NASA JOHNSON SPACE CENTER SPACE SHUTTLE PROGRAM
TACIT KNOWLEDGE CAPTURE PROJECT
ORAL HISTORY TRANSCRIPT

JOHN S. CHAPMAN
INTERVIEWED BY REBECCA WRIGHT
HUNTSVILLE, ALABAMA – MAY 16, 2008

WRIGHT: Today is May 16th, 2008. We are in Huntsville, Alabama to speak with John Chapman, who currently leads the External Tank Project Office at the Marshall Space Flight Center. The interview is being conducted for the JSC Tacit Knowledge Capture Project for the Space Shuttle Program. Interviewer is Rebecca Wright, assisted by Jennifer Ross-Nazzal. We thank you for finding time in your schedule to talk with us today. We'd like to start by you giving us an idea of how you became involved with the Space Shuttle Program.

CHAPMAN: I've been interested in things that fly since I was too small to describe here. I remember making model airplanes when I was six or seven. I've been interested in things that fly ever since then. It doesn't matter what kind of flying machine it is, whether it's kites or model airplanes or balloons or hot air balloons or real airplanes or jets or sailplanes or rockets or spacecraft. Anything that somehow cheats gravity has been very appealing to me since the very earliest days, and that has shaped almost everything that I've ever been involved in.

In fact, my dad has a picture of me when I was about nine years old at the old [Smithsonian National] Air and Space Museum on the mall in Washington [D.C.]—when the rocket display used to be outdoors, when it was at the Castle part of the Smithsonian there, the old reddish-brick building. I'm standing right next to an Atlas rocket that's there. Dad says that right after he took the picture I told him that I was going to be involved in making rockets. He can still remember this very vividly, and we've got the slide in the family archives. So this has been an inevitable type of progression that I would end up here doing these things. Very interested in all things aviation and aerospace-related.

The standard old story: built model airplanes when I was in junior high and high school, built my first radio-controlled model when I was watching [President John F.] Kennedy's funeral on TV, in fact. I can remember sitting on the floor in the den sanding on the ribs and the wing while I was watching the funeral procession. If you were to go to my house today and were to go downstairs to my little model-building shop in the basement, you would see the current radio-controlled model airplane I'm working on right now. That has not changed at all. The equipment has changed, the planes have changed, but Chapman is still building model airplanes.

I have also been very interested in full-size aviation as well, not just models. Back in high school while I was working on a particular model, I went out to the local general aviation airport because I had heard that you could go to the mechanic’s shop at the airport and buy in bulk quantities—like quart cans and gallon cans—some of the liquids that you use to make models at much better prices and larger quantities than you could at your friendly local hobby shop. So I went out there and asked the guy who ran the shop if I could buy some of that material, and he said, "Yeah sure, come with me." So we went out back to the storage room, and he found a gallon can of this stuff called clear butyrate dope that's used to seal up the covering material on a plane, and I bought it from him.

Just casually, as I was walking away, I said, "Do you guys ever hire anybody for summer jobs?" He said, "Well, we might be interested. Why, are you interested in working out here?" and I said, "Yeah, I sure might be." One thing led to another, and he offered me a job. I started working there in the 11th grade. Worked there for over four years —full-time that summer, part-time during the school year, senior year in high school, full-time for the next summer and the next summer and the next summer—in other words, coming back from college, any weekends that I came home from college, I'd work at the airport.

Over those years I progressed from starting off sweeping the hangar and getting it cleaned out, to four summers later, designing and installing aircraft avionics and navigation systems for general aviation aircraft. Along the way I learned about engine overhauls and all the general aviation airframe and power plant mechanic stuff. It was an absolutely fantastic job! Looking back on it, I probably learned more stuff directly related to what I do on a daily basis today in that job working at the airport than years in college and with the theoretical stuff. The airport job gave me so much of the practical knowledge of what it takes to ”cheat gravity”. You're going to hear that theme throughout all the discussions that we have today.

In the middle of that airport job I went off to college at Georgia Tech [Georgia Institute of Technology, Atlanta, Georgia], where I started off in aerospace engineering. I switched over to industrial engineering about halfway through, principally because of two reasons: First of all I was disappointed that the program at that time at Georgia Tech was highly theoretical with very little practical aerospace engineering. I'd already earned my private pilot's license (I took my flight test the day before Apollo 11 was launched in July of '69), so here I was flying as well as working at the airport in the summers.

I'd come back to Georgia Tech and I'd ask questions of a practical nature about “Why do you do this, and why they do that, and what is the purpose of this other thing?” The answers would always come back from a theoretical standpoint and say that, “Well, from a theory standpoint that doesn't make any sense, and you shouldn't be doing it.” But I knew for a fact that this was being done, and it was being done for a very practical and solid reason. So even at that point I could see this gulf between theory and practice that folks weren't really following. From my point of view at the time, the theoretical side of aerospace was not as tightly coupled with the practical side as perhaps it should be. I found this to be very disappointing.

That coupled with the fact that in the early 70s the aerospace business was really falling on hard times, and the potential of getting a job when I got out of school in '73 was looking pretty bleak with aerospace. So I switched over to industrial engineering because it looked like I could still do aerospace-related things but would have a little bit broader capability, in case I had to bide my time before going into specific things in aerospace. Turns out that industrial engineering was a very good fit for me, and it worked out well.

I graduated from college in August of '73, had several interesting job offers, mainly in manufacturing type things, not aerospace manufacturing but just manufacturing in general. Those were not for me, because I'd already resolved early on that I was going to do something to do with flying. It didn't matter what it was, and I might end up moving from South Carolina, which is where I was born and raised, out to Seattle [Washington] if I had to work for Boeing, or to Wichita [Kansas] if I had to work in General Aviation there, or to southern California, which was the heart of a lot of the aerospace business, or wherever. I really wasn't sure, but I was going to do something to do with "cheating gravity". It was not going to be just making diesel engines or automotive brake parts. It was going to be something to do with flying machines.

My college roommate at the time was also very enthused about aviation and aerospace. He was about as much of a space fanatic as I was. In fact, we had journeyed together to watch several Apollo launches at the Cape [Canaveral, Florida] while in college. We wrote off to my U.S. Senator and managed to get passes to go to the launches, and so went down to watch Apollo 15 and Apollo 16 and then the Skylab Workshop launch—by the way, the 35th anniversary of the Skylab Workshop launch, which was the last Saturn V flight, was yesterday—I was fortunate enough to be there to watch the last Saturn V launch.

My roommate found a job over here in Huntsville, Alabama working for a company called Northrop Services, which was euphemistically known as the “sweatshop division” of Northrop Aircraft. They had a support contract with this U.S. Government NASA outfit in the little town of Huntsville, Alabama called the Marshall Space Flight Center. He got that job and came over and started. And after his first day I talked to him on the phone, and asked, "Tell me what it was like." He was enthusiastically describing what it was like, and I said, "Well, do you think they'd be looking for anybody else?" Again, I had not accepted a job anywhere, and I had finished college about three weeks before. He said, "I don't know, but I'll check." So he checked and amazingly they *were* looking for people. So on October 1st of 1973 I started work for Northrop Services over here as a support contractor for the Marshall Space Flight Center, working in support of the engineering laboratories out here at Marshall.

The very first thing I started working on was this brand-new program called Space Shuttle. Again, this was in October of 1973. Shuttle had only been authorized by the [U.S.] Congress a year or two earlier. In fact, it was authorized while Apollo 16 was on the Moon. If you look at some of the tapes of John [W.] Young and Apollo 16 on the Moon, he gets relayed the message. It’s really interesting. Here's Young on the Moon with Charlie [Charles M.] Duke, and he gets the relayed the message that the Congress has just approved this new thing called the Space Shuttle Program. Young's response is, "Well, that's great. The country really needs that Shuttle." Then some ten years later, John Young is in the Commander's seat for the first flight of that very same vehicle. It's just interesting that it went full circle there.

Anyway, I came over here to Huntsville in October 1973 and started working at Northrop in the Space Shuttle Program doing theoretical things. I say theoretical only because the vehicle had not yet been built. These were "what-if" exercises… for example, trying to figure out specifically how much reusable hardware for this new portion of the Space Shuttle Program called the solid rocket boosters would you need if you were going to fly a certain number of flights every year. Each one of the components on the solid rocket booster had a different useful life; some might be usable for five flights, some might be usable for ten, some might be usable for twenty flights. They had different attrition rates. In other words, they might get banged up when they hit the water, or they might get involved in industrial accidents that would take some parts out of the flow, just on the ground as a normal flow of things.

But given all that, and how much time it took to get them ready, how many of those parts and pieces did you need, ,to fly a certain number of flights. I was writing computer programs to simulate and compute how much hardware was needed. Little did I know that here I was helping to calculate the amount of hardware that we ultimately needed to order—and then some 20 years later I would be in the position of Acting Project Manager for the shuttle solid rocket booster and would have to live with those very same hardware quantities that my software had helped predict. So I couldn't do anything but look in the mirror and accuse the person in the mirror of not having recommended enough hardware because we were having trouble supporting the mission model.

