UNISEC-Global The 45th Virtual Meeting

June 15th, 2024, 22:00-24:00
(Standard Japan time GMT +9)

The following report was prepared by UNISEC-Global Secretariat
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Japan

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1. Opening Remarks

Rei Kawashima, UNISEC-Global

Rei Kawashima has contributed to micro/nano/pico satellites for education and business applications through her leadership role at UNISEC - the University Space Engineering Consortium- that she founded in 2002. In 2013, she was appointed as the Secretary-General of UNISEC-Global and the organization was accepted as a permanent observer of UNCOPUOS in 2017. She organizes training programs and technology competitions to facilitate university's participation in space projects worldwide and especially, in emerging countries.

Pictured: Rei Kawashima while giving the opening remarks

<u>Highlights:</u>

- Expressed a warm welcome to everyone in the meeting
- The topic is "CubeSat History Project"
- The meeting today has many historic people
- This is indeed something to mark as a very important day from 10 years later
- Each activity done previously is a part of history
- Shared a picture from 1 year anniversary of CubeSat of Tokyo university: launched from Russia
- A CubeSat holds a lot of human history
- In the past 25 years, lots of changes has occurred
- Nobody believed University students could design, build, launch and operate a satellite
- 1999 – Prof. Twiggs proposed CubeSat concept
- All the small and big thought and actions in the past have created history
- What we are doing and thinking now will be history in the future; We are all history makers
- Today, we are learning about CubeSat history projects
- In 2003, Rei Kawashima witnessed the launch of The First CubeSat
- Rei Kawashima collected comments on what, when and how it happened -> launched a book in kindle
- Japan has a CubeSat history book -> Effort to keep a record -> help to refresh memory after many years
- Launching a satellite is a lifelong event
- More than 60 CubeSats have been worked on in Japan
- Space Debris is something that we also need to think about now
- Suggests to write everyone's CubeSat story: A photo, a written record, interviews, comments, etc.
- UNISEC-Global may plan to launch those stories online on the website
- Currently, Dr. Aaron Zucherman and Prof. Robert 'Bob' Twiggs are working together
- Prof Bob and Prof Jordi had worked together to standardize the CubeSat standard – important figures
- They are writing a history of the origin of the CubeSat Book
- You can contribute by emailing azucherman@gmail.com
- You can support by going to https://www.gofundme.com/f/cubesat-history-project

Pictured: Kawashima-san giving a brief description of the past satellites born from UNISEC activities

2. Panelists Introduction

The moderator of the panel discussion is Dr. Aaron Zucherman. He is a recent graduate of Cornell University earning his PhD in systems engineering and is studying interplanetary CubeSats. He is currently working with Professor Robert Twiggs to capture the early history of the CubeSat through The CubeSat History Project as a lead Co-editor.

2.1. Robert Twiggs, Twiggs Space Lab, Co-inventor of the CubeSat Standard

Professor Robert Twiggs has been working with academic small satellites since 1982 and has had six student built small satellites launched into low Earth orbits. Prof. Twiggs had 20 years of industry experience in the development of high-power microwave tubes and software development. Prof. Twiggs was the director of the Weber State University, Utah Center for Aerospace Technology from 1985-1994. Prof. Twiggs was a consulting professor at Stanford University Department of Aeronautics and Astronautics starting in 1994 where he established the Space Systems Development Laboratory. While at Stanford in 1999, he was the co-developer of the CubeSat concept.

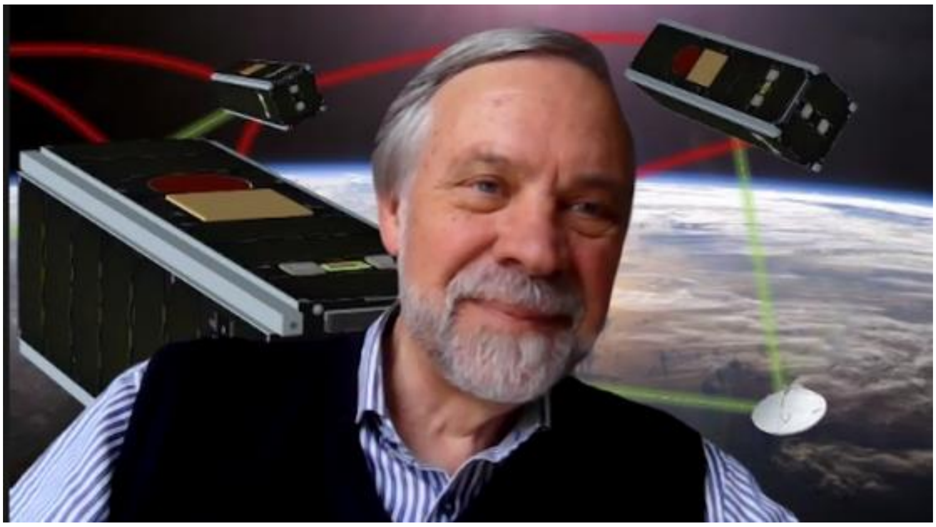

Pictured: Robert Twiggs during his introduction

Highlights:

- Appreciate the opportunity to get back
- Started off with getting into the satellite program at Weber State University at Utah
- NewSat-1 was developed: education for both student, professors and ambitious groups of mentors
- Immense practical training ->later worked at Weber State University to launch 2 satellites
- He then transferred to Stanford University -> worked on MicroSats
- Conclusion - The larger the spacecraft; the longer it takes
- With the help of Jordi, they started looking for something small ideally about 10cm
- Jordi along with his students made the idea into a reality
- First launches of the CubeSats was an exciting adventure
- Educating the student was the main core concept
- Dr. Aaron and he has been involved in interviewing the initial students of Stanford Satellite Project
- There wasn't much money for commercial satellites
- Miniaturizing the components worked a lot of their favor
- Interesting perspectives from Jordi is also featured in the book -> development and launch of initial CubeSats
- Book also mentions non-technical aspects required in a project
- The perspective of making this educational has been mostly lost
- He believes to taking this CubeSat idea back to high-school students to build something simple
- This will inspire the high-school generation and prepare them to create much more in their university
- Focus is always to get students interested and get them educated
- Looking forward for a good panel discussion

2.2. Klaus Schilling, President of the Center for Telematics A former professor of Robotics and Telematics at the University of Würzburg

Klaus Schilling, born in Bayreuth in 1956, studied mathematics, physics and biology in Bayreuth and Munich. After completing his doctorate, he moved to the space industry in 1985: at Dornier System, he headed the "Mission and System Analyses" group in the scientific satellites division. On behalf of the European Space Agency ESA, his team was then responsible for the conception of the interplanetary space probes HUYGENS (to the Saturn system) and ROSETTA (for comet research). Afterwards, until his appointment at JMU, Schilling taught the fields of artificial intelligence, computer science and robotics at the Ravensburg-Weingarten University of Applied Sciences. There he was also elected Vice-Rector for Research and International Relations. In 1992, he founded the Steinbeis Transfer Centre ARS, which focused on the use of advanced control, robotics and computer technology in industrial production.



