IPMU Interview

with Junichiro Kawaguchi

Interviewer: Edwin L. Turner

Hayabusa: High-risk high-return mission

Turner: Let me start by congratulating you on the amazing success of this mission which has commanded the whole world's attention, astonishment and admiration.

Kawaguchi: Honestly, it's been amazing — I was just very fortunate.

Turner: The thing that struck me the most about the Hayabusa mission compared to other space missions with which I have some familiarity, mostly at NASA, is the very high tolerance for risk — your willingness to accept the possibility of failure. Was it a conscious decision to take that sort of courageous or bold approach?

Kawaguchi: Actually, it was full of risks. It was a kind of high-risk, high-return mission. In 1995 we proposed the mission to the government when our organization was part of the Ministry of Education. At that time, the main body of the present JAXA was NASDA, and it was separate from the government. Since our organization was dedicated to research and development, the mission was proposed as a form of research. The government accepted the proposal and endorsed the project, even though it was a single-role mission — a technological demonstration of ion engine propulsion. Our minimum success criterion at that time was to get the ion engine to work for just one thousand hours. Also everything in the mission occurred in sequence. That meant that if something failed in the middle, the subsequent portions would be lost. So that was a very

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big risk, and it was already noted and acknowledged by the government when we proposed the mission. So the government accepted a certain amount of risk.

Turner: And of course there were many close calls. Was there any sort of formal mission failure assessment? Did you actually have an engineering assessment of how likely you were to get, say, the sample return which was the ultimate step, I guess?

Kawaguchi: No such rigorous process was performed. There was a kind of notional and qualitative discussion about the mission that consisted of the first ion engine propulsion, autonomous touch-down and sample collection, and also the re-entry of the vehicle. Supposedly, everything had around a fifty percent chance of success, so the overall possibility of completing the mission was extremely low, right? We were aware of that, and the government also noted it. To be honest, even we were not sure that the mission could be completed. So that was a major challenge.

Turner: I very much admire the courage of doing that, because although it is possible to define mission success as testing the ion engine, I am sure after you have devoted many years of your life, and many people have also devoted years of their lives, to the work you really are very anxious to have full success.

Kawaguchi: Right, thank you.

Recovery of lost communication: a miracle

Turner: I also wanted to ask you about the high drama of this mission, so many almost disasters, so many brilliant recoveries! What would you say was the most satisfying success? When did you feel the best? About what event?

Kawaguchi: There were a few occasions, but ultimately it was when the capsule was recovered. However, on our way to re-entry, we lost all contact with the spacecraft for five or six weeks at one stage. So it was also when we received a radio signal from the spacecraft after the hiatus in communications of around seven weeks.

Turner: That was because of loss of pointing of the antenna?

Kawaguchi: No, the whole spacecraft and system were down. We gradually turned on the instruments one by one, and attempted to transmit various commands to the spacecraft. It was kind of a miracle even to us. That was one major instance. The next one was when we were able to restart the ion engine by devising a new configuration of the ion engine system.

Turner: Yes, I read about that. Amazing!

Kawaguchi: When that

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combination actually worked, we realized that we might be able to get the spacecraft to return to Earth. That was the second instance.

Turner: Great. I guess the partner question must be what was the most disappointing failure or loss on the mission?

Kawaguchi: The highly sophisticated technology, the ion engine, the autonomous navigation guidance, and also the re-entry worked very well, which probably came as a surprise to us. However, if we look at things such as the reaction wheels, which are a kind of low-level technology, those are the instruments that failed during the journey. That was very disappointing. We did not expect that such basic things would be subject to failure — extremely disappointing.

Turner: What about the little robot that was going to hop around on the asteroid?

Kawaguchi: Right. We were supposed to jettison the robotic lander while the spacecraft was above the surface. We intended to make that happen when the spacecraft actually touched down. We thought we should avoid such a complicated operation whereby the robotic lander would be separated prior to such a major event. However, at the time, our navigation control skills were not ready to make that separation occur. That was our fault. The lessons learned will be incorporated in the next mission. In addition, the sample collection projectile did not fire. When the spacecraft tried to pick up the sample from the surface, it was intended to shoot a projectile to the surface. But the projectile was not actually shot due to a programming failure. That was also the result of human error.

Turner: Was there anything in your involvement with the mission that particularly surprised you, any event that you just never imagined happening?

Kawaguchi: We actually adopted the appropriate measures for all difficulties and incidents. We thought that they should work based on certain assumptions, even when the restoration of communications was actually planned. We thought about what boundaries and what areas our measures could work for. However, there was no guarantee that our assumptions were correct. Whether or not those assumptions were actually correct was not something that could be controlled by humans or by our project itself. So we believe we had plenty of good fortune.

The Japanese asteroid explorer Hayabusa, launched on May 9, 2003, arrived at asteroid ITOKAWA in September 2005. This artist's image shows Hayabusa's approach to ITOKAWA (courtesy: Akihiro Ikeshita). Hayabusa touched down on the surface of the asteroid and collected soil samples. It returned to the Earth and re-entered the atmosphere above the southern Australia sky on June 13, 2010.