So that's how I got over to Huntsville, and how I began working on the Space Shuttle Program. Passionate interest in all kinds of aerospace, including rockets and Apollo and everything. At the time I got out from college, the Space Shuttle was at the absolute leading edge of the aerospace business. I've been involved in one aspect or another of Shuttle ever since—and have been involved in one way or another in every launch, ultimately of every propulsion project for Shuttle at the Marshall Space Flight Center, either in the role of business manager, or assistant project manager, or deputy project manager, or project manager. Those have been my roles so far.

WRIGHT: Through all these roles, your duties changed, your responsibilities evolved. Share with us some of the challenges that you faced going through the roles that you've had, some of the memorable ones, and some of the lessons that you learned from those that you continue to use in your management position today.

CHAPMAN: Probably the greatest challenge in this business is the complexity of the systems , which is a direct response to the complexity of the ground and flight environments in which these systems operate. In a NASA project office— and most of my time has been spent in project offices—there's a need for a renaissance approach to things. An approach in which you don't focus just on one aspect of a problem, but you try to be knowledgeable about many, many aspects. As I have moved between Shuttle propulsion projects—between solid rocket propulsion (the Solid Rocket Boosters and Solid Rocket Motors), liquid rocket propulsion, (the Space Shuttle Main Engine), or propellant storage and flow (the External Tank)—there are many different challenges in each one of those, and each one of them is an incredibly complex system in itself. They are complex not because we at NASA love complex things, that's not what drives it at all, it's the fact that we deal with an extremely complex physical flight environment.

Any time we talk about the kinds of things that we do in this business that involve going into orbit around our planet, by definition we have to begin from a standing stop. In our country's case, means being bolted to a launchpad that's on the East coast of Florida. Then, after lift-off of the rocket, some eight and a half minutes later, we're going 17,500 miles an hour. That, in anybody's estimation, is a gigantic challenge that requires a tremendous release of stored energy. To release that energy in a controlled and safe manner that minimizes the risks involved, is a tremendous, tremendous technical challenge from many different perspectives.

Probably the biggest challenge that I've faced as I've been involved in different aspects of this is to be able to fully grasp what all of those constraints are and to be aware of the historical ways in which we have dealt with these constraints or challenges. Challenges such as: how do you keep a vehicle together when it's going through that kind of velocity change? How do you cope with the changes in going from atmospheric pressure at sea level on the coast of Florida to the vacuum of space? How do you deal with machines that have temperatures that on one side of a quarter-inch-thick piece of metal may be 423 degrees below zero and on the other side of that quarter-inch-thick piece of metal may be 7,000 degrees above zero. What are the challenges involved in making the systems work and making them work safely and making them work correctly time and time again?

That's probably the thing I would say has been the biggest challenge to me: to continually be curious and to always ask probing questions like, “Why is it done this way? What were the historical lessons learned that led us to this path? What did we try and if it didn't work… why not? Why did we try that? Why do we do it the way we do it now? What are the problems involved in the way we do it now? What are the soft spots of how we do it now? Are our solutions robust? Are they really able to cope with changing situations that we hadn't necessarily thought of when we designed them, or are we successful just because we have been lucky?”

You never want to have "we were just lucky" be the answer in engineering. You want the design solution to be successful because you've put a tremendous amount of thought, analysis and testing into it, and you know how much margin you have on either side of the middle-of-the-road answer and how much it can tolerate things being a little warmer, a little colder, a little faster, a little slower, a little higher-pressure, a little lower-pressure—how your solution can cope with all those "off-nominal" conditions.

WRIGHT: You used the expression "need a sufficient knowledge of the broader view." How would you best share some techniques or some instructions on how new people coming on board, or those that you feel would be up-and-coming leaders within your area, how do you get them to grasp that? How do you get them to understand how broad of a knowledge base that they need to have? What lessons have you learned that will help get them to understand that?

CHAPMAN: Let me take you back to something I said earlier when I was talking about the first real job that I had, which was working at the airport. The really neat and important thing to me about that kind of a job and experience—and how it affected me and continues to affect me—is I got to see up close, real world, "go out and touch it" hardware designs that were solutions to real-world "cheating gravity" problems. You could walk right up and look at the physical piece of hardware, and the longer you looked at that piece of hardware—whether it was a landing gear strut or a part on an aircraft engine or a control cable and pulleys or electronic cables and connectors and things like that—the more you looked at it, the more you could almost read the mind of the designer that came up with that solution.

The more you looked at it, you could almost decode what the environment was and the problem that the designer was trying to solve. In a connector he had little tabs that made sure that it locked in place when it plugged in so that any environment over the life of the airplane wouldn't cause it to come unplugged and cause you to loose communication or something like that. Or the way the threads were designed on a bolt so that it gave a tighter connection. In other words, not being theoretical, but actually looking at the practical thing in front of you. Then from that saying, "What was the theory that led to that? Why do we need to maintain that way? What was going through the designer's mind when they did that, they came up with those dimensions or those thicknesses or that type of material?" Starting from the hardware and moving from the hardware back toward the theoretical numbers-based understanding.

To me that's critically important, critically important. Too many times as I've watched people work in this business, I've seen situations where folks had a stunning grasp of the theory and the numbers involved in it, but had zero understanding of the actual hardware and what the practical aspects of what all these numbers really meant. So probably more than anything else, I would say that we need to work much harder today than I believe we do on getting people, from the top to bottom of the organization in new programs in touch with the flight hardware, and with the people that build and assemble and maintain the flight hardware.

There's a tendency in this business to keep theory and practice separated, and to say that the designers can go off and design stuff, and then hand their design off to the builders, and the builders go off and build it. And everybody's happy, and then the designers can go off and design something else. What you find is when you talk to the builders that have to build the stuff designed this way is that if great care is not taken in the design, you can end up with a design that's not buildable. Not buildable at all. You just absolutely can't make it. So what happens is the builders have to, in essence, do what's sometimes termed as “crutching” the design. You modify the design and change it a little bit here and a little bit there to make it buildable. There's a process for doing that, but ideally if the design is correctly crafted to begin with by people who know and understand what it really takes to build flight hardware, then the design will have those features built into it, and it will be buildable to start off with.

> Perhaps the most telling thing I could use to illustrate that was back about five or six years ago I was serving as the technical assistant to the manager in the Space Transportation Directorate, which is an organization that no longer exists here at the Marshall Space Flight Center. It was a really neat organizational experiment in which technical and project organizations were all under one umbrella rather than having two separate organizations. This was created in an attempt to foster good communications between the Project Office and the technical arm—Engineering, let's say—supporting that the project. For a variety of reasons we've gone back to the older way, which separates those organizations in the organization structure at the Center here, for very valid reasons.

Anyway, I was a technical assistant to the director of the Space Transportation Directorate. Several folks one morning came into my office, and these were folks that were senior manager types in the Space Transportation Directorate. They came in and they all had cups of coffee in hand and they said, "Gee, Chap, you used to be chief engineer of solid rocket booster over in Shuttle, right?" I said, "Yeah, sure did." They said, "Well, how long were you there?" I said, "Well, I was there for about three and a half years." They said, "We're really curious. Tell us—what did you do during a typical day in a flight program like that? What kind of stuff did you work on?"

I had not gotten my cup of coffee yet that morning—and these were sharp, sharp folks. I said, "This is a real interesting question you're posing. But I'm going to turn it around, and I'm going to ask you to tell me what YOU folks think I did as chief engineer of solid rocket booster over in Shuttle, this ongoing flight program." So they looked at each other and they said, "That'd be easy to do. Fine." So I erased my whiteboard and said, "I'll be back in five minutes. Here's a fresh marker and a good eraser. You have at it, mark on the board however you want, and I'll be back in about five minutes and you can tell me what you think I did."

So went to the coffeepot, got my coffee, came back, walked by my office, there was a lively discussion going on, stuff being marked on the board, so I walked around a little bit more, and came back—totaled about ten minutes. Said, "Okay guys, time's up, tell me what you think I did." They had this wonderfully esoteric view of what I did as chief engineer on an ongoing flight program. They said, "Well, we believe that probably three quarters of your time is spent by trying to figure out how to get more performance out of your systems to make them work better and faster and to work with the Project Office to shave cost off. The Project Office is probably always pushing you to cut cost, cut cost, cut cost, and do it faster, faster, faster. You're probably always trying to resist that by saying no, no, we need better and more technical performance, and this and that and the other. You're continually trying to enhance the performance of the system in the face of the tightwads in the budget world that would try to keep that away from you. Probably that may take even 85 percent of your time."

