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INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: This oral history interview is being conducted with Dan Mulville in Greenbelt, Maryland. Today is June 13th, 2013. This interview is being conducted for the NASA Headquarters Oral History Project. Interviewer is Rebecca Wright, assisted by Sandra Johnson, and we thank you for coming over this morning and talking with us and spending time with us. We'd like to start with your decision to move over to NASA. We know that after a long career at the [U.S.] Naval Research Laboratory [Washington, DC] and at the Naval Air Systems Command [Crystal City, Virginia], you began working for NASA in 1986 as a Deputy Director of the Materials and Structures Division, Office of Aeronautics and Space Technology. Why did you decide to make that move over to the space agency?

MULVILLE: In the Navy, after the Naval Research Lab and a little time at the Office of Naval Research [Arlington, Virginia], I moved over to Naval Air Systems Command, and I was responsible for the Structures Technology Program for the Navy's advanced aircraft—F18, AV-8B and air launched missile projects. In 1985-86 I was the Navy representative on a National Academy of Sciences study on composite material technology for commercial aircraft. The government study leader was Sam [Samuel L.] Venneri, a former Navy employee I had worked with in the past, and he had a position open in his division at NASA Headquarters. Sam was the Director of the Structures and Materials Division in the Office or Aeronautics and Space Technology. We had worked together a number of times in the past, and he mentioned that they were trying to expand the composites program at NASA and asked me if I'd be interested in coming to NASA. I thought, "It would be a great opportunity, I'd love to do it," and so I told him I was interested. That's how it worked out. I'd known Sam for a long, long time, and we've worked together throughout my career at NASA and after I retired from NASA, so it's been a great experience and a great relationship.

WRIGHT: A nice partnership.

MULVILLE: Yes.

WRIGHT: The [Space Shuttle] *Challenger* [STS-51L] accident happened also in 1986. Can you give us an idea of how that tragedy impacted the area that you were working in?

MULVILLE: That was interesting. I was with the Navy at the time and was at the Industrial College of the Armed Forces [National Defense University Campus] at Fort McNair [Washington, DC]. The day of the *Challenger* accident, I was with the students watching the TV coverage of the Shuttle launch. It was just unbelievable. When I came to NASA, it was after the *Challenger* accident—I came in November 1986—there was a lot of effort ongoing on in the recovery program, and in particular, the people at the [NASA] Langley Research Center [Hampton, Virginia] and [NASA] Marshall Space Flight Center [Huntsville, Alabama] were working on the structures issues associated with the solid rocket motor cases and the design and issues related to the seals. Sam's organization had a significant involvement in the structural analysis and redesign.

I didn't directly participate in the Shuttle Return to Flight, but I was aware of the Centers technical analysis of the solid motor case structure and discussed their proposed redesign with the people who were involved. Sam had the responsibility for working on the structures technology—what kind of solution do we have that would enable us to solve that problem and ensure safe flight in the future? It was an interesting time to come to NASA. NASA was in recovery mode, and it actually took a few years to get back to the point where we returned to flight. It was a difficult period.

WRIGHT: Kind of an interesting time for you to transition, too.

MULVILLE: It was. There were a number of structures technology activities, but of course, the main focus of the agency was on human spaceflight and what could be done to get back to safely launching the Shuttle.

WRIGHT: The culture, I guess it didn't change for you because what it transitioned to was the new culture that you became a part of? The safety aspects?

MULVILLE: That's true. When I came to NASA, I had been working in aerospace materials and structures technology with the Navy, and so I was moving into the same area, continuing with the materials and structures technology development. In addition to the Return to Flight for the Shuttle, there were a number of programs in the OAST, Office of Aeronautics and Space Technology, we supported that were related to human spaceflight. As an aside, in 2011 Ray [Raymond S.] Colladay, who was the head of OAST when I was there, was asked by the

National Academy to lead a study of what NASA's technology should focus on for the next two decades. One of the issues discussed was a suggestion that NASA should consider reconstituting an office of aeronautics and space technology so NASA could realize the synergistic benefits of developments in both aeronautics and space technology. It turns out that recently, NASA has reestablished a space technology organization. So that's a step toward having a technology focused organization within the Agency.

In OAST we were involved in a number of different areas. There was a big effort to develop heavy-lift launch vehicles, and there was considerable research on reduced structural weight using composite materials and aluminum-lithium. Aluminum-lithium is the material that was used on the new external tank for the Shuttle. At the time, aluminum-lithium was a new material and a lot of work was required in order to get it to the point where it could actually be used in an operational space system. We were also involved in aeronautics technology. There was the incident of the Aloha [Airlines Flight 243] aircraft, which led to an assessment of the aging aircraft problem. NASA was involved in working with the aircraft industry to try to identify what the cause of the Aloha failure was and what the fix would be in order to assure safe aircraft travel. There were a lot of different things that were going on at OAST at the time, in addition to the effort to support the Return to Flight of the Shuttle.

WRIGHT: I think sometimes, people don't understand that NASA does do more than just put people in space. You do lend the expertise to the FAA [Federal Aviation Administration] and with the aging aircraft issues.

MULVILLE: They call it the little A in NASA, the aeronautics part. If you looked at the budget, I don't think it ever reached $1 billion. It was usually $400-$500 million of the NASA budget which at the time was perhaps a total of $12 billion. So it was less than 10 percent. Now, if you include the manpower costs for the four NASA Aeronautics Centers, then it probably gets up to about $1 billion, but it's not well-recognized and not as obvious, I think, to the American public as the space side of NASA.

WRIGHT: They forget that that's the A that the agency was built on, right?

MULVILLE: That's right. That was the beginning.

WRIGHT: As you stayed a few more years, you became the Director of the Engineering Division in the Office of Safety and Mission Assurance [S&MA]. You were working in S&MA when Fred [Frederick D.] Gregory was there, and George [A.] Rodney, and then also made responsible for developing NASA's standards when they were designing and developing spacecraft. Explain that process and how that evolved, and what that responsibility really meant.

MULVILLE: When the *Challenger* incident occurred, those responsibilities were in the Office of the Chief Engineer that included a number of safety and mission assurance functions. After *Challenger* the Office of the Chief Engineer was disestablished and an Office of Safety and Mission Assurance [OSMA] was created to focus more on issues related to mission safety and quality assurance. George Rodney was the director, and the Headquarters function and the Safety and Mission Assurance organizations at the Centers were primarily focused on mission safety and quality assurance. OSMA did not really have an engineering function within that organization. In 1991 OSMA established a Technical Standards Division, to expand their role and take on some of the engineering functions. I applied for the position as division director and, fortunately, was selected. That was my first opportunity to really work with the Safety and Mission Assurance Organization.

George Rodney was great guy, very strong leadership and was well respected within the agency. George wanted to establish a strong link with the engineering organizations, and so he worked with agency senior management to put in place an Engineering Management Council [EMC], with the idea that the chairman would be one of the heads of engineering of the NASA Centers. The deputy of the council would be from the Office of Safety and Mission Assurance, and that was the job that I had, in addition to all the other things we were doing on the day-to-day business. One of the Technical Standards Division functions was to assess commercial standards and where necessary develop NASA technical standards that would enable NASA to have guidance for design, development and safe operations for NASA systems.

The connectivity with the engineering organizations was actually a key objective of the EMC. George Rodney wanted to integrate the output from the Safety and Mission Assurance organization into what was being done within the engineering organizations. The Technical Standards Division later expanded into the Engineering Division. In addition to technical standards, I had responsibility for the NASA [Aerospace Flight] Battery Program to evaluate the batteries that were being designed and used on spacecraft and other systems, and the EEE [Electrical, Electronic, and Electromechanical] Parts Program, which included electronic parts and electronic packaging programs to establish guidelines for parts and packaging safety and reliability. We were also responsible for software engineering programs; the difference between software safety, software assurance and software engineering was a little convoluted since all of those elements are integrated in software development and application. There were other engineering functions which we supported such as tools for analysis of mechanisms, tribology, and radiation effects on electronic systems. We were doing a number of projects to support development and operation of spacecraft systems.