Pictured: Klaus Schilling during his presentation

Highlights:

- Started off the career with traditional satellites
- Inspired from Prof. Twiggs while in Stanford
- Involved in learning and teaching about interplanetary spacecraft
- First activity in Würzburg was to build a CubeSat -> inspiration for students -> international co-operation
- Focused on miniaturization during CubeSat Project
- Eventually, worked on flying CubeSats on formations -> multi-satellite systems
- Not as expensive as traditional satellites and work o “co-operation” in formation satellites
- 4 nano-satellites used to demonstrate multi-satellite systems
- Robotics and automation required while producing multi-satellites in short time frame
- Currently working on production small satellites on small series
- Focusing on industrial concepts after leaving university
- Taking a step from academia to industry
- Idea is to work on Constellation/ Formation of satellite -> innovate sensor network in orbit

2.3. Yuichi Tsuda, JAXA Professor at ISAS-JAXA, Project Manager of Hayabusa2 Asteroid Sample-Return Mission

Dr. Tsuda received his Ph.D. degree in aeronautics and astronautics from the University of Tokyo in 2003 and joined JAXA in the same year as a research associate. He was a visiting scholar at the Dept. of Aerospace Engineering, the University of Michigan as well as the Dept. of Aerospace Engineering Sciences, the University of Colorado Boulder in 2008-2009. After serving as a deputy lead for the IKAROS project, the world’s first interplanetary solar sail mission, Tsuda became the Hayabusa2 project manager in 2015, being the youngest project manager in JAXA’s history. His research interests are astrodynamics, spacecraft system, and deep space exploration.

Pictured: Yuichi Tsuda during his presentation

Highlights:

- Honored to be a part of the meeting
- Currently a professor at Institute of Space and Astronautical Science (ISA) and works in JAXA
- ISA is a Japanese institution for space science
- He has worked on areas of spacecraft systems, astrodynamics and solar system exploration
- Career started with CanSat projects -> CubeSat Projects
- He was a part of the 1st Generation CanSat and CubeSat Projects
- He has then participated in deep space missions too

- CanSat Project – 1998 – supervised by Prof. Nakasaka
- Prof. Twiggs proposed the ides of making a satellite in a Coke Can
- He and his supervisor and colleagues were involved in the projects
- Initially thought the idea was stupid to make a satellite in a can and that too, as students
- One year later, launched the CanSat in Nevada, US by an amateur rocket team
- Although CanSat could not go to space, all the building, testing and launch could be experienced
- This was a basis to work on as a space engineer
- One year later, they came together again and make a cube satellite – U of Tokyo "XI-IV"
- All feedback were incorporated from the CanSat learnings
- 10 cm cubic shape could accumulate all of satellite integral parts rather than the tiny Coca-Cola can
- They did everything themselves from making a clean room to developing the CubeSat
- Many supports were provided from many professors
- XI - IV - the CubeSat was launched 30th of June
- 11 years ago and it is still alive
- Based on the CanSat and CubeSat activity
    - Achieved the position of PM at JAXA
- Learned that we cannot always do everything we want because of lack of expertise

Prof. Yuishi Tsuda sharing glimpses from his CanSat and CubeSat Projects

- The experiences of the project were crucial during his missions later
- Lack of expertise, money and time persisted a lot
- Each project mission taught members an experience that contributed a lot
- Personal and career development by enhancing one's ability
- Apart from technical aspects, one also learns importance of teamwork
    - Working as a team is critical

2.4. Jordi Puig-Suari, former professor of Aerospace Engineering at Cal Poly, Co-inventor of the CubeSat standard

Dr. Jordi Puig-Suari graduated from Purdue University with a Bachelor of Science, a Master's of Science and a PhD in aeronautical and astronautical engineering in 1988, 1990, and 1993, respectively. From 1994 to 1998, he was an Assistant Professor in the Mechanical and Aerospace Engineering at Arizona State University. In 1998, Dr. Puig-Suari joined the Aerospace Engineering Department at CalPoly, San Luis Obispo as an Associated Professor. In 1999, Dr Puig-Suari and Prof. Bob Twiggs at Stanford developed the CubeSat standard. This small satellite standard has been adopted by over 100 universities, companies, and government agencies worldwide and has become the standard in the university and small satellite communities. Dr. Puig-Suari has maintained a leadership role in the CubeSat community.

Pictured: Jordi Puig-Suari during his presentation

Highlights:

- Born in Barcelona, Spain
- Wanting to do aerospace was a beginning of many "you cannot do that"
- There was not much of such opportunities previously
- But CubeSats seem to have opened them up for countries to enter into the space industry
- The idea of building things was not important back then
- All of the building were learnt only when one entered the industry
- He was working on satellites the same time Prof. Twiggs (Bob) was at Stanford's satellite
- The findings were similar; they wanted something miniaturized and simple
- Initial projects did not work out but works were being done on the idea
- CubeSat standardization – getting everybody together to build something similar
- A few 100 satellites were launched by CalPoly through pea pods
- Most of the CubeSat startups/ companies eventually came out of the university teams
- Before this started, nobody felt capable to start a private space company
- Making a CubeSat by oneself changed it
- When the needs grew, CubeSat adapted -> 1U to 16U -> ensured a longer stay -> standard is still there
- The backwards compatibility was still present
- Like Bob said, we seem to be getting more industrial-focused
- People said it is too small -> not worth time and money -> during 1999/2000s
- Wanting big things is okay but there is still a vast number of things one can do with small satellites
- Small satellites come in play especially during Inter-planetary missions and low-cost projects
- There is a space to make mistakes and amend them
- The vision is still to get people engaged and creative

3. Panel Discussion on CubeSat History Project

Q: Moderator Aaron Zucherman: Well, thank you all for the great introduction. Hopefully, the audience knows you are all immensely qualified to talk about the early history of The CubeSats. You touched on it a bit, but I want to hear from the other panelists. Now, we take for granted that a school or an elementary school can build and get a CubeSat launched by NASA. Perhaps starting with Prof. Twiggs, would you like to talk about some of the early reactions when you talked about, we are going to build a satellite this small and get it launched that you know, weren't so positive?

