WEBINAR SUMMARY:

# Innovation in Space

With Naoko Yamazaki & Professor Sara Russell

*Thursday 30 November 2023*

**Introduction by Professor Sara Russell:**

It's such a privilege to be able to talk to the distinguished astronaut Naoko Yamazaki about innovations in space and about international relationships in space. At the beginning of our explorations in this field, exploration was fueled by competition between the United States and the former USSR, who were both wanting to be the first to reach the big goals like reaching the moon. But today it's a very different landscape. Today the key word is cooperation, with nations working together. I've just come back from Japan after working with the Japanese Space Agency on a very exciting mission of theirs called MMX. For those of you who don't know about MMX, it is a Japanese-led mission that's going to go to Phobos, the largest moon of Mars. It's going to collect a sample from the surface and bring it back to Earth in 2029 for the world's scientists to analyze. Although it's led by Japan, it definitely involves international cooperation. For example, there's a German-French team that's building a little rover that's going to go across the surface of Phobos. There are also American teams and French teams who are building parts of the instruments that will be on board.

However, international collaborations are not completely without risk. There was a sad story a couple of years ago. The European mission ExoMars, which was due to launch in 2022 to search for past life on Mars, unfortunately had to be postponed. This is because it involved collaborations with Russian partners, which weren't possible following the invasion of Ukraine. That story has got a slightly happy ending in that now Europe has found the funding to go it alone with that mission. The UK Space Agency actually recently announced that they are going to fund Welsh and English scientists to build one of the key instruments that will be on board that mission. This instrument is a spectrometer that's called Enfys, which is Welsh for rainbow. So that mission is back on track, and is going to launch in 2028. This is an example of how the space exploration world changes so quickly and is expanding so quickly as well. I'm really keen to hear the views of Naoko-san on these issues.

**Discussion:**

**Professor Russell:** Welcome, Naoko-san. My first question for you is, there are a number of actors from new countries getting involved in space exploration, as well as the private sector getting involved. What do you think are the main changes that have been made since you started your journey in space, as it were?

**Naoko Yamazaki:** Space exploration has been changing rapidly because more players are involved in space exploration. On the lower Earth orbit missions, the current ISS, International Space Station, is the main platform. 15 nations are involved. Now we're switching to a commercial space station and commercial platforms for lower Earth orbit. Governments now are focused on what's beyond the lower Earth Orbit. They are interested in the Moon and Mars. We are currently trying to build infrastructure there, not just going there and coming back. To build infrastructure, this involves power, electricity, water plants and so on, and therefore just one nation or one company can't afford it all. That is why collaboration is key. It is a more chaotic environment with more players, but it's still very important to collaborate all together.

**Professor Russell:** Yes, this cooperation has always been regarded as important, as you rightly said. But as I referred to a little bit in my introduction, there are some geopolitical frictions among global powers, which can cause problems for collaborations. What do you see as the main challenges in that field in the future?

**Naoko Yamazaki:** Recently, the University of Exeter opened up the SpaceGov platform, which is connecting governments, private sectors, and academia all together to mitigate risks and increase sustainability in space. So I joined its advisory group. There are 15 nations involved in the ISS, the International Space Station, and now the Artemis programme involves 32 nations. I expect more countries will join Artemis, of course. In comparison, China and Russia have a plan to build the International Lunar Research Station, ILRS. So far, Pakistan, United Arab Emirates, and APSCO (the Asia-Pacific Space Committee organization led by China) have all signed the agreement. I also expect more countries will join in that programme as well.

For the International Space Station, the two major countries, the United States and Russia, cooperated together. Even after the Russian invasion of Ukraine, this cooperation will continue until 2028. But for lunar exploration, it's going to be separated, as well as the Russia-China alliance and the other Artemis alliance. So this is a big challenge. This is because for the Artemis programme or the China-Russia program, they are aiming for the same spot, the South Pole. The Artemis programme selected 13 candidates for human landing sites, near the South Pole because it should have plenty of water, good communication to the Earth and have good conditions in the summer. Now there is a lot of competition for these 13 places.