We had some limited resources to focus on technical problems related to design, development and operation of spacecraft systems. What are the problems we are having today, what are the things we can do to fix them? The engineering organizations at the Centers were actually working on these projects, and we would provide some resources for them to be able to expand their efforts in some way, or provide some additional funding so that they could solve some problems that would enable them to do their jobs more effectively. It was a great job, loved it, and working with George was a great experience. Then later, after Fred Gregory took over responsibility for the Safety and Mission Assurance, I enjoyed working with him as well. It was also a good experience and a pleasure to work with Headquarters and Center S&MA organizations.

WRIGHT: How did the Centers react to a thought of standardizing different areas within those fields that you were qualifying?

MULVILLE: Technical standards have a benefit in providing guidance for design, development and operation of space systems people. We worked with the Centers, used the best technical information available and tried to present the standards in ways that were not prescriptive. Except for safety standards, which were required, we weren't mandating that specific standards be applied. The selection of applicable standards was the decision of the project managers. Over time NASA evolved and moved away from having our own quality control standards to adopting ISO 9000. So, instead of NASA having its quality control standards, we were going to adopt the international quality standards. In that way NASA didn't have to maintain the standards; we didn't have to go through the rigorous process of updating them. The same thing applied to a number of other standards. There were military standards and standards that engineering organizations, such as the AIAA [American Institute of Aeronautics and Astronautics] and the ASME [American Society of Mechanical Engineers] developed that were adopted by NASA project managers. So our approach was to recommend national standards as opposed to just NASA standards. That was a big evolution to move away from NASA-unique standards.

There are some things that we did retain because generally, there were not many other organizations that did the space related projects that we did, so NASA had standards, for example, for use of liquid oxygen and hypergolic fuels to ensure safety operations using systems that had low-temperature materials or hypergolic-type fuel systems. I think over time the Centers became a little more comfortable with national standards, and not the NASA-unique standards that we generated ourselves, and so did industry. Industry was very interested in adopting national standards since the policy of the Department of Defense [DoD] was to evolve to use of national standards, and the last thing Lockheed Martin or Boeing wanted was unique, separate standard for NASA projects. It costs money, and creates problem.

One of the issues we had was related to the use of the metric system. There was a requirement that we move toward greater use of the metric system of measurement, and we had to report to Congress on a regular basis about our progress in that direction. There was always a concern, that somewhere, somehow, there was going to be a problem, and it turned out on the

Mars Climate Orbiter that that's exactly what happened on the propulsion system. Standards really count; you just have to be assured that you adopt the right ones and ensure they're applied correctly.

WRIGHT: That's a very interesting piece of the foundation that was laid at that time that is still being utilized today.

MULVILLE: Now when NASA takes on a project, project managers identify the standards that they believe are the ones that will be necessary for them to successfully implement the project, and so, those are the ones that are put in place. Some safety standards are mandatory, but the engineering standards adopted are those that the project managers decide are appropriate. When they're communicating that to the contractor, they want to be sure that contractors follow appropriate guidelines, so that the hardware meets the requirements, is space-qualified, has gone through rigorous testing—a test as you fly approach, and that they have traceability of the parts. That's always a problem—substitute parts can create a serious problem if you don't have as means of assessing the parts pedigree. It's evolved a bit over time.

WRIGHT: One of the Shuttle missions that occurred during your time in S&MA was the Hubble [Space] Telescope [servicing mission], which has been called one of the most challenging, complex missions. Was your office involved with getting that mission ready to go?

MULVILLE: I personally did not have direct involvement in that mission. The problem with the mirror occurred early on in the course of the program and the corrective optics solved a lot of the problems. We had some interaction with Jet Propulsion Laboratory [JPL, Pasadena, California] on the upgrades, such as the Wide Field Planetary Camera. There were a number of projects we implemented that supported their test and evaluation programs. We worked with JPL on improving their test standards and qualification standards, but I did not personally have any direct involvement in Hubble or any of the hardware that went into it. My involvement was mainly supporting the technology and technical issues related to the program.

WRIGHT: Talk about some of the duties and responsibilities as the technical readiness and the execution—throughout the NASA program, you've been talking about the standards—were there other issues and other policies that became a part of the NASA tradition and culture?

MULVILLE: During the time I was in the Chief Engineer's Office there was an effort within NASA to provide agency wide guidance for program project management. I'm not sure the program and project managers were enthusiastic about it, but there was concern that there wasn't consistency in the way the projects and programs were being developed and executed across the agency. Carolyn [S.] Griner, who eventually became the Deputy Director at [NASA] Marshall [Space Flight Center, Huntsville, Alabama], was working with Jack [John R.] Dailey, the Associate Deputy Administrator, and the Office of the Chief Engineer to develop an agency guideline for program project management, 7120.5 [NASA Space Flight Program and Project Management Handbook]. I don't know why that number sticks with me—but there was a major effort to put in place guidelines for program and project managers. Developing the 7120.5 guidance involved participation from all of the Centers.

At that time projects were developed and executed through a number of phases. There was a phase A, phase B, phase C, phase D, and phase E of the projects, where you would have conceptual development in phase A, preliminary design and development in phase B, final design, build and certification in phase C, deployment and operation in phase D, and finally system retirement in phase E. That was the whole lifecycle of the program. The new program project management guidance had a little different structure to it, but buried underneath all that was still the phase A, B, C, and D, and people continued to speak that language when they talked about projects. In the Office of the Chief Engineer we were involved in putting 7120.5 together, which was a major effort. As part of the new guidance, NASA established a Program Management Council [PMC] to review all major projects during their lifecycle. Jack [John R.] Dailey was the Chairman of the Council, and I was Chief Engineer at the time, which, to me, was just a wonderful experience.

A little side issue on the Chief Engineer's organization: I was the Engineering Division Director in the Office of Safety and Mission Assurance and the S&MA Deputy on the Engineering Management Council. [J.] Wayne Littles, who was the Head of Science and Engineering at Marshall at the time, was the Chairman of the Engineering Management Council. I got to know the chief engineers in all the Centers because they would alternate as Chairmen of the Council. Every year, a Chief Engineer from one of the Centers would be appointed Chairman, so as deputy I worked with many of them on engineering issues across the agency. That was a great experience. Wayne is a first-rate engineer, and it was a pleasure to work with him. He was the chairman of the Engineering Management Council, and Dan [Daniel S.] Goldin wanted him to come up to NASA Headquarters and be the Chief Engineer. If they're going to reestablish the chief engineer' office and needed somebody that was a rock-solid engineer, Wayne's the guy. When Wayne came to NASA Headquarters he needed a supporting organization. Wayne said he needed a deputy chief engineer, and he said that I'm the guy—which I thought was wonderful. That worked, and then Wayne was offered the position to be the [Center] Director at Marshall. That's what Wayne really wanted to do. His family was in Huntsville; being in Washington was interesting, not what you want to do for the rest of your life, and so he took the Center Director job.

After rotating another Center engineer into the position of Chief Engineer, they decided to have someone fill the position on a permanent basis, and so Dan Golden and Jack Dailey asked me to take that job. I loved it—to be the Chief Engineer at NASA, it doesn't get much better than that. Being the Director of the Mars Program, that might fun, too, but the chief engineer job was excellent.