A: Robert Twiggs: *Yeah, we got lots of interesting comments. I am sure Jordi did. The aerospace industry and particularly, kind of the amateur satellite community was very critical of us. I remember some of their comments were of course that it is too small to do anything useful. Besides that, the university people are not smart enough to build a satellite. You know what happens when somebody tells you that you cannot do something. You recruit a bunch of really smart students and take credit for what they do but it's an interesting thing. To me it is such a fantastic thing to put something in space and study space and we keep seeing that there is still a big spark out there for young people that are interested in space.*

From when we first started, you know, a few big projects had started the constellations for communication and effectively they went broke and nobody would put any money into it but you know, right now it seems like the venture capital people are chasing people around trying to get them to spend their money, maybe not always the best way but there is some real successes when you look at. A number of them are doing absolutely great things that you would have never thought that they would do but again from the education standpoint, the one of the things that we in the university program suffered was when it became popular, especially from the commercial side is we lost low-cost launches. Original launch was like $30,000 and boy, it jumped up to $120000. Well, you know it is pretty hard for a university to raise $120000 for one CubeSat but fortunately NASA eventually jumped in with what they called it the ELaNa Program really brought it along a lot of ways and was able to get the universities involved.

We have a program I'm working with Nick Pugh down at The University of Louisiana. Nick is actually launched. And I kept talking to him that I wanted to build something that was really inexpensive, and we had a program earlier called ThinSat that we launched on the second stage of the Antares Rocket and the way you can reduce the cost of launches is you got a given volume. Make more than one satellite in that volume. So, we are back on a program that is like The ThinSat we just call it SlimSat which is another name for that we can take a 3U and launch 20 or so of these little SlimSats out of it and we want the SlimSats to be very simple. If you built the satellite for the first time and you get simple data back for it. Maybe you got a magnetometer, or light sensors, or looking at what the battery is, that is new to you. You don't have to get data from the universe in order to be new to a student. So, we are looking at building a small satellite. Nick has got a design that he has used a lot on balloons that we think we can put together with Lora Radio which is not going to give you much data but that is okay. Get some data back but go through that cycle. We hope to do that, and we put in a proposal to NASA in the CSLI program which is the ELaNa Program. We put in a proposal for that, and we thought, well, you know, after 3- or 4-years proposal will get accepted. They accepted it the first time and we were, oh, we got to do it now.

So, we have a CSLI launch Program and NASA seems to be favorable of what we are trying to do so at the rate we are going, we want to pick up students that are freshman or no more than sophomores in high school and have them launch their SlimSat before they graduate from high school and I think if we can do that; I know we can do it, there is no question about it; then imagine what they are going to do when they get in university. They have been through that but one of the things that we kind of shield them from is the difficulties in doing this. It is the difficulties in getting a launch and meeting all the FCC requirements and all of that. But the new CSLI program is really helping on that because NASA gives them a budget of $300,000 to run that launch. So, they will get consultants. They will get all the things that you need to make sure you have a successful project with their budget. We don't get any of it but that's okay. That puts the challenge on us. So, I hope that we can prove the SlimSat project and what we want to do is launch off the station but not release anything till we get down so we have only got about 6 months of orbit life before we de-orbit and if we could get one or two of these launches a year, think of the opportunities that the students will have. I am really excited about it because as Aaron and I have done go back and interview a lot of the students that were in the CubeSat Program, it is the highlight of their life, and we often hear senior engineers saying why didn't we have something like this when we went to school? And so, it's something that is good. It changes students. It gives them confidence and it gives them something that really makes their education different and very, very useful.

So, thank you Jordi for doing all the hard work that you did in getting this program going, you know, all I did in this program, I get credit for but all I did was buy that little plastic cube and work on a prototype for The Pea Pod. Then I sent them to this guy that I knew he and his students do things, they made things and he did so really, I picture myself as the little guy that has his battery on his back with a couple of jumper wires and I go around and I try and get projects started. I don't know how they are going to get done but if I can get people enthusiastic about it, they are going to get on it. That is so fun!

A: Jordi Puig-Suari: *Well, thank you Bob and I have to jump in because the thing about the infusing is a critical part. And I go back to the idea that we had 20 universities from the beginning building group sets all around the world and that was Bob going around the world and telling people we are doing this. My students still tell stories about the days that I would walk in the lab and say that we need to get this thing figured out because Bob has already sold another 3 or 5 or 15 satellites. We got calls from universities* *saying where the standard is, you know, because we need to start building and that was interesting to see how Bob could energize people. But that is the other thing that I think we both of us committed to the standard and we did not have anything like that before. Nobody could start building and say that I am going to put this thing together and I know it is going to be able to fly because there is all these rockets that have standardized accommodation and that did not exist. Everything was custom, the analysis took forever. Couple loads on all the satellites on all the rockets and only universities could have done that. If industry had tried to do something like this, they would have been competing and keeping things proprietary and it would have never happened. So, that is I think one of the ways in which industries said you cannot do that, or it is not going to work because they were looking at it in their own way and we got a lot of people that said "Why don't you make a bigger one?", "Make it 12 cm instead of 10 cm", " I need a 15 cm one and I have money" but we were like, you may have money but I don't have the horsepower to re-qualify people and that is bigger. Because we didn't have any funding and the students were just doing their best qualifying one system and that actually worked to our advantage. If we had infinite funding and infinite time, we would have launched the 3U once and next launch would have been bigger satellites with a bigger box, a different design and everything would have been changing all the time and the fact that there was no funding forced us to be through and to reuse the things that we had already built and I think that made a humongous difference. It also allowed Bob to go around selling more of these things so that I had to worry about putting them up.*

Q: Moderator Aaron Zucherman: Perhaps, Schilling, I think it is your turn now.

A: Klaus Schilling: *Thank you. I think standardization was the key so not everybody had to reinvent was the key. So, different partners would combine their equipment. One produces telecom and the other one produces support computers, batteries and so on. The combination was quite helpful, so it raised international co-operation a lot. What we also saw in the early days is that agencies jumped in. Like NSF promoted payloads for CubeSats. So, new measurement instruments came up. The programs were also initiated in other countries, not only in the US but also in Europe, in Japan, everywhere and this contributed a lot to the success and to a lot of student exchanges. In our team, we had Japanese students and Romanian students. The team was composed of 10 different nationalities. Before this was not possible but thanks to this standardization, it became reality.*

Q: Moderator Aaron Zucherman: Professor Tsuda, I wanted to ask, do you have anything to add to that? But I was also wondering; because you mentioned it in your introduction that a big part of the process of developing your CubeSat was the minimization of the complexity of The CubeSat; could you talk more about maybe how that helped as well.