Interplay between science and engineering in space missions

Turner: In such space missions there is usually some interplay between science and engineering considerations. So the scientists would like certain sorts of data, and the engineers have certain constraints and practical considerations. The interface between these two can be a very complex and delicate balance. How was that handled for the Hayabusa mission?

Kawaguchi: This was proposed as an engineering mission and a technology demonstration. If we had just wanted to perform the technology demonstration, we would not have had to actually fly to the asteroid. So ion engines could have propelled the spacecraft just within the vicinity of the Earth, and re-entry could have occurred from that point. However, even a technology demonstration mission should accompany or take advantage of the flight opportunity to perform scientific feats. That was our intention. So we decided to actually undertake the space flight to the asteroid. But this was just for our case. There are two types of missions: science-driven and engineering-driven missions.

Based on my personal experience over probably 30 years, my impression is that science can be performed within engineering missions. Some scientists would say that the mission should be driven by scientific purposes, and request the technology required to that end. However, sometimes the technology is not adequate or is not mature enough. In that case, the planned scientific mission may be threatened with cancellation. The space business is extremely expensive and involves significant investment from the government. To ensure that the missions are performed safely, all science missions need to be planned by looking at the engineering foundations. That means that scientists should not request excessively complicated missions. So an engineering-driven mission is a very good way of doing things, in a sense. That is what I think.

Turner: In this particular case, I guess the science driver of visiting an asteroid introduced a serious engineering complication of doing operations with a long time delay for the signal travel time. Did that make the operation significantly more challenging from an engineering sense?

Kawaguchi: Yes. Even from an engineering perspective, that longer communication time makes exploration or scientific observation difficult. However, what we realized is that the people, operators and researchers, can easily become accustomed to performing such operations. At the beginning of our stay near the asteroid, we actually had a great deal of difficulty. However, it was handled gradually. We believe that even at a very great distance, the operations of that mission were able to be performed. It was not such a major difficulty.

Turner: So you learned something.

Kawaguchi: We learned a great deal.

Turner: What was the time delay, roundtrip?

Kawaguchi: It was approximately 35 to 40 minutes — which is still not particularly large — but if some spacecraft goes farther away in the next five to six years, the travel time will be significant.

Turner: Yes, that is going to be a major issue for exploration of the Solar System. Is there anything major that you would do differently if you were doing the mission over again, either before launch or after launch, not about specific problems but as far as overall mission design or mission choices? Were you happy in the end? Of course in the end it was a big success, so you must be pretty happy.

Kawaguchi: As of now, I am relatively satisfied, regardless of how seriously the spacecraft was damaged, because the spacecraft was able to survive and return home. That means that we are able to say which portions need to be more rigid and should be compensated for in subsequent missions. This is a significant advantage. If the mission had been interrupted partway through, we would not be able to say this.

Turner: So, the Hayabusa mission must now own several world records. The sample that was returned must be the most distant material ever brought back to the Earth.

Kawaguchi: We hope so. Some of the detailed results of the analysis will probably be available in a few months. Still, we have to wait for those results. Even though what we were able to get was very minute and consists of only small particles, I am sure that some of the particles will contain compounds from the asteroid's origin.*

Turner: There was already a publication of major results in a special issue of Science Magazine, in 2005 or 2006, from the data that was radioed back by telemetry. Will there be a similar publication of a large amount of results from the analysis of the returned sample?

Kawaguchi: I think so. What will come out early next year will probably only be the initial results of the analysis. But that will probably be a new set of results that can be shown to the world. In addition, we plan to issue an AO (announcement of opportunity) to the world to solicit proposals. We will distribute samples and results to scientists.

Turner: That means that scientist around the world would have an opportunity to study the material?

Kawaguchi: That is correct, if a number of particles are obtained.

Dream come true

Turner: I would now like to ask you a few slightly more personal questions. To lead such an amazing mission of exploration seems like an almost romantic development in life. Did you ever, when you were young, a child or a young man, imagine that you would get to do such a thing?

Kawaguchi: It was my dream. The time when I was a child and while I was at primary school fully overlapped with the Apollo, or Gemini, or Mercury…with the Gemini and Apollo era. We were provided with a large number of opportunities. The Russians and NASA were in competition in the space race during the Cold War. I experienced actual real-time TV relays from the surface of the moon.

Turner: I remember it vividly.