To get back to the Program Management Council, Jack Dailey was the chairman. The members were the Chief Engineer, Chief Scientist, a representative from Safety and Mission Assurance, and all of the AAs [Associate Administrators]. Under the 7120.5 program and project management process, the program or project manager would present a review of the technical and budget elements of the project and proposed future activities to get approval to continue the project and move to the next step. To go from phase A to phase B, project managers had to go to the Program Management Council, here's what we're doing, here's why we're doing it, here's how much it's going to cost, and here is the margin that we have, and here's the risk associated with the project. The Council would decide, "That makes sense," or, "We don't think you're ready, go back, do a little more, and come back and see us."

That was a good experience, and one of the outcomes of implementing the 7120.5 program project management guidelines is that it added some rigor to the program and project management process, some checkpoints along the way, so that you didn't have programs just going off and doing their own thing. Still happens, of course, but at least there's a roadmap that they're supposed to follow.

I don't think anyone was wild about this or enthusiastic about the 7120.5; it was a hassle for a lot of them because it takes time to make these presentations, and if a program was in trouble, of course, that's an unpleasant experience and not a good day. Some programs escaped a 7120 review, which was interesting because even though it could have been a high budget program, if it was an operational system it was not subject to a Program Management Council review. The Shuttle Program never came to the Program Management Council because except for a few new developments they were an operational program. There were a few items they would bring forward as specific development projects, the advanced turbo pumps for their propulsion system, a hydrogen pump and the oxygen pump; the aluminum-lithium external tank, those projects come to the Council, since those were development projects that would then feed into the Shuttle Program.

The [International] Space Station [ISS] Program presented their development projects to the Council on a few occasions. The Space Station people were not happy about it because they were in deep trouble, both cost and schedule, from the get-go. If you talk about the problems we have with the NASA budget today, well in NASA, if you're billions short—its lot of money. Today, they talk about the James Webb Space Telescope, the $8 billion telescope, well, there are problems, but it's nothing like the way it was with Space Station. Station came in to the Program Management Council couple of times, but then they said, "We've got so many things going on, we just don't have time to put this together," and so the Space Station didn't come to the Program Management Council when the cost over runs were in the billions. There wasn't much the Council could have done at that point anyhow. Still ISS is a successful endeavor and a tremendous asset. I don't think a lot of people really appreciate what it does or any of the details about it.

Unfortunately, ISS doesn't get a lot of publicity, so you rarely see items in the media highlighting its accomplishments, "This is the technical output from the Space Station, here's what the return is on investment, new things that have been discovered on ISS." Occasionally, someone goes up, someone comes back, using a Soyuz vehicle, so you'll hear about support and re-supply missions. Just recently, an ATV [Automated Transfer Vehicle] was launched by the Europeans to Station for re-supply, but what's happening there? It's in a black hole as far as the media and public are concerned, and I think that's unfortunate. You're not going to get a lot of support from the American public if they don't know what you're doing on the ISS. Just an opinion, but I don't think we do a good job of telling NASA's story about what we do on ISS and why it's important.

WRIGHT: No, no, that's a true statement.

MULVILLE: After Apollo and the early Shuttle Program successes NASA's had a problem in communicating it's vision—that's one reason why the OAST hired an executive from Disney Imagineering to try to help NASA tell its story. His view was that while NASA had great stories to tell, NASA was not a good storyteller and people respond to stories. If you've got a message, "Here's what we've done, why and how it worked, and what the benefit is to the Nation," people can relate to that. It's a culture thing, and he said NASA just does not do that well, and when they do try to communicate the results of the NASA programs, it's usually technical people talking to technical people, so unless you have a decoder ring to figure out what the acronym stands for, you're lost. He said, "NASA needs to get better at telling stories."

Absolutely right, and unfortunately, it happens kind of serendipitously. The Canadian astronaut who was on the Space Station recently and did a little singing gig, his son set it up, that was a highlight! I mean, that was good, and they should do more of it. That was sporadic, and it wasn't planned by NASA. That was his thing and his son's, I think, who was actually the one who helped with the whole technical part of it. Now, he's a rock star in Canada. You just need to have more of the good news and stories about ISS research accomplishments. What's the bang for the buck? Hubble was great. Pictures are wonderful, and people really relate to the pictures. The interpretation was missing; sometimes you didn't get the real meaning. Great photos, but how does that tell us something? The [Mars] Rovers have helped a lot in terms of the Mars efforts. Those are just a tremendous NASA accomplishment.

WRIGHT: Those were a good bang for the buck. One's still going. It was amazing.

MULVILLE: That's right, and it's far beyond its planned mission life.

WRIGHT: You mentioned a few minutes ago that Dan Goldin wanted to reestablish the Office of Chief Engineer. Why do you feel that that was an important decision for the agency? What purpose does a chief engineer serve for an agency?

MULVILLE: The purpose it serves is to have a focal point for engineering within the agency, just as having a chief scientist is a focal point for science. If you want someone who can actually say, "Here's what NASA's engineering programs are, here's why we strive to have an outstanding engineering workforce, and here's what we intend to do in terms of improving engineering capabilities," having a chief engineer is a good thing. The Chief Engineer's Office had a budget which, frankly, I think was a bit of a distraction. The programs managed from the Chief Engineer's Office were those transferred from the Safety and Mission Assurance when the Chief Engineer's Office was established. It wasn't much money as far as the NASA budget goes, and was focused on a variety of topics, aerospace batteries, electronic parts, software engineering, and technical standards. It probably would have been better to have not had any money at all, and just been able focus on outreach and building the engineering capability across the agency.

I guess you can go either way on that one. The Chief Engineer serves a purpose and if you have a strong engineer in that organization—and the first one under Dan Goldin was Mike [Michael D.] Griffin, and he's a solid engineer, and later became NASA Administrator, a guy that really is on top of the engineering—he can provide leadership to the NASA engineering organizations and get them to jointly work on program activities. There's always been some insularity within the Centers. Marshall and the Space Flight Centers have excellent engineering capability. There was always some competition, between [NASA] Goddard [Space Flight Center, Greenbelt, Maryland] and JPL. There was always the question of which organization had best capabilities for design and engineering of satellite systems. I believe that competition led to better engineering tools and methods across the agency. Being able to have the engineering organizations communicate more effectively, work together better, have a person who can speak for engineering in the agency and be an outreach person, just as the Chief Scientist is responsible to speak for science, is valuable. Dan Goldin set up the Chief Engineer's

Office to provide a focus for agency-wide engineering, and Mike Griffin was an excellent choice.

WRIGHT: That's the nice part about this.

MULVILLE: The Chief Engineer's Office has been very successful.

WRIGHT: Let's talk about Shuttle because very much a focal point of what was going on was the missions, and there were some issues that, while you were in those positions, impacted the Center. One was after the STS-62 launch, [Space Shuttle] *Columbia*, there were some concerns about some misaligned or faulty welds that were on the high-pressure fuel pumps. Then, initially, it was reported through the NASA Safety Reporting System. Talk about that situation and how you resolved it, and of course, many people in the media were citing that the budget concerns were affecting safety, so if you bring us back to that point and how you managed to survive that?

MULVILLE: That was very interesting. There was a technician that worked at Rocketdyne, I can't recall precisely where he was or what group he worked with, but he was very concerned about the turbo pump welds. The advanced turbo pumps, which were being built by Pratt and Whitney were designed as replacement for the older pumps, eliminated a lot of the welds. The concern was raised because the welds in the original turbo pumps were difficult to make and inspect, and there was a possibility of a major accident if one of the pumps failed during a Shuttle launch. That, of course, was a concern that led NASA to support development of the advanced turbo pumps. The technician felt, and he may have had some justification for his feeling, that there were some flaws in the welds and there was a potential disaster in the making. If you lost a turbo pump, you'd lose the engine; and if you lose the engine, you're probably going to lose the Shuttle. A turbo pump failure could lead to a catastrophic failure of the Shuttle. He filed an anonymous safety alert, and NASA's Office of Safety and Mission Assurance had the responsibility for investigating to determine if there was any substance to the his claim of a safety problem. I met with the people from Rocketdyne, Marshall, Stennis and we went through a review of the pumps manufacturing, inspection and certification, how their processes were implemented, the numerous inspections that they go through; the proof testing that takes place on all the engines down at [NASA] Stennis [Space Center, Mississippi] before they're actually installed on a Shuttle.