A: Yuichi Tsuda: *Yeah, so in a very early era of CubeSats, the CubeSat activity was active because everything was new and because we were ignorant. So, we did not know how to make this satellite so before we knew how to make a CubeSat, we did not know how to make an actual satellite which was more satellite. So, because of that, we had a lot of freedom, and we could challenge ourselves. It is also even though the satellite professionals already know how to make and fabricate the real satellites. We sometimes challenge something that was already done but in a new way or in our own way but in that way, we could make our own world and then we can get back to the satellite in their real industry and that kind of feedback on the cyclic process was one of the very big contributions to the CubeSat activity. I am now still in academia and what my concern was that I used to think that we want something innovative and because the cubes became so popular, so it was not new enough for me. So, what will be the new things? So, standardization is a very good thing, very good to broaden the activity worldwide*

But at the same time, we don't stop our activity and we should make something new based on the current standard. Maybe expand into a smaller satellite or like previously said to younger generation or like I am now doing, follow a deeper space and so on. So, CubeSat is already very popular but I think that is just the initial step to the next world.

Q: Moderator Aaron Zucherman: I think that is actually a good transition to another question which I had which is: What advice do you have for those listening both to how they should approach

CubeSat program and then maybe how should they use their CubeSat experience to continue working in space?

A: Jordi Puig-Suari: *Let me say one thing and I will let everybody else jump in. I think you said a word that is very, very important. You said "CubeSat Program" and one of the things that we saw, because we were launching so many, we saw a lot of different universities doing different things, is that if you start a CubeSat Project that is a satellite, you will launch one satellite and stop but if you have a program where you say I am going to use CubeSat to learn whatever my university or my nation or my group is interested in and on the first one, we will do this and on the second day, we will do this and the third one, we want to do this, those are very successful and resilient program. Even if the first one fails, you are already working on the second one and nobody can really stop you. But if you have a single project, that is a lot more fragile because we had some universities that had a ton of support from the Dean and the president of the university, everyone was excited to launch the satellite and then when they ask for money for the second one, they say well, we already did it so it is not that exciting anymore so we are going to go fund something else so don't think about a satellite, think about a program which is exactly what you said. I do not want that to go lost.*

A: Robert Twiggs: *I completely agree. I like that.*

A: Klaus Schilling*: Program is important but a question that usually arises is how do we form the transition between different student generations? How can we keep the experience? So, this would be an essential part of the program to answer these questions and usually you can use PhD students to supervise younger students and guide them this way to have an evolution of the program but it also needs organizational efforts.*

A: Robert Twiggs*: Yes, one of the things in the STEM education that I see is you will have people who will provide something for students for a particular mission and the students will do that mission and then like you say nothing else is done with those students after that. It is kind of a one-shot thing and I think in the STEM education program, what we need to focus on is providing something for the students to do a mission but like you say, it needs to follow on with that. One of the things that we were involved in here is to provide a device to use during the eclipse that we had. We had the eclipse run right through our place in Texas and we made a device that could record temperature, pressure, humidity and store that so you could record what happened during the clips but when the eclipse was over and they got the data and looked at it, you know, it was great. They're not doing anything more with those devices but one of the things that maybe I will challenge you to think about to get students started is what if you can give them something that they wear like a badge that measures the environment. We see so many times the environment at the school, the air quality, other kinds of pollutants around students but if they can wear this badge all the time, they can pick that up. They can monitor it and put it in a national database and hopefully have some influence on what is done in the environment around their schools. There are so many schools that are next to a freeway. You know what the environment in that school is like and I am trying to think of things that students could build, or you could help them build as a project, but they have a continual use for it. So, think about that as a starter, one week. Start students in a program even at university level. The first thing we teach them is how to solder and we have this little thing called a jiggy which is a little PC board that has a motor that has a light on it and a battery on and what you do is you put wire legs on it, and you turn it on, and it runs around. Okay, they have got something that moves here. What is the next thing? Do something that they can fly on a balloon and progress. That is the way you progress up, you cannot lay a satellite design in front of them at the very beginning and say, okay, build a satellite. So, it is the progressive program that you need but we need things that go into the school for the kids that have continual use like monitor the environment and so on.*

A: Jordi Puig-Suari: *One other thing that I would say if somebody is starting is that there is a huge community and a huge legacy of CubeSat missions and I think sometimes people feel like they have to do everything themselves like have to go study and I won't ask the professor for help. I think that is a mistake that sometimes people will make. There is a wealth of resources out there that you can call and most people in the CubeSat community will help you if you have a problem. You have a question, and they will* *jump in and answer and try to make you succeed because that is how the whole thing started and everybody benefited at the beginning.*

Even when you go to companies and like Bob said, their memory of the CubeSat is very positive and if somebody goes to those guys and says "Hey, I am starting a program, can you do something or can you tell me something, some advice on how to start?" They will totally do that. So, that is another thing that is very important to take advantage of the people who have been there before.

Q: Aaron Zucherman: Professor Schilling, do you have any advice for programs that are starting out both on how do they set up a program or how do they approach a program that maybe wasn't discussed further?

***A: Klaus Schilling**: Well, I think usually agencies are very willing to support to provide some budget for program development so in our facilities, we had support from the European Union and The National Government. One could this way set up related programs. Say always we are very keen to include hands-on exercises. Usually, space programs are theoretical before the time of CubeSats but now we can have hands-on in this which is something that industries appreciates a lot. So, we can integrate support from all kinds of sources to develop programs, we just need to look around. I think international cooperation is a cornerstone of security programs usually. Yeah, so you should not be afraid to approach us.*

Q: Aaron Zucherman: I agree. I believe just reaching out to those who have flown CubeSats already even if you are from a country that has never flown a CubeSat, you could reach out to just another CubeSat Program and they can provide excellent mentorship.

***A: Klaus Schilling**: I would also say space education programs nowadays are mainly international so if you get scholarships to go abroad, you will find international student programs, including CubeSats.*

Q: Aaron Zucherman: Professor Tsuda, do you have any kind of things to add or we can move on to the next question.

