DISCOVERY PROGRAM ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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NIEBUR: This interview is with Ralph McNutt, who has been involved with—now, you've been involved with all three of APL's [Johns Hopkins University Applied Physics Laboratory] Discovery missions, correct? Were you involved with NEAR [Near Earth Asteroid Rendezvous]?

MCNUTT: Oh, yes. I was the instrument scientist on the x-ray/gamma-ray spectrometer instrument.

NIEBUR: There you go. So, NEAR, CONTOUR [Comet Nucleus Tour], and MESSENGER [Mercury Surface, Space Environment, Geochemistry and Ranging]. I should note that this interview is taking place in his office at the Applied Physics Laboratory in Laurel, Maryland. It's July 31st, 2009. My name is Susan Niebur, and I'll be conducting the interview. Ralph, thanks for agreeing to speak with me.

MCNUTT: And you should note that it's 1:15 p.m. Eastern Daylight time.

NIEBUR: Precisely. [laughter] Excellent. Well, Ralph, so we're going to talk about MESSENGER mostly, then. So, why don't you tell me about when you first heard of the MESSENGER concept? Or maybe you were part of developing it.

MCNUTT: Oh, I helped develop it. Actually, we were—and I can tell you within a month when the birthday was. It was March of 1996.

NIEBUR: Wow.

MCNUTT: Because there had been some meetings going on about—well, of course Discovery was already in full swing at that point. And we were all looking around here at the lab going, "You know, we really need to do something because otherwise we're going to all be in trouble with having anything to be working on."

And so, Tom [Stamatios M.] Krimigis was heavily involved. I guess there had actually been one of the committee meetings, and I don't remember which committee, Tom was at that. Several of the people that had been involved with the NASA study on a Mercury orbiter mission, which I think was in '92, were also at that meeting, and they were talking about that. I wasn't at that meeting, but I was talking with Rob [Robert E.] Gold here at the lab and some others about what might make sense. And one of us, and I like to think it was me but I can't remember, said, "Well, how about a Mercury orbiter mission? We ought to be able to do that, and that ought to knock everybody's socks off."

So we got to talking about it. We had a few meetings that were involved once Tom and the others got back from some of the other meetings that were going on. And I've got notes someplace about this, so I'm just trying to remember as best I can off the top of my head. But that was in March. We looked a little bit at what people had done. We said, "Oh, well, you know, what we've got to do is a small probe. And we ought to be able to pull this off."

At the time, the AO [announcement of opportunity] was—I think that the draft was out or it was supposed to come out soon. And we started talking with people about potential members of the science team, and within a month we had gotten linked up with Sean [C. Solomon]. I think we had put together probably 90 percent of all the co-investigators within about a month.

Now, this takes us back into late April to early May of 1996. And somewhere about that time, I think they decided to slip the AO. So, that didn't come out. Those of us that were involved were trying to keep the effort going so we would have more time. And it was like, "No, no, no. We don't have the money to be working on this stuff." And so, finally, one thing kind of led to the other. Finally, things got started again. We put in the first proposal, and that was in—I think it was December the 10th of 1996 was the due date. I remember I was working over the Thanksgiving holidays.

NIEBUR: You remember that?

MCNUTT: Oh, yes. I remember—there's a lot of this I have tried to forget, let me tell you. It was not the—putting these proposals together is not—anybody that's done it knows it's not the most pleasant thing in the world. You've always got more work to do than you realize you needed to do. Suffice it to say, we put that one in. We won. We actually won in the first round, and it was even worse than that because MESSENGER won in the first round, CONTOUR won that year in the first round, and Aladdin won that year in the first round.

NIEBUR: You had a good year.

MCNUTT: Well, I just remember one of the guys here came to me and had this look of horror on his face. And I said, "We didn't get any of them?" And he said, "No, we got all three of them." And so, it was like, "Oh, my God," because now we had to field three teams. We had to keep everybody firewalled off from each other.

NIEBUR: Wow.

MCNUTT: Oh, yes. So, that had its own interesting challenges. And, of course, CONTOUR did get selected that time around, so that was the first contact with CONTOUR, and neither MESSENGER nor Aladdin did. We were all really irritated that we didn't win. But looking back on it, there were some things that needed some more work.

And so, we came back around and reassembled the team. And the next time around, when we re-proposed it, and we won phase one again, and so did Aladdin. And the next time through with the concept study, we managed to get that in and we won the mission. And we were actually—I was trying to remember. I think we were notified that MESSENGER won—I want to say July the 7th of 1999, sometime in the summer.

About a week after that, I think that one of the Congressional reports had zeroed out the Discovery program for the next year. [laughter] And so the Discovery program finally got all put back together in—I think in conference committee in August, or after the August recess.

Again, you'd have to go back and check the record about that. So, that was an interesting emotional roller coaster to be on. And then, finally we went into development in 2000.

NIEBUR: Was that something that everyone was aware of at that point? I mean, did it immediately percolate through APL, knowing what happened?

MCNUTT: I don't think so. You mean about it being selected or about the—

NIEBUR: Zeroed out.

MCNUTT: No, because actually Sean and I and some others were down at NASA Headquarters and we were talking to somebody, and it was because of MESSENGER that we were down there. And one of the people said, "Well, you know, the program's been zeroed out."

And we were like, "That's not very funny."

They said, "No, no, no. Quite serious."

NIEBUR: Wow.

MCNUTT: That's how we found out about that. There's a certain amount of staying power that you have to have in your personality to be involved with these programs at NASA. But the rewards are good. What can I say? Not for the faint of heart. Anyway, we got into development in 2000.