There is a significant process in place to build, inspect and test each engine before flight. Generally, if you're going to have a failure in a weld in the turbo pump, it's probably going to happen early on because you're putting a lot of stress during its start-up and initial operation, high stresses and temperatures. If the turbo pumps pass the certification tests at Stennis, that generally is a good indication that you're going to have a successful flight operation.

So, we felt, "We have a pretty safe operation, we have not had any problems, and we have not detected any flaw growth." That's not saying you will not detect flaws in the welds. The question is, "Are flaws in the welds of a critical size that would cause a failure during operation of the turbo pumps?" The findings came down to the fact that we believe that the things we're doing guarantee with some of level of assurance that we have minimum risk for the propulsion system and the turbo pumps. I don't think the technician agreed with the findings, but the findings were made public and there were a number of these media interviews on the topic. One of the interviews appeared on the Syfy [Science Fiction] Channel. Who knows how these things go?

There was another that was more of a national news event, in which the media presented their investigation in a very dramatic way. I had a discussion with the woman who was doing the interview, and said, "We believe that we've taken all the appropriate steps and made the measurements and feel that we have the appropriate level of quality assurance to assure a safe flight." Then they flashed to a picture of the Shuttle *Challenger* [STS-51L] explosion. You get two sides of the story: I think they were looking for something that would be a sensational issue; turns out we never really had a problem. Fortunately there was never a failure of the turbo pumps during a Shuttle flight.

NASA replaced the older turbo pumps with the advanced ones, those worked extremely well, and so it was pretty much a non-issue. At the time, though, it put a lot of pressure on the agency because it appeared that NASA wasn't doing due diligence. We'd had one Shuttle failure already, and the media was looking at possibilities of another failure. I think when the Shuttle designers were concerned about a failure, the turbo pumps were a major concern. It wasn't the solid rocket motors, and it frankly was not the thermal protection systems, I think those were not really perceived as being as high a risk as a turbo pump failure. Turns out it wasn't low risk for the solid rocket motors or the thermal protection system, either.

WRIGHT: While you were Chief Engineer, the Americans moved into a partnership with the Russians to have American astronauts reside on MIR [Russian Space Station]. Were you involved in those discussions during that time period, when we know there were a couple of accidents? That keeps falling into your category. How were you involved with the information as far as not necessarily negotiating, but the incidents that were happening on MIR and for the safety for the astronauts?

MULVILLE: I personally did not have any involvement. The MIR interaction was conducted primarily by the people at the Johnson Space Center [Houston, Texas], and their Russian counterparts. The Russians, of course, had the responsibility for all the hardware. NASA did not have a lot of insight into that. We were relying on the Russian safety and mission assurance organization to assure a safe flight. They'd been fairly successful in the past, so it was hard to argue that they don't know what they're doing. I really had no involvement in that at all, aside from just being somewhat aware of what was going on. They had some problems with the oxygen generating system, apparently, but that was about the level of it. I never really went to Russia on any of these trips or had any kind of connectivity on that part.

WRIGHT: Let's talk about the International Space Station, and your contributions or involvement with any type of the discussions that were talking about the engineering aspects of the assembly flights and all of the issues that are going to be dealing with those.

MULVILLE: You've talked to Bill [William H.] Gerstenmaier, and he has a wealth of knowledge on that topic. Bill is probably the most knowledgeable of anyone at NASA on engineering aspects of ISS. He knows the history, good and bad, and everything that happened along the way. The Chief Engineer's Office had limited involvement because it was an operational program being executed by Johnson. Aside from two ISS reviews early in the program, it wasn't something that came to the Program Management Council for any review or assessment. There were some things that we did in the Battery Program, when it was in the Office of Safety and Mission Assurance, which demonstrated methods to extend battery life and potentially minimize the need for additional Shuttle flights for battery replacement. A lot of work was done on hydrogen battery cells, which were deployed on Hubble, enabling it to have a longer life. The advanced hydrogen battery systems on International Space Station enable ISS to operate for a longer period between replacements, and so some of the technology that flowed into the Station was a product of the work that was done earlier by OSMA.

We actually had little direct involvement in the Shuttle, in the Station Program aside from the development of upgrades and new hardware systems. That worked pretty effectively—there were some issues that came up, which might be technical issues, problems with the manufacturing, but in many cases, the Johnson people would ask some of the other Centers to provide some assistance. When Boeing was building some of the ISS elements, JSC would involve the Structures Group at Langley and ask for some assistance in terms of the design or manufacturing issues. We may have had some connection in meeting with JSC and Langley to see what they were doing, see if they had the tools that they needed to do the job, but we really didn't get involved in the design. That was all done by the contractors, really. That was a Boeing job, so Johnson was managing Boeing's construction of the Space Station as a contract, and consequently, NASA's involvement was really more in monitoring. We didn't build many things ourselves.

One interesting project that Johnson conducted in the 1990's was to build an inflatable TransHab [module]. Transhab was a very unique and challenging option for ISS crew habitat and one that may be employed for future Mars missions. Due to cost and risk factors an inflatable habitat was not accepted as a replacement for the baseline aluminum crew habitat, but the concept was great. Bigelow [Aerospace] intends to build and deploy an inflatable system to the Station in the future to demonstrate the capability. The JSC Center Director, George [W. S.] Abbey, was supporting the TransHab module as a new, innovative technology that could lead to future space and planetary habitats. In fact, having an annulus of water within the Kevlar shell structure surrounding the crew quarters could reduce some of the cosmic radiation threat to astronauts. That concept is currently being considered for future asteroid and Mars missions. JSC was also developing a Crew Return Vehicle [CRV]. We had a lot of involvement with the proposed design and operation when the project was brought forward to the Program Management Council for review.

WRIGHT: Let's talk about those because you had the Crew Transfer Vehicle, you had the Crew Rescue Vehicle; you had the Reusable Crew and Cargo Transfer Vehicle. You had all of these different concepts, so give us an idea of what it was like at the Program Management Council when these would come through.

MULVILLE: We reviewed the CRV project with the project manager at JSC, but we also conducted independent assessments with agency engineers independent of the project, and had [NASA] Ames [Research Center, Moffett Field, California] and Langley involved in looking at some of the concepts, to have an independent assessment. Later, when Mike Griffin was the Administrator, he set up an independent program review office, Office of Program Analysis and Evaluation, to conduct technical reviews on selected topics independent of the organizations which had responsibility for the projects. The objective was to have a group doing an independent analysis that did not have a vested interest in the outcome. The Office of the Chief

Engineer did some of those things as well. The program objective was to have a Crew Return Vehicle attached to ISS that could hold six-passengers. Currently we're relying on the Soyuz for both astronaut transport and return. Since the Soyuz is only a three-passenger vehicle; that limited the number of people that you could have on Station. Unless you had two Soyuz return capsules on ISS, you couldn't have the six-person crew.

