Oral History of PMR Head and Media (Yoichiro Tanaka, Hiroshi Sakai, and Koichi Terunuma)

Interviewed by:
Chris Bajorek

Recorded August 1, 2016
Tokyo, Japan

CHM Reference number: X7916.2017

Interview of Toshiba, Showa and TDK contributors to the first commercialization of PMR media and heads in Japan

Chris Bajorek: One of the most significant recent technology developments was the commercialization of perpendicular magnetic recording. Starting in 2005 adoption of perpendicular magnetic recording significantly facilitated an eightfold increase of data capacity in hard disk drives. Hard disk drive capacities of up to 10 TB are the norm today. This breakthrough was made possible by use of a unique perpendicular magnetic recording medium, known as the oxide medium, first developed in Toshiba under the leadership of Dr. Yoichiro Tanaka. The oxide medium was adopted by the entire hard disk drive industry. The first generation of this perpendicular magnetic recording disk was manufactured by Showa Denko. It was matched with a first generation perpendicular magnetic recording head supplied by TDK. This oral history records the three-way collaboration between these companies that resulted in Toshiba's first PMR hard disk drive. The interview will include Messrs. Yoichiro Tanaka from Toshiba, Hiroshi Sakai from Showa and Koichi Terunuma from TDK.

Chris Bajorek: Well, I think we should start by having each of the interviewees introduce themselves. Tanaka-san, perhaps you could lead the way. Tell us a bit about yourself, your name, place of birth, where did you grow up, your education. Please go ahead.

Tanaka: I am Yoichiro Tanaka. I was born in the city of Yamagata in the northern part of Japan and grew up in the same city. I joined Tohoku University in 1977. And entered to the graduate school in 1981.

Bajorek: Please, perhaps you could go next.

Hiroshi Sakai: My name is Hiroshi Sakai. I was born in Ōmachi City in Nagano Prefecture. And then I grew up in the same city. And I graduated from Waseda University.

Bajorek: What did you graduate from, what year?

Sakai: What year I graduatet? In 1996.

Bajorek: Thank you. And how about yourself Terunuma-san.

Koichi Terunuma: My name is Terunuma, Koichi Terunuma. I was born in Ibaraki Prefecture, north of Tokyo. And born and grew up in the same city. And I joined to Ibaraki University and graduated 1983.

Bajorek: Very good. Could you also, tell us a bit, maybe we'll go back to you Tanaka-san the companies you worked for and some of the early-- examples of the most important research projects you worked on?

Sakai: Excuse me. Sorry. I made a mistake. I graduated in 1986. Sorry, I said 1996. It's 1986.

Bajorek: Thanks for correcting that. No problem. Thank you.

Terunuma: So he is young.

Sakai: Too young, sorry.

Tanaka: That surprised me. Oh.

<group laughter>

Sakai: Sorry.

Tanaka: Actually, we are the same generation almost.

Chris: Yes, yes, yes

Sakai: Almost.

Tanaka: So what was the question, again?

Bajorek: Oh, I just wanted to give us-- have you each give us a sense of the -- which companies you worked for and what were some of your major responsibilities or accomplishments in those companies.

Tanaka: After I was awarded the master's degree in the Tohoku University in 1983, I directly joined Toshiba's R&D Center. And so we started a PMR, perpendicular recording research and other high density recording devices such as GMR. And I continued to focus on the technology of high density magnetic recording until the completion of PMR commercialization in 2005. In addition to that, I worked on the hybrid drive architecture when I was in the United States, in Silicon Valley to lead the team there. And now currently I am a senior fellow with Toshiba and working on the advanced recording, advanced storage system architecture especially for medical science applications.

Bajorek: Thank you. And how about you?

Sakai: I worked for Showa Denko.

Bajorek: Directly from the university also?

Sakai: Yeah. I graduated from Waseda University, with the master's degree in 1986. And then immediately joined Showa Denko. And after three years of working for Showa Denko I worked at the MIT as a visiting scientist, for two years. And after coming back to Japan I joined the hard disk division. And from then, I've been working on hard disk media for more than twenty years. So I'm responsible for R&D media, R&D for Showa Denko hard disk media. Actually, Showa Denko has four factories and four R&D sites. So I am responsible for all sites of R&D. And I'm now the senior corporate fellow in Showa Denko.

Bajorek: When you were at MIT what type of work did you do? Which department or group?