NIEBUR: Were there changes before you got to that part? During the concept study, were there major changes in the concept study?

MCNUTT: There weren't really any major changes. By the time we had gotten around to doing this the second time, we had added a plasma instrument onboard, and we brought George [M.] Gloeckler in as one of the Co-Is. I think the second time around, was when that Jim [James W.] Head was added as a Co-I from Brown [University]. But the rest of the team, for the most part, was intact. I think there were a couple of changes within APL. We had a different program manager than we had the first time around.

The instrument concepts were—again, I think nothing had really changed. We had gone back through all of this. We re-looked at it. The price went up between the first time and the second time around. But the most important thing we had done is we had actually funded some thermal testing on some of the materials.

NIEBUR: Nice.

MCNUTT: We were able to convince ourselves, and apparently the site review committee, and the other people that we really did know, what we were talking about.

NIEBUR: Did the price go up because you felt you knew what would be expected with more certainty, or was it increased labor costs in the out years?

MCNUTT: No, I think what happened was the thing that always happens on these projects, and it's one of the reasons that people carry around margins. We went back through it the second time. And you pick up things here and there that you say, "Well, maybe we were low on this." And there is inflation and there are changes in overhead rates. There's puts and takes all over this place.

NIEBUR: Sure. There wasn't a big scope creep or anything?

MCNUTT: No. No. Of course, one of the big issues that all of NASA is dealing with right now is price increases. And there had been some sort of rules of the road about how much money that you basically need to spend to go in, to actually technically define a program in order to really give a good cost estimate. And what typically happens is the amount of money that's really needed to do that usually isn't available, and so you miss things.

So one of the ways that you try to make up for it, and this is what NASA Headquarters does, this is what organizations like APL do, is that you try to do the best job that you can, but then you also want to have some reserves and some margins put in. It's the usual story when you're trying to do a high tech anything. Basically you go out and do it, and then once you've done it the first time, well, then you know what it's really going to cost and how to really do it. And then, you can go back and do it right. Of course, except in this business, you don't do things the second time.

NIEBUR: Right.

MCNUTT: You just do them the first. You go back and you look at the historical record, it's something everybody's been struggling with since 1957 [n.b. Sputnik was launched October 4, 1957]. So, none of that is new.

NIEBUR: Sure.

MCNUTT: And a lot of the rules change. The other thing that changes—and in our prices, we went over. It's a matter of record that we did go over on the cost when we were developing this. Looking back at it, a couple of things happened. One was that there were problems with MCO [Mars Climate Orbiter] and MPL [Mars Polar Lander], and it changed a lot of what had been the risk posture that people had and the amount of supervision that they thought one needed. And if you get more risk averse and you need more supervision, costs are going to end up going up, and I don't think anybody's got a really good feel for how high that you drive them up. I think that that's something we're still struggling with now.

The other thing that happens is in the space business, of course, you rely on a lot of subcontractors—many of whom are in niche markets. You're building a racer for the Grand Prix. You're not building Chevys or Fords or whatever on an assembly line. And so, you've got a lot of one-of-a-kind things. You're going out to a lot of people that do one-of-a-kind work. Sometimes, the next time you come around they're in business, and sometimes they're not. Sometimes the product lines have just disappeared. Sometimes some of the parts, it turned out they had problems. And so, that had to change around. And usually when things change, the prices do not go down.

NIEBUR: And MESSENGER had one that was a pretty major one where the supplier was sold out in El Segundo. That was MESSENGER, right?

MCNUTT: Yes.

NIEBUR: Were you part of that?

MCNUTT: Oh, yes.

NIEBUR: That recovery?

MCNUTT: Actually, we ran into—who was that? That was both MESSENGER and—

NIEBUR: DI [Deep Impact]. Was it DI?

MCNUTT: It was either—was it Deep Impact? I was going to say it was either Deep Impact or Genesis. I think you're right. I think it was Deep Impact.

NIEBUR: Yeah, Genesis was launched at that point.

MCNUTT: Yes.

NIEBUR: So, both MESSENGER and DI were relying on that part.

MCNUTT: Right. And it had to do with the fact that the subcontractor was sold to another company. And the other company, to cut costs, decided that they were going to move it to a less desirable part, according to some people, of Southern California. And so, most of the people that knew how to do this stuff retired, and so it was a new crew. And theoretically everything is all written down.

NIEBUR: Heritage is people, not just parts.

MCNUTT: Heritage is people and it's their knowledge. And that's something that I think is a problem throughout society these days, understanding of that. You've got a certain amount of investment in capital, and it's not something you want to squander because it's very hard to get it back. So, we had that. We had issues with some other subcontractors.

Of course, every time you have problems, you have slips. We had internal issues as well. Things got to be a little more complicated than we had realized. And again, part of it's just growing pains. You don't commonly build spacecraft to go in to 0.3 astronomical units. And it's a hard thing to do.

NIEBUR: It's a hard task.

MCNUTT: I think that our colleagues in Europe who are building BepiColombo [European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) joint mission to Mercury] are finding out that it's a hard thing to do as well. They've been having their own sets of issues. We got into some interesting discussions with some of the folks at NASA Headquarters about what was considered prudent levels of testing and checkout. They won. They're the customer. That's okay.

NIEBUR: Was that an end of development type—I don't seem to recall those discussions. Maybe I was shielded from it.

MCNUTT: Well, they certainly happened.

NIEBUR: Oh, I'm sure they did. [laughter] There's no doubt in my mind.