**Professor Russell:** That's really interesting to hear. Do you think that this competition between China and Russia on one hand, and the US and others on the other, do you think that will kind of make us all do better because we have this sense of competition? Or do you think that complete cooperation would work better in the exploration of the moon and other places as well?

**Naoko Yamazaki:** Back in 1967, just before the Apollo 11 moon landing, it was very fortunate that lots of nations agreed to sign a space treaty. 100 nations signed a space treaty. It regulated basic concepts about space activities. For example, no nation can own properties on any planet or even an open space. It should be a common space. Also for astronaut rescue, every nation should support each other. It is very fortunate to have the Space Treaty because it's kind of an umbrella to regulate the basics. But it didn't regulate commercial activities, and it did not prepare for the future, as nowadays space exploration is much more active. There are lots of grey areas which are not covered by the Space Treaty. It is very difficult now to make an update of the treaty, because some nations have different philosophies, and therefore it is very challenging to come up with one agreement. That is why now we have a kind of alliance system, like the Artemis Alliance and the China-Russian Alliance.

**Professor Russell:** Do you think the time has come to maybe rip the Outer Space Treaty up and start again and try and produce a new treaty that's more fit for the 21st century?

**Naoko Yamazaki:** Yes, that needs to be done. It's too complicated. But, for example, with Artemis, if some space agency or even some private company builds a lunar base or some facility on the moon, or even sends an unmanned spacecraft to the moon, to avoid conflict, there should be a safety zone around the facility or space probes. But that would almost be like owning property on the moon. So it is a very grey area.

**Professor Russell:** So you referred to private companies being part of the new exploration of the moon and other places. What do you see as their role going forward in the next decade or few decades? Do you think that ultimately they will kind of rule the space waves as it were? Do you think that would be an advantage or a disadvantage to space exploration?

**Naoko Yamazaki:** In a decade or two, if we move forward with space exploration, then we can probably update the treaty. For example, for the space debris problem, it is getting very severe during a low Earth orbit. This is because more satellites have been launched recently. So with some basic guidelines outlined by the United Nations, each nation is now getting serious about creating its own regulations. These movements will probably apply to space exploration as well. I would like to hear your opinions as well, from your perspective, on space exploration.

**Professor Russell:** The work that I've been involved in is more kind of beyond low Earth orbit. It's more to do with looking at moons and Mars and asteroids. I think that we're at a really exciting time in the world. I'm sure that commercial operations are going to become more important, like SpaceX, for example, being involved in the launches of many NASA missions nowadays. So I think that's going to become more important. But I think you're right to point out the problems that we have at the moment with the Space Treaty and the need to deal with things like the debris in it that's currently in low Earth orbit. I think that's certainly something that's going to become increasingly important to try to sort out. It can only be done from an international perspective, as it is something that affects all of us. What space projects are you most excited about coming up next?

**Naoko Yamazaki:** I'm excited about a lot of space missions, but in particular there are many new interspace vehicles coming up like a starship, which is fully reusable. It can land on the moon. It can go to Mars. So it is very exciting. Also, airplanes, space-flying types, vehicles like Virgin Galactic spaceships. In terms of satellites, space communication with satellites is so powerful now. Many other companies are now getting involved in space communications. Even space hotels are coming up in the next decade.

**Professor Russell:** What do you think about the balance of space exploration between having humans in space and robotic space missions? Obviously you have this very rare experience of actually being a human in space. Do you think that adds a lot of value in what we can do in the space environment?

**Naoko Yamazaki:** When I was a college student, I researched space robotics. I loved robotics. I had the privilege of operating a robotic farm on board the space shuttle and space station. So I know and I believe in the power of space robotics. At the same time, I believe in the capability of human beings as well. Once we collaborate more we can achieve bigger goals. For the low Earth orbit, we can probably delegate lots of tasks to space robotics in an automatic way or, you know, remotely controlled from the ground. Then we can send humans beyond the moon and Mars eventually.