Sakai: Oh, I joined the ceramics processing center in MIT. And at that time I worked on the barium ferrite perpendicular magnetic recording like it's a powder. So also Toshiba-san working on the barium ferrite at that time.

Bajorek: Yes. This is for magnetic, for particulate media like tape, the barium ferrite?

Sakai: Yeah. And I also tried to send our barium ferrite powder to TDK, TDK-san also.

Bajorek: Very nice. How about you, Koichi?

Terunuma: I graduated a master's course in 1983. And also joined TDK R&D Center. And first my mission is the development of high B_s high flux density of soft magnetic film for head by sputtering. After that I joined the head division and started development of reader and the writer, advanced reader and the writer such as GMR head, TMR head, and also perpendicular magnetic recording.

Bajorek: It's interesting how close you all are in terms of finishing your studies, university studies. And how you joined the respective companies roughly at about the same time. I'd like to shift to the collaboration that lead to the creation of the components and the first PMR drive. Again, perhaps we start with you Tanaka-san. Can you describe the overall working relationship between the three companies and who were the key individuals, when did it start? How was it started? And all three of you are welcome to comment about that but, please, go ahead.

Tanaka: We started perpendicular recording study some long years ago. I heard that, before I joined Toshiba, Toshiba already started. That was the cobalt-chrome based research and also barium ferrite based research. In terms of the collaboration that was the year 2000. So after we launched a proof of concept, a very highly stable write structure with PMR. At the time so we have established some of the development, some of the manufacture -- not manufacture, it's the deposition process of cobalt-platinum based perpendicular media with uniquely formed oxidized grain boundaries in the media. It resulted in very high squareness, large nucleation field, cobalt-platinum oxide media. We were seeing cobalt-platinum-chrome oxide media at the time. That was the principal concept to prove the very stable write structure is a must have thing for practical perpendicular recording with the long time reliability and stable writing structure. And that was a kind of upstream research. Then the next step will be the shaking hands with partners which were Showa Denko and TDK with us. So we did not have any facility to make a device production for volume manufacturing. So that was the phase we have to have a collaboration with sophisticated manufacturers of the devices. That was Showa Denko and TDK. But we made close design-in- cycle: make, test, feedback, improve it, test. So those are the short cycles. Thanks to the location we are relatively close in places. And also a good partnership in communications. So we made such cycle and to speed up, that was a very effective way to build a complete disk drive, integrated disk drives.

Bajorek: How did you provide the heads before? I imagine you were working with -- needed heads before 2000, before you started the collaboration. Right? How did you procure those heads? Were you able to prototype them within Toshiba? Or did you also get them from TDK?

Tanaka: At the time, well before 2000 the available heads were the ring heads or the thin film head. And the thin film head could write to the perpendicular recording media but this was not the ideal case. But we did not have the process to produce it even for a prototype. I came up with the idea to use the focused ion beam etching to make a single pole like head based on the thin film plated head. But I never succeeded.

<Laughing>

Tanaka: The fundamental structure is quite different. So only the shape look like a single pole type perpendicular head but it was not functioning.

Bajorek: Not functioning single pole head.

Tanaka: We asked the partner TDK to build the single pole type head. And the TDK started their own research to design and processes. And so Toshiba [sic] ….TDK supply those sample heads. And we tested, combined with our media, the Showa Denko's media and we made a small feedback loop.

Bajorek: What were some of the most important challenges during that collaboration with Showa and TDK?

Tanaka: So one of the biggest challenges we had was the collaboration schemes. There could be in many ways in collaboration… provide IP….Instead we get some products or where money trades or everything. But fundamentally we did collaborate in equal manner. So more importantly the theme of relationship was to trust each other to have this shared dream or shared goal to achieve. That is the one that we have had. Luckily we had that scheme. And we worked together towards that single goal. So that was a great stuff for us.

Bajorek: Were there other players in the companies above you? I imagine this also required encouragement and agreement at more senior levels of management at the time? Were there such agreements? Or, who were some of the key players who helped put the glue together, right?

Tanaka: Yes, a pointing head in terms of planning ahead, in fact my boss Yasuichi Hashimoto in Toshiba, he was the technology executive. And in the Showa Denko side it was Sasaki-san. He was the top of the media division. And they agreed to work together. So they actually led us to a very close collaboration together.

Bajorek: Was there equal involvement from a senior person at TDK? Or did that happen later?