The CRV was a concept based on some early lifting body studies. JSC had an interesting re-entry concept using a parafoil as part of the vehicle system. The CRV would deploy from Station, enter through the atmosphere, and then deploy a large parafoil to land safely. There was high risk associated with the concept. On the other hand, it would be a U.S. return vehicle, we would not need to rely on the Russians, and it would enable us to staff up the Station completely. Great idea and a good concept, but it was never fully funded, and for a number of reasons, didn't get support. That kind of went away, unfortunately. I think it would have been a very, very interesting development. There were other projects, X-37, the X-34 that were going on at the time, X-33; all of these programs were looking at innovative launch vehicles and flight systems. Some of which matured and some didn't.

WRIGHT: The Program Management Council would get updates on where these programs were going through?

MULVILLE: The PMC would have the responsibility to review programs and projects to see if they were ready to go forward. There was not much "hands-on" involvement in the projects, but if problems came up, Dan Goldin would ask me, for example, "I think we've got a problem with an element of a spacecraft, I want you to go take a look at it, do an analysis, come back, and tell me what the story is there." Every time we had a failure of a launch vehicle, there was always a big effort to determine what went wrong. Working with Langley, we developed a reliability analysis to determine the number of consecutive successful launches required to demonstrate a desired level of reliability. For example, how many launches do you need to get to the point where a new launch vehicle is as reliable as a Delta II?

The analysis predicted that if you had 14 consecutive successful launches, you're at the 95 percent reliability at the 50 percent confidence level. I don't think the launch vehicle industry was too happy about the analysis—Orbital Sciences [Corporation] in particular because they had a number of failures with their early Pegasus vehicle—but in the end, many of the commercial launch vehicles have achieved that level of reliability. It really gave the launch vehicle industry a target to shoot for so that the launch vendors and the project managers could feel comfortable about putting their spacecraft on a launch vehicle. If it's the first or second launch, you get a little nervous, and with good reason.

WRIGHT: I guess different organizations have different levels of accepted risk compared to what you would be looking for?

MULVILLE: With a spacecraft like the Mars Curiosity with a $1 billion-plus payload, you better be sure that you've got a very reliable launch vehicle. On the other hand, if you're doing some student payloads or smaller missions, you can probably take a chance and go with something that has less demonstrated reliability and less cost. SpaceX with their launch vehicles is one of the new launch companies coming along. They've been very successful; and their hope is to be competitive in launching crew and cargo to ISS and launching payloads. Orbital Sciences had some problems in the beginning. They're much better now. Pegasus had problems in its early development, and there were a number of payloads that were lost for a variety of reasons. I think the concern is that if you don't have a good, solid launch vehicle development, you're putting a lot of risk on the payloads.

WRIGHT: Since you're talking about those two, I think back in '98, you made a presentation on commercial space transportation for a forum. Talk about while you were with the agency, the thoughts of using commercial partners and how that evolved, or how it didn't evolve, while you were there, compared to where we're looking at now.

MULVILLE: NASA was asked by Office of Management and Budget to conduct a Space Transportation Study—but I should mention that NASA actually proposed a study to the Office of Management and Budget [OMB], they say it sounds good, so they ask you to do what you asked them to ask you to do, if that makes sense.

WRIGHT: That's good to know.

MULVILLE: OMB asked us to conduct a space transportation study, and the Office of the Chief Engineer had responsibility for conducting the study. OMB's objective was to phase out the Shuttle by 2010, and that was it. So, the question is, what's the replacement? The study was intended to look at various candidate launch vehicles to assess alternative commercial vehicles, not NASA vehicles necessarily, that would be able to fulfill the function of the NASA missions.

When we embarked on the study there were a number of different companies involved. SpaceX was not one of them, but Orbital Sciences was involved, Lockheed, Boeing and a few smaller companies. There were a couple of others that were small, start-up companies that had very innovative concepts. Some of them proposed, like Orbital, to fly a large airplane with a launch vehicle held captive and then launch at some altitude. You buy yourself a big payload gain if you eliminate that first phase of the launch, and have a reusable system do that. Kistler [Aerospace] was one of the companies looking at reusable systems. Industry participants went through an analysis, and came back with a number of recommendations. Each company had its different proposal about what it would take to get to the point where they could have something that would support the NASA missions and other commercial ventures as well.

It was a very interesting study. In the end, I think OMB decided not to support building one of these launch vehicles, but to put the money into launch vehicle technology. There may have been some political reasons for that, cost to develop a launch vehicle in particular, but what OMB's decision did was to funnel the technology program down to Marshall so Marshall could do work on propulsion systems. There was no decision on a next generation system to replace Shuttle. It's hard to know everything that goes on in those discussions, but what came out of it was Kistler was awarded a contract to provide access to Station—which never materialized because Kistler was undercapitalized and never built a vehicle.

There were lots of new launch vehicle starts and stops. A number of these small start-up companies wanted to get into the launch vehicle business, but unless you're heavily technically-engaged and have the resources to make it happen, it's a problem. [Elon] Musk [SpaceX founder], of course, has the money to make it go and the technical team to make it happen, two key things that were missing on some of the others programs. Although Kistler had good people, they needed a lot more money than they had to pull it off.

WRIGHT: I'm going to jump up a few years because you went to work for the CSI, [Constellation Services International]?

MULVILLE: I was actually a consultant for CSI. CSI wanted to build a capsule domestically to provide crew and cargo to the Space Station. The idea was great. CSI proposed to buy the Soyuz design from the Russians and build a derivative of the Soyuz in the U.S., so instead of having to go to Russia to launch astronauts or to launch cargo in a Russian capsule, you could launch CSI's capsule from the U.S. on a U.S. launch vehicle and you'd have a U.S. capability in addition to the Shuttle. It made a lot of sense. This was before SpaceX, when the only way to get to the Station was either the Shuttle or through the Russian Soyuz. CSI's approach would have been a fairly low risk system; you would base the CSI design on "a space-qualified system," which had already flown. There was an arrangement whereby one of the major aerospace suppliers would build the CSI capsule in the U.S.

The major issue was enabling the agreement with the Russians to be approved, so that CSI would be able to support the modifications. Russia would do the design modifications, for example, change the volume or some of the internal configuration, and then transfer that technology to the U.S., so the U.S. could build directly from the blueprints. CSI's capsule could launch on an Atlas V or a Delta IV, so the U.S. would be independent of launching on a Russian vehicle. You'd have to build adaptors for the U.S. launch vehicles and analysis to account for a different launch vehicle loads since it wouldn't be launching on a Soyuz rocket.

One major problem was, the INA, the Iran Nonproliferation Act, which said in any program activity we have with Russia the President has to certify that none of the U.S. funding goes to Iran for any kind of weapons development. That's hard to do. You can't really guarantee it in the first place. All you can do is have some assurances from the Russians. We're able to get around that on the Soyuz launches because that's the only option we have.

In any contractual negotiation with the Russians we'd have to pay them to get the Soyuz system design modifications, so there would be a transfer of money to Russia to get the modified design and bring it back to the U.S. It was just too hard to do. Congress would have to approve that; you'd have to get the okay from them.

Lockheed, I think, was willing to build the CSI capsule, and if you look back on that, if we'd have done it, we could be launching today from the U.S., we wouldn't be paying $70+ million each for launches to ISS from Russia. I was just a consultant; I never got paid for any of this. CSI would cover travel expenses but that was about it.

WRIGHT: Must be interesting, though, connection of those early talks, just a few years before, when you were at the agency and all of the other vehicles that were undeveloped, not in development.

MULVILLE: The vehicles concepts came and went including recently the Constellation [Program], which unfortunately never made it. Conceptually, Constellation was a great idea—I know there's lots of interest in capturing an asteroid and bringing it into Earth orbit, but I still think if there were a lunar mission it would get broad national support, people can resonate with that. It's easier to understand and if we don't do it the Chinese or other countries are going to be there before we are, and then everyone will look back and say, "What happened?" It's all about the money.