**Professor Russell:** Tell me about the S-Booster that you have presented here.

**Naoko Yamazaki:** Yes, the S-Booster is a space business contest held in Japan every year. This year there were six S-Booster contests. The prize expands to Japan and Asia Pacific areas. The Grand Prix was awarded to Astro Mine, which is a JAXA venture company. JAXA took part in the asteroid exploration, Hayabusa, Hayabusa2, where Sara contributed to those missions. Thank you so much, and congratulations on the recent asteroid ORISIX REX missions as well. They want to make more frequent asteroid observations, so they're planning to send a small micro spacecraft on an orbit. It will observe various asteroids monthly, so that they can create a database and they can sell those databases to space agencies or private companies.

**Professor Russell:** Wow, that's amazing. So eventually it will be a commercial idea, and the mission will pay for itself and ultimately be profitable. Is that the idea?

**Naoko Yamazaki:** The idea is from the Space Agency, JAXA. But it's going to be a business on a business basis.

**Professor Russell:** That's incredible. Could you say a bit more about what instruments will be on board? What sort of measurements will they be taking?

**Naoko Yamazaki:** They will send them Procyon. It's in a 6U site and a small space probe. it's flying by some asteroids. They will utilize Procyon's technologies. It's almost the same observation experiments, like optical cameras and so on.

**Professor Russell:** Do you know when it will launch?

**Naoko Yamazaki:** They're planning to launch it in the mid-2020s. So in a couple of years. They are planning to send 12 spacecraft into orbit.

**Professor Russell:** So, you mentioned Hayabusa and Hayabusa2. Are these your favourite Japanese space contributions? What do you see as Japan's major contributions to space?

**Naoko Yamazaki:** For space exploration, JAXA focused on sample return missions. Hayabusa was the world's first sample return from an asteroid. Hayabusa2 was the second attempt. The next mission was MMX. Sarah mentioned that. This mission involves going to Phobos (Mars' moon) and bringing samples back. The reason why JAXA is focusing on a sample return is because one small spacecraft can achieve the mission, meaning it is a very cost-effective way to get new samples and new knowledge of the asteroids.

**Professor Russell:** Just to say, I think Japan has been absolutely world-leading in this field. For me, since I work at a museum, I think sample return missions are really important for many reasons. There's many analyses that you can do on a sample that you have returned back to Earth that would be really difficult for a spacecraft to be able to do in orbit, or even a rover that's on the surface of an asteroid or moon or planet. So I think having sample return missions is so important. They're also so important for public engagement as well. You can put them in a museum and people can come and have a look and they can sort of share that space experience as well. Also, the samples are around for hundreds and hundreds of years for all of our descendants in hundreds of years' time to answer new questions about the sample as well. I think it's fantastic that Japan has chosen to specialise in this area. I think it's going to be really important. Obviously it's really important for projects like the one that you're describing here to learn more about asteroids, to see if there might be some resources in there that we could use.

So you mentioned earlier about the moon. I wondered if you could say a little bit more about why you think there is so much interest now in visiting the moon. If we can go back to that.

**Naoko Yamazaki:** During the Apollo era, reaching the moon – you know, sending a human to the moon was the big goal. It was a moonshot. However, now the goal is to explore the moon as an outpost to expand our frontier. To Mars. We found the existence of water on the moon. If we utilise that water, we can get drinking water on the moon. Or if we can separate out oxygen and hydrogen, they can be utilised as a propellant for rockets to reach further orbits to Mars and beyond. So, the moon has a lot of resources, actually. Water is a very precious resource in space. So, how to utilise water on the moon is the key. We don't know how to extract water from regoliths or from ice. So this is the next step. If we utilise the water on the moon or not. That's why we're trying to send spacecraft and humans near the South Pole area to examine how to utilise the water. Those results are the key to expanding our frontier.

Some Japanese universities and architecture companies propose to build an artificial gravity facility on the moon and on Mars. If we create a lunar base or Mars base, and we spend generations on the moon and on Mars, then probably we might need artificial gravity.

**Professor Russell:** Yes, I know astronauts can really suffer in space. If they're in a gravity-free environment for a long time. Did you have any health experiences from the lack of gravity during your trip?

