ORAL HISTORY 8 TRANSCRIPT

GLYNN S. LUNNEY
INTERVIEWED BY CAROL BUTLER
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BUTLER: Today is December 9, 1999. This oral history with Glynn Lunney is being conducted in the offices of the Signal Corporation for the Johnson Space Center Oral History Project. Carol Butler is the interviewer and is assisted by Kevin Rusnak and Sandra Johnson.

Thank you again for joining us.

LUNNEY: You're welcome. Glad to be here.

BUTLER: We talked before about Apollo-Soyuz, so now we're moving into the interim period and then moving into Space Shuttle. You were involved, I believe, with some of the payload integration work at that time. What were your responsibilities there?

LUNNEY: That was an interesting time. When the Apollo-Soyuz Project ended, we had a project office with about, I don't know, twenty-five, thirty people in it, and they'd been together a long time. We'd been together a long time and had been through the thing with the Russians. It was sort of like, "Well, what are we going to do now?"

The rest of the center was fully occupied with the Shuttle development going on at the time, and, of course, there was the program office and all the appropriate assignments made for that activity. But one of the things that was empty was the fact that the Shuttle was being designed to carry lots of payloads, all kinds of payloads. I'll talk about that in a minute, too. But there wasn't any real easy way to integrate them into the Shuttle yet. There wasn't an organization for it. There was some preliminary steps taken, but they were very preliminary.

We realized, as we began to set up what we were going to do next, that this was a big hole for us, so Chris Kraft, who was the center director at the time, reorganized our office and labeled us Shuttle Payloads, Integration and Development Project Office, Program Office. At the time, he and others had in mind that there would be a lot of payload development; that is, where the Johnson Space Center here would develop payloads, in effect, gain the business of developing new payloads specifically for the Space Shuttle, and it would end up being kind of a new enterprise for the center as a whole and for the people at it.

So the emphasis in the front offices was on the development of new payloads, although integration was recognized of the ones that we were going to fly. All the other ones that were going to fly on Shuttle was recognized as something we'd have to start addressing. As it turned out, as history would show, we didn't really get much in the way of development. I can't think of anything that was assigned to us to develop, exactly, except miscellaneous pieces of hardware for the Shuttle.

So we didn't really get a lot of development of new payloads, but, I mean, we walked into a whole world that none of us could foresee very clearly. It was an entire activity of meeting people who were using space and flying payloads, from the communication satellite industry, from the Department of Defense, from the Air Force, from the NASA centers, and from other people. It was like we just opened a door to a whole new world of activity that we at the center were fairly remote from. Most of the programs up till that time had basically been self-contained within the manned space flight, even space flight organization, and there weren't too many outside connections, although we had a lot of scientists and so on on board for the Apollo and for the Skylab and so on. But it wasn't a real strong focus for a large part of the center. So we set about to do this, stumbling through the door to find out what we were going to do in this new world of Shuttle integration.

The program status at the time was interesting. As the Apollo Program neared fruition, in 1969 President [Richard M.] Nixon chartered a group, called the Space Task

Group, that was led by Vice President Spiro Agnew at the time, that was to focus on what was the country going to do next. Most of the people in the space community had the idea that we would build a new transportation system and build a space station. As a matter of fact, the very term "shuttle" connotes shuttling to and from something, you know, Washington to New York. Well, we had a Washington which was Earth, but we didn't have a New York.

So early on, most people saw the two as very much of a coupled program, but for economic reasons, just because they cost so much, they got spaced out considerably differently. The Shuttle started to fly in 1981, and the Space Station has really just begun to be assembled here in the very late nineties. So it's twenty years later before we'll really be operating Space Station. But originally that was seen as kind of a coupled enterprise.

The Shuttle, as defined by 1976, say, was a very aggressive development in terms of what was trying to be done. It was, of course, a very large reusable spacecraft with a lot of new development problems associated with that. It was recoverable even in boost stages with the solid rocket motors, solid rocket boosters, large external tank, and the Marshall Center was involved in designing and building the tank, the solid rocket boosters and the main engines that went on the back of the Orbiter. They had their contractors, of course, to actually do the implementation. JSC was involved in the Orbiter and in the integration of the total thing as a stack, and then we got this other job called payload integration.

Shuttle was a tough development. As a matter of fact, I think it's kind of interesting, because when we came on the scene, it was clear that people had started off with the idea that the Shuttle would be a relatively easy access system to low Earth orbit space, and that it would be relatively cheap. As a matter of fact, early on in the justification, in the selling of the Space Shuttle, and this primarily happened at the Washington level, Washington headquarters level, people created these economic models and flight rate models, mission models, they called them at the time, that had very, very high flight rates. The highest was

sixty flights a year originally specified, and that gradually ramped down to today we're probably capable of ten or twelve if we had the activity to support it.

But they did the economics based on high flight rates so that all of the fixed costs would be a low part of the recurring cost per flight, and it was assumed that it would be easy to amortize fixed base costs like the populations at Johnson Center and at the Kennedy Center, and that the only extra costs would be the tanks and rockets. As a matter of fact, the first number I remember for what was supposed to be the cost per flight was about 10 million dollars per flight, 10 million dollars per flight. Of course, that was in '72 dollars, which, if you escalate it today, would be quite a bit more than that.

But, nevertheless, for reasons of wanting to sell the program and having, I guess, to adopt a strategy of—I shouldn't say demonstrating—of selling it on the basis of a low cost per flight, people went to extremes to justify and to calculate what it would take to do that. In retrospect, you know, it was quite a bum rap, because it set certain kinds of expectations for what the cost of the Shuttle was going to be every flight, and they became increasingly unrealistic, if not impossible that anybody could ever meet them.

