Lunar Communications for the Artemis Program

IPNSIG Academy - October 30, 2024

Dr. Alberto Montilla - IPNSIG: Good day, everyone, and welcome to the best moment of our week, the IPNSIG Academy. My name is Alberto Montilla. I am a board member of the IPNSIG. As we go to the presentation today. Let me tell you a smaller story. I was on a party this last week and while meeting one of my friends, he asked me about, the endeavors of my company and I was talking about, testing in the ISS and I was talking about our projects for Lunar Communications, and he asked me a question that made me think what companies are, working to try to not only get us to the Moon, but to provide communications to the Moon.

And this question, or the answer to this question, is central to our topic today. Today, you're going to hear how a global company, KDDI with their vision 2030, aims to support. Our endeavors and our communications on CIS lunar space. So please pay attention because the the story is fascinating. With that, I'm honored to host an incredible leader, Shuichi Ichimura.

He will be presenting us from the KDDI perspective, Lunar Communications for the Artemis program. He is the strategy lead of space, business and technology at KDDI Corporation. He is currently overseeing lunar navigation and communication projects, including 3GPP, also known as Mobile Technologies and the Moon, and before joining KDDI, He was engaged in research with regards to lunar based structures at JAXA, the Japanese Aerospace Exploration Agency, and also served as JAXA flight director of the International Space Station and led the flight controller team in the Human Space Program.

Shu earned a master's degree in aeronautics and astronautics from the University of Tokyo. Shu, welcome to the APNC Academy, and thanks for being with us today. Floor is yours.

Shuichi Ichimura - KDDI Corporation: Thank you, Alberto, and thank you everyone in the audience for having us. So, good evening, good afternoon, and good morning in Asia Pacific as well. So, currently I'm working at KDDI. I'll introduce my company a little bit later on. But today. As Alberto mentioned, Lunar communication will be a very essential infrastructure and very important element to lead Artemis program into success.

So, this session, I would like to introduce what we are aiming and what we are currently working on with the Japanese government and other companies as well. To start off this is my self introduction. So, currently I'm the strategy lead of the space business and technology at KDDI. I used to be used to live in the States with my family when I was a kid, so I started.

As a very I was very excited watching Space Shuttle back in the 1980s. I was, I went to the Kennedy Space Center, my family took it to the Kennedy Space Center. So I was really crazy about space and one day I was I'm still dreaming about going to outer space as well. So this is my how I started my space career.

And when I was at graduate school, I went to the JACS Sagamihara campus which studies on various kinds of science, and my study, research theme was to study on the lunar base human lunar base, so that so I was trying to design a, like a lunar base that I will be living in the future.

And after that, after graduation, I went to the JAXA Tsukuba Center to be part of the Human Space Program, which you can see at the very bottom. International Space Station, I was doing both the training and also the operation as well. And I was one of the JAXA flight directors of the International Space Station.

I enjoyed my job very much working with the astronauts and also other flight controllers all over the world and the instructors. That was a great moment, but it was great fun for me, but I thought I should use. Spend my rest of my life trying to contribute to use this space technology to solve issues on Earth as well.

So, like, space business yeah, so that's why I moved to a company, KDDI. Yeah. KDDI is one of the Japanese telecommunications companies. So I'm trying to use my network with the space community and tied to a Japanese industry to use its Japanese industries assets to leverage that assets to accelerate the establishment of the Lunar Nav and Comm system.

So, who we are, KDDI, again, is a telecommunications company like AT&T and Verizon and Orange and Global. We have more than 60,000 employees and connect 190 countries using the fiber optic subsea cables, 40 plus data centers in 13 countries. This is the picture of our strategy, business strategy domain, and of course you can see the 5G, the 5 generation 3GPP network with the data driven generation generative AI in the middle surrounded by the digital transformation and the finance and energy sector of the business.

But we also have space at the upper right. This shows that, as a company, we are trying to accelerate the the space business on our own and also globally as well.