***A: Yuichi Tsuda:** Let's see. Yeah. So, in addition to the talk, I think that I am now in JAXA and like a national agency is, we are willing to support this kind of CubeSats activity but we are not trying to make our own CubeSat by the national agency because it is too small or too incapable. From the viewpoint brought from the national agency but we know that it is very effective for the education or for technical skill development, so I think that there is a lot of room between the current groups that are in CubeSat level and much bigger satellite. I think that there are a lot of useful ways of using the CubeSat in real space missions but there are a lot of missions that cannot be done with the CubeSats that only bigger satellites can do. So, in between that, there are a lot of real serious technical hurdles that we can deal and in that portion, we think there is a room for investment in terms of technical educational opportunity or international collaboration opportunity and so on.*

Q: Aaron Zucherman: Excellent. Another question I would like to ask you is you started out as a student in the CubeSat world. So, what do you think programs can do to further entice students to come and join and stay motivated to work hard and see these missions through to the end?

***A: Yuichi Tsuda:** Okay, so from my point of view, when I was a student, I was really fascinated by the concept of CubeSat because no one had done it yet and you know, innovative and new things are always attractive to younger generations so that is a very, very huge motivation. So, what is the attractive things for the current young generation is the question that we have to raise and one of the very single answer would be to go to somewhere we have not been like deep space, mars or Jupiter. 10 years ago, we did not have CubeSats but now we have lots of CubeSats all over the world but we have just led few numbers of deep space missions with very small satellites like CubeSats. 10 years later, we do not know. Probably many young people will be attracted by that. Just an idea.*

Q: Aaron Zucherman: That is a great idea. Anyone else would like to talk?

A: Klaus Schilling: *I think CubeSats have a limited power budget usually but for deep space, we need bigger ones. But CubeSats play a role as companions. We can have baseline distances for observations. So, CubeSats are a great tool to complement the big satellites. So, I would not play a conflict between small and big satellites but we should take the best of both worlds in order to have the best performance at the end. CubeSats are a great tool for distributed systems. So, yeah we can complement big ones. We can also do a distributed measurements system. Sensor networks in orbit. When I was young, I was grown up in the big world in computer science with IBM mainframe computers. Today, we have the same performance in our pocket with smartphones and it is a distributed network system. And I am sure also in space we will encounter something like this to have small devices but distributed and cooperative. So, new measurements principles will become possible this way and I think also in education. We must focus now possibly on constellations and multi-satellite systems. Yeah, this might be one of the next steps we will encounter in space. Cooperating Spacecraft, small ones as well as small and big ones composed.*

A: Jordi Puig-Suari: *One thing I think this is very interesting that the collaboration with the big and small satellite but I think one of the things that we learned from CubeSats which was very interesting was we didn't know this but a lot of the rockets had a lot of margin. There was a lot of pounds of launch capacity that were being wasted every year and we use those to learn: by doing things that were small satellites and I think we may end up finding the same thing. There is a lot of missions that go inter-planetary that carry a tremendous amount of margin and when they launch, you could put more things in that but we don't have the accommodations and people always talk about the Mars Landers have these Tungsten ballast for aerodynamic stability of the system that they drop and it is just hundreds of kilos of metal that they are flying all the way to Mars and they don't do anything with. So, another place where I see some interesting opportunities is the idea of making useful ballast. I mean that first CubeSat launch in the US, the orbital science team call it partially useful ballast and they put us in a place where usually there is a big plate of lead that is used to balance the rocket. Once they know what the margins are and what they said is "Well, we can take some lead out and put up 3 CubeSats." And I think we may see the same thing happening in interplanetary and I think that is one of the things where I think you are correct that the big satellites do more things but we cannot take the risk. I think that is the other part that we haven't talked about is that CubeSats allow people to take risk and say I have this idea for a new sensor but I do not know if it going to work. In theory, it should work and they put it up and it worked. Everybody thought that the XI-4 electronics commercial of the shelf are not going to last more than a month buy we put it up because we could try and take the risk and it is still working. So, it proved everybody wrong. So, I think we need to expand that risk taking and creativity beyond LEO and I think CubeSats or something similar is a good way to do that.*

Q: Aaron Zucherman: One note that I wanted to kind of add to this as my background is in Interplanetary CubeSats so I feel like I could add. You could also take the simplicity beyond Earth orbit taking very simple measurements using smaller instruments like they do in Earth orbit. Taking those measurements in a brand-new place could be a great way to get around concerns about needing too much power and volume and instead keeping the scope and ambitions of these Interplanetary CubeSats very small and narrow.

A: Jordi Puig-Suari: *Well, that is the thing that interplanetary. You got me going because this is my latest thought is that we need to start doing. There are these big calls like NASA has discovery opportunities and somebody proposes going to The Venus and somebody says let's go to Titan and somebody says let's go to Europe and they pick one. But that means that nobody is going to the other places. So, they propose a mission that gets tons of data and if he doesn't get selected, they got no data. So, what you are saying makes perfect sense. Send something to get a little bit of data. It is infinitely more than 0.*

Q: Aaron Zucherman: Prof Swiggs, What about you? You have a lot of experience about how do you get people engaged in new CubeSat missions.

A: Robert Twiggs*: Well, one of the things that I was just thinking about is NASA has this program through Nanoracks that is managing the lockers on The ISS and they have things called nano nodes which are* *essentially boxes that are the size of a 1U or 1.5U. I think maybe even a 3U CubeSat. You put your experiment in that and hook it up and they give you the power and communication. So, what you do is have your experiment in there and get your data back and send commands on the internet. That saves so many problems compared to having a free flying CubeSat. That opportunity like you say would be a really good payload on a big Spacecraft. What if there was a rack on the geostationary satellites that would hold a bunch of experiments and again be able to use their power and their communication. One of the things that when we initially started out, we were concerned about was if we could get the spacecraft to talk to us. We weren't too interested in payloads initially but once we knew we could communicate with the satellite, then we started thinking about payloads and from my standpoint, I am not interested in the satellite anymore, I am just interested in the payload. I want to get data back and are there opportunities like that like I say on some of these planetary missions to just fly your payload. I think there ought to be a challenge. Here is a box that you can put something this size and we will give you power and communication and I think they would find an awful lots of things that would do that and talk about an opportunity for a student for the second or third project beyond the CubeSat. It ought to be a program, not a particular mission. So, we ought to look for other places to put these payloads. To me, that is the fun thing: to build a payload. That does something that is unique to your interest so, I think what Jordi said and what we are hearing from Prof. Tsuda and Klaus is that there are opportunities just like there was led on the launchers. We can definitely put student experiments on them.*

A: Jordi Puig-Suari: *And one thing that is really great that you bring in nanoracks because that is one of the things about standards that they break molds and you start doing things that you didn't expect. Now, you have something that is inside the space station that has nothing to do with deploying into space but it uses the same size and the same form factor and you can make instruments that are standardized and you can put it in a CubeSat or you can put it in a spacecraft or you can put it in a type of station. And I want to show you an example. Do you guys all know what this is?*

Pictured: Jordi Puig-Suari showing a car charger as an example

That is a charger for your car and I remember the first time I told my kids that this was for the lighter to light up your cigarettes and that is why that was on every car. It was not there to charge your phone or plug in your computer or have an inverter, but it was a standard that was in all the cars. And once you have something like that which is standardized and in all the cars, interesting things happen. And that is what happened with CubeSats. You had the standard that was in all the rockets and you could launch it. Now, all of a sudden you make 12U and 6U and Nanorack makes things for the space station. So, I think that is the way to think about it. Once you standardize, expand and do other things with it. You do not need to mess with the standard but you can use it in very different ways. I think that would be fun to see.

