Jerry Sanders (00:14):

Hi, I'm Jerry Sanders. I am the ISRU System Capability Lead for NASA. It's my job to understand and promote the area of ISRU, and I'm glad to be able to talk to you today. So, I'm going to talk about In Situ Propellant and Consumable Production and what NASA is doing, and how small businesses can play an important role.

Jerry Sanders (00:40):

SO, when we go to the first chart, you'll see that the Space Technology Mission Directorate of NASA is coordinating all technology development areas through four major thrusts associated with exploration: Go, Land, Live, and Explore. And in the Live area, it's aimed at sustainable living and working farther from Earth. In Situ Resource Utilization falls into this category with the main outcome of providing greater than 75% of the propellant and consumables for human exploration from Lunar and Mars resources.

Jerry Sanders (01:24):

We've further subdivided that particular outcome into three major sub-outcomes. Resource Mapping/Estimation, how do we find and categorize and locate the resources and understand them? Oxygen Extraction from regolith, being able to produce oxygen from regolith at about 10 or more metric tons per year for at least five years. And then Water Mining, being able to enable cis-lunar commercial markets through the extraction of up to hundreds of metric tons of propellant per year, and how this would help reusable landers and cis-lunar transportation systems?

Jerry Sanders (02:06):

When we look at the next chart, which deals with lunar resources, we've kind of combined and looked at them into two major categories: resources that exist in the lunar regolith and resources that exist in the poles of the moon's permanently shadowed craters. So, regolith itself contains up to 40% oxygen by mass, mostly in silicate minerals, and can be subdivided into two rough categories: the Mare, the very black material you see when you look up at the moon, and the Highland/Polar regolith, which is the lighter material, mostly anorthosite. And that's the area that we are primarily interested in because Artemis is focusing on going to the South Pole.

Jerry Sanders (02:53):

There's also other resources, pyroclastic glasses, KREEP, and solar wind volatiles that might be considered downstream. But the real goal is water and other volatiles that might exist in the permanently shattered craters. There could be 5.5 wt.% in those shattered craters that we saw from the LCROSS impact, and it may be as much as 30 wt.%.

Jerry Sanders (03:16):

So, when we go to the next chart and we look at what is really ISRU, we've broken it down into the flow from understanding the resources, looking for the water and minerals, to the two different pathways, depending on the resource, being able to excavate and process regolith for oxygen and metals, or mine that water in the volatiles. And those products are primarily aimed at transportation and crew. So, the water, the oxygen, the hydrogen, and such would be then stored and then sent to the users. And some of these products could also be used for helping to build landing pads, roads, shielding, and structures.

Jerry Sanders (04:02):

On the next chart, we see that we've broken down ISRU into four major categories and crosscutting the destination reconnaissance and the resource assessment that I mentioned, how you acquire those resources, prepare them and deliver them, processing them into oxygen and metal and other consumables, and being able to create feedstock for construction and manufacturing. And the bolded areas are the ones that we are currently focusing on primarily. The two green arrows at the bottom show that we are working very closely with the Advanced Material Structures and Manufacturing group because many of the techniques and technologies that we're interested in will be used in those construction and manufacturing effort.

Jerry Sanders (04:54):

The next chart is just an idea of how each one of the different areas, functional blocks, flow with each other. So, we'll be looking at technologies that fit into each one of these boxes and understand how they influence the functional boxes before and afterwards as a way of helping us understand and develop technologies at a very small level that can fit into larger systems.

Jerry Sanders (05:27):

The chart after that, just shows the fact that to make ISRU work we have to combine technologies from across the board, robotics, autonomy, power systems, cryogenic fluid management systems, and such. And so, we've developed a way of how we track those interactions with each other. And this chart just allows us to better do that so that you can see what's going on.