So, when we talk about space business, we started as a SATCOM service provider back in the 1960s. So our first trans-Pacific connecting between U. S. and Japan. This was the first ever TV relay through the satellites. We started from there, and we have a lot of partners satellite satcom operators as a partner. We also provide Olympics TV. Also, when we have disasters, we cannot use our terrestrial mobile network, we use, of course, satellite network as a backup, and try to maintain the communications.

From the technology perspective, we have developed a couple of technologies. I'm not going to go through the details here, but including the the antennas, the big dishes, and also operational wise, how to optimize the satellite locations in the geosynchronous orbit.

We've developed a couple of user terminals as well. And, of course, always the video coding, like compression technology is also important.

So these kind of element technologies that we've provided has been incorporated in our SATCOM services.

We have a very large teleport at the western part of Japan in Yamaguchi Prefecture. Nearly 20 antennas, including these 30 meter plus dishes. We've been operating since 1969, which I guess is Apollo 11's landing on the lunar surface. So it's really had a long history.

When we talk about SATCOM services we are partnering with SpaceX since 2020 to provide Startlink services in Japan. What the role for us in Japan was to support SpaceX from the regulatory perspective. Of course, they need license from our government.

We also do need to do the coordination of the spectrum as well. And, of course, we need, land to put the ground stations on the the Japanese property. So, those kind of stuff -- technology, the ground segment support, and off the regulatory perspective, we've been supporting SpaceX.

And that's why we became the first partner in Japan providing Starlink.

This slide shows the the actual use case. In Japan, so we've been using it as a business to provide SATCOM high data rate services at the construction site, and also, like, support the remote monitoring of infrastructures, and use it in a disaster situation to provide communication to the drone or the the quadcopters to that will deliver medical equipments to the site as well.

We also provide communications through our ships. We own two ships like on the picture.

Also, we provide communications for the customers that who will like to go abroad the ship or boat, and provide Starlink service as well.

We also are doing a proof of concept type of experiment right now to provide a direct-to-cell service in Japan. Well, no later than December 2024 this year. I guess it was last week, that we've announced that we did a a test or the experiment about the proof of concept type of test in Japan, and it was successful, so hopefully we'll be able to start service in Japan as well.

That was a couple of background of what we're doing about space communications. I mentioned that we started our history back in 1960s, we're going to be trying to expand that to to the Moon as well. So, hopefully we'll be able to provide Moon to Earth or Moon Earth to Moon direct communications starting from like 2028, and also the 5G on the Moon as well.

When we talk about Lunar Communication Service there are three segments. Number one is if the spacecraft is within the sight from the Earth we can use our ground stations, like a 20 meter dish LEGS-compliant antenna dish to provide the communications between Moon and Earth. It's going to be DTE, direct-to-Earth type of communications.

If the spacecraft is orbiting or traveling on the far side of the Moon, we need a relay comm satellite that will be orbiting around the Moon to provide communications on the far side.

We are expecting many users and many astronauts as well to be on the South Pole region. There'll be a lot of nodes on the South Pole, and it will require high definition live video streaming as well.

Not just us, but also NASA thinks that, there should be a 3GPP communication mobile network on the Moon, like we have on Earth, to provide high quality communications, compared to Wi-Fi and UHR.

So, I know that Nokia made a presentation, and Alberto was the moderator of that session as well. Nokia is way ahead of us. They're working with NASA a couple of years

ago, doing similar kind of studies that we've been doing with JAXA. I'm going to introduce a couple of activities that we've been doing so far.

The first one is talking about our trade off studies about the end-to-end communication architecture. We've been partnering with, of course, JAXA, but also other satellite operators, Japanese startups to think about, start from, what will be the requirement? Who will be the users? What will be the requirements? Would it be audio or video? And how frequent that we will need the communication?

We about the restrictions. Of course, Moon is very far away. The satellite size will be limited because the launch cost is not cheap. So, we need to think about how many satellites that we will be able to launch, as well as what kind of orbit will be the most efficient orbit to provide the relay comm as well.

There's a ground station, there's an Earth orbiter, which is basically going to be orbiting or at the geosynchronous orbit. We also think about the optical communications versus the the RF communications, or the mix of that as well.