So the Shuttle Program, although all the people who were engaged in the development were not actively involved in this part of it, the program itself gradually began to, and still does, suffer from a rap that it never did meet the original promises which were made, which was true. I suspect that somebody ought to do a study on the selling of the Space Shuttle and how it got positioned in terms of how Washington viewed it, official Washington, because there are probably a number of lessons there for what you should do and what you shouldn't do.

They did create a real tough set of expectations, and the development was tough. They had to build these main engines that were very powerful and very light weight. They had to build this airplane-like flying machine with a very, very large cargo bay, 60 feet by 15 feet in diameter, so a very large cargo bay, much larger than anything anybody had done up

till that time. It had to be manned. It had to have a heat protection system, which turned out to be tiles and other things. It had to have a very sophisticated and reliable guidance system, because it turned out it was very much of a fly-by guidance digital system, and so many of the systems, the engines, the trajectories, and then the other systems were controlled by the computer itself.

So there was a large number of development difficulties facing the team of people, and it was consuming 95 percent of the Johnson Space Center and 95 percent of a lot of other things, too, but certainly here locally it was consuming a large majority of the center's attention. And most of it was focused on simply getting it developed and getting it to the point where it could fly. They did the best they could in terms of tradeoffs that would result in eventually lower operations cost, but there was also a cost limit on what the development was going to be.

So when push came to shove, the decisions were generally made to build things in a way that would minimize the development cost and let the ops cost be what it would when the time came. That was one of the reasons why at first it was considered to be, or thought to be, envisioned to be, a completely reusable vehicle. It turned out that that wasn't done, mostly for reasons of trying to keep the development cost under a ceiling, and they did their best to do that. So it was a fairly consuming thing for all the people.

The other aspect about it is, it was the only development that was under way for human space flight, so it was the key to the future of human space flight. It was all that we had, because all the other vehicles and systems were shut down. And in the process of creating these mission models, the argument was made that this ought to become the only launch vehicle that the United States had, so that it was going to become the sole vehicle. We were going to put the other vehicles out of business and retire them. Then it was going to become our launch system.

At the time, unmanned launch systems that the United States has—and by the way, still has today—were used to fly many scientific satellites for NASA, weather satellites. Also they were used considerably, and it was growing in terms of its use, by the communication satellite industry, people who build all the COMSATs that we now have so many of at high altitude and now increasingly at low Earth orbit altitudes.

So the country decided it was going to get to space in the future by this one system, it was going to be cheap, and the cost of it hung over us, as it still does, but the difficulty of designing a vehicle so that it could serve as all kind of payloads added to the complexity of the system, none of which I think we would change today if we had a chance to go back, but, nevertheless, the vehicle became a little bit of all things for all people, so it was hard to make it a single focus, lower cost system than the present systems or the current systems at the time. And certainly it was difficult to make it any more near what people had in the way of an expectation for what it ought to cost.

By being all things to all people, first off, as opposed to, or in addition to what launch vehicles did at the time, unmanned launch vehicles, this vehicle had people in it, it was built to deploy satellites, both small, medium, and large, all kinds of satellites up to a full 60-foot, 15-foot diameter. It was also designed to be a science platform. We were designing and building things, the Europeans were—I'll talk about in a minute—that would allow people to operate small laboratories in space or bring up a set of instruments.

The people were imagining that there would be a considerable amount of retrievals of satellites on orbit for one reason or another, and it had a remote manipulator arm that was used to move payloads in and out, to catch them, put them in the bay, take them out, and to do, as it turns out, a lot of other things that we now use the arm for. So it was a fairly sophisticated system and had capabilities far beyond what any launch vehicle had, any launch vehicle, all of them added together, didn't have the capability that Space Shuttle had. But

that meant that it was a fairly expensive development, and then it was a fairly expensive system to operate.

So when we came into the program, the Shuttle had been in development about five years or so, and it still had, at that time we thought maybe three, but it turned out to be another five years to go before we flew it for the first time. But it was under a lot of scrutiny, a lot of pressure, and we'd set a lot of expectations. By virtue of the fact that we were trying to make it the sole launch vehicle in the country, the other customers that had previously flown on other vehicles were now reassigned to the Space Shuttle, and that, by the way, carried over a set of resentments that played out over a period of probably ten years, where other people were not entirely happy with that kind of decision to put all the payloads on the Shuttle. They would have preferred to fly them the way they had been flying them, without this new system to worry about.

So, let me see if I've covered that. The other thing about it besides the other customers, the big customers like the DoD [Department of Defense]/Air Force and big customers like the interplanetary missions sponsored by JPL [Jet Propulsion Laboratory, Pasadena, California], was that we required a high flight rate, and many times a lot of the satellites that were built at the time were not big enough to take up the whole cargo bay. So we had this concept of mixed cargoes, which means you have an A and a B and a C and maybe even a D payload in the cargo bay. We had to figure out how to fly these things in a way so that they didn't interact with each other, so that their mission requirements were able to be met by the Shuttle and so on and so on.

So we had kind of a tough situation facing the whole team, far tougher, I think, than we going into ever realized, because we just didn't realize what a large undertaking it was to try to satisfy all these customers and then to try to run a system that would have to operate at very, very high flight rates. Even twenty flights would be very high, as it turns out. And we had to figure out a way to mix and match these customers so that they could fly together,

because sometimes the time of day they wanted to lift off was different, the attitudes that they wanted to be in was different. Sometimes they would have radio transmitters that would impinge on the other payloads, and on and on and on.