**Naoko Yamazaki:** Yes. In microgravity, because we don't have to walk, our muscles, bone densities get weak. To prevent that, we do exercise for about two hours every day. Then our muscles and bone densities are fine. We also found that there were some effects on our eyesight during the microgravity stay. About 40% of the long-duration crew members get affected. It has not recovered, even during the rehabilitation process. So that's a problem. There are lots of small effects happening on our bodies. But it's accumulating, and will have a huge impact. We have some experiments on board the International Space Station. While some fish and some frogs can hatch an egg, humans and chickens cannot hatch eggs in microgravity.

**Professor Russell:** So that's why your colleagues at University of Kyoto are planning this artificial gravity. Can you say a little bit about how it works?

**Naoko Yamazaki:** As shown in the picture it is spinning. It's centrifugal force.

**Professor Russell:** Wow, that's amazing. And how big would it be?

**Naoko Yamazaki:** The diameter is a kilometer.

**Professor Russell:** Oh, wow. Okay. Massive.

One other thing I wanted to ask you about is being a woman in the space industry. Of all the astronauts that have flown, not very many of them are women. I'm sure throughout your career, you've been the only woman in a whole field of men. I wondered if you could say a little bit about whether you've faced any particular challenges and if you've got any messages for girls who might want to follow in your footsteps.

**Naoko Yamazaki:** Right now, only 10 percent of the entire space flyers are women. This percentage has been increasing, and I hope that one day it will become more equal. In Japan, not many girls choose to study STEM subjects in university, especially not in engineering and the deep tech area. The percentage of those who study these subjects is 10 percent or so. We need to encourage more women to study STEM. We also need to improve the work-life balance in Japan, I guess.

The movie shown on the slide is a French movie, featuring a female astronaut and her daughter. The daughter is growing up while her mother completes her training. I have a lot of sympathy for the astronaut in the movie as she's French. France doesn't have its own human spacecraft, like Japan, so the training is away from her home. This can be quite lonely at the beginning. It's hard to balance your work and your home life during this astronaut training phase. It is challenging, but it's not impossible. I'd like to encourage more women to try to challenge themselves.

**Professor Russell:** I have a final question, which is about the Earthshot Prize. I know you're now working now with them, and that the prize is an initiative to search for solutions to the planetary emergency. I'm wondering how you got involved in this. I know a lot of astronauts see the world with a different perspective when they go into space. I was wondering if that was the case for you. Also whether you see any parallels in how we have to tackle the climate emergency in cooperation with all the nations together, the same way that we're going to explore space together.

**Naoko Yamazaki:** The Earthshot Prize was initiated by Prince William in 2020, and the idea came from the moonshot, actually. The moonshot made the impossible possible in a decade, sending humans to the moon. The Earthshot Prize aims to create a pathway to solve our environment on the home planet in a decade. So it's a ten-year award, and each year we award five winners from five categories. As a counsellor, I select the winners from the 15 finalists each year. We always have very hard, challenging discussions in order to select the winners. In the first year, 2021, a 14-year-old girl from India was selected as a finalist. She invented an ironing cart using a solar power system. A Japanese water recycling company, 'Wota box' was one of the finalists as well. Last year, 'Notpla' was the winner from the United Kingdom. It was very exciting and very inspiring. Instead of plastic, they utilise seaweed to create food containers and packaging materials. They are aiming to eliminate the use of plastic. There was also 'Low carbon materials' from the UK, which aims at making zero-carbon concrete blocks using OSTO, a carbon-negative alternative. This year, from the UK, 'Enso' has created sustainable tyres for electric vehicles with hopes of reducing tyre and air pollution. These are examples of finalists and winners.

The reason why I am supporting the Earthshot Prize is because the spirit of it comes from the same passion behind the moonshot, and I am passionate about saving the environment. Many ideas come from space assets and some finalists utilise space data to monitor the atmosphere or the landscape or land usage etc. Many technologies are now seamless from the ground and space and I really like the idea of connecting those two assets to save our home planet.

**Professor Russell:** Brilliant, thank you very much. And thank you for your work on the Earthshot Prize, it's so important.

Thank you so much Naoko-san, I learnt so much this last hour and it's been really inspiring talking to you. So thank you very much for your time.