So, there are a couple of trade-off studies that have been going on. NASA and ESA are doing the same thing as well, and on the right hand side, we've done an initial study of how to establish a mobile network. when we say establishing a mobile network, we're not just setting up a base station that can cover like 10 kilometers in diameter, but we also need to think about the the joint operation with the Lunar Relay Satellite and the direct comm with Earth as well.

So, as I mentioned in the previous slide, we need to combine these 3 segments: the ground station on Earth, the relay satellite orbiting around the Moon, and the mobile network on the Moon. So, when we say lunar communications, we need to think about using all of the assets or elements to provide services and switch the communications and services as well, so we need to think about those kind of orchestration type of thing.

Radio propagation? I think Nokia also mentioned, and they were also studying about this, and NASA is also studying about this. I know about that as well. But, KDDI has been doing this from like three years ago, I guess. We use the the regular stimulant, and basically we've measured a couple of how it reflects the RF emission and a couple of patterns. Based on those measurements, we have developed a simulation model using the digital elevation map of the Moon and simulating that, what if we set up a base station, like a 10 meter high base station, or 20 meter high base station, at this particular location, what kind of coverage we'll be able to have, and how the data rate will be as far as the astronauts or the rover walks away or moves away from the base station.

This is a future image of the Lunar 5G comm. So, I just put the 5G antenna tower on the Moon's surface, and I don't think this is going to happen in the 2020s. Somewhere in mid-2030s, hopefully we'll have this kind of image as a real picture.

I guess we're going to first start with setting up an antenna on the HLS, the Human Landing System, on top of the lander, and then when we find a permanent location on the Moon, I guess we'll be able to set up a lunar tower, but, this is the future image.

As I mentioned, this is not going to be just a communication service using this 5G antenna, but we will need to combine the communications from the Earth and also the relay satellites as well.

I guess, it was mentioned in Nokia's presentation as well, but why we are trying to develop this kind of infrastructure or provide a service, is because, if you imagine the astronauts walking on the Moon, if we don't have this 5G antenna, they will need to carry like a 50 centimeter or 17 centimeter antenna dish to communicate with the satellites and the Earth as well, and that is not realistic. So, instead, we have it in the smartphone in the pocket. Like the same fashion, it will be more convenient and it will provide more high data rate as well, since the lunar orbiter will be orbiting like 7,000 kilometers above the lunar surface.

So, if you want higher data rate it will be better to have the the communication infrastructure on the Moon as well. There are some discussions whether we will have like the 5G base station or antenna on the rover as well. It really depends on how far we will like to travel from this permanent base station or the antenna attached on the human landing system as well. It depends on the use case, and also what kind of comm requirements that we have.

So here's I'm going to show a video. I hope it will work. We've been doing the desktop research as well, but we've been doing our a proof of concept type of demonstration, and this is the video that we took with our partner, GITAI. GITAI is a wonderful robotic startup, and we've been partnering with them since the last year. They're very good at developing these inchworm type of robots and also rovers as well. Here's the five meter high base station that has been built only using the robotics.

So, we've been assuming that no astronauts, or no crane, or like excavators, will be on the Moon at the initial phase. We need to think about how to set up a antenna. This white pole is antenna, and it has been latched, and after the establishment, we're going to do like a connection, you'll see the light will be turned on like this.

We also did a disassembly demo as well, so that we can do the R&R or the replacement in the future, if we need to replace the antenna as well,

So, this module type of structure will help us in the future, just using the robotic technology as labor instead of the astronauts to assemble and disassemble and do the replacement if it doesn't work, that kind of stuff.

Instead of those kind of technology perspective, we also need to think about the spectrum as well, and I know that the audience that is joining tonight or this morning is aware of this, and, I guess, they are more experts than myself, but we're following the SFCG, the Space Frequency Coordination Group's activity, and we've been following also the LunarNET interoperability specification documentation as well, and the ITU activities as well, which is gonna be in the next slide.