MCNUTT: Well one of the things we did, and part of the philosophy that APL has historically had, and which I think has served the lab well. I think it's also a lot of the other people out there, I think they've done the same thing, although they might or might not admit it on tape or whatever that device is. You can't test for everything. Now, I'm not supposed to say that, because you're supposed to test for everything, but it's not going to happen. And you should test as much as you possibly can. You try to make sure that you don't—with all of the single point failures, you get those out of the system.

Unfortunately, where you tend to have problems with spacecraft is where you have multiple point failures and those get to be very, very hard to find because you have to have multiple things going on that are going in the wrong direction at once. So the way that you deal with that is you build the most robust system that you possibly can. You look for the interactions. You try to eliminate places where there can be interactions that will end up giving you adverse results that maybe you did or didn't think of. And that's basically what we did with MESSENGER.

It's got an autonomy system onboard that runs with a so-called state engine. We have to keep the heat shield pointed at the sun all the time. We think that if you get away from that attitude, we've got about 15 minutes to recover the spacecraft. That was kind of a design point.

NIEBUR: Wow.

MCNUTT: And when you consider that we could be in a situation where the one-way light time is around eight minutes, the spacecraft better have some smarts onboard to be able to deal with that itself. And we think we're there. I mean, we think we dealt with that. There were some issues on the testing, and we thought we were okay. Some of the other people in the process didn't think we were okay, and we actually slipped the launch window twice.

NIEBUR: Right.

MCNUTT: The first time was us and the second time was at Headquarters' direction. And the second launch slip, it turns out—well, one has to worry about Mr. Newton and his laws, and it did add some additional flight time to the cruise on the spacecraft. So MESSENGER's next flyby of Mercury is coming up on the 29th of September of this year, 2009. We will go into orbit on the 18th of March 2011.

NIEBUR: Yay.

MCNUTT: If we had been on the original, original, original planned trajectory, if memory serves correctly, we'd actually be in orbit now.

NIEBUR: Disappointing.

MCNUTT: Things happen. Disappointing, well, it is and it isn't. We've got a very healthy spacecraft. We have managed to do an incredible job, I think, I humbly think, of new science from the first two flybys of Mercury by MESSENGER. It's over 30 years since Mariner 10's three flybys of the planet. And we've already added a great deal of knowledge. And we've seen almost all the rest of the planet now. We've got IR [infrared] spectra. We've got other spectra. We've got gamma-ray spectra. We've got neutron spectra. We've got all kinds of spectra. We've got all sorts of things that simply were capabilities that you just didn't have on Mariner 10.

NIEBUR: And you're using them, too. The very fact that there's so much already in the literature is amazing.

MCNUTT: Oh, yes. Oh, yes.

NIEBUR: Really, it's almost an order of magnitude more than most Discovery missions have done, particularly at this point. And you're also the project scientist; do you see something that you can attribute that to?

MCNUTT: Yeah, we've got a principal investigator that keeps everybody in line.

NIEBUR: There you go. What does he do?

MCNUTT: Sean is an extremely good administrator, organizer, excellent scientist. Couldn't say enough for him, except for the fact that sometimes he doesn't let most of us get as much sleep as we might like to. Well, there's sort of a correlation there between the hours and the productivity. But no, all joking aside, Sean has done a marvelous job of helping to guide everybody and keep the results coming out. And we've actually got a special session set up for the American Geophysical Union meeting this December in San Francisco.

NIEBUR: Fantastic.

MCNUTT: And that will be the main meeting where we will have results from the third flyby.

NIEBUR: You just had a special session at LPSC [Lunar and Planetary Science Conference], the second flyby. Awesome.

MCNUTT: Well, that's right. And we've actually got some invited talks that'll be at the AOGS [Asia Oceania Geosciences Society] meeting in Singapore next month. We've been trying to make sure that results get out around the world because, of course, our colleagues in Japan are involved with the BepiColombo mission with the European Space Agency, from JAXA. They're certainly interested in what's going on.

And so, one of the things that we are trying to do is to keep getting the word out. We've had two special issues of Science [magazine] with Mercury on the cover. So, we've been patting ourselves on the back over that.

NIEBUR: You'll be having one for every orbit, right? [laughter]

MCNUTT: Well, so far. We'll see what we do with the third flyby. It'll depend on what kind of new science that we get out. But there's a lot of things that we're going to be doing. Every time we've flown by, there's been something new with the overall magnetospheric interaction, and we're going to be targeting some other emission lines with the UV [ultraviolet] instrument on this one. So, there's room for some new first-time discoveries here as well.

NIEBUR: Excellent.

MCNUTT: And we're going to be working that.

NIEBUR: And Ralph, tell me about some nuts and bolts. You were the project scientist. How does that role play here at APL?

MCNUTT: Oh, that's a good question. Lots of people have all sorts of different impressions of what that should be. And a good question to find out from everybody whether they agree with this or not. But I try to make sure that things are moving that we need to be moving on the science front. If we've got issues with things going on, I try to make sure that, if they're really important ones, that we get them to the right people. I can give you an example. One of the things that we did just recently that I've been heavily involved with is looking at the orbital inclination for the initial injection of MESSENGER into orbit around Mercury.

The original plan, which has been holding, was to go into an orbital inclination of 80 degrees. And that was the subject of a lot of tradeoffs that were done back in 1996. One of the things that's happened since then is, of course, that there has been a lot of work that's been done with the Lunar Prospector data looking for hydrogen deposits, possibly water deposits, on the Moon. There's been a lot of analysis that's actually been done on how well that one can do and what are some of the tradeoffs that you really get involved with with the nuts and bolts of that.