A: Robert Twiggs: *One of the programs that we are involved with is putting things on The NASA 0G airplane and we build a thing where you have a processor and a camera and then you have a 2-inch plastic box that is filled with something and the students put things in that box and then try to take picture of it while they are on the loop on the NASA 0G airplane. What we are also looking for is now is if we take this same concept and put those things in the Nano Tube or the Nano racks on the station. Can you extend what you are doing* *on the 0G airplane to the space station and then if you want something that is completely independent but there is so much complication and requirements to get you know out on a free flyer that maybe, we can get the students to start with just a payload that we get on the station and nice thing about that is they bring it back. You get it back rather than in your satellite, you lose it. So, maybe something to think about is what other things does NASA have in terms of resources that we could use? I know they fly balloons, they fly rockets and other things and maybe that is a first step for a lot of students.*

Q: Aaron Zucherman: I believe we might be a bit early but maybe we could start taking questions from the audience.

Q: Helen: Where do you find International CubeSat Programs?

A: Aaron Zucherman: *We could start with UNISEC itself is a great organization. Maybe anyone else would have some examples* they would like to share?

A: Jordi Puig-Suari: *I think UNISEC is the best example. Just contact Rei. Actually, Rei, could you give some information or maybe at the end on how to connect with UNISEC?*

A: Rei Kawashima: *Just e-mail to me and then I will arrange everything, don't worry.*

A: Jorge Del Río Vera*: KiboCUBE, JAXA and UNOOSA and PHI, hosted payloads with MBRSC and UNOOSA*

Q: How similar and how different is the experience of developing a CanSat to a CubeSat than a traditional satellite in terms of development timeline, looking for parts, manufacturing, assembly, risk management?

A: Aaron Zucherman: *I guess you could look at them as smaller and smaller versions. They are not just smaller and smaller versions of each other but how does a program scale differently as size.*

A: Yuichi Tsuda: *Yes, the difference between the ordinary satellite and The CanSat or CubeSat. The timespan is really short in the CubeSat and CanSat as the concepts must be completed before the students graduate from there. Like in Masters Course, you need to fabricate and complete everything in like 2 years. If students go to PhD or still this project must be 3 years or something. And yes, actually the way we did in the CanSat, we completed everything in like half an year and for the CubeSat, it started in 1999 and we completed everything in 1 and a half year but waited for like 2 years before we got the launch vehicle. So, we had to wait but yes, like one or two years. So, that is very different. So, every 2 months, we completed BBM and EM and FM and so on and everything is very fast and for that to be possible, we try to find it a way to test. So, we learn from the conventional satellite development but like vibration test and the thermal vacuum test and so on but we are trying to do in our own way. We sometimes use it just to shake but by using our hand for the vibration test and put the accelerometer in that and then measure the acceleration level to meet the requirement. By doing so many people understand what we are trying to do and many kinds of professionals lend the environment test equipment and so on. So, 2 or 3 years later, we are more good at doing those kind of tests but you know, once we learn the essence of each of the process like vibration test required level of vibration, what we have to do is simulate that in our own way based on or trying to keeping on the essence of that testing so in that way we could make our own way of fabricating and developing the satellites.*

A: Jordi Puig-Suari: *Let me add one thing to that. I think that is really interesting but one thing I want to point out and I think that is part of the success of the students that work on CubeSats is that because CubeSats are so simple and they are small, it is easier for a small group to understand all the parts. So, it is a really good system engineering training but the number of experts that you need, you know, the number of different things that you are working on is much smaller. So, a small team with a few people that can really understand the whole spacecraft and I think that is one of the things that makes the training really good. The people that come out of CubeSat don't just know power or computers or structures, they have to know everything and they can and then they become really good systems integrators and systems engineers and that is very hard* *to do with bigger satellites. They are so complicated. It takes years to get to that level where you can see the whole spacecraft.*

A: Yuichi Tsuda*: Thank you, Jordi. Yes, that is a really important portion. In reality, actually in our CanSat and CubeSat, we had a team of 15 to 20 students and in other missions, we were 600 people. But based on my experience in the CanSat and CubeSat, that was a really good experience for me and I could expand that experience to apply to the bigger missions.*

Q: Aaron Zucherman: So, I am going to paraphrase a question here. There are a lot of universities that have put out open-source bus designs. For example, there is the BIRDS Bus from Kyutech and then there are commercial buses. I was wondering could you share your thoughts on what are the advantages or maybe even pitfalls of using pre-designed spacecraft buses in your CubeSat program?

A: Jordi Puig-Suari: *Build or buy? That is the big question. I think one of the things that is very interesting today on a CubeSat is you can buy full access attitude determination and control, one degree of pointing for, I don't know, a hundred thousand. I mean you could never develop it on your own for that price. Just the parts you have to buy and the software you have to write and all that kind of stuff. So, when you get to complex CubeSat that have high performance it is really expensive to develop everything, and it makes no sense. You have these really inexpensive things. You can buy radios and all that kind of stuff but you learn a lot less because you are just buying that. So that is one of the reasons I think and Bob said it, we keep this thing simple and accessible. If it is simple, you can build a whole thing. You can solder the boards and you can connect everything, and you learn a lot from that. You make mistakes but that limits how complex and how much performance you can get at the spacecraft. If you need that performance because your mission requires a very accurate camera or something, it is very hard to justify "I want to develop everything myself" because the mass-produced component for satellite now from that world are so inexpensive. You can do so many amazing things you know. I remember Klaus was showing me some of the reaction wheels that are doing in Germany, and they are just crazy. There are these tiny things, they are super well balance, they are perfect and they cost a reasonable amount of money and you could never do that on your own because you don't have the capability so I think more than a buy-build thing, you need a decision on how complex your mission is and what you need. You probably don't want to do a very complex mission at the beginning even if you feel you can buy everything because it is still rocket science and it is complicated even if you combine all the thing, you need to make it all work together so you may want to wait a few missions before you get into complex things but when you get there, buying them makes a lot of sense and that is just my opinion.*