I said, "Well, what do you think the rest of my job was?" "Well, it's probably just a little administrivia type stuff that you have to do. But that's got to be it. That's the main part of your job." I looked around. They're all nodding up and down, "Yeah, yeah, that's what you do, that's what you do." So I said, "Well, guys, it's really going to come as a shock to you, but that's not what I did most of the time as chief engineer in the solid rocket booster project. And that's not what any chief engineer does in a flight project." The primary task of a chief engineer of a flight project, an ongoing flight project—and most of our big propulsion projects tend to be long projects—could be characterized by one sentence and one sentence only. That sentence is: "As built" does NOT match "as designed."

In other words, that hardware that you've got there on the launch pad or in stages of assembly is not really what you thought it was going to be. It's not exactly what the drawing says. Either it's not what the drawing says the hardware should look like, or the training that the troops that built it had wasn't exactly like the training you thought they had, or the ground support equipment that holds the thing and gets it from point A to point B wasn't designed exactly the way you thought it was, or the road surface that it had to drive over wasn't graded to exactly the specifications that you thought it was and it got a little bit bumpier and put a little more vibration into it, or the weather that you're going to fly it in is not quite what you thought it was going to be. In other words, what you envisioned is not exactly what you got.

They looked at me with just total disbelief. Total disbelief. Their response to that was, "Well, just make it match !!! The contractor has built this piece of hardware so just tell him to go back and make it match the design and the specifications." If your design, said that you needed three holes in a row exactly one inch apart on this piece of metal, and then you have discovered that the middle hole is a tenth of an inch slightly over to one side—let's say that that's the problem. Their answer was, "Well, go back to the contractor and tell the contractor to make it right. We designed it like it should be three holes like that. Tell the contractor to make it right." I said, "Guys, you need to spend more time with the real world flight hardware." Because seldom do you ever find out about such a discrepancy when you are looking at a part, just when it came out of the machine when it was being built. The place that you typically will discover this is after everything has been put together and built and assembled, and that particular little part is embedded way down inside the rocket with all kinds of other value added on top of it.

Someone will be doing a paper search and looking at what was done, and they'll come across a little indication that that center hole was over a little bit. To tear the rocket down and make it right, fix it, is way too expensive, way too costly in terms of schedule, could incur all kinds of other risk for the other parts associated around it that are already built up. So now you've got to figure out how do you cope with that. "Can you fly it like it is?", "Do you have to do analysis that says that it's okay for that center hole to be off by a tenth of an inch?", "Or is it truly a matter of: this is unacceptable, and we really do have to take the rocket apart all the way down to this little piece and change it out to one that has the center hole in exactly the right place."

They had zero concept of that. Zero concept, because the concept from the design perspective is: "I designed it that way, so why can't you build it that way?" But the real world that we live in says, "Just because you designed it that way doesn't mean that every one of them is going to be built that way." You need to understand that perhaps your design should be sufficiently robust that it will withstand that center hole being misdrilled by a tenth of an inch. It goes back to my premise, almost all the way back to my little story about working at the airport. The more familiar one is with the real hardware, and what it takes to build and assemble the real hardware, and how the instructions get to the folks on the shop floor that build it, and how it gets checked, how those checked pieces go into inventory, which ones get pulled from inventory to go into the rocket, how you build the rocket up—the more you understand about that process, the better and more effective your designs will be that will have to use that process in order to fly. There's no substitute for that.

In the good old days—around here at Marshall that is defined as the Saturn program—we used to build a lot of actual rocket hardware right here at the Center. The way things used to work in the “arsenal” concept, was we would come up with a basic design for a rocket or a rocket subsystem internally within the government, many times assisted with subcontracts to the major aerospace primes, or even the minor aerospace primes coming on site here and helping us with designs. We would then build the prototype of that rocket or subsystem in-house here at the Marshall Space Flight Center, in our laboratories. So the designers, the folks that were involved in putting lead on paper (in the good old days before we had CAD [Computer-Aided Design] systems), would be at most one building away from where the fabrication was going on, and they could walk right over and watch it work. Talk to the people that were getting those drawings and making those parts. There would be this tightly coupled feedback between the design organization and the fabrication organization. Realize we would not yet be in a production environment in which you'd be maybe making 10 or 15, 20 of them, but this would be in more of a “pre-production” or almost “prototype” phase. The result was an engineering design cadre that was acutely aware of the “buildability” of their designs and a manufacturing cadre that would produce pre-production hardware that was truly ready to enter production.

We don't have that today. So the question has got to be, from my perspective, “What can we do to at least get the essence of that?” I can't see us going back to the days where we built prototypes for every single rocket in-house within the government. But we should be able to set up programs that will allow designers, at certain key formative stages in their careers, to go spend time at manufacturing facilities where they will be able to see how we build things, what we do, how designs get translated into shop floor instructions, so that as they progress through their careers they can look back and draw on those experiences and design better hardware because of it. This is exactly the same way I look back on the time that I spent twisting wrenches and working on things at the airport those many years ago.

WRIGHT: It sounds like that would be an element of planning. Can you share with us more ideas that you have about things that you've learned through your career that you would like to see instrumented into the whole element of better planning?

CHAPMAN: What I'm talking about there in the sense of planning is almost career planning—"How should we plan for the workforce within the Agency or within the whole industry that is best postured to advance us to the goals that we have in the future?" In fact, to me it goes farther than just the technical aspect of things. I know if you look over the list of my employment chronology, you'll find a curious mix of things that I've been involved in. Several places on there you'll see that I've been involved in business management. I'll have to confess that wasn't a high-priority choice of mine to go do that, because there's a tendency in the view of the technical world that the money stuff is just an absolute necessary evil that you would rather avoid at all costs and let somebody with the green eyeshade and the arm garters go off and worry about that, because you'd rather work on the real "rocket stuff". But the reality of it is, it's not the rockets that put the man on the Moon, it was the dollars that purchased the rockets that put the man on the Moon.

So if you really want to go back to understand the full system—and it gets back to this broader view that I talked about before—you really ought to have some knowledge of the dollars, and how the dollars flow, and what it takes to rationalize and defend budget estimates. And to be able to convince those who have and control the money that your ideas and plans are well worth allocating scarce fiscal resources to fund. In this case the purse strings are controlled by the Legislative Branch. It's put forward in a budget proposal by the Executive Branch to the Legislative Branch, and of course we're part of the Executive Branch, so we have to assemble budgets in support of the Executive Branch and then defend those budgets as they go forward to the Legislative Branch in an effort get the resources needed to build the rockets.

The more people know about the inner workings of that process, the better the likelihood that we will be able to get those resources that we need to go build the rockets. I'm a strong proponent of everyone spending some amount of time in the business management world. The actual amount of time depends of course on the individual person and what their specific inclination—but for people who are inclined to progress up in the project management world particularly, there's no substitute for spending some time understanding how the resources flow and how that relates to making the rockets.

WRIGHT: Do you believe that investment would help in program or project efficiency overall?

CHAPMAN: Absolutely.

WRIGHT: Are there any other ideas that you have that would be good for program efficiency?

CHAPMAN: This is going to sound like I'm waving your flag here, because I know that part of what you're trying to do with interviewing folks that have been involved in Shuttle is to try to the maximum extent possible to capture lessons learned and to get those in a form that's readily passed on to other people so that we won't repeat the errors of the past and we'll build on the best practices to go into the future. I hope I captured what you're trying to do.

WRIGHT: Yes.

CHAPMAN: We don't do, in my estimation, a very good job of lessons learned. When we're working on a particular task, that task is all-consuming, and it's a miracle we even document what we did yesterday or the day before, let along step back far enough and document lessons learned. Then when the task ends, by definition we dropped all the tools related to that task and we ran full-blast toward the next task, and we don't have any time to look back at the old task. So we don't do a very good job capturing a record of what we did. I think we need to look hard at figuring out how we make it more palatable to capture lessons learned. From my perspective, the most interesting way to do that, and the way that—in my experience at least—has captured my imagination, is spending time listening to our forefathers. The folks that have built rockets before us.

There's a really nifty program that has been set up through the NASA educational world called Project Management Shared Experiences Program, PMSEP. I was fortunate to go through an early one of those classes. The first one was up at Wallops [Wallops Flight Facility, Virginia] for about a week. The next one was down at an FAA [Federal Aviation Administration] training center at Palm Coast in Florida, again for about a week. The particular group of current and former project managers that they brought in to talk to us was fantastic. It was really great.

It was Jim [James S.] Martin talking about the Viking Program, which was the first soft landing that we made on the planet Mars. That took place in July of '76—targeted for the same time as the Bicentennial—and he spoke at length of the challenges that he faced in designing that and getting this huge contractor team going and facing challenges that had never been faced before to soft-land on another planet. Fascinating stories. It was just a classic case of grizzled and hardened project managers sitting up on the stage almost in the spotlight, lights dimmed in the rest of the room, just philosophizing from real sketchy notes, telling war stories. Fascinating. Absolutely just wonderful stuff. There were many others that talked to us. Martin just comes to mind because of the challenges that he faced.