And David [J.] Lawrence, who's now on the science team, was heavily involved with the Lunar Prospector, and he's right down the hall here, so we talk a lot. And Bill [William C.] Feldman, of course, was also involved with neutron spectrometer there and has been Co-I on MESSENGER as well. He's been involved.

We've got the neutron spectrometer on MESSENGER and, of course, one of the things that has been a real issue is trying to really identify what's going on with the radar spots at the poles of Mercury that look for all the world like they're water ice in permanently shadowed craters. One of the ways you do that is, over an airless body, you look at the neutron distribution. If you're over regions that have a lot of hydrogen bearing material, the so-called epithermal, which are higher energy than the thermal neutrons, that flux will tend to be depressed because basically you end up scattering things downward in energy because the neutrons have about the same mass as a proton, of course, and you've got all these protons in the water. So, we've been looking very carefully at that.

And it turns out, from the high-resolution radar maps, and [J.K.] Harmon was the main one that did this with the radar facility that was run out of Arecibo, that most of these areas, of course, are concentrated toward the poles. And the reason for only going as far north as 80 degrees with this inclined orbit was in order to deal with the geophysics requirements, because we're trying to get a better measurement of Mercury's gravity field. If you go with an orbit that's inclined at 90 degrees to the plane of the equator, then some of the orbital parameters just don't allow you to work out the gravity field parameters that you need and you end up with large uncertainties. Then, those couple back into determining the libration of the planet, which couple back into trying to figure out how much of a molten core that you've got. So, there's a whole cascade of arguments and reasons and error bars that go into that.

Well, at the same time, the largest of the radar reflective materials at Mercury's north pole look to be in a crater. It's radar feature K on Harmon's maps, which is centered at 85 degrees north and extends just below that. Now, so the question is, in an 80-degree inclination orbit, are you actually going to be able to get close enough to be able to tell?

One of the other pieces with all of this which makes it even more complicated is that Mercury's gravity field. We don't know it that well. That's one of the reasons we're trying to measure it. But, depending upon what the perturbations are to just the gravity field of a pure sphere, the inclination will head northward. And yet, if you go too far northward, then the error bars grow on the parameters that you're trying to measure.

NIEBUR: Oh, strange. Wow.

MCNUTT: We have been doing a lot in the last couple of months—well, actually, more than that—but a lot of it's been concentrated now in the last couple of months to try to make a final assessment of what the trades are. You'd like to go further north using the inclination projection in order to do a better job with the polar deposits. If you go too far north, you're going to mess up the geophysics measurements, yet both of them are required for full mission success for the mission.

NIEBUR: So, how'd you resolve that? How do you go about it? What's the approach?

MCNUTT: Well, the project scientist goes out and does a lot of literature researching and talks to a lot of people on the team and has a lot of informal meetings with a lot of people. And we've made the decision to target the initial orbital inclination at 82.5 degrees.

NIEBUR: Okay.

MCNUTT: And so you go, "Two and a half degrees? My God, that can't make that much of a difference," except it turns out that in this case it does. I guess what I find myself doing most of the time is trying to keep an eye on the science vis-à-vis the project, keeping Sean informed, making sure that I help out with the talks that are going on, making sure that we've covered all the meetings, and especially looking at the interactions between the various groups and trying to see how that the science from each of the groups met between them, and looking for all of the synergies and putting all of that together.

NIEBUR: Oh, interesting.

MCNUTT: Well, yes, and it's kind of like this 2.5-degree thing.

NIEBUR: That sounds like the fun part.

MCNUTT: Well, it can be. It can be a little frustrating because it can be—I'm certainly not going into this as the absolute world's expert on a lot of these things. I started out in space physics, and I now know more about planetary geology than I ever thought that I was going to, although I still know quite a bit less than some of the members of the science team think that I should know. But everybody ends up learning from this. Even the “experts" are learning. And if there weren't room for that, you wouldn't do this stuff.

NIEBUR: Exactly.

MCNUTT: So, I don't know. Most of the time, on a nuts-and-bolts level, what I do is I come into my office in the morning, I look at the email. I see what's going on with MESSENGER, what's going on with other projects, figure out how to triage what I thought I was going to do for the rest of my day, and then try to concentrate on the one-third that really absolutely needs to get done on that day, and also figure out how I'm going to explain myself to the other people whose task I didn't get finished and who are absolutely unsympathetic to the things that I was working on.

NIEBUR: Gee, that doesn't sound familiar at all.

MCNUTT: Yes. But again, I think that living in America at the beginning of the 21st century is a lot like that for a lot of people these days.

NIEBUR: And I won't keep you much longer, because I really do understand you've got a lot to do with RPS [radioisotope power systems] and everything else right now. But I want to go back to development just a little bit. And you talked a lot about some of the technical challenges where things had gone awry, and things always do.

MCNUTT: Yep.

NIEBUR: That's just part of the space—

MCNUTT: Absolutely.

NIEBUR: As you say, it's part of the project. I think you probably had a unique perspective on that because you're co-located. You're here with the engineers putting the spacecraft together.

MCNUTT: Right.

NIEBUR: And several of the instruments were developed here?

McNutt: Yep.

Niebur: I can't remember how many. Four-ish?

McNutt: Oh, lord. Well, we did the major development on—I've got to count on my fingers here. We made the major development on MDIS [Mercury Dual Imaging System]. That's the camera. We did a lion's share of the development on the gamma ray and neutron spectrometer, although that was interesting because Lawrence Berkeley Laboratory, Lawrence Livermore Laboratory, the Space Science Lab at the University of California at Berkeley, and some other people all were involved with that, which I still think is the technological tour de force on the spacecraft.

