areas where we will be interested in investing in technology development to support those architectures.

This next slide is to give you some idea about our transformational and innovation driven R and T plans. Most of our efforts are going into architecture driven technology for CLPS, Artemis, cis-lunar, moon-to-Mars as shown on the far left of this slide. But we also, as I mentioned earlier, want to have some modest sustained investment in innovation driven research to support outer solar system and future interstellar missions, the middle of the slide. And advanced propulsion, to give you an idea of the type of systems we're talking about, you can look at the advanced propulsion landscape figure on the far right. And basically it shows you that we're seeking high... For rapid transit we're trying to achieve vehicle accelerations or thrust to waste ratios greater than 10 [inaudible 00:12:48] G. And if you examine that chart you'll see that drives you to advanced nuclear systems largely that are well beyond what can be accomplished with NEP or NTP. So these are truly advanced energetic propulsion technologies.

The next few slides are going to talk about the architecture gap indices that we've developed that include quantifiable capabilities traces to the key performance metrics that we need to achieve. So the first one here at the slide I'm showing is on the exploration architecture and it identifies the exploration technology gaps for both the lunar phase and the Mars phase. And the indices are indicated for reference purposes. And then if you follow the trace for each of those gap indices, you will come to a short description of the capability outcome and technology gaps that we're addressing. And if you follow the trace down to the bottom, you will come to the key performance metrics that we need to achieve in order to close the gap and enable the architecture of interest.

You will see that the Mars transport capabilities trace does have a split in it and that's because we have not made a decision on whether we will pursue the NEP chemical propulsion architecture or the nuclear thermal propulsion architecture. So for the time being both of those architectures will be pursued and we'll be pursuing investments to close the technology gaps for both of those architectures.

The next slide, discusses science, commerce and security architecture gaps. So we have the indices identified here, three of them for three of the architecture gaps. One for flagship electric propulsion, another for flagship nuclear electric propulsion, and another for extreme access concentrating on cold tolerant propulsion. There's a similar capabilities trace for each of those gaps, I'll leave for you to investigate on your own. The next slide is the remainder of the science, commerce and security gap indices. The first one is for high Delta V small spacecraft propulsion. So this is sub kilowatt, solar electric propulsion that would enable SPA class type of small spacecraft missions, science missions. There are unique platforms, gap indices for solar cell development and demonstration. And the final gap indices is for green propellant transition, where we're trying to facilitate and encourage the adoption of green propellant technology for future science missions.

And the last quantifiable capability traces is for transformational push technologies. I have two identified here. The first transformational R and T focus investment is on rotating detonation rocket engines. This is a technology that offers a lot of promise with a lot of risk, but it could truly transform the way we do future in-space transportation. And so we would like to maintain some sustained research and technology investment in that area. The other transformational research and technology area that we would like to invest in is advanced energetic propulsion. As I mentioned previously, as you move further and further out from the earth, further and further into space, the Delta V requirements and the distances involved really push us to some type of propulsion technology need that is beyond conventional nuclear thermal propulsion or nuclear electric propulsion capability. So this is another area of a transformational investment we would hope to sustain some investment.

Now, the next slide just quickly shows you the overlays, the technology, the evolution that we perceive for nuclear surface power in comparison to nuclear electric propulsion. And the point here is to show you that there's a very synergistic development strategy that can be put in place when we're developing nuclear surface power and nuclear electric propulsion. These are very synergistic power systems so there's much we can leverage when developing one to benefit the other.

And the next slide that I'm showing you is beginning to talk about our strategic cross program integration strategy. The first one here represents the Space Technology Mission Directorate technology life cycle. The thing to keep in mind for the Space Technology Mission Directorate is it is a collection of multiple programs. And each of those programs essentially tend to focus on a certain TRL range. So we have our early stage innovation programs, which tend to focus on TRL up to 3. Game changing development program, which is intended to focus on technologies that are in the TRL 3 to 6 range. And our technology demonstration missions program is primarily directed at technologies that really need to be flat demonstrated before they can be successfully infused and adopted for actual missions. And some of the specific programs that are how they relate to those TR levels are shown on the bottom and some of those go across the entire spectrum, such as the SBIR/STTR program, which is the primary interest of this innovation and opportunity conference.

So anyway, the key point here is that one program does not carry at all. We have to be very smart about how we develop our technologies and hand those technologies off between programs as technologies mature. And I want to talk about integrated program elements for a moment, because I think it's very important for you to understand as a potential offer of technology to the Space Technology Mission directorate. As I mentioned, none of our programs truly carry a technology all the way from initial concept, through early stage investigation, through the mid TRL maturation range, all the way to demo. It's a handoff from program to program as the technology matures. So we have to think very smart about how to utilize the STMD programs in not only in sequential way, but in a parallel way.

So this chart is an intent to convey how we might be able to do, how we envision we can do that. On the left, you can see that we're trying to increase the technical maturity going down until we reach an operational capability or commercial product or service of objective. And so, as you can see, as we initially start our technology mirror, we may have a tech program element that is internal to NASA. This may be tied to a parallel element, an SBIR/STTR, which is providing some contribution to that technology need. And there may be external program elements that also contribute. And all of these are going on in parallel aimed at an operational end game capability. And so, as you can see, as those programs mature, the TRL is envisioned that they would hand off to the next level in the sequence, another program element in most cases, and which would also proceed in parallel until you get to the point where the technology is matured enough that you've integrated all of these different elements into a final operational capability.

And the little diagram on the right is just essentially a capability development commitment partition that's meant to convey this cyclic development process where you may take one cycle around this capability commitment partition about one program and there would be a strategic inter program handoff for the next cycle and on through the next cycle, until you reach the operational capability that you're seeking.

That concludes my brief introduction to the Advanced Propulsion Strategic Technology plan. I hope it's been of benefit to you. I hope that you've gained some perspective on where headed within the Space Technology Mission Directorate, specifically with respect to advanced propulsion technology. I hope this innovation and opportunity conference is of great benefit to you. And I hope that this introduction to the strategic technology plans will give you some really good insight into what your company or organization has to offer, could impact the agenda that we have before us at NASA. Thank you.