That and the other examples, both in that first PMSEP program and in the follow-on, really set the hook for me to do more research on my own and go read about these things, to spend time studying about the trials and tribulations of other programs. The physics hasn't changed. All the things that Sir Isaac Newton said would happen are still happening. His laws of motion are still there. We’ve still got to deal with all those things on a daily basis. Just because the rocket looks a little bit different—the limitations of physics are still there. Liquid hydrogen is still just as cold today as it was when we first started working with it. It still causes all kinds of headaches today just like it did before. The thrust inside the thrust chamber is still hot and melts things and is volatile and gets out and burn things that you don't want it to burn, just like it did before. It still does that today.

So there can be a tendency to say, "Well, the lessons learned, those are lessons learned from a different age and a different environment, and it may not be applicable." My take on that is absolutely not. They're completely applicable. One of my favorite books is a book by [Walter] Dornberger called *V-2*. The book by Dornberger is the history of the development of

V-2 rocket. It's fascinating. The first time I read it in depth was when I was business manager on main engine after [Space Shuttle] *Challenger* [STS 51-L accident], and it was fascinating to read the problems that the rocket team at Peenemunde in Germany was having developing the components of the V-2.

I would read the book by Dornberger, and then look at weekly notes in the Space Shuttle Main Engine project, and realize they're facing very similar problems. The turbomachinery has difficulty, the control mechanisms are troublesome, the reliability of the materials is very troublesome, we can't get the materials to do what we really need them to do. Same stuff. If we can package things in a way that ignites curiosity, and we can motivate people to have the time and take the time to read about it and to learn about it, I think the quality of our decisions and therefore the quality of our hardware and the efficiency with which we get to our end goals will be significantly enhanced.

WRIGHT: You've worked with so many people as a manager and, of course, as an employee. Talk with us for a few minutes about where you suggest improvement for manager performance. How do you motivate those people who you are working with, that you're responsible for? How do you build the teamwork in those efforts that you need to get a project done and done well?

CHAPMAN: That's a great question. I've been really lucky to have worked with some just superb folks over the years, just superb folks. Folks that I treasure as friends and I treasure as mentors and examples in terms of how they manage. I'll list a few of them here just so you know who I'm talking about. Tops among them would be folks like Bob [Robert E.] Lindstrom. Bob Lindstrom was the head of Shuttle projects here at Marshall during all the development years of the Shuttle, up until about the 15th, 16th, 17th flight of Shuttle. So all of the propulsion element project managers reported to Bob. Bob still lives here in Huntsville. He's a superb technical manager. He doesn't get in and work the technical problems for his managers, but he makes sure they have the resources that they need to do their jobs, and then keeps things off of them where he can, to shield them from so many of the things that could be distractions. He would answer the questions coming from above that he could answer to keep his managers focused on their tasks without undue distractions.

Then there are the very detail oriented technical managers. Folks like Joe [Joseph A.] Lombardo. Joe was the main engine project manager after *Challenger*. Had been involved in liquid rocketry for years and years and years, first for the Army and then here within NASA at Marshall. What an incredible intellect. Dr. Lombardo went to MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts]. Just great guy, wonderful manager. Extremely personable. Knew the rocket, the main engine for Shuttle, inside and out. Incredible grasp of the history of why certain decisions were made in certain microscopic little places inside the engine that improved reliability and got us away from problems. Could always ask probing questions in meetings that were phenomenal. Learned a lot from him.

Another one would be a great guy named Royce Mitchell. Royce Mitchell, who also still lives here in Huntsville. has the distinction of having managed the biggest rocket and the smallest rocket within NASA. The smallest rocket was a little electric-powered thruster that was developed down here in the laboratories that produced a fraction of an ounce of thrust. When he retired from the Agency, he was the project manager of the advanced solid rocket motor, which was being built over in Iuka, Mississippi, and that was to be the most powerful single human-rated rocket motor that the Agency had fully developed. I was fortunate to be his deputy at the time of his retirement,. Both ends of the spectrum. A phenomenal manager, extremely personable in addition to having an amazing grasp of the hardware and the theory. Royce also has absolutely the best sense of humor of any manager I've ever been associated with.

I hope you're sensing a common thread here when I talk about the hardware and the theory, and hardware and theory, and hardware and theory. All three of those managers I just mentioned, all had a fantastic grasp of both. I truly treasure the ability to work closely with those great managers—even as I've progressed on in my career, I've been able to tap the resources that these managers can provide. We recently did a study within the external tank project, that I manage right now, in which we assessed the internal decision making environment within the project. To help us, we were able to bring in the original manager of the External Tank Project, a phenomenal guy by the name of Jim [James B.] Odom. Jim also works in town here although he lives over in Decatur [Alabama]. He was the original manager of external tank up through about the fifth or sixth Shuttle flight.

Jim then went on to become a spectacular manager in many other areas. The Hubble Space Telescope manager here at Marshall. He later moved on to become a manager in [International] Space Station. In fact, when he left the Agency, he was the Associate Administrator in charge of Space Station up in Washington. He subsequently retired and came back to live here in North Alabama where he works as a consultant. We got Jim Odom and Bob Lindstrom to come in on this consulting task and interview all of our people in the Project Office here to then give us a report and an assessment of how we were doing, were we asking the right questions, were we giving our people the right insight, the right authority, the right respect, the right education across the board. Very helpful, extremely helpful.

Again, trying to look at the lessons learned from a little bit different perspective rather than an individual kind of thing. You go tap the people that have the lessons and get them to come in and look at what you're doing and see how those lessons can be applied. I think that's something that is very beneficial. I guess from my perspective, in terms of philosophy and how I go about doing these things, I try to, where I can, push my people out in the limelight and try to, in general, stay back away from it. Unless it's certain things that I know that they really don't like at all that I'm very comfortable with. If it's those kinds of situations I'll bring them with me, but not necessarily push them out in front.

A classic case might be dealing with the media. Most engineering folks have this dread of dealing with the media, which is probably well-founded. But that's never bothered me at all. My mom was a teacher for 40 years. You can probably tell that. Probably doesn't surprise anyone. So I approach that as being this is my chance to teach the media what they don't know; I can tell them about this neat stuff we work on. Whereas other folks just go into lockup, I must admit, I enjoy talking to the media on most occasions. But other places, like particularly where it's technical expertise and dealing with a contractor or dealing with other parts of NASA management, I really try hard to get my folks out in front and involved.

I guess there's another aspect of employee development. Of course, there's always the one of MBWA—management by walking around—in which you try to talk to people, spend time in their offices, talk to people on the factory floor, talk to the engineers at the contractor, talk to the engineers in the laboratories here at Marshall, go on tours of the neat capabilities that exist across this Agency as much as you can. The time spent doing those things is extremely valuable… time that ought to be spent just to broaden your view of things.

The other aspect of this is—and this is Chapman's management philosophy maybe—if I was going to divide the world of folks that we work with (and that work for me and that I deal with) into two big categories, those categories would be: the people that thrive on structured problems and the people that thrive on unstructured problems. There's a place for both of those in the world of project management. Overall, it's probably best for us as managers to try to move our people from a comfort zone of thriving on structured problems—and I'll describe what I mean in a minute—toward the direction of being more comfortable in dealing with unstructured problems.

When I talk about structured problems and unstructured problems, what I mean is: If I'm going to give you a structured problem to work on I'm going to say, "Well, we got this problem. Here it is as I understand it," I'm going to describe it to you in gory detail, and I'm going to say, "and we need to go move it toward a solution that does this, this, and this." Let's say it's writing a report or something like that. "We got to write a report, and it's got to address this point, this point, this point, this point. It's going to go to these five people over there and their backgrounds are this, that, and the other, and this one will barbecue you on that point, this one will barbecue you on that point, this one will be asleep during the whole thing. The raw material that goes into that report, there's that document over there, there's that document over there, there's a research task that's going on, be finished up in two weeks. It'll be just a bunch of notes that come out of it, but you can use that to help write this." Basically lay out all this stuff. Say, "Oh, and by the way, when you write it you need to put it in MS Word format, and it needs to be readable by MS Office 2000, and you need to be sure you do backups." Really define everything, structure the problem to an n^{th} degree. There are lots of folks that really thrive on that, getting a problem presented to them that has a very high degrees of structure, of “Here's the framework that you need to use to solve your problem.”

There are other folks who really thrive on unstructured problems. An unstructured problem may be, "We've been asked to write a report. I got an e-mail that said we’ve got to write a report on this, that and the other, and it needs to be finished and sent in by such and such a date. I don't have a clue who's going to have to read it. I don't have a clue what the inputs need to be. But we got to write a report. The reputation of this organization is going to hinge on that report. Have at it." That's an unstructured problem, in which you give the person the freedom and latitude to go research what are the inputs I need, what are the constraints, what are the parameters that I operate within to do this, how polished does the final product need to be, what's the accuracy of it. Obviously it depends on whether you're talking about designing a piece of hardware, solving an analytical problem, writing a report, whatever. But still the concept of a structured assignment versus an unstructured assignment is valid.