Niebur: How on Earth did you get all of those groups work so well together? I mean, LANL [Los Alamos National Laboratory] usually does it themselves, right?

McNutt: Well, they didn't always work that well together.

Niebur: How do you herd those cats?

McNutt: You have to have a lot of patience.

Niebur: Yes.

MCNUTT: And there's a lot of people that would say that I'm really the pot calling the kettle black because they don't think I've got any patience at all, whereas I think there have been times that I've had an incredible amount of patience.

The whole team that was here that worked on that, I mean, I was involved. The technical stuff, Rob Gold was involved. John [O.] Goldsten was involved. Ed [Edward J.] Rhodes was involved. Jack White, who was a contractor, was involved. Jack's not around anymore. He passed away. He was a key part of figuring out how to put all this thing together. And there was a lot of, shall we say, wailing and gnashing of teeth on more than one occasion of getting this thing together. But we still got it done.

There is still a lot of nervousness about it. This is a high purity germanium cooled crystal that has a cryogenic cooler about the size of a Coke can that is a limited lifetime item, which is the core of the thing. There is no backup. It has to cool the cooler down to 90 degrees above absolute zero while you're 200 kilometers above one of the hottest surfaces in the solar system.

NIEBUR: Exactly.

MCNUTT: It was challenging. But, you know, and again, I would say that it's because of the people here and, to a very large extent, due to John Goldsten that that thing is working on the spacecraft. I still think it's going to be key to a lot of the results coming out of MESSENGER.

We did those. We did the digital part of the magnetometer. The analog part of the magnetometer came from [NASA's] Goddard Space Flight Center [Greenbelt, Maryland]. That was from Mario Acuña, who, of course, has also passed away not too long ago [2009]. We did the energetic particle detector here. We did most of the x-ray spectrometer detector here. Of course, the active elements on that actually came from Finland because nobody in the United States manufacturers them anymore.

NIEBUR: Oh, I do remember that. Yes.

MCNUTT: It was a problem.

NIEBUR: Did you guys just go and procure those?

MCNUTT: Oh, yes. We actually had come across that company because of the same kind of an x-ray spectrometer that was on the NEAR spacecraft.

NIEBUR: Oh.

MCNUTT: And it was an improved version of them. Except that with the ITAR [International Traffic in Arms Regulations] rules, well, similarly in place but, let's say, interpreted a bit differently, it was even more challenging on MESSENGER than it had been on NEAR.

NIEBUR: A lot changed between those years.

MCNUTT: A lot really had changed. Of course, the radio science that's a part of the telecommunication system, that was all done here at APL. The IR and UV spectrometer, MASCS [Mercury Atmospheric and Surface Composition Spectrometer], that's all out of LASP

[Laboratory for Atmospheric and Space Physics] at the University of Colorado. The laser altimeter, MLA [MESSENGER Laser Altimeter], that's all out of Goddard. [I did leave out FIPS (Fast Imaging Plasma Spectrometer) from the University of Michigan – but not intentionally. It's part of EPPS (Energetic Particle and Plasma Spectrometer).]

NIEBUR: But a lot of it really was done here. And I think that's something that APL—

MCNUTT: Oh, yes.

NIEBUR: Has kind of an advantage on, that you have, just in terms of an absolute advantage, both the spacecraft and many of the instrument developers in the same place.

MCNUTT: Well, we've got a lot of really innovative, really good people.

NIEBUR: Yes.

MCNUTT: It can be a little like herding cats sometimes, but, you know, it comes with the territory. If you want to do something that has never been done before, you would much rather have somebody that is an innovator and that needs herding lessons than somebody that is used to staying in a corral all the time and you can't get to think out of the box.

NIEBUR: That's good.

MCNUTT: And again, I think this is something that the U.S. overall is tending to lose the understanding of. When you're doing technological things, you need very innovative and creative people. And they've sometimes got their quirks and sometimes one needs to figure out how to accommodate that, if you want to get some of these things done. Otherwise, they're not so easy to do.

NIEBUR: Were the interfaces done—for those instruments that were here, that were here at the same place, the same, more or less, location for the spacecraft—was it easier doing the interfaces for those instruments? Did you all speak the same language, or did you have the same kinds of issues that you had with other instruments?

MCNUTT: Well, actually, you know, with all of the instruments except for MLA, what we did was we developed a common set of EPUs, the [event] processor units. And also, it was a common set of low voltage supply cards, so that what we would do is we had the interfaces here set up to work off of these cards. And what we could do is we could go supply the guys that were building the things another set of the cards. And then, we were actually able to make a lot of the plug and play work. It would have worked a lot better if we hadn't started running out of time when we did, because, well, a lot of these things were a lot harder to build than we thought. And the main issue there was mass.

NIEBUR: Mass?

MCNUTT: Mass was the issue during the entire MESSENGER program. We did that by setting limits because the problem is that we were limited in Discovery to flying on a Delta II 7925 Heavy. It was the biggest vehicle we could use. And you had to get up to a certain C3. That is a certain excess energy at launch. And we needed to have something on the order of a 2,200 meter per second onboard delta-v capability. And I'm here to tell you that 2.2 kilometers a second on a spacecraft with space storable propellants is not an easy thing to do. When MESSENGER launched, it was just over 1,100 kilograms, and 56 percent of that mass was propellant.

NIEBUR: Wow.

MCNUTT: Actually—no, I take it back. It was 54 and as far as I know, the only higher mass fraction was 56, and that was Cassini, which was 5.6 metric tons on the pad, and we were 1.1.

NIEBUR: Wow.

MCNUTT: Oh, yeah. MESSENGER was a flying gas can.