WRIGHT: While you were there at NASA, you had an opportunity here, lots of details about ideas because I think you were the chair of NASA's Inventions and Contributions Board.

MULVILLE: Yes, that's right.

WRIGHT: Can you share with us some of those experiences about some of the ideas that came forward and you were able to move even more forward?

MULVILLE: The NASA Inventions and Contributions Board reviews NASA patents and new inventions and provides awards for those they deem most significant. The idea is to review the patents, inventions and contributions that came forward over the past year, and identify those that are worthy of some special recognition. That worked out pretty well. One issue that is quite interesting is that you can't patent software, but you can copyright it, so there were no awards at that time for software innovations. There was a physical inventions and contributions focus by the board. There was a lot of NASA software development that was very interesting, but it fell outside of this group responsibility. I'm trying to remember whether we actually gave any awards for software systems. We had a lot of discussion about it. Perhaps that has changed since I was involved. I think it's good for the people in the agency to realize that in addition to getting a patent, there may be some other personal reward that would be a great advantage.

WRIGHT: You also got to serve as Associate Deputy Administrator in 2000, and then you actually became the Acting Administrator. Talk about the opportunity of being in those positions and what you were able to accomplish during those time periods.

MULVILLE: It was totally unexpected; I'll put it that way. Actually, I thought as Chief Engineer, I got to the point where I could retire, and I might go to one of the aerospace companies when I retired. But that changed when Jack Dailey got an offer to be director of the Air and Space Museum. I was Chief Engineer at the time, and Jack said, "Would you take this Associate Deputy Administrator job?" I thought, "Fantastic, I'd love to do it." It was a great job. Shortly thereafter Dan Goldin brought Chris [Marvin R.] Christensen in to the front office to handle some of the personnel decisions since he had a lot of experience with Headquarter and Center personnel matters. It was easier for me to just focus on technical and programmatic issues and let Chris deal with the personnel. Dan Goldin was transitioning out of the agency, and Chris and I worked well together. The Associate Deputy Administrator was an interesting job. You got involved in a range of things that were non-technical, put it that way.

The Chief Engineer's job was much more interesting for me personally than the Associate Deputy Administrator. Although there are a lot of things you do as the Associate Deputy Administrator that are rewarding, Shuttle launches, PMC reviews, and be involved in more of NASA's outreach activities. I'm trying to remember—I think I may have presented the Congressional testimony on the Launch Vehicle Transportation Study during that period, but I may still have been the Chief Engineer when all that happened. It was a good job, and it helped Dan in his transition too. I think Dan was hoping that the administration would select a NASA Administrator sooner than they did, but when they have a change of administration, NASA is down on the priority list of jobs to fill. NASA's not in the top 10 or top 20 agencies that need to have a new leader.

Time went by, and eventually, Dan elected to resign as Administrator. He'd been there a year or more after the election, they still hadn't picked a replacement, and it was clear they weren't going to pick him. It was interesting, working with Dan. He's a smart guy, quite a character, and later, after I left NASA, I worked with Dan on a number of different projects, the Japanese Space Agency systems engineering project and a few others. We had a very good relationship.

As Associate Deputy Administrator I was involved in a number of issues related to roles and responsibilities for the Centers, who's going to be doing what and how would the Centers work together. I also served as the NASA representative to the NASA Advisory Council. One meeting stands out in particular. I flew out to San Francisco, Monday evening, September 10th, from [Washington] Dulles [International Airport, Virginia], for a NASA Advisory Council meeting at the Ames Research Center. The next morning my secretary called shortly after 6 am Pacific Time and told me to turn on the TV. The terrorist attacks on the World Trade Center and Pentagon were underway. I was in Mountain View, California, for a week, no planes flying, everyone waiting to see if there were more terrorist activities. We had daily tag-ups with Headquarters to assess security at all of the NASA facilities. It was just an unbelievable attack on the U.S. when that happened. My wife was worried about me being out there—I have a son who was working in the Pentagon at the time, it was real worry until we found he was safe.

WRIGHT: Very unsettling.

MULVILLE: To get back to the Associate Deputy Administrator job, it was interesting, and I enjoyed working with the people. There was a lot more interaction with the Associate Administrators not just on the programmatic issues, but overall issues, budget, their interaction with OMB, and some Congressional interactions. When Dan left, the administration had a number of options in selecting an Acting Administrator. In fact, I'm surprised NASA didn't pick Joe [Joseph H.] Rothenberg. I still have no clue why that didn't happen. Joe was certainly well qualified. There were other people they could have picked, too, but it happened that Dan asked if I would take the job. And of course I said yes.

That was an interesting experience. I went down to [NASA] Kennedy [Space Center, Florida, KSC] for a launch a number of times—you know how these things are, it took three attempts before STS-108 actually took off. There were some things that came up at the Centers and OMB that I had to deal with, with the budget and program issues.

I was only Acting Administrator for a short period of time, about a month or six weeks or so, and then Sean O'Keefe came in. That was a little different. I think Sean was brought in, since he was the Deputy at OMB, to solve the Station problem. There was a $5 billion shortfall; that OMB wanted fixed. My sense is that's one of the reasons that he was asked to take that job, and it was interesting working with Sean. Different, completely different—Dan's very technical, and so there was a lot of engineering interaction with him. Sean, more of a business management type, and so the technical issues were things that I had more involvement with, working those with Centers, although Sean had a lot of interactions with Code M [Office of Space Flight] directly. I stayed on until Fred Gregory was selected as the Deputy Administrator, and then I felt I'd done all I could do, and that was the right time to go.

WRIGHT: When did you leave?

MULVILLE: It was the weekend of the *Columbia* incident [STS-107]. In fact that happened on the weekend I had finished up—I actually was on leave at the time during the last two weeks of January. It was first weekend in February [2003] that the *Columbia* incident occurred. I called back and told Sean's Chief of Staff, "I'll pull my papers if you need me to come back," but they had it under control, and that was fine for me.

WRIGHT: While you were in that month to six-week period, your friends at the NASA Advisory Council had sent you a letter that the future of the International Space Station depended on whether, "the agency could make the budget numbers fit its priorities," and cited NASA's management deficiency as part of the problem. You were only in that position for a few weeks and Sean O'Keefe was coming in. Were you able to share, or how were you able to talk with him about that?

MULVILLE: I went to the NASA Advisory Council a week or two after the $5 billion ISS problem exploded. Joe Rothenberg may have submitted his resignation by then. That was a very uncomfortable meeting. Everyone was very critical; NASA was now basically defaulting on ISS because of the $5 billion shortfall. It wasn't clear where we were going to get the money, and NASA might have to cancel the ISS Program. All the member nations had put money into it, and they wanted to know what's going to happen. Of course, I had no answers. That was the problem. I think Sean had worked an arrangement even before he came into NASA. It would have been incredible for him to come to NASA otherwise. I believe he must have had a fix in mind and an agreement with the head of OMB, "Here's how we're going to solve the problem: I'll go over to NASA and implement the fix." I can't imagine him coming in and then all of a sudden saying, "How are we going to fix it?"

He knew exactly what the $5 billion shortfall was and where the problems were. He had met with the people from Station, and after a while, he moved Bill Gerstenmaier into the position as ISS Program Manager. He was very familiar with what the difficulties were, and I think he had a solution in mind, so the ISS problem was taken care of.

Sean had asked me to put together a Station story. We had a timeline that lay out—here's what happened when, here's what's going to happen next, here's the resource it's going to take to fix it. It was kind of a Station map, if you like, and we would have meetings once a week or once every two weeks on Station status. We'd run through all the ISS problems to try to get ISS under control, and get some kind of a solution to the problem. That was his main focus. Early on, I think, for the first six months or so, he really concentrated on that. Then, let's see, he expanded out into other things, but he was only there a year before the *Columbia* incident, and then, of course, everything focused on *Columbia*.