We are aware that at the WRC 23 last year, there was an agenda proposed from the CITEL, or the Northern, Southern America region, to study about using the frequency bands on the Moon and also not just on the lunar surface, or between lunar orbit and the lunar surface as well, and that includes a couple of spectrums that we use on the ground as well.

Basically, we support this proposal. It covers the spectrums that we use on the ground, so it will be easy for us to apply the 3GPP standards as well as our knowledge and also technology that we've developed on the Earth as well. Hopefully this study will go as expected, and hopefully we'll be able to use the spectrums on the Moon and also in between the lunar orbit and the lunar surface as well.

As I mentioned, KDDI is supporting some activities as well. There's a chairman, Mr. Kawai, has been serving as a chairman of ITU-R, SG4, and Working Party 4C, which covers basically the SATCOM, like a mobile satellite service and also the radio determination satellite service, and we've also been supporting the SG7, community, to discuss about the lunar spectrum as well.

Okay, a couple of more slides.

Although, Nokia and NASA, and also ourselves, and with JAXA, have been studying about how to develop and provide communications on the moon. There will be a couple of discussions from other, perspectives as well. This slide shows a couple of discussion topics or areas of interest, if we were to apply the Internet protocol that we use on Earth to the Moon to Earth communication.

There'll be discussions about how to route and how to provide the address, schemes like the routing protocol and the multi-domain network, whether we need to think about combining the lunar surface communications, which hopefully will be like the IP, and between the Moon and Earth, which I guess, the DTN or the Bundle Protocol type of protocol has been being discussed, and on Earth we use the IP protocol. So, how to combine these, how to orchestrate those different protocols will be a topic as well.

On the transport layer, we'd also need to think about that timeouts, and the congestion, how to control the congestion or the flow, of course that we do on Earth.

Earth and Moon are far apart. It takes about 1.2 or 1.3 seconds one way in between Moon and Earth. So, if we just try to apply these protocols that we use on Earth, maybe we will be experiencing a timeout as well. Since I've been working as an International Space Station flight controller, I know that there are like tedious handovers, and so there are a expected loss of comm time for like 10 seconds loss of comm, when we handover from one TDRS satellite to the other TDRS satellite. I'm expecting that it will happen between the Moon and Earth communication, if we have direct communications, and if we use a couple of different or lunar orbiters, as well.

I'm not an expert on this field, but my colleague and I have been discussing about this, and if we were to apply the internet protocol that we use on Earth, some technology will not be able to deal with this expected or scheduled loss of comm, and treat it as a like a failure or something, so how to apply this kind of protocol that we use on Earth will be discussed.

And, application protocol? I guess there will be a couple of issues as well. It depends on the application, but let's see. One example is that if astronauts want to play a video game on the Moon as a part of entertainment, and they want to do a video game that communicates with Earth, it will be, of course, a delay, and so how to think about the application service will be another issue as well.

Of course the clock synchronization will be a huge topic.

So, when we talk about service level, there are a couple of issues that we need to discuss and think about from the technology perspective as well.

This is my last slide. I've been introducing our initial activity that I've been working with with JAXA and other companies on from a couple of years ago. Hopefully we'll be able to develop a lunar surface communication infrastructure and start providing services in like 2030, maybe, but the point here is that it will not be easy for just one company in one country to develop lunar surface communications -- not just the lunar surface communications, but also the entire lunar communication elements, including the ground stations and the lunar orbiter as well. So, interoperability would be the key element in order to establish a huge infrastructure like communications to contribute to the Artemis program.

I know that LunaNet would be a very good standard or guideline how to develop this kind of infrastructure, so that any users -- like, there's a rover running in between our network and also other 3GPP communication service providers' network, so, like the roaming on Earth, the driver of the rover will not be will not need to think about changing the communications, technically, they just walk through, or run through, drive

through one service area to another service area, and they'll still have the communications maintained.

So, that kind of is the picture that we need to establish, and from the Japanese contribution, japanese telecommunications provides, a high quality communication service in Japan. Japanese customers are very demanding, in a good way, about the communications service quality. So, for the QoS perspective, we've been jointly working with the vendors at the initial stage of the development of the 4G, 3G, and the 5G as well, including the chipset development to provide a high quality service with a mobile network service.