So being able to fly mixed cargoes presented a brand-new challenge that nobody had really dealt with very much before. I believe in the expendable vehicles at the time, the unmanned ones, that they would occasionally have some piggyback payloads, but they're basically small, no interference, no impact on the major payload and so on, so it was a relatively easy thing to do because they weren't even secondary, they were tertiary or less in terms of getting a COMSAT mission ready on an unmanned launch vehicle. But we had to deal with the fact that we would be dealing with full-up paying customers, several of them on the same flight, and they all had to be satisfied. So it was a new thing and a new challenge for us.

So we started in this environment, and some of this was clear at the time, probably not very much of it at the time we started, and some of it evolved over the years and some of it we just experienced as we went along, but we found ourselves, although the development guys were under their own set of heat for getting it done on time and on budget, we were coming into this community of people that had these other sets of expectations about how cheap it was going to be and how wonderful it was going to be, and how they could have anything that they wanted in terms of services from the Shuttle, and there we were to deliver all this to them with hardly any budget at all. So it was kind of an interesting time.

So we became primarily an office that dealt with the process of integrating payloads into the Shuttle. Now, by integrating, that means different things to different people, but first and sort of obvious, but it took a while, was you have to identify them, like who are they and how do you get them in a pipeline and how do you know when you've blown the whistle and started, and how are they serious, how do you know they're serious. Some of these things are just paper studies that never turn out to be anything.

But we had to identify them and then we had to tell them what it was going to be like to fly on the Shuttle in technical terms. We would have to specify all of the environments to them, like the loads that they were going to see, the loading on the spacecraft; the acoustic levels that they would experience, mostly on the pad when the engines lit; what the thermal environment was going to be with the doors closed, and then when we went up and opened the doors and went through various attitude profiles, what the thermal environment was going to be. And that varied, depending on what attitude you pointed the vehicle to. If you pointed it at the sun, it would be warmer in the cargo bay than if you didn't, and so on.

RFI, EMI, electromagnetic interference and radio frequency interference, all these things had to be considered. Then we had to deal with safety requirements, which I'll talk to you some later, because that turned out to be a big problem for people because we imposed a number of safety requirements. But we had to identify all these things to people and then we had to solicit from them their requirements. I mean, what did they want to do? What time of day did they want to lift off? How big were they? What were their special mission needs? What were their special plumbing needs, if any? Some of them required special cooling. They all required a large variety of electrical services.

When we first started, we inherited the Orbiter. What the development guys had done is, they had a big panel at the front end of the cargo bay called the 576 bulkhead for its dimensions. It was just full of connectors, of wires that carried voice telemetry, television, computer signals back and forth, control signals back and forth, and power. And here was this great big mess of connectors which would be fine if you had to wire those connectors to one thing in the cargo bay, but we had to wire them to four things in the cargo bay. So as it turned out, we had kind of like inherited something that I guess in electrical terms you would say it was like we had a central power station, but we didn't have any telephone poles or booster stations or any way to get it to your house. [Laughter] Because we had more than

one house to take care of with this power station. So that evolved, and I'll talk about that more later as to how we got to answer on those sorts of things.

The other thing about soliciting their requirements, especially if they were not a dedicated flight, which meant that they were the only payload on the flight, and if they were a dedicated payload on the flight, they, in effect, would purchase the flight, pay the price for that, and then they would have all the services. But we had this question of, well, if we're going to mix and match them, how do we know we're doing it right and how do we know that one is not affecting the other in some adverse way?

So we had to go into this process that we called manifesting, which was, okay, we can put these two payloads here and this payload over here and this one in the corner, and we can work out a way to satisfy all the requirements without impinging on each other in any way technically. That was quite a challenge. As a matter of fact, manifesting payloads on a Shuttle, which you think you might do every so often and publish a new one, became something that happened every day. I mean, it was a daily, almost hourly event that things would change for one reason or another, and we used to kid especially the people in Washington. Chet Lee ran the office that dealt with the manifesting. We used to kid Chet's office and Chet himself because it was almost as if they had to have a date and time on each one of these manifests, because whatever it was in the morning was likely to be something different in the afternoon because of things changing. So it was a very dynamic kind of a situation.

Then having both explained the Shuttle to people and then solicited their requirements and then find a way to mix and match them so they could fly, we had to go through a process of assuring ourselves and the payload people that the thing technically was going to work the way we had talked about and one wasn't going to interact with another in an adverse way. So we had to develop a process of assuring ourselves and them that we had

planned something that could be run and could be achieved and would not fall apart just by doing that.

There was another thing about it that was different, and it gave people a lot of trouble. Before the Shuttle, for example, the communications satellite company or the Air Force with one of their payloads would, in effect, purchase an expendable launch vehicle. Of course, when the mission was flown, the rocket itself, the launch vehicle was gone and the satellite was hopefully doing whatever it was supposed to do. But, in effect, they were buying the launch vehicle, so they had complete autonomy over it, and the launch vehicle was completely subservient to the requirements of the payload. As a matter of fact, the payload people even decided how much risk to take with the whole thing. There wasn't a great deal of concern that this payload would damage the launch vehicle, although people didn't want that to happen, so they tried to avoid it, but it wasn't like anybody had a vested interest in being sure that the launch vehicle was okay the whole time and be able to be reused as we ended up doing on the shuttle.

So people came into it with this mind-set that they owned the launch vehicle and the people who operated it should do whatever they say. So it was kind of like a control shift for them, because in the case of the Shuttle, we were reusing these systems and we were reusing what ended up being a very expensive national resource, including the fact that it was crewed, there would be people on it. So they weren't really buying the system to use; they were leasing it for the period of their flight. And that seems real obvious, but when people come to you and they have an owner's mentality, like they own the apartment house, well, that's a different attitude than one who's leasing one apartment in the apartment house.