From a project management perspective, while we need both of those, clearly I would rather have folks who are most comfortable in the direction of the unstructured problems, because as part of that they feel they need to understand how that task fits into the broader scheme of the project. As a result, not only will they be doing that project well, that task well, but they'll be working in a way that is synergistic with the goals of the project overall. Whereas if it's up to me to structure the problem and I miss something, then the response can be, "Well, you didn't tell me it had to be in Arial font. Times New Roman was what I thought you wanted, and I did it in Times New Roman. Now you're telling me that Arial was all they would accept, and you should have told me if you wanted it that way."

An answer that says, "I would have thought maybe you would have asked what kind of font you would have had it in, what the requirements, the style manual, said to do, and you should have told me." Those sorts of things can get you into almost what a former boss of mine used to wonderfully describe as “malicious compliance,” in which they're maliciously going to comply with what you directed them to do and almost take joy in the fact that you didn't supply tight enough specifications. And, therefore, the failure of the product is on your ticket and not on theirs.

Whereas with an unstructured problem—associated with that is ownership of the problem and the solution, malicious compliance is not an issue. So one of my roles as a manager is to try to move people, move their comfort zone—through assignments and other coaching, mentoring, all this—out of the structured problem arena and toward comfort in and satisfaction in and pride of use of an unstructured approach, in which they are starting to take ownership of the broader view and goal of the project and saying, "What do I need to do to help?" It's like having somebody help you in the kitchen. It's a whole lot easier to have somebody help you in the kitchen if you just look around and all of a sudden that task is being taken care of and you didn't even have to tell them to go take care of that task. As opposed to giving explicit instructions, and sure enough that explicit instruction got complied with, and the next thing I know they’re standing in the corner saying, "Well, you haven't assigned me another task yet."

That's a biggie for me in project management, and to me that's applicable across everything that we do—to try to move them toward that way. It also ties back into the business about flight hardware. If folks recognize that they will be better at solving unstructured problems—and the solutions that they come up with for those unstructured problems will be better—if they continually accumulate an understanding and a background of the hardware and the hardware processes in advance of when they may need them to go solve a problem. It's like if you're out in the boat and the boat starts sinking, that's not the time to start pondering whether you should have learned to swim or not. It's back to that kind of stuff.

WRIGHT: Speaking of boats and things, it leads into risk, because so much of what you've done and the decisions that you've had to make through the years always have underlying elements of risk that you have to take in consideration. So share with us about risk assessment and also risk mitigation.

CHAPMAN: Great topic. The way we do risk type things in this Agency is one of my pet peeves. There's a strong, strong tendency, from my perspective, for us to not adequately differentiate between our risk assessment tools and our risk communication tools. We will go into never-ending round-and-round-and-round discussions about whether the likelihood and consequence of a particular failure mode, what that value is. “Is it very likely, less likely? Are the consequences higher or lower? Whether you should put the checkmark in this box or that box.” We will spend tremendous amounts of time arguing and going round and round and round to decide which one of those boxes should it be placed in. Without modifying the hardware.

The hardware is sitting there on the launchpad or in the processing flow literally laughing at us while we go through these big arguments about “No, no, no, the X ought to be in that box.” And the real issue is: does the decision maker that is going to decide it is time to “push the button” and launch this thing or not launch this thing—does that decision maker understand what the risk is? Not which box the checkmark is in, but have we adequately communicated that? And once we've identified that there is some controversy over how risky it is, as long as the decision-maker has the inputs to say it's somewhere between here and here, and here are some arguments on this side and here are some arguments on that side, then it's time to quit arguing about it, because there's no more value added in that.

Along those lines, one of my real pet peeves is that our scarce resource—particularly in the Shuttle Program right now as we're winding down, or in any new program in NASA—our scarce resource is brainpower. The question should always be “how much brainpower should we devote to this problem?” If we surround a nonproblem or a minor problem with more brainpower than that problem deserves, we are doing a huge disservice to this other problem over here, which may be crying for assessment and attention. But we're not looking at that because this is the “problem du jour” and we're really focusing on this one. We really need, from a risk standpoint, to frequently back off as we're talking about risk and managing risk and reporting risk, and ask ourselves, "Do we have this in the right perspective?" There can be a tendency to say, "Well, the reason that we're focusing on this particular risky area is because there's a whole lot of interest and talk and discussion about that." That shouldn't be the basis for deciding whether this is risky or not, just because a whole lot of people are talking about it.

We ought to be talking to the smart people who know the systems and say, "What keeps you awake at night? What are the risky areas from an “expert practitioner” standpoint? What are the risky areas that bother you?" If you talk to that expert and they say, "This area over here that is the current popular high-risk topic doesn't bother me at all, because I know and understand the hardware.” It all gets back to that, there's no substitute for that knowledge. "Because I know and understand the hardware, I'm not worried about that one. I am worried about this one over here that nobody's focusing on because it doesn't happen to be the popular one of the day." Or, worse than that—from a risk standpoint—if we oversubscribe the brainpower in looking at problems that have already been identified, then there is no brainpower left to contemplate the areas that we haven't thought of yet.

WRIGHT: Can you give us an example of where you might have been able to apply this theory for risk mitigation?

CHAPMAN: Probably the most immediate example, to those of us in the External Tank Project, would be with the little bit of foam on the tank that we call the ice/frost ramp. An ice/frost ramp is a wedge-shaped piece of foam that is sprayed onto or molded onto the outside surface of the tank, and it goes around a little metal bracket. The metal bracket is attached to the metal part of the tank, the part that's covered with foam all over. The lower part of the tank has got liquid hydrogen in it. It's 423 degrees below zero. So any metal that comes in contact with stuff that's 423 degrees below zero gets real cold, and then any metal that's in contact with that little bracket sticking out, it conducts the cold—my thermodynamics guys would get mad at me for saying "conduct cold," because you don't conduct cold, you conduct heat—it pulls the heat out and gets rid of the heat so the bracket gets real cold.

In the case of the Space Shuttle, if the bracket gets real cold and the bracket is exposed by itself, just a piece of metal sticking out there real real cold in humid Florida air, little beads of moisture form on the outside of it —the same reason that your can of Coca-Cola gets wet. If it got real cold it would make those little beads of water on your Coke can turn into ice, and that's exactly what would happen to a bracket sticking out in hot humid Florida air if you didn't surround it with foam and insulate it to keep ice from forming on it. And ice on the outside of the tank is bad because it could possibly break off during ascent and damage the orbiter. So what we do is we pour some foam around that bracket that has to stick out there because the bracket holds some metal pipes and a cable tray. You need the bracket, but you don't want the bracket to form ice on it. So we surround that bracket with a piece of foam, and this little wedge-shaped piece of foam is called an ice/frost ramp. We've got a whole bunch of these ramps going all the way down the side of the tank.

We went through a big, big technical discussion about the potential of shedding foam from ice/frost ramps because we saw a previously unidentified failure mode with that foam on the ice/frost ramp, specifically with the way that foam touches the foam underneath it and then the metal of the tank below that. We noted some things in the tank that had been filled up with liquid hydrogen several times at the Cape, and then we decided not to fly it for a variety of reasons, and it got shipped back to the manufacturing plant in New Orleans [Louisiana]. As a result, that was the very first one that we'd ever had a chance to look at full-size, honest-to-goodness flight external tank that had been gassed up and drained and gassed up and drained and gassed up and drained with this 400-and-some-degrees-below-zero liquid and then we got it back into the factory in New Orleans so we could look at it real close and see how it actually performed.

When we started dissecting some of the foam and looking at it and cutting it up and seeing what was there, we noticed some places where that foam had come loose. That caused great alarm on the part of some folks that said, "Gee whiz, if that comes loose in flight, then that piece of foam will come off, and here we go back down the path to [Space Shuttle] *Columbia* [STS-107 accident] again." So big ordeal about what to do about it: “We need to redesign the ice/frost ramps to keep this from happening.”

It turns out that early into that process of redesigning that the ice/frost ramps, those of us in the Project Office, as well as within Marshall's engineering organization, realized that the effects that we saw there on the launchpad, on the one that we dissected and we took back to New Orleans, really were not applicable to what you would see in flight. The aspect of the physics that would cause that piece of foam to come off are really not present during flight. We were in the process, while this was all going on, of our test programs increasing our understanding of the physics. The more we could see that it really wasn't nearly the problem that lots of people thought it was, because the real world flight situation would never get you to a point that would cause the forces that would cause the foam to come off. Even if you had cracks like we saw in the foam, the forces would not be there to cause the foam to come off.