A: Yuichi Tsuda*: Yes, I think it depends on the objective of the mission activity so if you want to pursue something educational, then you have to always think about how to maximize the educational effectiveness and that does not always mean you have to pursue very higher precision, attitude control, or higher data rate and so on. You have to compromise, or you have to limit to a certain level but if you can have your students make it themselves, then they can learn much more. So, I agree with Jordi.*

A: Klaus Schilling: *I think we currently have a split. We have professional high performance missions which are constructed by research teams, and we have the educational ones where simplicity and limited timeframe matters. Yes, so they are different objectives and of course, they complement each other but on the other side, we see 2 avenues now, branching off and both of our CubeSat I think is of great benefit that we have this flexibility now in the CubeSat world and that we have a lot of commercial components reflecting this. So, we do not need to start from scratch like we had to do 20 years ago. We had to build a lot more but now we can take advantage of the benefits to have such commercial items available*

Q: Inbisat Yousuf Nath: What advancements in AI do you foresee having the most significant impact on the future of CubeSat constellation planning and management?

A: Robert Twiggs: *The thing I can say about the AI is that Chat GPT sure does write good code for processors. You know, I used to get a lot of stuff off of YouTube and other places, but it is so easy now to just ask Chat GPT with just saying "Write me some code for this processor that works with a stepper motor". May not be perfect but it gives you what you need to tweak it a little bit and it is really amazing to me that they can do that. Before we were trying to use our artificial intelligence to try and get around on the internet* *so we could find that code and not write it all ourselves so, I think more and more, it will produce some very interesting things in the future. Now, when you put it on a spacecraft and have it do things on the spacecraft, that is something I don't know enough about it to imagine but maybe the rest of you can see an application there.*

A: Klaus Schilling: *No, I would say we never do unintelligent solutions as humans. Sometimes we do but usually not in technology and so, it is some kind of tautology to talk about AI what we surely can say is: the software has an increasing role in the small satellites because miniaturization of course raises deficits and the new amazing fact is that with this advanced software with filtering technology, control technologies and so on, we can reduce the effects of disturbances. So, software in this respect placed on small satellites and using commercial off-the-shelf components helps us to reduce the effects of disturbances quite a lot and makes satellite systems more reliable when we include related redundancy concepts also controlled by related software.*

A: Jordi Puig-Suari: *The other thing that it is going to do is it is going to change the software and I think that is the key software processing capability. One of the big things that CubeSats were always in trouble with is the amount of data we can bring down because we are power limited so communication is very power hungry. So, the data rates are slow but if you can do a lot of the processing on board the spacecraft, then the amount of data you have to send is much less. So, I think that is one of the things that is going to start happening. We won't send raw data down a lot. We will have a lot more process results coming down from the spacecraft and then the links get simpler and you can still do it with a GPS because the sensor was not the problem. The radio and the antenna and the power was the problem and we can reduce that. It is one of those weird things where the software team can help the radio team and the power team and everybody else by doing more work on board than on the ground.*

Q: Aaron Zucherman: Alright, I believe we have 5 minutes in conclusion. Does anyone have any last comments that they want to make?

A: Robert Twiggs*: Well, you know, I need to pick up on Aaron here in his attempt or what he has done with respect to The CubeSat History. It was one of the most educational things for me and I hope others will have an opportunity to take advantage of what all we learned here and I would also like to thank the UNISEC People for putting this on because it is always very interesting to get views from a group like yourself. So, I hope that they do this next year because this world changes awful fast and thank you very much.*

A: Jordi Puig-Suari*: I will say something too. Thank you as well to UNISEC as well for putting this together and for all that they have done for years because they have really been a pioneer in bringing CubeSats and space technology to parts of the world that nobody expected would be doing satellites and they are now. So, Rei, congrats because you guys have done an amazing job. I always like to finish with the same thought and that is how fun! I mean this thing is a lot of fun like the first time you see a satellite attached to a rocket or you hear it beeping on the ground station. There are a few things like that which is a lot of fun and if you get too bugged down into things working and not working, don't forget to have fun and enjoy the ride because it is really unbelievable that we can do these things and enjoy a right in space which is pretty cool.*

A: Klaus Schilling: Well, I think we still have a lot of exciting problems in front of us and we want to thank Bob to have initiated the basis t*o approach them also at university level and also for our friends at UNISEC to distribute all this knowledge worldwide. So, I think a lot of things is to be done and let's go together.*

A: Yuichi Tsuda*: Okay, so form me, I would also like to thank all the participants and also the UNISEC Global meeting and I would like to tell one story. I actually heard this story from Professor Nakasaka about Professor Twiggs. So, one day Professor Nakasaka asked Professor Twiggs about the concept saying "How did you come up with such an innovative idea as Cansat" Do you remember that?*

A: Robert Twiggs: *Haha yes! We were in a conference in Hawaii and we had a good group of Japanese students there and the purpose of the meeting in Hawaii was that at Stanford, we were building satellites and hands-on things and at that time, apparently the Japanese students weren't doing that but one of the delightful things that I was going on and on about building things and I had a Coke Can sitting down and I look down* *at that and we are talking about size and look down at that Coke can. I lift it up and I said "Why don't we put a satellite inside of this Coke Can and put it up in the space?" Then the Japanese students stood up and said "Can do!". Is that the right story?*

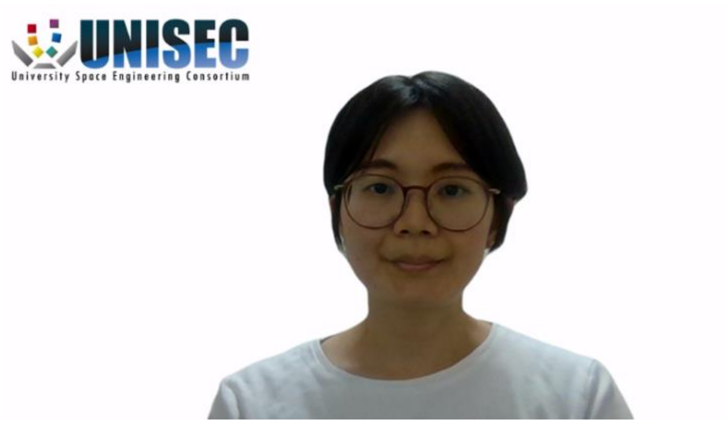
A: Yuichi Tsuda: *That is right. I remember that clearly and that is the actually a big milestone for me and my career. When Prof. Nakasaka asked that, he, I think, of course expected a very insightful answer from you but your answer was "because there was a coke can sitting on a podium".*