We stumbled over that quite a bit, because people automatically carried over, as we all human beings do, their past experience, and they always saw this thing in terms of, "Well, for my mission I own this thing, and I ought to be doing this and I ought to be doing that." This is especially true of government users. It was not so much true with the commercial

people in the communication satellite industry. They were perfectly willing to go along with the arrangement, but the government people carried over this sort of owner's mentality and struggled with the idea that it was going to be a lease deal, where they didn't own it, and that there was a whole group of people here at the center and other centers, but primarily here, who were concerned with the continued ongoing health of the Orbiter system, who wanted to be sure that nothing happened that would damage it in any way and that the crews would be safe, because we carried the crew responsibility and the responsibility for ensuring that Orbiter was safe, that nothing untoward would happen to it from the payloads.

So that was a kind of a shift that is obvious when you articulate it, but it wasn't so obvious to the people at the time. It wasn't so obvious to us at the time, and it took a little grumbling and working with people before it began to dawn on us how they had previously worked and what their expectations were and why this was different and why in some respects we were having some friction here and there on the subjects that would derive from that mentality.

So, there we were getting ready to do this, and the other thing about the Shuttle was that it only went to lower Earth orbit. It went to about 100, 150 miles orbit. A lot of the people wanted to go to altitudes that were quite a bit higher than that. The communication satellite industry all goes to 22,000 miles. The Shuttle doesn't get remotely near that altitude. So there was a need for the variety of upper stages that would adapt them. At the time we entered the fray, there weren't any that were compatible with the Shuttle. All the upper stages had been designed on top of other launch vehicles, and there just wasn't anything. There was an empty cargo bay.

So as we began to experience what people wanted, it became clear that somehow or another we needed to arrange for a family of upper stages that would take them to where they wanted to go in terms of altitudes or orbits, other than those that the Shuttle itself could reach. And that set in motion a variety of things that I'll talk about, too, as we go along.

So here we were coming out of ASTP [Apollo Soyuz Test Project] with this little band of thirty people who'd had a lot of experience negotiating with the Russians, the Soviets at the time, and so we got into business of negotiating with all these people who wanted to fly in the Shuttle, and we didn't have any idea of how to go about it or what they were expecting or how we should offer it or how we should package it or anything. It was a complete learning experience from the ground up. We just didn't have much in the way of guidelines to help us.

Our first experience was misleading in some respects, but it was helpful in others. At the time, the European Space Agency, which was about a dozen European countries and Canada—Canada [unclear]—about a dozen European countries were involved in the creation of something called Spacelab, which was a big pressurized vehicle that would fly in the cargo bay and could house, like a small space station, could house a lot of experiments. They also had pallets that could be put outside, in the cargo bay, but outside of the pressurized compartments, that could carry a variety of instruments. It was a fairly complicated device. It had its own computers and so on. It is a fairly sophisticated device.

It was fairly well along in development. It was being developed in Europe, but within NASA, the Marshall Space Flight Center had the responsibility for overseeing that development. They didn't really have the responsibility for integrating into the Shuttle. That was what we ended up adding to it. They were mostly monitoring it from the point of view of a development program unto itself. So we started to work with Marshall and then ultimately with European Space Agency for how would we put this Spacelab into the Shuttle.

Now, it sounds like a simple question and the answer ought to be obvious, but it wasn't so much at the time. We had to figure out, well, how are we going to attach it? What are all the loads going to be on it? Then all these environmental questions. It also produced its own environments that we then had to be sure didn't interfere with Shuttle systems.

Plus I go back to this set of connectors up here on the wall. When I turn the electrical guys loose to go find out and to work out how many connectors and wires we needed to take from the Shuttle power station over to this big house called the Spacelab, people spent months. Each little wire and signals that got carried on it, they'd put them on this pin and that pin and change them, and on and on and on. The Spacelab, the people in it were sort of disposed to use all of the services that the Shuttle provided so they wanted access to all of these capabilities so that they could use them in ways that they didn't even know yet what they would use them for in some cases, but they knew they would use them, or they felt they would use them. So they wanted to find a way to take all these wires up here and get them inside their vehicle so they could access all of these data systems.

It was a long, tedious process, and sort of towards the end of it I asked our electrical guys, "Okay, how are we going to do this when I've got three or four paying customers in the cargo bay, not just this one thing, but three or four paying customers? Are you going to sit here and bunch up a bunch of wires to one, then a bunch of wires to another, then come back later and found out you gave away the wrong wires to the wrong payload? How are you going to do that?"

They said, "Oh, no, we're going to do it the same way." So I'll talk about it when I talk about the comsats, but we ended up with a different arrangement for the services, the electrical services, based on how many communication satellites max we could fly on a given flight. And at the time it looked like the sizing was such that the maximum we would ever fly was four. The maximum we were physically capable of flying was four, after we figured out how to package them with an upper stage.

So this didn't happen right away, and it didn't happen at the time of the initial Spacelab discussions. What was clear at the time of Spacelab is we needed to find a better way to do this. In the end, we ended up taking all the connectors up here and dividing them into four equal sets of connectors at four stations in the cargo bay, which had one-fourth of

all of the utilities, the electrical services, that we were providing for the Shuttle, so that if you were this size customer, you got one-fourth. If you were twice as big as that, you got two sets. And if you were a full cargo bay dedicated flight, you could have all the services.