Unfortunately, things had already been set in motion that caused a tremendous amount of work to be done in that area. Even though there were other areas on the tank that we were struggling with and anxious to put resources on to mitigate risk in other places, the die was cast that we needed to go focus on risk mitigation in the ice/frost ramp area. We did, and one of the high points that I have on my little list here of success stories, would be the lessons that we learned from dissecting that one that came in back to the plant. That particular one was called ET-120 [External Tank], which ultimately flew on STS-120. We repaired it, we dug out those cracked areas that we found on there, we came up with a new way of applying foam in those areas. We don't think that the cracks reoccurred. But our understanding of the physics was such that we could say that even if they did reoccur, the foam would not come off. Then we flew it, and the results of that flight—the flight performance was spectacular, and we didn't lose a single piece of any of the ice/frost ramps all the way to orbit. It was confirmed by the separation photography, so it was a spectacular success story.

The problem, though, is from a risk mitigation standpoint, that investigation and its subsequent redesign activity was a huge consumer of resources, and it consumed resources in a way that we're still paying the price for today, because it pulled people away from working on downstream tanks that are still to be delivered. As a result, some of the things that influenced delivery schedules downstream have caused those deliveries to have pressure put on them to move them farther out, which is just the opposite of what we want to do. We want to deliver them sooner, because right now—I'm not sure if you guys are aware of this or not- the critical path to completion of the Space Shuttle Program is delivery of external tanks. That is *the* critical path. Everybody else has got their stuff there and ready and okay to be assembled into flight vehicles.

External tanks are still being built, and we are absolutely hand-to-mouth. Finish one at Michoud [Michoud Assembly Facility] in New Orleans, put it on the barge, ship it to the Cape, stack it, and fly it. There are no extra tanks in there in surge flow, and so we are absolutely hand-to-mouth. For the Hubble rescue mission we have to deliver two external tanks—because there will be two vehicles on the pad at the same time—the Hubble flight and the potential rescue flight. Since we don't have the lifeboat capability of Station when it goes to Hubble, we've got to have the rescue flight on the pad ready to go no more than seven days later. So that means we've got to have two external tanks down there together, as opposed to being spaced out by the flight-to-flight-to-flight time that we have had in the past, which is causing us to have to really put resources on those next two tanks, and so the subsequent tanks are going to suffer a little bit in *their* delivery schedules.

My overall point in this: in terms of your question on risk reduction, I don’t believe we do a very good job of looking at risk in a relative or global sense. I believe we should say, "Gee whiz, I may be minimizing risk in this area, but when I do that, what's my effect on risk overall in other places?" By putting my resources—my scarce resource, the brainpower—on this risk and not distributing it over other risky areas and looking at what I can do there, or by not having some free time for my risk assessors to sit back and say, "What have I not thought of yet that may be causing me risk?" Am I really increasing my risk when I think I'm decreasing it? Because I'm really putting it on an area that *may* be the problem area. I believe we really we need to rely more on our expert practitioners to advise us on where we need to focus risk mitigation activities, and not just let it be wherever the thundering herd happens to be going right now.

WRIGHT: We can jump a little bit to more the future, because we've talked a little bit about what we need or what would be good to instill in the next group that's going to come behind you to be the leaders of the Space Agency. Could you share a little bit more on your thoughts about how best to train and equip this next generation of leaders? Including in that, how would you teach them how best to know who to trust as experts, and how to trust the people that they pick to choose to work with them to get their missions accomplished?

CHAPMAN: That's also a great question. I'll confess I've got real mixed emotions on this one. I could be characterized as being the ultimate Shuttle hugger here, so you have to take this with a little grain of salt, because it's a spectacular vehicle. It's time to move on. There's no question about it. It's time to move on. But I feel that we are missing a spectacular opportunity in the waning days of the Shuttle Program, which has been by all accounts—even despite two terrible accidents—by all accounts, an unbelievably successful program.

If I look at the capabilities that Shuttle has brought forward, the advancements in the state of the art, the fostering of creativity and out-of-the-box thought across the board in the development of the flight vehicle itself, in the payloads that we've flown, in the impact on education—across the board, it's been a spectacular success. If we simply fly out these next ten, eleven missions and then dust our hands together and say, "Ain't we great. We did a wonderful job. Thank you very much, go read about it in the archives, go look at the pieces in the Smithsonian," we've missed the boat. We've truly missed the boat.

What we ought to do, in my estimation, is look at the remainder of the Shuttle Program as a learning laboratory. Right now, it is the only human spaceflight program outside of the Russians, and the small—but admittedly potentially getting bigger— program that the Chinese have. But it's the only routine large-scale human spaceflight program that exists, certainly in this country. When it ends in 2010, there's going to be a gap between this program and the next one. While the next program is coming along, they really haven't been able to take the time to look at Shuttle in detail and learn from it in terms of "What does it really take to cheat gravity on a day-in-day-out basis? What are the pitfalls? What are the high points, the low points? How you deal with the people? How you deal with the technician workforce? How do you deal with the physics? How do you deal with the weather?"—all these things that it takes in the real world to make one of these programs work. If they can't take the time to really learn these lessons, then I believe we've missed the boat. Shuttle is the absolute perfect "learning laboratory."

In my estimation, it would be marvelous if we could, in some way, cycle as many people as we could through our ongoing manufacturing programs. In our case, the external tank down at Michoud—which will still be building tanks right up until 2010—and through the launch site at the [NASA] Kennedy Space Center [Florida]. We should consider setting up a specialized educational program where people could come and spend, say, a two-month, three-month, four-month, five-month internship. They could spend time in a structured formal educational environment that would be at those locations so that they could really see and absorb: What does it take to build the hardware? What does it take to make this work? What are the systems by which we disposition nonconformances? In other words, where *as built* doesn't match *as designed*. How do we get around that? What do we do? How do we still come up with a flyable product? What are the meetings that are involved? What are the decision boards that we use in the factory? Who do we have to convince that our hardware is good and what's the rigor that we go through to do that? If we don't use these remaining several years as a learning laboratory to get people up to speed, we're going to really miss things, because what's going to happen is: either those techniques and approaches will have to be reinvented with a new program, or they'll fall through the cracks.

We'll have serious problems. Big investigative boards will be set up, people will be tortured (as a project manager would say) and someone will say, "Well lookee here, if I go back to NSTS 07700,"—which is the bible of the Shuttle Program—and we say, "Well look at volume yak-yak of paragraph yak-yak of section yak-yak of 07700. It says set up a program that does duddle-uddle-uddle-uddle-uddle-duh, where is that on the new program?" Either the answer would be, "Well, we looked at that and we decided that was too inefficient, and we didn't want to do it," or, "We didn't know about it."

What I worry about is there can be—and I've already seen some of this—a tendency to say, "Oh, that crappy old Shuttle. The reason that we're building this new thing is because the Shuttle is so inefficient. It takes so many people to go do it, it takes billions of dollars to fund this thing on a year-to-year basis, and we only get a handful of flights out of it. We're going to come up with a new system that is far fewer people and all that." Which is wonderful, I applaud that idea; that is a great approach. What I think is missing is we got to be careful that we don't throw the baby out with the bathwater and just say a priori, "It's that crappy old Shuttle, we're going to do something different."

To me the better way is to say, "Well, why did Shuttle do it the way they did it? What's the history they brought forward that caused the management systems, the evaluation systems, the shop floor control systems, the way they build hardware—why do they have the systems they have?" Because I now understand how it works, then I can say, "I can come up with a better system that will capture the essence of those lessons learned. And they will do exactly that, utilizing the newer technology that we have today with IT [information technology] resources and all that." A better way to do it that will keep us from falling into the potential inefficiencies of the type the Shuttle has, but will still capture the essence of what shuttle is doing.

I sense that in some places this is actually going on, but in a lot of places it's not. I think that if we just let this remaining two years go by, and we don't utilize Shuttle as a learning laboratory to teach the future generations, we're really missing something. There obviously are arguments on the other side. These are principally, "I don't have time to study all that old history stuff because I got to go develop the new system. If I were to take half of my resources that are off developing the new system and send them to school on Shuttle, then I'm not going to meet my development milestones."

So they'll just have to pick up this knowledge at the water fountain, and ask when they put their silverware on their tray at the cafeteria, or talk to the guy next to them in line at the Credit Union and say, "Why'd you bring that change request forward on this?" and learn it that way. Is that really the way we want to do this? I don't know. There's no good answer for it. But

I think that's something that we need to strive to do. I also think that having things like the Program Management Shared Experiences Program, is a way that is very conducive to attendance and participation.

The way to get very little participation or grudging participation at best is to tell people, "You got to go through all this preparation work to get to go to one of these classes, and you got to document all these things, and I want you to go pull all this from your archives, and here's a whole ton of reading material." What you're going to get is malicious compliance again, and folks are not going to really get from it what they should. If they show up at some of these classes and they find themselves saying "Wow, this is really fascinating! This is like sitting in an armchair next to an old friend, having that old friend reminisce about the important and critical lessons learned. And I find myself taking notes, because I want to take notes on it because it's really fascinating. And I want to find out what are the references that he's discussing and where can I get a copy and does Amazon still sell them?" That's the right way to do it to make lessons learned forums extremely palatable and interesting.