NIEBUR: Because the trajectory is so hard?

MCNUTT: Because the trajectory is so hard. Because you're going in close to the sun, and, I mean, we've ended up using all of these planetary gravity assists. Every time we fly around Mercury, we're slowing down by about another two kilometers a second.

NIEBUR: Wow.

MCNUTT: And even with that, we still needed about 2.2 left onboard in order to do the mission. And that's hard to do. I think another thing that people don't understand, until you get into one of these things and kind of have the global view, is it's real easy to come up with a piece of a spacecraft or a piece of mission. When you've got to put it all together and it's got to all fit, it's a bit more of a challenge.

NIEBUR: Yes.

MCNUTT: And, I mean, basically what we did on the payload, Rob Gold was our mass czar, and he told everybody what the mass of their instrument had to be. And during the development, some of the guys would say, "Well, we're not going to make the mass allocation." And the question was, "Well, by how much?" And if they said, "I'm going to be over by 200 grams," they were told to go back and work the problem.

NIEBUR: Wow. He really had to run a right ship, then.

MCNUTT: Oh, yes. And there were times that there were some liens that were actually given to some of the instruments. But anybody that got up to 100 grams on the instruments, it was a major issue.

NIEBUR: Wow.

MCNUTT: And so, it gets back to, "Well, you told me a year ago that you could build this thing for 3.3 kilograms. What's this 3.45 stuff?"

"Well, I didn't know as well then."

"Well, go back to the drawing board and sharpen your pencil."

NIEBUR: Were the instruments relatively mature at proposal, though?

MCNUTT: Well, we thought they were.

NIEBUR: Touché.

MCNUTT: I think that answers the rest of the questions.

NIEBUR: Touché.

MCNUTT: Well, no. I'll tell you. It's interesting. You can go back and you can look at the proposal. The camera, it turns out, ended up being totally redesigned. And the reason for that was that when we did the proposal, we did not think we were going to need to do any optical navigation with the camera because all of the ephemerides of all the planets were known well enough; we'd be able to track the spacecraft well enough. Well, we got into that one and it turns out that was a little bit of an issue.

Now, it turns out we've got actually more flexibility built into the camera now than we originally had, and it's probably one of the things that's saved us on some of the mission planning.

NIEBUR: Really?

MCNUTT: It ended up being driven by the fact that we missed that. The other major change, and again, it gets back to the gamma ray spectrometer. Originally, we had a solid-state gamma ray spectrometer using scintillator crystals, very similar to what we had on NEAR. Well, it turned out the NEAR gamma ray spectrometer didn't really work that well until we landed on the asteroid. Signals were low, backgrounds were high, and this all didn't really come up until you look at where NEAR was and you look at where we were with the development of MESSENGER. It wasn't until after we'd been accepted that we realized that we really had a problem if we were going to get real data.

So, that was when we had a long series of meetings and ended up changing over to this high purity germanium crystal which, to say that it was more of an engineering challenge than the scintillator approach, is a vast understatement. But you do what you have to do to make this stuff work. And everybody on this project has just been incredibly committed, and during development was incredibly committed, toward making this thing work. If it hadn't been for that, we wouldn't have made it.

You've got to be both an optimist and probably a little bit of a masochist to get involved in one of these things. But it's got a hell of a payoff. I mean, we're out there and it's—I've told the team on more than one occasion, and in a way it kind of rings hollow, but we really are making history with this thing.

NIEBUR: Absolutely.

MCNUTT: And sometimes it's pretty hard to realize you're making history when you're really in the middle of making it. But we've already rewritten the books on Mercury. And we're going to do some more of that, too.

NIEBUR: Fantastic.

MCNUTT: But it has not been all smooth sailing. And there's a lot—there are war stories that I think everybody that's ever been on one of these missions, that they've got. Rob Gold and I were talking about doing the proposals. I think Rob Gold has the best quote, so this is a good one for you to put in the book. I don't have the date written down, I don't think, although I used to keep pretty good records. He said, "You know, once you've done six of these proposals, you die. I've done five. I'm not doing another one."

NIEBUR: Oh, my. Oh, my.

MCNUTT: I think that kind of sums some feeling up when we finally got MESSENGER selected for flight.

NIEBUR: But don't you have to do a detailed proposal like that to have any chance of implementing your plans?

MCNUTT: Oh, yes.

NIEBUR: I mean, there's no way around that, right?

MCNUTT: Yes. No, there's not. There's not.

NIEBUR: It's just a really hard, hard thing to do.

MCNUTT: It's a hard thing to do. And, you know, anybody can go out there and look on the Web and see these AOs come out. But I'll tell you until you have written a—let me say a successful proposal for either a New Frontiers or a Discovery mission, you really don't have any idea of what goes into all of this.

NIEBUR: And all the things that were done that get left out.

MCNUTT: Oh, yes. It's an interesting exercise. You really have to have a good team and you have to have the teamwork. And then, on top of that, you have to have a great deal of tolerance. I think everybody probably bit through their lips probably a few dozen times in the process of putting all of this together.

NIEBUR: Well, there were times—certainly this project, like all of them, had difficult times. Could you talk just for a minute about external pressures on the program? Things like, oh, when the Mars failures happened.

MCNUTT: You mean where there was us and there was NASA Headquarters? Now I am going to get in trouble.

NIEBUR: No, no, no. You're not going to get in trouble. No, but before that, actually, say when the Mars failures happened and all of a sudden, the NIAT [NASA Integrated Action Team] report came out and there were new requirements, so also new opportunities for money. These things they've been talking about with all of the projects.

MCNUTT: Oh, yes.