Hopefully we will leverage that kind of knowledge and experience to this global effort, and, yeah, hopefully in the future contributing to the EVAs, and also providing wider coverage cooperating with other service providers, and redundancy as well, and maybe higher throughput by the carrier aggregation, and more precise PNT. It will be better to have not just one base station, but more than two as well.

Okay, so that's it for my presentation. I guess I'll Give. It back to Alberto and take some questions.

Dr. Alberto Montilla - IPNSIG: Thank you for the presentation. I see questions coming through. Let me start with one.

KDDI has an extraordinary history, starting from satellite communications to mobile networks, all the way from, 3G, 4G, 5G and now with their 2030 vision, aiming to continue expanding on that, going to the Moon. KDDI being a service provider, are there any initial learnings on the operational side? For example I got amazed by the video on the partnership with GITAI because, for example, my first job, I had to climb on the towers, with the tower person, to basically move antennas up and down, tilting etc.

I see the operational advantages of, yeah, you're on the lunar surface, better this stuff installs itself. So, are there any initial operational learnings from your initial prototypes, or just from the KDDI heritage?

Shuichi Ichimura - KDDI Corporation: Thank you for the great question. So, yeah, there are a couple of lessons learned from this demo and other studies as well. The main topic that we've been thinking of is how to jointly operate the base station, and also the lunar orbiter, and also the direct to Earth Moon type of different elements.

But, when we talk specifically about this the demo it really depends on the lunar surface. This is like a five meter tower, so it's not that difficult. Well, actually some kind of issues happened during this demo as well, but if you were to build it higher, or the taller tower, it will have to have a stable base on the lunar surface.

To establish that kind of higher or a taller base station, we need to know how the regolith reacts, and how the regolith is, whether it's soft or not, or if you have a hard surface, how stable it is, and how the horizontal and the vertical angle will be, so how to detect the angle of the slope, and how to establish a vertical tower, that kind of technology and operation will be necessary. It has to be done autonomously.

So, that kind of issues that we have been trying to find out.

Dr. Alberto Montilla - IPNSIG: Awesome. Thank you very much. So, let me go to the 1st question from the audience.

This is from Eric Klein. When folks talk about 5G on the Moon, given the time scales involved in the deployments, 2030 and beyond, is it the intent to deploy the latest 3GPP service, let's say 5G or 7G or, whatever it is at the time? Or is it 5G specifically the only candidate for deployment?

Shuichi Ichimura - KDDI Corporation: I think that is a very good question, and it really depends on the timing. Currently, 5G has been developed and start the service a couple of years ago worldwide. Our assumption is that start providing this mobile 3GPP communications on the Moon in early 2030s.

So, if we think about the generation of the 3GPP, 4G technology or components or elements may not be existing, or may not be the major component, on Earth at that time. 6G maybe. The initial phase, or the service providing, will be started in the early 2030s. When we look at 3GPP standards, communications, or coordination, there are lots of discussions still going on for the 5G element as well.

So, again, if we think the timing is that the early 2030s to start this kind of service, 5G will be the best choice from the generation development perspective. Hopefully by 2030, there will be more world standards development, more lessons learned, incorporated, and technology wise, we need to have high reliability technology, including the components, and also the subsystem as well. So yeah, maturation wise, I guess 5G, that's why we're talking about 5G.

Dr. Alberto Montilla - IPNSIG: Awesome, thanks for that. And if I may add, consider that also, at least the plans from NASA, I think that one of the goals is to replace the existing user communication architecture, which is decades old, and use basic UHF push-to-talk for that matter.

So, even 4G is a big leap from the current communication that is aimed for EVA.

I think there is a little bit of urgency to looking at and testing the technology. For example, the Nokia demonstration is based on 4G, on LTE, and it might be viable as a

technology to replace existing UHF-based user communication. So, as you said, time will probably say everything.