Tanaka: In the collaboration scheme, in the media part it's very close. In the head part of TDK, it's the… most processes we cannot touch. So TDK contributed on the design.

Bajorek: Very good. Perhaps, we could get you to talk about the medium. By the way, don't be constrained by my questions. You know, the important thing is to tell the story of how this happened. So take it from here. How do you remember the medium happened?

Sakai: Okay. So today actually I brought the 2.5-inch drive. So this is Toshiba-san's first prototype PMR drive. And they installed Windows -- installed. So actually this…. Showa Denko started to make PMR media using CCPB a cobalt-chromium-platinum-boron type of media which is very close to LMR. And as

Tanaka-san mentioned that is actually it's not like, for example, the hysteresis loop has a positive nucleation field. So it's not thermally stable. But actually we started to make it. And actually we made a disk drive and still I keep the disk drive. It's my kind of treasure. So in the—but, once we made the drive, but very difficult to improve more. And also it's because of positive nucleation field. So, it was difficult to achieve the better stable media. So Tanaka-san's group introduced the CCP oxide. Actually, it's reactive CCP, reactive, auto reactive sputtered media. So it's a grain, grain boundaries, or grains were well-segregated by oxygen, like an oxide. So previous CCPB…. is a CCPB medium is chromium is segregated to a grain boundary. So anywhere case it's C-axis is this direction <Sakai-san pointing by hand>. So the chromium segregated in this way, this way <Sakai-san pointing the direction by hand>. So it's well segregated. But PMR C-axis is this direction <Sakai-san pointing by hand>. So this type of chromium is very hard to segregate. So that's why we were kind of stuck. And the oxygen will segregate but it's a reactive, oxygen reactive sputtering. That mean it takes a long time to sputter. So we try to minimize the sputtering time with the Toshiba-san's group. And actually, we couldn't achieve it. But later, other guys like Fuji Electric started to use granular type, like SIO_2 or other oxide material type……..

Bajorek: In the target.

Sakai: Yeah, in the target, oxide is in the target.

Bajorek: Yes.

Sakai: And then that can sputter faster. So we also adopted it. But the problem with the granular media, has a very high H_c (coercivity) distribution. So like when you make a loop… So like hysteresis loop, is like tail, is like trailing <Sakai-san gesturing about the shape of the hysteresis loop>.

Bajorek: Very long tail?

Sakai: Yeah, very long tail. So H_S (saturation magnetization) is very high. So it is very difficult to get the higher Overwrite. So that's why the media itself, it looks good. But in the drive, it doesn't work. It didn't work. So we also stuck, again. But Showa Denko used a capping layer on top of the granular layer, so it's a continuous layer. So because of the continuous layer its Hc distribution gets small. And they can write. So then we move forward and it becomes the real product.

Bajorek: So even in that prototype that was not the advanced medium you just described but that is a TDK -- I mean a Toshiba drive with a Showa Denko disk and a TDK head.

Sakai: Yes, yes, that's right.

Bajorek: I'm sure that must have given you a push, right? To keep going. Right?

Sakai: Right. Yes.

Bajorek: Even though you were running into these problems. Right? Because that's a major milestone. Perhaps could this be the first prototype in the industry?

Tanaka: It probably was not first, but this is the first prototype to show publicly some months later.

Bajorek: But how do you-- it seems to me-- I want to calibrate ourselves as to whether it could have been the first such prototype in the industry. Did anybody else do a PMR drive, prototype, before you guys did it?

Tanaka: I hope so. I think so.

Sakai: Yeah, this is 2001. I think Toshiba-san is the first.

Bajorek: So it was the first, right? Because I think that was -- I was not aware of this prototype but you show it. And I think it's probably the first one. I mean I know you may have had internal prototypes that you didn't publish before this. But this is probably the first one that was made public.

Sakai: Yeah, it's already fifteen years passed but there is still data, it's not erased yet.

Bajorek: It hasn't been lost.

Sakai: No, not lost. Even the positive nucleation field is still okay.

Bajorek: Very good. Well, maybe we could switch it and talk a little bit about the head. How did you get involved?