For instance, our former manager of Shuttle, [N.] Wayne Hale [Jr.], as part of the Shuttle Program Management Council, ordered and distributed a series of books for his managers to read. The most recent one he gave us was called *Angle of Attack: [Harrison Storms and the Race to the Moon* by Mike Gray], and it's the history of Apollo, specifically about Harrison Storms. Wayne sent those copies out to everybody, and I was particularly enthused because he autographed the copy he sent to me. It said, "As a history buff, I think you'll really enjoy this one." Fascinating story. Absolutely *Fascinating* story. Plus, when I looked through the references books that the author lists, it turns out that probably half of them were favorites of mine anyway. So I'm automatically going to like it.

Through that sort of thing—and that's a little bit tough, because it's a reading assignment. But it's a reading assignment that sets the hook very quickly because it's such a readable book. By having things like that, and intentionally making time to do that the reading, and making sure that the managers both of the existing programs and the new programs know that it is important to look at lessons learned and history and how things need to flow from one program to the other and not just to be so consumed with delivering the product—and I'm not implying that delivering the product is not important. Absolutely it is; that's our most important product, and what we deliver has got to work, it's got to fly.

But we need to make time to learn lessons and to think about what's the best way to go forward. If we're so oversubscribed with what we're doing with the tasks at hand that we don't have time to reflect on "Do we have the right tools? Do we have the right perspective on history? What does history tell us about how we ought to go forward?" then our product is not going to be as good as it should be.

WRIGHT: What do you believe is the hardest lesson that you've learned in your career? Or maybe the best lesson?

CHAPMAN: Probably communication. Situations where you form your method of communication—the use of anecdotes, or the way you phrase things, or the depth of detail that you go into—largely based on your experiences and what you've done and what you've come from and what you've been involved with. Obviously everybody comes from a different background and different things and all that, and I'm not talking necessarily about technical communication in the sense that "Here's a list of specifications,"—those tend to be pretty routine and fairly cut and dried. What I'm talking about is status information of where a certain program is, or problem areas, or what we're doing to improve the production flow, or how we're addressing problems—more soft-side type things rather than the hard technical communication. There can be many instances where you think you're communicating, and then you find out later on that you really haven't communicated to the extent that you thought you did. We can see that across the board in almost everything that we do.

I think it's probably very valuable to continually look for and seek examples of both sides of that coin… examples of where there was communication taking place that was totally ineffective, and what lessons can be learned from that; and to see communication that was taking place that was phenomenally successful and what can be learned from that. To me, one of the classic examples of a great way to do communication—and he would probably die if he knew I was telling you this—is a guy who used to be an astronaut. He left the Astronaut Corps. And is now working in private industry His name is Jim [James D.] Halsell [Jr.]. Jim was an Air Force Colonel who for a good while was the launch integration manager for Shuttle down at the Cape. As part of that assignment, he chaired the Noon Change Board [Daily Program Requirements Control Board]—which occurs at one o'clock Eastern Time, (which is funny in itself, because people say, "Well, no wonder the Shuttle Program has got problems! You run this thing called the Noon Board and it occurs at one o'clock." That's right up there with the "Who's buried in Grant's tomb?" question.)

Anyway, Jim ran the Noon Board, and I really enjoyed working with him—back to this communication question—because of the way he would run this board. The launch integration manager has the responsibility to run the program level decision-making at the launch site and there were some very thorny issues discussed in this forum. Typically items such as "As built does not match as designed. What are we going to do about it?" You got to really listen to all the people that are involved. You may not know the individuals that are talking, you may be intimately familiar with the individuals who are talking. You may not know the particular subject, you may be intimately familiar with the subject. The whole range, the whole gamut.

Every time that Jim would run this thing, there would be some thorny discussion, sometimes taking just a few minutes, sometimes taking an hour or more. Every time, at the end of every issue, Jim would summarize it. He would say, "Okay, here's what we just talked about." He would say, "These were the issues that were brought forward. Here were the topics and this the way we dispositioned them. There was discussion this way and that way and here are the action items that came out of it, and here's the decision. Any comments?"

More times than not, somebody would say, "Well, now wait a minute, did we really do it this way? I didn't really understand it that way," and so they'd go through some more clarification and discussion about it. After that happened, Jim would go back through and summarize it again: "Okay, one more time." Now if there were things upon which there was agreement, he would hit those really quickly, but he would focus on that topic that was reexamined right there and say, "Okay, and we now just have clarified that duh-duh-duh-duh-duh-duh on this topic. So the actions still are boom, boom, and boom, and here's the decision. Any questions?" Every time, like clockwork, every single issue was done that way.

As a result, when you got through with a Jim Halsell-run Board, there was wonderful communication. You knew exactly what had been decided because the feedback to all the participants was alive and well. So many times in this business we will be so rushed and hurried that we will not seek feedback on our discussion topics, and as a result there can be the assumption of communication when it really does not exist. I would say that in terms of most important lesson learned, it would be that lesson from Jim Halsell. Like I said, he would probably fall over on the floor right now if he knew that I was talking about that. He lives up here in Huntsville now, works for ATK [Alliant Techsystems], so I see him more frequently than I did for many years. Great lesson—that we need to focus on communication; that in many cases that can be where things fall through the cracks.

WRIGHT: Before we close, I wanted to give you a chance to look at your notes. I didn't want to lose any other best practices or sound ideas that you'd like to pass on in this conversation.

CHAPMAN: I think we've covered most of these things. Mentioned some names to you—I mentioned Royce Mitchell and Joe Lombardo and Bob Lindstrom, and Jim Odom. There's another guy here in town that if you needed to talk to. He'd be a great resource, that's a guy named John Thomas. John Thomas worked for Marshall for many years, and retired back in the late eighties. Worked in private industry for Lockheed for a while, and now is part of a consulting partnership here in town and has lots of key project management experience.

Again the ones that I'm mentioning to you—specifically, Royce, Joe Lombardo, Bob Lindstrom, John Thomas, Jim Odom—they're particularly good resources because they've worked on both sides of the contractual fence. They've worked on the government side for many many years, retired, gone to work on the contractor side, and have been in very, very influential positions addressing issues from that side of the fence. So they provide a perspective that is invaluable to folks that have not worked on both sides. I'm fortunate that I've worked on both sides of the fence. That really helps you understand what it takes to get this done, which is a real partnership.

Just some basic little tidbits: Frequently we have failure investigations. We either have a problem—sometimes it occurs during flight and it's an in-flight anomaly type investigation following flight, or sometimes it can be something that we've discovered during checkout and planning before we get ready to launch—and we have a big investigation and a big hurrah about how we're going to do things. There can be a tendency, whenever we have one of those, to not adequately staff the investigative body. We typically overdo it in terms of the technical resources that are available to help out, but we drastically underdo it in terms of the administrative help.

A lesson learned from my vantage point is we need to always make sure that whenever we set up an investigative team, we ensure that that team has adequate administrative help to help with making charts, producing documents, tracking action items, setting up meetings, getting out minutes… all those things. Because if we make the technical leadership of the investigation responsible for doing all the administrivia too, the administrivia is going to suffer and thus the end product is going to suffer.

So I think we need to really do a better job at making sure that we have that critical resource. The investigative teams that I've been involved in that have worked very well, the common thread in lots of those have been twofold: One has been clear and concise leadership of the investigative team, *and* good administrative help that can set up websites to distribute information—now that we're in that age—good production of presentation material, good coordination of telecons to get it going and talk to people, so that the leaders, the technical leadership, does not have to worry those problems.

Another thing dealing with investigations and things—we need to always put at the highest point of our list of things to think about when we set up investigating groups, Tiger

Teams, to go solve problems—clear and concise definition of roles, expectations, and limitations of the investigation. Because if not, these investigations can tend to almost have a life of their own. All the members of the investigating team can be unclear as to what the extent of the expectation: Are they supposed to solve *this* specific problem on *this* flight vehicle? Are they supposed to solve it for now and forever more? Are they supposed to solve it in this area and like areas? "What do we need to do?"

If all the team members don't have that clear charter in mind, and if the leadership can't continually go look at a piece of paper or e-mail or something that says, "Here are the limitations of this investigation," then it can get out of the box and it can go on forever. Folks will all feel that they're not really contributing like they thought they should. So it can be a good thing to concisely define expectations and limitations, because the participants can then feel the self-actualization that, "I feel like I'm contributing to the final thing." We really need to think about what types of personalities and capabilities we assign to Tiger Teams and that sort of things, to make sure that when we do that we are not just getting the best technical capability, but that we are getting the best system to go solve the problem. The system would be personalities involved—"Are we setting up ourselves for failure because we have personality clashes?" Frequently that can get in the way of getting to the end answer that we all want to get to.