But that wasn't very apparent to us at the time when we got started again with Spacelab, and Spacelab was an experience mostly in how not to do it. I don't say that with any criticism of the folks at the time either on our side or on the side of the European Space Agency; it was that we were both learning and trying to struggle with how do we do this. But it was clear that Spacelab was a model that was not going to be the way we wanted to do all of the satellites that we wanted to fly.

Let's see. There was another thing that happened to me, and I lose a little bit track of dates and even years here, but in December of 1976 until August of '77, I was asked by John [F.] Yardley to come up and be his deputy. John was the associate administrator for Office of Space Flight, which was all of manned space flight, and it included, by the way, the NASA management office for the expendable launch vehicles, the unmanned launch vehicles. Joe—Irish fellow, last name starts with an "M." I thought I'd never forget it. He was the guy that was running the expendable launch vehicles at the time.

So I went up to John's office for eight or nine months. We arrived in Washington, D.C., about Christmastime. It snowed and it snowed and it snowed, to the point where I couldn't get the car down the driveway, because it was a steep hill, so I parked the car out on the street for the first month that we were there, because it all got iced over. But Marilyn and I took the kids up, out of school, and we put them in school up there and so on, and it was quite an adventure for me.

John Yardley was an incredible manager, incredibly gifted man in many ways. He was a solid technical person, very solid, but he was a good businessman, he had a good sense of the requirements and the constraints and the expectations on the program. He was good with the Washington bureaucracy. He was good with budget numbers. He was good in

testifying on the Hill. So I had a chance to be around him for about nine months, watching him and helping him deal with all of the myriad of problems that he had.

One way I described John was, as opposed to the way a lot of people think, which is from a single point of view, John had this talent of being like a jeweler. In other words, he could put his little eyepiece on and he could look at this stone, and then he would turn it and he would see something different. Then he would turn it some more, and he had this ability to look at things from multiple points of view.

I'm using a stone analogy, but by that I mean he could look at it from a technical point of view, kind of from a political point of view, from a congressional point of view, from a DoD/Air Force point of view, from a budget point of view. So he had this ability to look at issues from multiple points of view and through that process, by airing them, sort of arrive at a reasonable answer as to what he ought to do, which was usually pretty good because he considered all these things and he didn't just consider the technical and then get blindsided by one of the others. He was very good at that, and it was a real learning experience for me to spend time with him and watch him do that. I began to call him "John the jeweler" because of this really valuable knack that he had for being able to look at things in so many ways.

I was there, as I said, for about nine months, which was just about an annual cycle, so I saw Washington through an annual cycle of the hearings and then the committee deciding what the numbers are and the mark-ups and the testimonies and the questions and on and on. It was quite a valuable thing for me to see Washington at work. I came away quite impressed with the level of insight and intelligence that the congressional offices, the OMB, the Congressional Budget Office and others had with respect to these subjects. I mean, you think that people can't understand intricacies of a program like Shuttle, given the fact that they've got a whole government to run, but they're organized in such a way that they had good people doing that, and it was quite a learning experience for me and quite an enriching one in the sense of getting a sense of what goes on inside the federal government as they deliberate

these budget things and make decisions on what they're going to do and so on. So it was quite a good time.

Now, about that time, because all these payloads were showing up, and on the commercial side, communication satellites, and with the Department of Defense, one of the first questions was, what is this going to cost. What's the price? What am I going to have to pay to get this? And NASA began—John Yardley began what he called a pricing policy. They had to derive a formal document, a formal methodology, I should say, then put it in a document, a formal methodology for how are you going to price this thing. So we had to figure out, well, what is a total flight cost, and then we could divvy it up by how big a person was.

Coincidentally, we were dealing with price segments that were about equal to the way we divided up the cargo bay for the electrical services, so the regular communication satellites were about a quarter of the cargo bay, so they would pay about a quarter of the price. And filling up the rest of the cargo bay was on NASA. It wasn't their risk. They paid their quarter fare, and then it was our job to mix and match the rest of this thing.

So we developed a pricing policy with a built-in assumption of about—I can't remember, 75 or 80 percent efficiency in terms of manifesting, so that we allowed for the fact that we might not always have it completely full, in the way we priced it to people. But that was an activity that went on for some considerable length of time, because there was a great deal of debate on what should be in the cost, that you then divide and get a per-flight thing, what should be in the cost and what should be excluded from it.

After innumerable harangues about it, it seemed to sort out that things that were recurring, that had to be done every flight, kind of got put into the cost per flight. Things that were done for new developments or special things for the cargo bay got put over here on the side under development. So we began to deal with just recurring cost.

But even within recurring cost, there was a great debate about what to put in. For example, things that might not occur to people, the astronauts use a T-38 fleet out here, you know. We've got about thirty or twenty-four of those, dozen, two dozen airplanes out there, and we use them for various things, traveling around, but mostly to keep their flying skills up. Well, they got put into the cost per flight because it was recurring and so on. So there was a lot of discussion about what should be in it and what should not, and we had some standing working groups that went on.

I think Jerry [C.] Bostick was one of the fellows that was involved from JSC, and he was doing that, I don't know, probably for two years, and it just continued because once he got it set up, then the numbers would change every year, change a little bit so it all had to be updated. But it was quite a deal, because John had to derive the sort of methodology for pricing and then find out what kind of cost he was dealing with.

The other thing that was happening in Washington is, about this time Ariane [European rocket] showed up on the scene as a competitor, and we found that especially Chet Lee, who did a lot of this manifesting and negotiating with customers in Washington, payload customers, especially communication satellite industry people, the pricing policy would end up deriving a certain price. Well, these guys would go talk to Ariane and come back 5 or 10 percent less. Well, then NASA would go into a scramble about, "How are we going to—" Because they were competing, as they saw it, for market share. They wanted to win as many customers as they could in order to substantiate these high flight rates that the whole economic house of cards was built on.