Terunuma: TDK individually started PMR head development in 1998. Two years later, started collaboration with Toshiba and Showa Denko. And so Toshiba gave us a HDD device for HDD point of view. And Showa Denko gave us the… supplied the PMR media. At the time, I'm responsible for read GMR read head. And PMR recording is very effective for read head because their read back signal is much higher than longitudinal. And also read track width is much tighter than longitudinal. So reader head, reader development was very helpful. And also the magnetic PMR writer so many issues we have.

One of the most serious issues is pole erasure. The pole erased the data. That's a very serious problem. But Toshiba advised us and also Showa Denko gave us many kind of media, gave us, and we had a solution. And one more very interesting thing is magnetic head performance is much dependent on the media. Even in the same head performance for this media very good but another media, very bad. Very dependent on the media. Well, that's very interesting but very serious problem. That's it.

Bajorek: I think part of the head now is in the media.

Terunuma: Yes, that's right. Right.

Bajorek: So it's no longer just media. It's a combination of head and medium. As we come back to the medium what were the most important challenges you ran into? You mentioned this coercivity variance. Right? The tail. And a capping layer helped. Were there other challenges?

Sakai: Yes, the main challenge, I think, there were four main challenges. So one is the soft underlayer. So because the soft underlayer has a domain wall and that domain has a spike noise. So we have to suppress the spike noise. So initially we tried many things like multi layers of soft underlayer. Or pinning by HAMR. Or even we use a…tried to use an electroless plating. So, because it's a… really dependent on head. But at that time we need a very thicker soft underlayer. So maybe plating is maybe easier. So we also tried it. But finally AFC-SUL-AFC, soft underlayer, ruthenium, soft underlayer. So it's an AFC coupling that could be working. So we solved that. So maybe everybody, I think, will use that film. And that is one item. And the second one is the granular medium, as I mentioned. Because Tanaka-san mentioned it's a very beautiful like higher negative nucleation field. So it's really good for PMR. So that is a second one. And the third one is the capping layer as I mentioned also in there. And the fourth one is the breaking layer. And so right now all media use a breaking layer. So actually there are many, many magnetic layers. So in between there's kind of like a break so a normal layer in between magnetic layers. And recently many, many, like more than two or three or even more breaking layers. So layers are stacking more like compared to previous. So, but Showa Denko actually use this breaking layer from the first product in 2015. So now… breaking layer can improve writability and SNR. So now everybody like, use it. But that one also a kind of breakthrough to achieve the PMR media. So that four items I think were the key challenge.

Bajorek: I was personally not familiar with the breaking layer. Is it a nonmagnetic layer?

Sakai: Yes.

Bajorek: And it's below that capping layer so you have a magnetic capping layer, a break layer and then the data layer in terms of major building blocks.

Sakai: Yes. Right. So now maybe first generation is maybe one granular layer, breaking layer and the capping layer. But now there are many, many granular layers. So in between granular layers and also breaking layer.

Bajorek: When I last worked on film media I think I counted about ten layers starting from the substrate like nickel phosphorous plus the layers on top -- this is in longitudinal media. Roughly, how many layers do you say are currently?

Sakai: Today, many, actually. Many…I can't say the exact number.

<group laughter>

Bajorek: No, roughly.

Sakai: Roughly maybe 18 or 19 or something layers. More than 18…

Bajorek: Amazing. It's become a very complex device.

Sakai: Very complex. Yes.

Bajorek: It's extraordinary. Coming back to the SUL, the soft underlayer, you solved it with antiferromagnetic coupling.

Sakai: Yes.

Bajorek: Was it coupled through a thin layer of ruthenium in the SUL?

Sakai: Yeah. But we also have our IP but that one it may be other media maker did first in the -- yeah, the first prototype.

Bajorek: But you were using in the equivalent. You were trying to achieve a synthetic antiferromagnet.

Sakai: Mm-Hm.

Bajorek: Very good. Coming back to the head how did you ever solve the erasure problem? Was it a head solution or a combination head and media?

Terunuma: Of course head and media. For head wise, the material, pole material and also the stress, external stress to the magnetic pole. And the combination of that we fine tuning to the domain structure of the perpendicular recording head pole. That's a very important issue. Of course, media is important.

Sakai: Yeah, we worked closely. We also from media side we tried to minimize the pole erasure

Bajorek: Yes. If I'm not mistaken the first generation had or maybe even more than first generation was an unshielded pole had.

Terunuma: Shielded pole.

Bajorek: The first one was…

Terunuma: Shielded pole head.