NIEBUR: They all have had different, you know, responses to it and how it went.

MCNUTT: Well originally, with the Mars failures—I think when those happened, it was noted but there was no real thought about it other than, well, we were always planning on doing the best job with this, and that's not going to stop us. I think what did happen was then the NIAT report came out, and it was like we were told, "Okay. Well things are going to happen differently. And to the extent that you guys need more money to deal with this, well, you need to tell us and we need to know in a month." I'm probably making that up. I don't know how long it was. And we kind of looked at this. And, of course, we were in the middle of trying to get this thing pulled together when all of this was going on.

And quite frankly, I think looking back on it, it's not that we didn't take it seriously, it's just that if you're going to keep your budget down, you've got a certain number of people. And unfortunately there are only 24 hours in the day and occasionally it's probably good to sleep during some of those. And so we had actually put in an original amount of money, which we got, which was, looking back on it, way too small considering what was going to be coming down the pike at us. And as you know, as all of this started coming together about what the implications really were, we were going, "Wait a minute. We're not going to make it." And we got into a bit more hardball with some of the powers that be at that point.

NIEBUR: Well, what do you do, when you realize that you're not going to make it?

MCNUTT: Well, we tried to go back and we tried to pull together a more honest assessment of what we thought the cost impacts were going to be and we presented those. And some of them were disagreed with. Some of them were, "Well, why didn't you tell us this six months ago?" Well, six months before, we didn't know. It had really been a bit of a moving target, certainly in terms of perceptions and trying to understand how all this was going to cascade through the system, because none of this is terribly transparent.

And we got a little bit of what we asked for. We didn't get nearly all of what we'd asked for. And we were like, "Well, you know, we're not going to give up. We're going to keep marching forward." And we did have to go back and ask for more money. And I don't know how much of this Sean went over with you.

NIEBUR: Some. And there's some in the record, too.

MCNUTT: Yes, I'm sure not all of it's in the record, though. I'm going to write a book one day, but it isn't this one.

NIEBUR: Oh, good. Because being on the other side, I don't think we got the whole story.

MCNUTT: It was—well, let's just say that again, Sean ended up giving presentations to four of the different NASA advisory [sub]committees down at NASA Headquarters.

NIEBUR: I remember that, because [Associate Administrator Edward J.] Weiler asked him to do that so he could ask them for permission to bust the cap and take the money.

MCNUTT: And were you in any of those meetings physically?

NIEBUR: I was in the Planetary Science Subcommittee meeting.

MCNUTT: Oh, okay. All right. That one went better than the others, I think.

NIEBUR: I would suspect so. At least they had a vested interest in seeing MESSENGER succeed. It was their priority.

McNutt: All the committees agreed that it should go forward. There were some other people down at NASA Headquarters that weren't very happy with that assessment. But, they said, "All right. You're the rest of the committee and you're the rest of the community. It's your funeral."

Niebur: But the team must have felt vindicated at that point.

McNutt: Well, we did. I think we all felt a bit—well, I think everybody was frustrated. It wasn't like we felt like we were coming up roses. We certainly didn't feel like we had—I don't know if it was so much a feeling of vindication as the feeling that we had managed to evade the executioner's blade.

Niebur: [chuckles]

McNutt: Sorry. You asked.

Niebur: No, it's fine. It's vivid.

McNutt: And we were able to go and we would be able to fight another day and we would be able to keep the effort moving.

Niebur: And how far down did this penetrate? Did the engineers, did the science team, were they really affected by all of this? Or was it kept pretty close?

MCNUTT: Oh, I think some of them were. The project scientist probably wasn't as discreet as he should have been during a lot of this. Well, now, like I said, you're bringing this on yourself because you asked.

NIEBUR: No, I really want to know. Because I was there, but I was young, and I would like to know.

MCNUTT: Well, I was younger. I've got a lot less hair and what's left has all gone gray. And I'll tell you, a lot of it has to do with this project. I have always had the attitude, which is not necessarily universally shared by a lot of people in society, that if you've got a team of people, what you really need to do is you need to level with them about what's going on. And because I believe that if you've got the right people on the team then they've got a commitment and they need to be able to share in the triumphs and they need to be able to help in the case that things are going in the wrong direction. And people that don't think that's appropriate, well, I don't think they ought to be on a team that's doing stuff like this, because you are way too close to the edge of what is barely humanly and technologically possible. Because that's what all this is about. It's about pushing the envelope with a vengeance. And that means it's not easy to do. What a concept, right?

NIEBUR: That's right.

MCNUTT: So, I think you have to level with people and let them know what's going on. And, you know, quite frankly, I don't even remember a lot of the stuff. It just seemed like it was just an ongoing thing that was like the—who was it? What was the quote? I think it was Averell Harriman when he was the Secretary of State. Somebody asked him what was it like being the Secretary of State, and he said, "You want to know what it's like? It's like one damn thing after the next."

And during all of the development, we had issues that would have to be resolved. And the thing was, again, with MESSENGER, you have this insane thermal environment. You have these insane propulsion requirements. We were trying to make sure that we maintained all of the science capability. And we even went down to the point that—one of the things that is always an issue on deriving spacecraft mass is the harness. People don't think a lot about the harness, but that's—

NIEBUR: Right.

MCNUTT: You're running the wires, right? Why should that be a problem? Well, if you think about going out and building a house, and you were to go out and weigh all the nails that went into it, you'd probably be surprised at how much the nails all weigh.

NIEBUR: Sure.