So Chet and John were in a never-ending loop of getting a price settled, quoting it to somebody, then the guy would come back and say, "Well, Ariane offered me 10 percent less," and that's what Ariane was doing. They weren't working with a formal pricing policy methodology, to my knowledge; they were working with a market-driven price. Whatever the Shuttle charged, they were going to charge a little bit less.

I have to say that at that time, I don't know about other people, and maybe they had a little bit of the same feeling I did, but I guess I probably didn't take the threat of Ariane competition as seriously as it turned out I should have. I knew it was real, but I just could not quite imagine them capturing large chunks of the market, but they did. They captured a lot of it as they went along.

And then after *Challenger*, they captured a great deal of the market because at the time of *Challenger*, a number of other accidents occurred, on the Titan, on the Atlas, and on the Delta, all the unmanned launch vehicles that the United States had, and there was a whole bunch of satellites queued up waiting for a ride, and then Ariane was still flying. So they were in a unique position at that time to capture a lot of people, and they probably have retained a fair number of those. As a matter of fact, they have a very high market share in the communication satellite business today. But that was coming on line, and it was really interesting.

They had other issues like third-party liability. What happens if this thing crashes and the payload or the Shuttle hits somebody on the ground? Well, there's a lot of debate about that, but in the end, the government provides what they call third-party liability. But it was a big issue at the time and people flailed around with it, with the idea being that nobody else could insure for it. And about that time, as I dealt with the communication satellite people, I became aware of how they used insurance. One of their tricks—techniques, I should say, not tricks—is a standard business technique, which is, if they're taking a risk, they insure it. So they buy this launch vehicle that's got, who knows, 80 percent liability. Well, they'll buy an insurance policy on the launch vehicle and on their satellite. So at least financially they are protected. Now, they would have another problem because they weren't flying and they weren't in space delivering their services, and, by the way, they could buy insurance for that, for loss of revenues and so on.

So we got involved with how all that worked for them, and it was quite an eye-opening thing to see how people insured. I never thought of insurance as applying to the space business from my little old going-to-the-moon perspective over here, but these fellows who were in it for a business used insurance and they used it very effectively to protect themselves, protect their companies from disaster, with respect to this.

The insurance industry that provides that insurance has gone up and down. Sometimes they're making money, sometimes they lose a lot of money, because it seems like accidents happen in streaks. Several rockets go down in the same period of time and then the insurance companies are really hurting for a while. Of course, they up their premiums. So on it goes like that.

Let's see. What else did I want to tell you about? It was interesting being with John in terms of dealing with the customers at the senior level. At the time we were planning to fly some of the interplanetaries on the Shuttle. I remember Bruce Murray, who was—I don't know if he was the center director at the time out at JPL or not, but he was a key player at JPL. Bruce came in and wanted John to buy Titan Centaur backups for all the Shuttles, at 300 million or so a throw. So here was John put in a position of, "I'm budgeting for the Shuttle and asking Congress for that, and you're asking me to go budget another 300 million for two, 600 million, 300 times 2, for two separate interplanetary things." John says, "You don't understand. I don't have any part of that."

Bruce was very mad about it at the time, but it was kind of typical of some of the carryover mentality that people still had. They still weren't sure, and they had a right to be not sure that the Shuttle was going to be there. "So if that doesn't show up, how am I going to get flown? Why don't you buy me one of these?" Well, John didn't do that.

Forrest [S.] McCartney came in, [Lt.] General Forrest McCartney, whom I met later out at Space Division, and he was Kennedy [Space] Center Director for a while. I remember Forrest was in charge of a communication satellite called FLEETSATCOM. It was a

communication satellite to service all the communications with the fleet, all of the logistics and food ordering and orders for people, all the things that you have to do in the way of Navy communications. Forrest was the manager for FLEETSATCOM, and they were flying on Atlas vehicles that NASA was providing to them. General Dynamics was the builder, but NASA was sort of the government agent for them.

Well, there were extra charges and charges still rolling in, and John had to tell Forrest that these were valid charges and he'd have to pay for them and NASA couldn't eat them and, in effect, subsidize his satellite system with NASA funds, because that would be illegal. But it impressed upon John, and it was one of his examples to me of how when we price the Shuttle, we just need to fix-price it. We can't have this dribbling in of cost and, therefore, prices to be passed on to the user, the customer, two years after he's flown. It's just not fair. So we ended up with this fixed-price pricing policy that says, "Here's the price and that's the deal," and so on.

When I got back to Houston, we had to take that price and service people within it, and part of that price included a little sliver for the work that we did, the integration work, but we found in many occasions that people wanted additional services of one kind or another, so we struggled with that for a long time and then we began to talk about standard services which were included in the price and optional services, which they would have to pay extra money for. Yes, you can have that, but if you needed an extra cooling device or an extra radio or an extra this or that, you can have it, but you have to pay for it. Well, that generated a lot of anger and resentment amongst people, because they just wanted to order up whatever they wanted, and they didn't want to pay any extra money for it. So that was tedious.

While I was in Washington with John, John had come to the government from McDonnell-Douglas [Corporation], and I don't quite know what all the legalities were, but

when it came to dealing with McDonnell-Douglas, John didn't want to do that, so he had me do it.