Bajorek: I'm just curious, do you think the first commercial one was shielded? The 2005 drive was it unshielded or shielded.

Terunuma: The 2005 drive is shielded pole, is it?

Tanaka: On one side.

Terunuma: One side.

Sakai: One side.

Tanaka: It's the simplest as it could be. It's the main wide shielded but some sense of…

Terunuma: Trailing shield.

Tanaka: Trailing shield.

Terunuma: Trailing shield. Yes.

Bajorek: Okay. Thanks for clarifying that because I wasn't sure. I was curious when the first shields were introduced. So you're saying from the time zero, the first generation had the shield.

Terunuma: First commercial generation is trailing shield.

Bajorek: Okay. Very good.

Tanaka: Yeah, because the media, it placed -- it's pinched by the head and the soft underlayer. All of the flux path is in the loop including heads and media combined. So we cannot tell only the heads, only the media. All of the test and design and feedback group has to -- all in has to be all in one in the heads and the media. So that's the biggest difference between LMR and the PMR, especially for fighting against a pole erasure stuff. This is not exceptions. Heads and media has to be combined to fix that problem.

Bajorek: Yes, the interdependence was higher than ever before.

Tanaka: Right.

Terunuma: Right.

Bajorek: You had to design a self-consistent system for all of the components. Right? Otherwise, it wouldn't work. Very interesting. I also was curious how…. if you were influenced with those collaborations with some of the academic efforts in universities like the joint industry academic efforts like the storage research consortium. I'm not familiar with all of the Japanese collaborations. But was this done among yourselves? Or was there also input from the universities?

Tanaka: SRC was founded I think It's the middle of '90s, '94, '95 and to motivate the university researchers and also support the university researchers to do the fundamental physics and the materials and the related technologies and magnetic recording including heads, media, chemicals, lubrications, even the signal processing. And that was a big step inside of Japan to raise the combined academic interest into the world of real development with the industry. And our collaboration in the three company is now, did not engage into the real project in the SRC. SRC is very much the academic side. But we learned a lot from SRC research and results and academic point of view. So we had many check and review of our internal research, checking with the result from SRC which is right, which is not. It was quite good references.

Bajorek: So there was not a direct collaboration but you were taking advantage of the knowhow.

Tanaka: No, it's not knowhow. It's physics. It's different. Knowhow and physics are different. And we funded them. And we learned the physics. How to understand the physics. And bring them into our knowledge. So that was the relationship between SRC and our collaborations.

Bajorek: And all three companies were members of those…

Tanaka: Yes.

Bajorek: Very good. I thought it might also be interesting to update the world about the status of the industry. How many drives, how many disks, how many heads do we produce today, per year? And the position of Toshiba, Showa Denko, TDK in terms of market share in the industry.

Tanaka: Yeah, in terms of the size of the hard disk drive market the other supplier produces about 400 million units plus per year currently. And Toshiba is positioned as number three. And with the unit shares it's about eighteen percent including mobile and enterprise products.

Bajorek: And how many disks does that 400 million drive set require?

Sakai: Yeah, last year the media market was about 870 million pieces. And then maybe this year down to 800 million probably. And Showa Denko market share last year is about twenty-three to twenty-four percent.

Bajorek: And heads?

Terunuma: Head total volume is roughly three times HDD shipment of hard drive. That mean each HDD drive and HDD has three heads in a…

Bajorek: That's an interesting ratio.

Terunuma: Yeah, three heads on average. TDK share is about twenty-five percent.

Bajorek: So with a ratio of three heads per drive, does it mean that some drives have some surfaces without a head.

Terunuma: Right. One surface or two surface or many disks, average is three. I think it's gradually increased, 3.5 or something, because a nearline drive is increasing. The nearline drive has much more disks and heads.

Bajorek: Those are the drives that are used in the enterprise space.

Terunuma: Right.

Bajorek: We talked a little bit earlier about it but I think it's good to summarize the progress that's occurred in the technology measured in areal densities since the introduction of the first drive. Where are we? I think I read we crossed a terabit per square inch areal density recently. And the first drive had an areal density of…

Tanaka: 133 gigabits per square inch.

Bajorek: So it's about an eightfold increase. That's amazing.

Terunuma: Right.

Bajorek: And since you're all actively involved at the battlefront how do you see the future of perpendicular magnetic recording?