Anyhow, let's go to the next question. Has KDDI spent any time considering a Bundle Protocol, that is DTN, delay and disruption-tolerant networking architecture, to address some of the application protocol routing, connectivity, requirements you mentioned towards the end?

Shuichi Ichimura - KDDI Corporation: Thank you for another great question. We've been talking with JAXA from last year, and the specialists of DTN in JAXA. And so, the answer is yes. We have not been deeply engaged yet, but when we discuss about the network between Earth and the Moon, including the lunar orbiters and the Earth-orbiting satellites.

We need to think about the different protocols that have been used and how to orchestrate those different protocols. DTN is, of course one of the options, or the mainstream at this point. So, yeah, the short answer is yes, but we've just started about that kind of discussion.

Dr. Alberto Montilla - IPNSIG: Awesome. Thank you. There are a lot of enthusiasts of DTN in our community, but as you said, the most important piece is to make sure that we can connect to the Moon.

Next question. Do you see any issue that is specific to 5G, to the lunar environment?

Shuichi Ichimura - KDDI Corporation: Yes that is a great question.

Well, I guess there are many issues that we need to solve at this point. Nobody has tested or developed a 5G infrastructure on the Moon. So, we also, of course, need to think about how to apply hardware-wise, need to make it more light and more low in power consumption, and how to deal with the radiation, those kind of hardware issues as well.

Of course, one of the issue or the topic that we've been talking internally is which , 3GPP standards that we'll be applying for this lunar operation. There are many, I mean, thousands, or more than tens of thousands type of standards, I guess, and if we simply just try to put all of the standards that has been incorporated into the system, that will be easy for us, because we just need to think about whether the system will be able to handle the lunar environment physically.

But, if you want to make the system smaller, and also if you want to add some kind of specific standard or functionality, then there's another discussion there how to minimize which standards we need really to pick, to make the system more simple and

reliability. But, on the other hand if we we customize the 3GPP standard that been incorporated in the system.

We need to do go through the verification test as well, because the current 5G system on the Moon has been optimized and tested, and lots of lessons have been incorporated as the standard as is. So, yeah, that kind of issues that it's getting more software-wise, and it's getting more complicated when we talk about 5G, so, yeah, there are many kinds of issues there when you think about.

Dr. Alberto Montilla - IPNSIG: Indeed, and as you said, we will learn more, as more testing, simulations, and initial deployments happen.

So, let's go to the next question, and this is more to looking towards the future. Do you see a constellation of satellites in the future, so that there will be full coverage direct-to-cell on the Moon?

Like, with a trend with Starlink here on Earth?

Shuichi Ichimura - KDDI Corporation: Yeah, that will be an ideal case. Well, when we just talk about the the service point of view, yeah, we've been talking about this, and it really, it's really a cost effective, balance type of thing.

And also, we also need to think about the the distance from the lunar surface and the satellite, if we want to maintain the satellite, or if we want to minimize the amount of the propellant to control its orbit. There's a good frozen type of orbit around the Moon, and that orbit will be 7,000 kilometers apart from the lunar surface.

So, from that perspective, it might not be good to send video streaming in between the lunar surface and the lunar orbiter. Maybe just the text, or the emergency call, that kind of stuff might work. But, so we also think about how the altitude, where to put the orbit, and how to make it sustainable from the business perspective as well.

Dr. Alberto Montilla - IPNSIG: And yeah, I think you were hinting also to the fact that, at the end of the day, the application decides whether it is feasible or not. NASA is initially thinking of, or is progressing to make the 3GPP primarily for EVA, and one of the primary users is the communication with the astronauts.

And, they want to do 4K media. That's going to be very hard to do direct-to-cell just because of the throughput that is required. So, lunar surface communication infrastructure might be required for those use cases. Then other use cases, as you said, IoT or similar then might be more suitable for direct-to-cell.

Awesome.

So, this is a different question. This is from Max Medina, it's more like an architectural or construction question. The question is related to the design of the tower. Does it have to be vertical? And the main question is related to the fact that the signal will hit in different directions, depending on the location of the Moon.