MCNUTT: Well running wires around a spacecraft is a little bit like that. And so the decision was made early on that we were going to go to a much smaller wire gauge for the harness, which meant going to smaller connectors. And we ended up having a lot of issues about that, because what it meant was you couldn't be as lackadaisical about plugging things together. And even then, lackadaisical wasn't being lackadaisical. I mean, you had to really be careful because the connectors would break.

NIEBUR: Because they weren't as sturdy as the big ones?

MCNUTT: Because they weren't as sturdy because they were smaller. But this was one of the ways that we dealt with the mass issue.

NIEBUR: Wow.

MCNUTT: And so, this is a project where if one person sneezed, everybody else could end up with pneumonia. And we were always having to keep an eye on it.

NIEBUR: The mass really was tight.

MCNUTT: Oh, yes. Well, somewhere, I've got the curves of what the mass looked like on the—the current best estimate of the mass looked like as a function of time and what the—

NIEBUR: No.

MCNUTT: And James Leary kept this, and I've got the graph someplace. And what the published capability of the Delta II Heavy [launch vehicle] was. Both of these curves marched upward and they kind of went asymptotic, and that's when we launched.

NIEBUR: Wow.

MCNUTT: Oh, yeah.

NIEBUR: Nerve-wracking.

MCNUTT: Oh, yes. There was one point in there where everybody had one of these rocket cams onboard the launch vehicle.

NIEBUR: Right.

MCNUTT: We didn't have the mass for it.

NIEBUR: You're kidding.

MCNUTT: That's why it didn't fly.

NIEBUR: Wow. I remember people asking why there wasn't one.

MCNUTT: There was no room left in the mass. We topped the tanks off and we were there. There was not another couple of kilograms to add a camera onto the launch vehicle.

NIEBUR: All right. That's tight.

MCNUTT: That was tight.

NIEBUR: That's tight. Wow.

MCNUTT: We put a lot into this, but knock on wood, it's still working. You got to be an optimist in this business. There's no two ways about that. And then, of course, there's the other one that I like about what's the definition of a pessimist. A pessimist is an optimist who's also a realist. So you go into these things with a little bit of that as well. But, again, you're pushing the envelope and nobody ever said any of this was going to be easy.

NIEBUR: And I think the team has done some amazing work to get where they are today and to get the amazing pictures back from MESSENGER. I'm admiring your picture of the team up there.

MCNUTT: Yeah.

NIEBUR: I really like that. I've been in a lot of offices and I haven't seen those framed like that. And to me, it just kind of brings down how important the people are.

MCNUTT: Well, the launch picture is down there on the floor. I haven't gotten that one hung up.

NIEBUR: That's a nice picture, though. I might ask you to put me in touch with someone who has it.

MCNUTT: Oh, okay. They did a nice job on that.

NIEBUR: It's a good reminder that an awful lot of people worked very, very hard to get it where it is.

MCNUTT: Well, yes. One of the things that we did—of course, there were NASA group achievement awards that went out in getting this thing off the ground. And I'm trying to remember. Peter [D.] Bedini, he was the project manager, ended up pulling that together. And I remember going over that with Peter. And I think the count was about 980 people.

NIEBUR: Nine hundred and eighty.

MCNUTT: Yes. And these were basically people that at some point had put in a total of at least two months of work on pulling this thing together.

NIEBUR: And most of them here?

MCNUTT: You know, I think maybe it was somewhere between a half and two-thirds here, and the others are subcontractors.

NIEBUR: How big is APL? That had to be a chunk.

MCNUTT: APL is—what are we running now?

NIEBUR: I know the space physics is not that big.

MCNUTT: Well, the space department's running about 500 or 600 these days. I think we were probably about 100 less when MESSENGER was coming together. And the overall laboratory is something like about 10 times that size. But MESSENGER was eating up a large share of the resources, more than were really planned at one point. But that's another part of some of the issues that we ran into.

NIEBUR: Not uncommon.

MCNUTT: No, it's very common. But I'll tell you, the other part, and you need to be sure to get this down. I went back and looked and still have been trying to figure out the exact numbers. I went back and I looked at the original proposal, and MESSENGER had originally been proposed for less than $400 million real-year dollars. Now, that was in the original proposal.

I don't think that's public, but I don't know. Let them shoot me. Right now, what is public, it's in the press kit, is that we're right at the estimated run out cost of $446 million. That's what we're currently looking at. And, yes, that went through the cap, and da, da, da, da, da.

Well, if you go back and you look at Mariner 10, which went to Mercury, it was touted as being this insanely cheap space mission, all right? So, I've still been trying to get a full breakdown on the numbers. The primary mission, which consisted of the launch and the first Mercury flyby, is quoted in a NASA publication as $98 million. There is a different one that Bruce [C.] Murray wrote that I think said that that number did not include the launch vehicle, which was Centaur at the time, and those cost about $30 million. So, I'm not quite sure whether the launch vehicle was included in that. They did the other two flybys for another 2.5 million, and then basically Mariner 10 ran out of fuel. So, if you take the $100 million and you inflate it to today's money, that's about $380 million.

NIEBUR: MESSENGER looks pretty good.

MCNUTT: I think MESSENGER looks insanely good. And I think everybody got a bargain. And yes, we went over budget. And yeah, we busted the cap and da, da, da, da, da, da. Well, you know, what can I say? You have to break some eggs every time you make an omelet. But you can make some pretty good omelets, and I think we did a pretty good job with this one.

NIEBUR: Excellent. Well, thank you, Ralph. I think we'll end there.

MCNUTT: Okay.

NIEBUR: I very much appreciate all your time today. This has been great.

MCNUTT: Well, you're very welcome. You're very welcome.

[End of interview]