Tanaka: Based on the PMR so we have more options to assist the writing process by energy. So there are two kinds of energy are now being studied. So one is heat. There's another one with microwave agitations. So there are two ways to do assist to make the write performance more powerful to adapt the higher coercivity media at the small grain size. So this is the one recording scheme in the future. And so another aspect is use more magic I would say. Signal processing scheme with two-dimensional writing, two-dimensional recording. It's called a TDMR. It squeeze more tracks and also treat adjacent interference between tracks next to each other. So that is considered to write in the right manner and read, avoiding any big interference between tracks. So those are signal processing related directions, in hard disk drive configuration.

Bajorek: So I get a sense that you're optimistic about the future. That there are enough things going on that will continue to see technology advancements.

Tanaka: Because optimism makes more ideas than pessimism.

Bajorek: Absolutely right. How about you? Is your view consistent with that?

Sakai: Yes. So current media situation is pretty much similar to the end of the LMR. So it's almost reach the limit of the "trilemma". So "trilemma" is an SNR, thermal stability and writability. So we now improve, try to improve SNR. And always encounter some instability. So we have to increase the K_u (magnetic anisotropy). So if we increase K_u the writability is an issue. So we need assisted recording. But still HAMR or MAMR technology take time to be realized. So until the HAMR is nearly coming we have to keep improving the current PMR. So maybe we change the magnetic media configuration and maybe other changes. And we try to keep improving conventional PMR.

Bajorek: I was also curious about your perspective on how you managed the cost of the disk because you describe the disk has become much more complicated. Has that affected the cost in a dramatic way? Or you succeeded in squeezing all of this at current cost?

Sakai: Yeah, that is actually issue because we have to compete with SSD. So SSD prices dropping and then going down and down. So also hard disk drives have to be lower. And so that means the media and head should be lower price, low cost. But drive prices lower but actually technology getting difficult, harder and harder. And the more technology, for example, the media case, more layers and need more sputtering chambers and this is higher cost. But we try to also reduce it as much as possible. But HAMR is also very high cost. So that's also another issue. I mean now maybe the performance is a first but we also consider how to minimize the cost.

Bajorek: But the heads are inexpensive, right? Easy to make? All it has is one pole and a tunnel junction. Right?

<chuckles>

Terunuma: I agree with you, them. But a head is really complicated. For example, there is a thermal assisted -- optical devices will, should be included to the magnetic. Magnetic plus optical.

Bajorek: All integrated into the same device.

Terunuma: Right. Very complicated process. The process time is much more, much longer than conventional. And also microwave assisted also complicated. But we should do two ways in parallel. The process time is much, much longer than conventional. That's a headache.

Bajorek: I can see that. Well, I conclude from your remarks that we will have to find a way how to continue to refine and advance the current system as we know it, right, because these other improvements have not yet been fully mastered. Lastly, does the collaboration continue at the same level between the three companies? Or did it change after the first success?

Tanaka: So we adaptively changed the inside of the collaboration, contents of the collaboration. So phase by phase. So this is very flexible.

Bajorek: Okay. But you're continuing at some level the collaboration. Very good.

Tanaka: So the three of us have our own expertise. Drive, media, heads, those has to be combined to make a big success for everybody.

Bajorek: Yes. Well, before we end I just wondered if there's anything else you wanted to cover? Any other subject you wanted to discuss?

Terunuma: Nothing. No.

Bajorek: I'll end by telling you what an honor it is to be able to interview you because this is a very, very critical breakthrough, the commercialization of perpendicular magnetic recording. And I thank you for providing that opportunity. And I congratulate you, again, on making it happen.

Tanaka: Thank you very much.

Sakai: Thank you very much.

Bajorek: Thank you very much.

Sakai: Actually, we are independent, not vertically integrated. But for the PMR, when we make the drive we really worked very closely. So it's a virtual vertical integration. So that's how we made the PMR drive.

Terunuma: We have learned very important scheme of the collaboration through PMR.

Bajorek: Yeah, I can imagine that's very critical. And maybe if you do it right you might have an advantage over the vertically integrated teams because none of you can afford to be parochial about it. Each party's life depends on the success of that collaboration. Right? That urgency may not be there in all of the other companies. I know it’s an extra challenge but you’ve managed to show that it’s possible to manage it. Right?

Tanaka: Yeah. We’re a great team.

Bajorek: Thank you very much.

Sakai: Thank you very much.

END OF THE INTERVIEW