WRIGHT: Yes, almost like you were going back through that again, weren't you?

MULVILLE: Yes, well, I came and left just in the interval between these disasters.

WRIGHT: That's an interesting mark right there, isn't it?

MULVILLE: Yes, it was.

WRIGHT: Although you retired, you continue to be involved with NASA, and you led a number of technical reviews. Would you like to share some of those? You did the Near-Earth Object Study, Lunar Robotics?

MULVILLE: I did that. In the first review after I retired, I was working with Kennedy, Marshall and Johnson on a review of Space Station Utilization. The review planning started before the *Columbia* incident occurred, when I was still the Associate Deputy Administrator. The study leader from KSC called and told me she was leading an in-house NASA group doing the study, and said she'd like to have an external group to provide an assessment as well. She asked me if I would head that up."

I said, "Fine, I would be pleased to do it". That was my first job after NASA, and I started a week after I left. The study focused on future plans for Space Station utilization, and of course, with the *Columbia* accident, all of the Shuttle access to Station went away. It was an interesting study; it really focused on how do the researchers ensure that they're going to be able to conduct their research? What is the priority? What's the mechanism for selecting these items, and how are we going to go forward in the future because with the *Columbia* accident, it was clear there was going to be a delay in access to ISS. Plus, the focus after the *Columbia* accident was more on Station final assembly than on research.

ISS research got secondary priority in any of the Shuttle flights to Station. There were some cargo flights that would add some of the science mission elements. When we finished the assessment we presented the results to NASA Headquarters. They thanked us for the input and the contribution to ISS research. I don't know if it really had much impact. Most of the future

ISS research was directed to focus on human spaceflight to Mars, rather than the broad science missions initially planned.

Safe human flight to Mars is the big challenge, and some of the other research on physics issues or crystal growth in microgravity were not seen as high a priority as any of the research issues dealing with radiation protection and how that affected the human body. The big challenge was, "Can we go to Mars safely?" Station was a laboratory to try to identify the humans to Mars challenges and try to solve the problems. It's a big challenge.

That was my first consulting job, and then there were a number of spacecraft problems that I worked on. There was one that was most unfortunate, and that was [NOAA-N (National Oceanic and Atmospheric Administration, NOAA-19)]. Lockheed has what they call—aptly-named, I might mention—a tip-over cart. It's a large platform used for rotating the satellite from a vertical to a horizontal position. NOAA-N is one of the series of geostationary Earth-orbiting satellites. The platform rotates a satellite horizontally so that the technicians can get access to install and test the instruments. The carts are used at Lockheed Martin by both the Air Force and NASA for their spacecraft programs.

NASA's tip-over cart was unavailable, so NASA used the Air Force's tip-over cart for a spacecraft operation. This was being done on a Saturday, and the Safety and Mission Assurance representative apparently wasn't on site. The platform on the tip-over cart was not bolted to the tip-over cart, so when they mounted the spacecraft onto the platform and began to tip over the spacecraft, it fell right on the floor. That was a very interesting study in Lockheed's processes for spacecraft assembly and test and the problems with multiple users of the same equipment.

The Dawn spacecraft was another study, which was fascinating. Dawn is designed to rendezvous with an asteroid, using ion propulsion system to transit to the asteroid, and it was in trouble. It was a JPL program with Orbital Sciences as the prime contractor. The Science Mission Directorate had a technical team and a management team reviewing the program, and I was a member of the management team. JPL had baselined a new ion propulsion system, which was critical to the whole project. It was the first time ion propulsion had been used on a major spacecraft mission. The propulsion system was being built by a subcontractor to the prime, and it was costing a lot more and taking longer than planned, but the cost was below the threshold that was used by JPL for major oversight. JPL didn't realize they were in trouble until they were in serious trouble. Eventually, Dawn got to the point where it was launched successfully, and was on its way.

There were a number of projects I was working with Dan Goldin and his company, Intellisis. We worked with the Japanese Space Agency, JAXA, to improve their systems engineering and with [NASA] Dryden [Flight Research Center, California] on UAV [Unmanned Aerial Vehicles] systems.

In 2005, Bill [William R.] Claybaugh called me and said, "We've got an issue with the Lunar Robotics Program and need to do an architecture study. The question was, "What lunar robotic activities are required in order to safely execute the Constellation Program of returning to the Moon?" We went through a discussion of the technical challenges and what could be done to mitigate the risk, and what robotics activities, if any, are required? How much would it cost, when would you do it, what's the profile?

We completed the study in 60 days. I presented the results to Scott Pace and then to Mike Griffin. Some of the issues were, if you're going back to where we went before on the Moon, you probably don't need to do a robotics mission because we've been there. But what robotics mission if any is needed if you're going someplace else? That was the question that needed to be answered. If you're going to the Polar Regions, which was one of the candidates landing sites because you have continuous daylight, that would be the ideal place to set up a solar power system. You would not need a nuclear system to generate power, which would be something you'd probably have to do if you went to one of the central locations on the Moon that were in darkness for two weeks, so you might want to do a polar mission. A robotics mission could be implemented to explore a candidate landing site, identify any potential landing problems and demonstrate precision landing capability. Precision landing would be one objective and establishing a solar power system to ensure an adequate power for 24 hours a day operation.

The other issues were environmental hazards; there was a question about lunar dust and whether that was going to be a hazard, and if so, what steps need to be taken. Those were the three things that looked as if they would support conducting a robotics mission. There was also a question about communication, but I think that could be adequately addressed; even without a mission, you probably would be able to do that. At that time there was Goddard Center spacecraft in development, the Lunar Reconnaissance Orbiter, designed to measure the lunar gravational field and conduct other science. Measurements of the gravity field were important for precision rendezvous and docking—if you know precisely what the gravity field is, then you can do a more precise rendezvous and docking. That was the outcome, the result was that perhaps there was one robotics mission that could accommodate the objectives, but you didn't need multiple missions to do this.

Many of the Centers were developing plans to conduct lunar missions. Marshall was identified as a Center for Lunar Robotics Missions; Ames wanted to be involved; Langley wanted to be involved, all of them wanted to have some piece of the lunar program. Mike

Griffin had a problem because he needed money for Constellation launch vehicles, and while the robotics missions were interesting, were they really necessary? That was the question. In the end, I think it came down to the fact that there might be one robotics mission that would benefit the program, but even that mission would not necessarily be critical for the Constellation Program.

We landed successfully in the Apollo Program; we can probably land successfully in the Polar Regions in the Constellation Program. The idea of being able to get power wasn't too big an issue. NASA felt they could conduct a scenario mission, one where astronauts went for a short period of time. NASA could do a landing, stay a week or two and return, in preparation for establishing a permanent outpost. There was maybe one robotics mission that was of interest in exploring a permanent outpost capability. It was an interesting study, and I think helped a little bit going forward, but by that time, it was getting to the point where it was clear NASA wasn't going to have money for lunar robotics missions. In the end, it was clear that NASA didn't have enough funding for the Constellation Program. That was true from the very beginning of the program.

The next program Bill asked me to lead was an assessment of detection and mitigation of near-earth objects. NASA had a program to detect Near-Earth Objects [NEO] greater than 1 kilometer in diameter. The program objective was to identify Near-Earth Objects 1 kilometer or larger that are within 7.5 million miles of the Earth or 0.05 astronomical units. It seems like a long ways away, but actually, that's pretty close. A 1 kilometer asteroid in near Earth orbit is a serious problem.