Kawaguchi: That was a major historical event, and I was actually greatly impressed by it. However, the Apollo 11 mission took place in 1969, and one of the first small Japanese satellites in the lowest orbit was launched the following year. Even though our satellite launch made Japan the fourth country in the world to reach orbit, it still meant that we were ahead of the rest of the world. However, the gap between Japan and NASA's or Russia's activity was enormous. I wondered what we could do in terms of space exploration. And I was skeptical about the future of the Japanese space development program while I was in high school. But I was extremely interested in space exploration. Although there were still significant uncertainties, I decided to go to post-graduate school to undertake research into space development. During this time, I had an opportunity when Japan was attempting to launch the first interplanetary probe to Halley's Comet in 1985. That was a major trigger for me to change my point of view and take a different approach. What I mean is that I had been skeptical up until then, but beyond that point, I made a decision to devote myself to space development. The biggest events that affected my life were Pioneer 10 and Pioneer 11, Viking 1 and Viking 2, and Voyager. Those were the deep space missions that really gave me a true sense of how accurately those spacecraft were navigated and guided to their destinations. That was another significant area of impact on my life. So I started thinking about remote or autonomous automation, or control, or guidance. Controlling a spacecraft to an extremely

* This interview was held on October 16, 2010. Later, JAXA announced identification of the origin of the particles brought back by Hayabusa. They have been identified as rocky particles, and most of them were judged to be of extraterrestrial origin, and definitely from Asteroid Itokawa. See http://www.jaxa.jp/press/2010/11/20101116_hayabusa_e.html.

distant location, making that spacecraft perform robotically and autonomously, and then making it fly back to Earth is exactly what I wanted to do. Years later, my dream truly paid off.

Turner: It is wonderful that you can have a life dream that comes true.

Kawaguchi: Yes, I was quite fortunate.

Turner: And to reach out and touch an asteroid is an amazing dream. And your dream really caught on with the public even throughout the mission and certainly since the mission ended. Hayabusa has had a tremendous following in the public. I think maybe the Mars landers might have been similar and trips to the Moon, but in many ways this is one of the most popular space missions ever.

Kawaguchi: Especially in Japan.

Turner: All over the world, but especially in Japan. Did you expect that? Does that seem surprising to you or natural?

Kawaguchi: I had scarcely imagined this happening. I was not planning to do this, to produce this reaction from the public. But we tried to make our activity transparent to the outside world, especially when we performed touch-down events — through the internet and the readings of the transmitter, what we did was shown just as it was. And for the return journey and re-entry we did the same thing. So everything could be clearly seen from the outside.

Hayabusa imparting a feeling: not just a machine, but an actual falcon

Turner: There is something about the going out and coming back that gives the whole mission a sort of human emotional tone. It is like someone going off from his or her home and having a great struggle and then returning, almost like the plot of a novel or a folktale. It is easy, I think, for people to relate to Hayabusa in emotional terms. Of course as professionals, engineers or scientists, we understand that it is just a machine, just like a tape recorder or cell phone or automobile. But at the same time, it is easy to feel that it almost has a personality — in English we would say, anthropomorphize the spacecraft. Did the operations team do that to some extent? Did you begin to feel like Hayabusa was not just a machine but an actual falcon?

Kawaguchi: Before the launch, while the spacecraft was under development, we did not have that feeling. However, right before the launch, we had not expected it, but some musicians composed some jazz tunes. They issued a CD and they shared with us what they were feeling and what the mission was. By composing jazz tunes, they imparted the feeling that the mission was not just on a machine or a spacecraft. It would return like a baby to the ground. They had already noticed that, but we did not have that impression. However, after the launch, the spacecraft was fully equipped with highly sophisticated autonomy. Autonomy can be programmed. So we had accumulated numerous rules that were programmed into the spacecraft. Without this autonomy, even ion engines could not be driven. So many, probably hundreds or thousands of rules, gradually accumulated in the spacecraft. We had to count on the fact that the rules would be followed autonomously by the spacecraft. It meant that, for seven years, we had *raised* the spacecraft. Gradually the project team began to think that it was not a machine, but almost a child that we had raised.

Turner: You *raised* it! I think that is a very natural human reaction. I imagine during the mission, you must have spent much or most of your time working on this particular mission itself. I know you are also director of the JAXA Centre for Space Exploration. How are you spending your time post mission? Or how are you looking towards its end? Or what are you looking forward to in the future?

Kawaguchi: First of all, the next mission will be undertaken by the next generation so that we are able to increase the number of specialists who can carry out this kind of activity. The transfer of that technology, knowledge, and the like is a very important aspect of nurturing the next generation. I will not actually be concretely involved in the next mission. However, I can work as an adviser. Supposedly, I was the first generation; Hayabusa's first generation was asked to build and operate a spacecraft; that was probably easily done. However, it will not increase the strength of the community of the next generation. I still probably have another 8 to 10 years before my retirement. I am attempting to propose the next mission, which may not be readily endorsed by the government. But proposing new missions and new programs is what we have to do. I hope the project team will have another generation that will be responsible for that.

Turner: My last question is about the name "Hayabusa." I understand it is a kind of bird of prey which in English is called a falcon. How was that chosen?

Kawaguchi: It comes from the way the spacecraft picks up and takes hold of the samples. Hayabusa, the falcon, makes a steep descent and touches down, then seizes its prey. The work undertaken on the spacecraft and the sampling is also carried out using the touch-down and go method. That is why we named the spacecraft Hayabusa, the falcon.

Turner: Very interesting. It has been a wonderful pleasure for me to hear about all of this directly from you. It is certainly a remarkable story. Thank you.