Now let me return to the fact that the Shuttle didn't have any upper stages for the Shuttle to take the payloads to where they wanted to go. Well, McDac, McDonnell-Douglas, had built upper stages that were used for taking satellites from as far as the first couple of stages that the rocket would go up to where they wanted to go. And we began a venture with them where they would fund, they would provide the funds. McDonnell-Douglas would provide the funds to build something that would be the equivalent of their upper stage on Delta, the Delta unmanned rocket, and would take a communication satellite from where the Shuttle left it off to where it wanted to go. And then included in the price to the customer would be the price for the Shuttle and the price for the upper-stage services, and McDonnell would recover their money via that extra charge for their services.

We had two classes of satellite, one which was—the majority of them were called Delta. They flew on Delta, so we called them Delta-class, Delta rockets, so we called them Delta-class satellites. And they fit very nicely. McDonnell-Douglas came up with a design that had a little cocoon that you opened up when you wanted to deploy the vehicle, and it spun on a table and shot out of the cocoon, and you closed the cocoon up. The cocoon was wonderful because it thermally isolated one payload from the next, and it also isolated the payload from whatever attitudes the Orbiter would go to while it was on orbit. So it was a relatively effective, neat solution to helping us manifest the normal satellites at the time.

There were bigger ones. For example, there was an Atlas-class. INTELSAT mostly used the Atlas rocket. INTELSAT is the organization that provides international communications. At least they were at the time. That's grown more. And we tried to provide an equivalent thing for them that would be bigger, that would be Atlas-sized. It couldn't launch up out of the cargo bay because it was so big. It was bigger than that. It couldn't fit in this cocoon. You had to lay it down and then tip it up. We worked on what we

called a payload assist module, Delta-D, for PAM-D, which was the Delta-class satellites, and then we also worked on the same thing, the payload assist module, PAM-A, for Atlas.

INTELSAT was a different organization to deal with. They had an office two blocks away from NASA headquarters. They were in John's office every week, looking for the best price, the best deal, and so on and so on, but they always conveyed a sense of "We really don't want to do this with you guys." As a matter of fact, they never did. INTELSAT never launched a satellite on the Shuttle. We recovered one for them, INTELSAT, I think STS-49. Dan [Daniel C.] Brandenstein. We put three people outside to grab it and so on.

But they never flew with us, but it was over a period of maybe two years, maybe longer, three years, we had this continuous running discussion with INTELSAT people, all of whom came to the table kind of not wanting to be there, letting us know it very clearly that they didn't want to be there, but they were here to listen to what we could do for them and so on. It was a complete different attitude than everybody else that we ran into in the communication satellite industry. Everybody else that we ran into was cooperative, helpful, positive, constructive. I mean, they were all good.

INTELSAT was difficult. It was difficult. They just, for some reason, didn't want to fly, I guess, with NASA on the Shuttle, and they went through all the motions and sought the best deal and the best arrangements and on and on and on, but I think the whole time they weren't serious or they were playing a game or they were only half serious. It was annoying to us, because we spent a lot of time dealing with them, because they were always inventing issues to worry about, and they were two blocks away from headquarters, so they would be in every week with another round of stuff, and it was tedious.

At any rate, I ended up, since I was the McDonnell-Douglas dealer in John's office, working this arrangement for McDonnell-Douglas to provide these propulsion assist modules for the communication satellites, and they did a great job. That turned out to be a very neat

system and worked very well for us as long as we flew those kind of customers on the Shuttle. INTELSAT never did fly, but they were difficult.

Let's see. Let's see. Either before I went to John's office or afterwards, I can't remember which, one of the first—it was probably before—one of the first things we did at JSC was to say—we had this book called Volume 14, it was part of the Shuttle spec. Fourteen didn't have any connotation, it was just one of the numbers. Volume 14 was the environment spec and the payload spec for what payloads would have to see and do to fit, what they would experience and what they had to size themselves to, etc., to fit into the Shuttle. It wasn't how you do it; it was this is what the environments are and the dimensions and everything like that.

Well, we took that and we went around to the NASA centers early on, while we were still naive and innocent. God, we ran into this hostility, just hostile people, and it was annoying to us. I mean, one, it surprised us, but, two, it was annoying to us. People had the attitude that "We don't want to fly in this machine of yours. We're being forced to. We don't even want to talk to you, and everything you tell us we don't like," and blah, blah, and on and on and on. So it was like having a discussion with somebody who comes in the room absolutely determined to disagree with you and make it clear that he's disagreeing with you all day. So it was tedious.

There were some notable exceptions to it, but it was a tedious process for us. When we got done with this round robin of the NASA centers, we came back with a whole new appreciation for again how difficult this was going to be. The exceptions that I can remember were at Langley they had a thing called the long-duration exposure facility, LDEF. They were a pretty cooperative bunch of guys. That went pretty easily.

At Goddard [Space Flight Center, Greenbelt, Maryland], Frank Ceppolino had this idea of building a satellite that was retrievable and reserviceable by the Shuttle, and he was all on board with doing things with us, because he wanted manned retrievable, reservicing,

and whatever else needed to be done, to be an integral part of spacecraft like the Hubble [Space Telescope] repairs are. His concept was, we're going to be putting expensive things up there, we ought to be able to reach it. So his concept lives on more in Hubble than in the spacecraft he was working at the time, but he was pro in terms of working with us.

But a lot of the other people were negative, and it was quite a shock to us. I guess in a way we'd grown up in this manned space flight environment and we had been successful, and we were surprised to run into this reaction, hostile reaction, from a lot of other professionals at the other NASA centers. They didn't like the idea. They didn't like us. [Laughter] They made it clear. So it was quite a learning thing.