A: Robert Twiggs: *The other thing the Japanese have done is an event that is in Nevada each year and the first thing was we put CanSats in a container that was in the top of the rocket and they ejected that out when they got up to the apogee on it and that becomes such an easy thing for the Japanese students after a few years. We want another challenge. We want to build a rover to put in that can and it has to come back autonomously and to the launch site and what they do is they launch these rockets on a big dry legbed and that went on for 5 years. Nobody ever made it back to the flag at the launch site until the fifth year and the group that did that obviously was so excited when they saw that little rover drive up to the flag and stop. Imagine that one now. That was a real challenge because you got his carrier that is about 6 inches in diameter and about 10 inches long. You have to build a rover that fits in that, gets ejected into apogee, comes down on a parachute, gets rid of the parachute which some of them initially got all tangled up in and then drive across the leg bed which is not smooth because a bunch of guys get out on the legbed when it's muddy and there is all kinds of track in the legbed and I have some movies that are absolutely are so interesting with these little rovers coming on and hitting that legbed and they go combo across it and then all of a sudden they stop and it is off towards the flag. Talk about engineers, designers and I'll bet that is what they put on the asteroid project they put. I know one of the gentlemen that was on that set going to Nevada and doing that with the program was a really good education for him. There are so many other things; the rockets, the balloons, all this other stuff you can do an awful lot on that before you get to your CubeSat.*

A: Yuichi Tsuda*: Yeah, so that is what I wanted to say that everything started from the Coke Can so we have to thank that but that is the way innovative things happen. So, innovation occurs when you walk around what you are interested in so, stay tunes and always think about space and have fun seriously. That is the important thing.*

4. Announcement and Acknowledgment

Haruka Yasuda, UNISEC-Global



Pictured: Yasuda-san announcing the latest updates from UNISEC-Global

Highlights:

- **CLTP13 (CubeSat Leadership Training Program)**
    - Date: August 19-29, 2024
    - Venue: Nihon University, Chiba, Japan
    - Application has been closed.
    - Notification of Acceptance: June 13, 2024
    - CLTP Website: http://cltp.info/index.html

- **9th Mission Idea Contest**
    - The MIC9 theme is “Lunar Mission”
        - Category A: Lunar Orbit CubeSat Mission (LOCM)
        - Category B: Lunar Surface Rover Mission (LSRM)
    - Requirements can be downloaded at PreMIC9
    - Website: https://www.spacemic.net/
    - Important Dates:
        - Abstract Submission Due: July 24,2024
        - Notification: September 10, 2024
        - Final Presentation: November 27, 2024 (South Africa)
    - Contact: info@spacemic.net

- **13th Nano- Satellite Symposium**
    - Date: November 25-27, 2024
    - Venue: Protea Hotel Technopark, Stellenbosch, South Africa
    - Abstract Submission: July 7, 2024: https://www0.sun.ac.za/UNISEC-SAR/nanosat13/call_for_papers/
    - Early Bird Registration: August 23, 2024: https://www0.sun.ac.za/UNISEC-SAR/nanosat13/

- **Launch Opportunity: J-Cube**
    - Special Discounted opportunities
    - 1U, 2U, 3U, deployment from International Space Station
    - Collaborate with UNISEC-Japan’s University
    - Technical support will be provided
    - Contact: info-jcube@unisec.jp , http://unisec.jp/serviceen/j-cube

- **Next Virtual Meeting**
    - Date: July 20, 2024
    - Theme: Industry-Academia Collaboration for Sustainable Satellite Project
    - Host: UNISEC-Malaysia
    - Moderator: Fatimah Zaharah Ali (Universiti Teknologi MARA)

5. Participant Statistics

203 participants registered from **42** countries and regions for the 45th Virtual UNISEC-Global Meeting.

Country/Region	Number of registrations	Country/Region	Number of registrations
Algeria	1	Namibia	1
Argentina	8	Nepal	5
Austria	1	Netherlands	2
Bangladesh	1	New Zealand	1
Bhutan	1	Nigeria	3
Bosnia and Herzegovina	1	Peru	4
Brazil	1	Philippines	13
Bulgaria	3	Portugal	1
Burkina Faso	4	Romania	1
Canada	1	Russia	6
Chile	3	South Africa	2
Colombia	10	Spain	4
Dominican Republic	1	Taiwan	6
Egypt	6	Tanzania	12

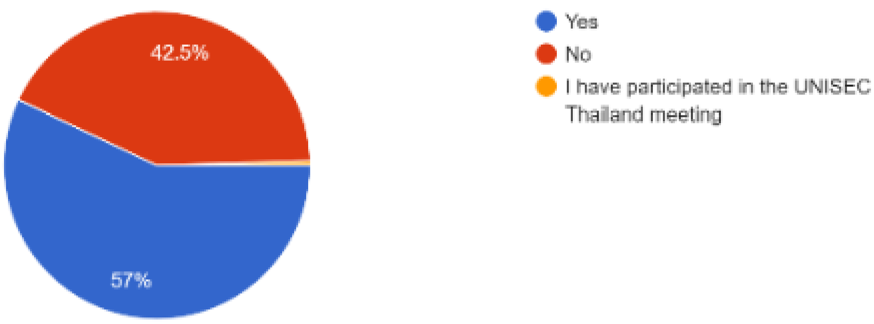
Country/Region	Number of registrations	Country/Region	Number of registrations
Germany	14	Thailand	11
India	14	Tunisia	1
Indonesia	1	Turkey	2
Japan	37	Uganda	1
Kazakhstan	1	UK	5
Malaysia	3	US	6
Mexico	3	Zimbabwe	1

Student or professional?

203 responses

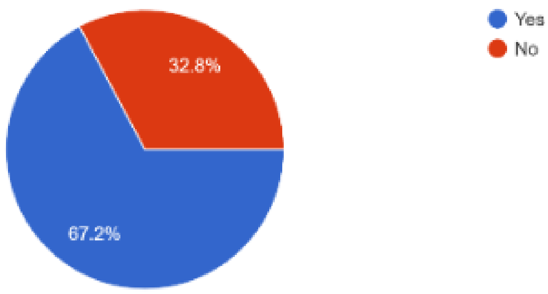
Have you participated in the UNISEC-Global Meeting previously?

200 responses



Are you familiar with CubeSat history?

195 responses

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6
UNISEC GLOBAL

Thank you