Jerry Sanders (05:56):

The next chart shows the basic evolution of how we plan on extracting and processing these resources into products. We can't get to that tens and hundreds of metric tons of product right away. So, we start working at a demonstration-scale, which would then lead us to an end-to-end pilot that demonstrates all of the aspects associated with producing oxygen or water and propellants at a scale, but not necessarily in a mission-critical role. And that would then feed into how we implement ISRU at a larger scale for maybe crewed ascent vehicles or reusing the descent stages, or even a single stage lander that can go up and down on propellant. So, it gives... It allows us to understand how those technologies will need to be scaled up and how other areas such as power and cryogenics and such have to scale up with us.

Jerry Sanders (06:54):

The next chart shows that the way that NASA and the Space Technology Mission Directorate is looking at ISRU and these two paths is to look at the fact that if we can mine water and turn that into oxygen and hydrogen and have that water available. That's game-changing, that can change how we do all of our architectures. So, we're primarily focusing on that as our leader, if we can make that work, then many things can happen. But we recognize that there is uncertainty in what are the resources in the permanently shattered craters. We know a lot about the regolith from our Apollo missions and such. So, as a follower, as a backup and a risk reduction activity, we're also pursuing oxygen extraction and metal extraction from regolith in parallel.

Jerry Sanders (07:49):

When we look at the next chart, we kind of see this flow of... Starting at ground development activities on technologies, such as drilling and working on simulants and ground development of oxygen extraction from regolith, that's going on right now, to very early missions, to look at how we would understand the resources and the permanently shattered craters. Prime One and the VIPER mission in particular, are set to fly in the 2022 and 2023 timeframe to help us better understand and provide ground truth of those polar resources. That will lead us to flying on the order of two to three different types of demonstrations at a technology scale to see how ISRU operates in the real lunar environment with real lunar regolith or in permanently shadowed craters. And based on the lessons learned of all of these different activities, we'll pick one of the two pathways, whether it's oxygen extraction from regolith or polar water mining and processing into oxygen and hydrogen, as our step for the pilot plant. Once the pilot plant is done, we can then go into full-scale production for landers and other applications.

Jerry Sanders (09:13):

The next chart kind of shows a concept of operations that we might use associated with looking for water, whether it's a very short exploration, exploratory evaluation, or a very detailed, focused exploration that might be needed to understand the resources.

Jerry Sanders (09:33):

The chart after that starts to talk about the water mining aspects. We're currently at a very low technology readiness level. And we understand that to select this mining technique, we really need to understand, not just the mining technique itself, but also how we're going to get power into the permanently shadowed crater and how we're going to remove the water from the permanently shadowed crater to where we set up our bases outside, where the astronauts exist. So, we started to look at a number of different technologies. None of them are perfect at this point. And so, we're pursuing several different pathways.

Jerry Sanders (10:12):

The chart after that shows basically our concept of operation for oxygen and metal extraction, where we have a lot more experience. We've developed several technologies, we've performed system level tests at analog sites in Hawaii, but there are a number of different factors that we have to understand and a number of options that exist when furthering this work.

Jerry Sanders (10:39):

So where are we today on all of this? Well, this last chart is somewhat of an eye chart. Hopefully, you'll have a chance to look at it in detail on your own, but it starts to break down what are the gaps that we see when we look at these three major efforts? How do I find the resources and assess them? How do I mine water and permanently shadow craters? And how do I extract oxygen from that lunar regolith? How do we demonstrate the techniques that are scalable operating under these extremely harsh conditions with extremely abrasive regolith for very long periods of time?

Jerry Sanders (11:19):

And to give you an insight, we have been working with small businesses for decades, allowing them to develop different technologies that flow into our systems. And in particular, on the left-hand side, I'm showing what areas we focused on and what were some of the technologies that were selected to give you an idea of what we've worked on in the past. And to let you know, we look at SBIRs very seriously to such an extent that our second field test in Hawaii was made up of hardware that had been developed through partnerships with small businesses in all the different areas and we called it Dust to Thrust because it included the ability to excavate, process, store, and utilize the products, in particular oxygen, from the Hawaii tephra. And with that, I'll bring my presentation to a conclusion. Thank you.