So, he offered some ideas on that and happy to connect and share later. So, Max definitely just reach out to the IPNSIG Academy. We can make a connection.

Shuichi Ichimura - KDDI Corporation: Yeah, thank you very much. It's a very interesting question. The reason that we've been looking for this vertical type of tower is because we want to stretch up high as possible so that we can have the sunlight, and also to emit the the RF signal as far as possible.

So, we just started. Those are the assumptions that we've started thinking about when we established about the tower, but if there are other topics that we need to think about, issues, and also if there are other ideas, we'll be more than happy to discuss about it. Thank you very much.

Dr. Alberto Montilla - IPNSIG: Next question, this question is from Scott Johnson. As you make technical decisions on the architecture, are you focused only on Earth to Moon connectivity? Or do you expect that your architecture will escape to higher latencies? I would imagine that he is talking about other planetary bodies like Mars and such.

Shuichi Ichimura - KDDI Corporation: Yeah, a very interesting question. Thank you very much, Scott. As far as we've been studying so far, we've been only focused on between Moon and Earth. We never thought about expanding this, or starting from the Mars to Earth communications, and then, as a step stone, the Moon. We never thought about that.

Dr. Alberto Montilla - IPNSIG: Okay, that's great. Last question. What are the requirements or considerations for standardized communications around safety of life use cases like 911, 999, on the Moon?

Shuichi Ichimura - KDDI Corporation: Yes, that is a great topic, and I don't have the answer at this point. This kind of topic needs to be talked at the LunarNet community, or internationally with NASA, ESA, and JAXA.

I know that there are search and rescue type of functionality that will be incorporated or required at the LunarNet infrastructure, and I guess, when we talk with astronauts, they say that, hey, we don't need a sophisticated or a complicated communication technology, what we want is a high reliability communication method, so that we can communicate in case of an emergency, that kind of stuff. So, there will be a requirement. I'm sure there'll be one, but I don't know how.

We need to think about how we have been done in the space industry, and maybe have some people or specialists from the ground, the terrestrial mobile network specialists, how, which technology will be the most reliable.

But, we use it for the satellite SATCOMs on Earth as well for this kind of emergency call. So, I guess there's kind of a couple of options to discuss about.

Dr. Alberto Montilla - IPNSIG: Yeah, indeed, as you said, LunaNet has LunaSAR specified, or being specified, which is search and rescue services, basic distress signal, and from their responses, I think that the good news here is that the 3GPP systems already support, as you said, emergency services and, that's a low latency channel and mechanism to connect emergency calls. So, I think that, that could be those 2 things would end up providing emergency services, but there is more specification going because LunaSAR right now is an idea or an objective, but it's not fully specified yet. NASA is working on it with the different partners. As soon as that is specified, then it might be easier to see how this would map to 3GPP primitives.

Awesome.

So, with this, shall we get to the end of the questions and the end of the presentation?

On behalf of IPNSIG,, I want to say a big thank you for letting us listen, and experiencing the great progress that KDDI is doing, contributing to the the creation of the Solar System Internet. This is what this is all about. This is what we, as IPNSIG members, are passionate about. So, thank you very much.

With that, let's close the academic session with a couple of reminders. The first one is, this keynote and previous keynotes are available in the IPNSIG website. You go to ipnsig.org/events. And, if you have any questions or comments, please reach out via email.

The work of the IPNSIG is volunteered. We do run into administrative expenses, so we kindly suggest you donate, whether it is $2, $5, $100, $1,000, it's up to you, but please contribute to our mission to expand networking and with the objective of making the Solar System Internet available to everyone.

We are more than 1000 members currently. We want to continue growing. We want to continue being a global organization. So, for those of you that are attending that are not members of IPNSIG, please join us. You can send a message to membership@ipnsig.org, or you can go to the ISOC page and subscribe to the Interplanetary Chapter from there.

With that, I want to say thank you again. Thank you, Shu, and thank you for all the attendees and the organizers, and we will be redirected to a short survey. Thank you very much and have a nice day.

Shuichi Ichimura - KDDI Corporation: Thank you, everyone.