JPL manages the NEO program and over a 10 year period they found about 1,000 of the 1 kilometer or larger NEOs. JPL's primarily detection method is using Earth-based telescopes.

The telescope in Arecibo [Puerto Rico], run by the National Science Foundation is a huge radio-telescope, and that gives very precise trajectory measurements. Anything that comes close, Arecibo can get a pretty good fix on its trajectory and whether it's a hit or miss.

NASA was tasked to conduct the study to search for smaller asteroids because Congress wanted to know how many NEOs there were down to a size of 140 meters, below which there may be less of a problem, and what could be done to reduce the threat? The number of NEOs grows exponentially with reduction in size. If there are 1,000 NEOs that are 1 kilometer, there may be 10, 000 to 100,000 that are 140 meters or larger. From the recent incident in Russia, where there was a prediction of a NEO on the order of 100 plus meters passing Earth, and an unexpected smaller asteroid impacted, it was clear that asteroid detection is critical. The asteroid that impacted was one that hadn't been detected, that was on the order of 30 meters. There are lots of those, and we have no clue where they are. Our final report stated that there would need to be a significant increase in the funding if NASA was going to detect NEOs down to 140 meters by 2020. That was the goal. One option besides ground observations was to build a satellite and have it in a Venus-trailing orbit to search out in the solar system for NEOs. That was an interesting study. The report went to the Congress in 2006.

There was a lot of discussion about NEO mitigation; not a lot you can do, to be perfectly honest. Evacuation is probably the answer, if you know a NEO coming and where it's likely to impact, but even then, it's hard to predict precisely the impact point. There is no immediate risk in the near term from NEOs that JPL has identified, but the study was fascinating. It was an interesting study in technical areas where there is high risk, but low probability, not unlike earthquakes, hurricanes, and tsunamis.

My time with the Navy and NASA has been a wonderful experience. It was a great career, I couldn't have asked for anything better, I never really thought it would get to the point that it did. I'm still shocked and amazed that it worked out as well as it did.

WRIGHT: You've talked to a lot of people to explain a lot of things, as well as analyzing, and you mentioned a while ago about Congressional testimony—do you still have nightmares, or is that okay? Was that a difficult part of your job?

MULVILLE: You can't take it personally, that's the key thing. If they say something and its negative, they're not talking to you. They're talking about what you've said or what's going on in the agency. It wasn't too bad. I had a couple of House hearings on the Space Transportation Architecture, and Congress wanted NASA, I believe, to make a commitment to have more involvement with the commercial sector. That's my sense of what the real objective was. What Congress wanted was for NASA to come forward and say, "Yes, we're going to go forward with this new architecture and we think this is the right thing to do."

I told them, "This is the study we took on, these were the objectives, this was the outcome, and we're working with the Office of Management and Budget to see if we can get support to go forward with the program."

There were a couple of the people from the small launch vehicles sector presenting as well, and their objective was to encourage NASA to do the technical things that would enable them to set up a business so that they could conduct launches as a commercial entity. It was generally a friendly discussion. The only hostile questions were, "Is NASA going to do this? What's NASA's position? Are you going to argue this, will this be in the budget?" That was the sort of interaction with the Congress. You have no idea on that—all you can say is, "We'll work with OMB to ensure that we'll address this appropriately, and we can go forward and implement the recommendations".

WRIGHT: Do you recall when that was or how often that was?

MULVILLE: I'm trying to think. I think that may have been in 1999 – 2001 timeframe. It was before SpaceX was established. I believe a representative from Kistler testified, as well. There were a lot of small companies that wanted to get into the business. There was one that was really interesting, Rotary Rocket, [Incorporated]. Rotary Rocket had a roll-out in Mojave [California] of their launch vehicle mock-up. The rocket was built like a large cone. It had engines all around the periphery at the base with a helicopter rotor at the top. During launch, they planned to lift the vehicle off the ground by the helicopter blades and ignite the rockets at some elevation. When it got up high enough, then the engines would kick in. This was real Hollywood roll out.

At the roll out I was there for NASA and Patty [Patricia Grace Smith] was there from the Department of Transportation. Patty was the Department of Transportation AA for commercial space. As the Rotary Rocket gets rolled out of the hangar—and it's a pretty good size, 50 feet high, something like that—as they do in these Hollywood events, a lot of smoke was coming out of the base of the rocket, so it comes out like it's floating in the cloud. Very dramatic, the grandstand was full and there was a lot of applause. Rotary Rocket never launched, they just rolled it out.

Tom Clancy, the author of *Hunt for Red October,* was there. He apparently was one of the investors in Rotary Rocket. He told me that his objective was to put NASA out of business.

I said, "Please do! The sooner the better." That was very interesting, but that was an example of the small rocket companies that wanted to build new systems, but were way under-funded. I don't know what the real cost is to develop a new launch vehicle—it's probably $1 billion for a company to actually get something to the point where they can launch successfully—and these companies never had that much money.

WRIGHT: As our time is closing out, I wanted to ask you what you felt might have been the most challenging aspect of your career with NASA?

MULVILLE: That's interesting. I guess the most challenging part was not hardware issues or spacecraft problems—those get fixed—the challenging part was really the leadership issues. To get to the point where you can actually put together an engineering team and get them focused on some engineering issues.

One of the capabilities we tried to put in place was a computerized design analysis capability across the agency, so that all the systems would be able to be interconnected, that they could do an online, computerized analysis. It was a challenge to, first of all, get the resources to be able to do it, but to get the Centers focused on that, so they would have engineering teams that could do these virtual designs, enhance or improve their engineering skills and capabilities so that you could build a world-class engineering organization. We actually had an outstanding engineering organization, so it wasn't a question of not having good material to work with.

Our objective was to take it to the next step, getting the computer technology and all the computational engineering tools and methods available so the Centers could use them easily and communicate them among the Centers. If you had an expert who was at Johnson in some particular area, or at Marshall, you could take advantage of their skills and capabilities so that they could all work interactively on projects. I think that was one of the biggest challenges, to do that, to move into the 21st century, so to speak, in terms of the engineering. Leading that was probably the biggest challenge, along with all the other things we did in the Chief Engineer's Office. I don't know, I suppose I'd have to call that the biggest challenge.

The other issues in management and at the senior levels, there were challenges, no doubt about that, but I think from a personal point of view, leading the engineering organization was the one that I felt was the biggest challenge, and the one that was the most rewarding, in the end.

WRIGHT: That was what I was going to ask you to end with, what you feel was the greatest contribution you made while you were there. I guess it has to be setting up these balances for the engineering department?

MULVILLE: I feel better about strengthening the engineering organization than the other things. It was wonderful in OAST and S&MA, and I enjoyed the technical part and the technology part, but being in the Chief Engineer's Office was really special.

WRIGHT: Was there anything else you'd like to add before we close today?

MULVILLE: It's been a pleasure participating in the oral history project. I think this is a wonderful idea, to capture some of the thoughts of the people that have worked at NASA in the past. NASA is a unique organization, different from a lot of other agencies. I must admit, when

I was with the Navy, I really loved it. It was rewarding to work on national programs and efforts that benefited national defense.

NASA has a particular character and culture that is unique. In addition to the exciting exploration missions and human space flight operation, NASA's people are talented, dedicated and committed to their missions. It was a pleasure to work with the NASA community over the years. Just as it was rewarding to see the Navy planes fly, it was rewarding to see the Shuttle fly. You have a very similar feeling. It's obvious what you're doing, it's clearly visible what the objectives are and what the accomplishments are from every mission. You get a special sense of accomplishment with NASA. It's a wonderful place to be, and it was a miracle that I was there. I had a lot of help along the way.

WRIGHT: Thank you. Thanks for being here today, we appreciate that.

MULVILLE: Thank you, it was great.

[End of interview]