You asked for best practices. I'd say to anybody, the absolute best practice has got to be to be to listen more and talk less. And always be curious. Do as much reading as possible, discuss technical details as much as possible. Just keep asking, "Why? Why did you do it?" You asked for some specific examples and things. The specific examples of the things that I've been involved in that had memorable outcomes and had risk reduction would be solid rocket booster, specifically dealing with the flight STS-97 when I was booster chief engineer. We had a pyrotechnic device that did not fire. We discovered this when we got it back and found an unfired pyro device. So that set us off onto a big investigation to figure out why it didn't fire when it should have The redundant side did fire, so the mission was a complete success.

But doing the failure investigation, we found that we had a problem with a cable. The cable had broken internally, and it was not evident through our testing that it had broken. Because when it broke internally, when it flexed back together, it was making what we call "kissing contact" inside the insulation, and it was still providing a conductive path. What happened, though, is during ascent, with vibration, it opened up and we couldn't get the electrical signal through there. So we launched a big investigation to see what was going on there.

Some of the lessons learned were that folks that were involved in the reusable, refurbishable cables were making assumptions that the testing that would be done on this refurbishable piece of hardware would detect problems later on, and it would not get back into the flight inventory if problems were found. So it was treated as "flown hardware" but not "flight hardware", if you see the subtile distinction there; that in order to be flight hardware again it was going to go through a whole bunch of exhaustive tests, and that testing would show whether there were problems or not, and if there were problems it wouldn't get back in the flight inventory. So they could treat the hardware—I won't say with wild abandon—but when they pulled these cables off they could flex them, they could move them around—with what they felt was confidence that it would be tested in a way that if it was broken, it wouldn't be flown again.

It turns out our testing was not as robust as we had hoped it would be to catch those problems. We ended up installing a cable that had a break in it. When it was in a particular position it was making contact, when it was in another position it wasn't. We did the testing when it was making contact. When we installed it, it was just barely making contact. So the big lesson there is to communicate to everybody that flight hardware is flight hardware, there's not a differentiation between flight hardware and flown hardware—that you got to treat it with care and kid gloves throughout the process and not assume that our testing program is always completely robust to catch any problems.

Other things that were particularly satisfying to me—when they gave me this job for external tank, we had just had the first Return to Flight mission (STS-114) following the Columbia accident in which a part of a tank foam came off that was, much to everyone's chagrin, this part of the tank called the PAL ramp, which stands for Protuberance Air Load. We already had an activity underway to remove those ramps. We'd done studies that showed that they really were not necessary. They were put on from a standpoint of conservatism early on in the program, when our analytical tools were not as sharp as they are today, and we were able to go back and redo wind tunnel tests and redo analysis and show that we really did not need that foam. After that foam came off on that first Return to Flight, we were subsequently able to demonstrate to the whole community that it would be okay to remove the ramps and that we would not cause any deleterious consequences because of that. That was proven with the next flight (STS-121) that flew successfully, and everything worked great.

That was a big success story for me to be involved in. That was basically getting a diverse team together to capitalize on ongoing work and keep an eye on the very near future, and keep them moving in a direction that could quickly support resumption of shuttle flights. But, again, that was a good example because the team that we put together was very focused with a clearly defined objective.

There were other areas of the STS-114 investigation where we didn't characterize the scope of what the investigative team needed to work on, This lack of scope definition coupled with a lack of specific limitations caused the failure investigation to drag on much longer than necessary, which caused a corresponding delay in the resumption of shuttle flights.

Already talked about the tank known as ET-120—which was the one that we tanked up several times and brought back to the factory and dissected and evaluated. While many people said, "That that's a perfect tank to go to the Smithsonian. No project in their right mind would ever fly that thing again, because it's been sliced and diced on. There's no way you're going to get it back to a flight configuration." But we had the confidence that we could return it to flight configuration. And it was one of the most successful flights that we've had so far, in terms of debris generation. That was, again, a matter of keeping everybody focused on the task: to make the repairs, do a good job on them, prove that we had a good tank, and then go fly it and get the photographic proof that it worked.

One of the most recent examples of best practices would be the investigative and repair work leading up to the successful flight of STS-122, which was the flight that was going to take place early last December, and we had problems with this little itty-bitty piece of hardware called an ECO sensor. ECO stands for engine cutoff. It keeps you from running out of gas. You MUST turn the engines off before you run out of gas, because if you run out of fuel before you run out of oxidizer, then that's a bad day. So this little thing tells you when you're about to run out. It tells the computer, "Hey, time to shut the engines off," so you don't get a bad problem.

It turns out that because part of that system has to operate at 423 degrees below zero, it does strange, strange, strange things. At temperatures that cold, air turns into a solid. That's right… the air we breathe becomes solid at 423 degrees below zero. Solid air is an insulator. It's not conductive. So if you let solid air form in a connector, because it was gaseous when it entered and then it became liquid because it got colder and colder and then it became solid because it froze, and then as it gets colder and colder still, it causes things to contract. As things get cold they shrink up, and then that caused the connector to go together and the pins of the connector to ride up on that solid air—and now it doesn't make contact anymore. Then you do an investigation after it's warmed up and that solid air becomes liquid air, becomes gaseous air, and it makes contact again—you look at it and say, "Everything looks good, what's happening? Why isn't it working?"

We figured out what caused the problem through some brilliant free time detective work by our chief engineer and the contractor's chief engineer and one guy from one of our laboratories here at Marshall. Principally because we freed up a couple days of time where we said, "You don't worry about anything else. You can go think about this problem, and don't worry about the administrivia involved in the investigation. Don't worry about the fact that the program is breathing down our necks to fly this flight again and figure it out; you go think about what could be causing it, and think outside the box, and see what you can come up with."

They came up with the scenario and came up with a fix for it that we then demonstrated in our test lab out here beyond a shadow of a doubt that that would fix the problem. Made the repairs to the flight hardware, flew it two and a half months later, and it worked absolutely perfectly. It totally solved the problem. We had complete confidence that it would solve the problem. This was truly a great success story. Those kinds of things are very satisfying. Again, it's a matter of having the right people and not burdening them so much with extraneous stuff, and let them work on the problem with a concise understanding of the objective.

The last thing I was going to mention was acronyms. We got to be really careful in this Agency with our use of acronyms. It gets back to communication. Remember that was one of my things: “Are we communicating? Do I think I'm communicating with you, and am I really not communicating with you?" If everything I say is in acronyms, then the only way I'm effectively communicating with you is if you know those acronyms. If you're not familiar with those acronyms, then I might as well be speaking a foreign language to you. When we both know them, it's a wonderful shorthand that allows us to communicate ideas and concepts quickly without having to go through all these long gobbledygook names that we have in this rocket business. But I'm convinced that acronyms, on a not infrequent basis, are used as a weapon.

What I mean is: if I wanted your help on a certain problem, I would make sure you understood what I was talking about. But if I wanted a quick test to find out if you really knew what I was talking about, I would describe my problem in acronyms to you. And if you didn't understand the acronyms, you wouldn't feel like you could add anything to my problem. Even though it might be that you may have direct experience that could be very applicable to my problem by abstracting my problem a little bit into some other area. But if I describe my problem in acronyms to you, then it's like saying, "Well, if you don't understand the acronyms, then clearly you're not going to be able to add any value to this discussion I have. So I'm going to use my acronyms as a weapon to keep you from taking my valuable time in having to answer any of your questions."

I believe this is a very, very real issue in this program. From my perspective, I think we need to do a better job at reminding all aspects of the program—because we're all, in varying degrees, guilty of using acronyms too much—to make sure that we're not unfairly impeding conversation and communication across the program. I have a tendency, when I look at charts in big reviews, to count the acronyms on the page. Here in recent months I've seen a chart at a shuttle flight readiness review that had 44 acronyms on a given page. One page had 44 acronyms on it. That does not foster communication.

If the object is to make certain that *the* one person that I am talking to knows exactly what I'm talking about, as long as that person and I both know those same acronyms, that's perfect. That works great if that's the objective. But if I have been asked to put all the other activities that I have going on on the back burner and come attend this meeting, and then those acronyms are being used to the person that is the target of that communication, then I've got to ask, "Is that a good allocation of time to go have a huge meeting and then embed huge number of acronyms in the presentation material?" and as a result exclude a significant portion of the audience from understanding the issues..

Because one of the premises that we have here—and in general it's true—is by assembling a brain trust, each time we have a flight readiness review for example, that we will end up with better assurance of our success of the flight by having a lot of smart people involved in it. If somebody over here hears a topic that's being discussed that they're not really sure is the right conclusion, they can ask a question about it. If that topic is so laden with acronyms that it excludes that question, then we're missing the boat.

WRIGHT: I appreciate all the information. I think it's going to be very beneficial. Appreciate all your time.

CHAPMAN: Let me know if there's anything else I can do.

[End of interview]