Now, when I get back to JSC after my tour of duty with John, the whole thing about beginning to engage the communication satellite, beginning to engage the Air Force, pricing policies, price cost, standard services, optional services, all these things were beginning to take form. But the other thing that was driven home to me in those days was the difficulty of building a high-volume, high-flight-rate system that had to fly a lot and fly with mixed cargoes. I mean, it was clear that was kind of a problem that captured us for a good while. The mixed cargo part was one that lent itself to us finding solutions for. Flying a lot of times was one that we have always, and still today, struggle with, how many times can we fly the Shuttle in a year. But there it was in front of us.

The thing that the high flight rate and the mixed payloads drove home to us is, we need to have simple solutions and standard solutions, and what we were experiencing with people is, those words were anathema to them. They didn't want to be considered simple and standard. They all viewed themselves as very important projects, and it somewhat offended them for us to talk in terms of standard services, because their attitude was, all the services I can imagine are ones that I want to have. So they struggled with that idea, and outside of the communication satellite industry, most of the payloads who came to us from the government, either NASA or the Air Force, wanted lots. They wanted a lot. They weren't interested in

simplicity and standards, although they were interested in very low prices and they were interested in getting all this stuff for free and so on and so on. So it was quite a conflict.

About that time then, I have already done this so far, but we began to address things in different categories. We began to address the payload community in difficult categories. We clearly had a focus on the communication satellites, and that experience for all of us was wonderful. I mean, except for INTELSAT, they were all simple, straightforward businesspeople. They wanted to get their satellite in orbit, they wanted to get it there at a good price, they wanted to get it there reliably, and they were willing to work with whoever the government said was going to fly them. In this case, it was going to be the Shuttle. They couldn't have these other launch vehicles anymore.

So they were very constructive. They were very can-do. The companies that own these communication satellites, sometimes they were governments that owned them, like Indonesia had a set of satellites they were putting up, called PALAPA. The Mexican Government had a set of satellites they were putting up. Saudi Arabia did. The Canadians did. Australia did. All these countries were sponsoring things, and then there were companies that were doing—like Satellite Business Systems, they were trying to put up video conferencing satellites. So within America there were companies. Overseas we mostly dealt with representatives of the government who were the owners of and procurement officers for space systems that the countries were investing in. But, nevertheless, they were all very positive.

It was interesting. I can't remember all the names of people. There was one fellow, I think it was from India, and he was the most informed man in the communication satellite industry that I have ever seen in any business. I mean, he knew everything that was going on in everybody else's satellite program and his own, and so on and so on. Whenever I wanted to know anything about what was going on or couldn't figure something out, I could call him and he would explain to me what was going on and insurance this, and so on that.

By the way, we learned to respect the fact that these folks came to us and they came from different cultures and different places, and they would come with constraints on them, not unlike our experience with the Soviets in Apollo-Soyuz. They would come with political constraints perhaps that we would not be aware of, nor would we comprehend if they told us what they were. So we always felt that there was a certain respect that we owed their positions, even if we didn't always fully understand them, and we sort of tried to build that into our people, that, yes, these guys, sometimes they don't do things the way we do, but they have their reasons. We could not possibly fathom them all. Some of their insurance policies were complicated and would cause them to do things one way rather than what we thought would be the obvious way, and on and on and on.

The best example I can give you of that is, later on in the flying stage, we flew two satellites, Westar and PALAPA. We put the Westar vehicle out first, and the bloody thing stopped working, I don't know, 20 or 30 seconds into its burn. Something went wrong. We didn't exactly know what. Something went wrong with it, and the satellite was stranded in low Earth orbit and basically useless for its mission. By the way, we went back later and retrieved it and another one.

So here are these Indonesian guys over here in our control center, little guys, and they're worried, and they have all their own constraints on them, which we don't even know what they are. I don't know what kind of system they live in or what their incentives for success and penalties for failure are. I don't know. So all of our little NASA engineers, especially our people in headquarters, were jumping up and down, trying to give these guys advice. I used to say to them, "Look. Shut up. You have absolutely no right to give this man advice about what to do." The question was, should they go ahead and deploy their satellite. This thing that they were flying on, this PAM-D, the upper stage, had not worked. They had the same kind, same type. So was theirs going to work or not? I don't know if it's going to work. Nobody else did either. But all these NASA guys were trying to influence

these guys as to what they should do, and I said, "Look. You have no understanding of what it is that's motivating these guys and what their constraints are and what they've been told to do and not do and so on. They've got to decide in their own system of values and their own system of business arrangement and political constraints, whatever they might be. They have to figure out what they want to do."

Well, I had to hold off my Washington office, Mike Weeks and General Abrahamson. They just felt like they just had to tell these fellows their best opinion, which was not to deploy. I said, "It's not our call; it's theirs. If they want our opinion and ask for it, we can tell them. But if they don't ask for it and they don't make any attempt at wanting to know what we think, then we ought to stay the hell out of it."

Well, I had to be away for a couple of hours, had to go to [Texas] A&M [University, College Station, Texas] for something or other with one of my kids. I got back, and I'll be damned if I didn't find out that the two Washington guys had tried to influence the little Indonesians about what to do. God, I was so mad at them, I was hollering and ranting and raving at them. The Indonesians did what they thought they should anyway. But it was an example of sort of this NASA culture now dealing with all these other things, and not being able to contain itself. I mean, we at NASA march to our own drummer. These folks march to different drummers, and we're trying to make them march to our drummer.

So when I got back, I hollered and yelled at all my management for messing around with my customers, and they deployed, it didn't work, and we retrieved them nine months later, but that's another story.

Let's see. Where did I get here? So, DoD, they had good contractors, Hughes, GE, RCA, Ford, and others, but the standout company was Hughes. Hughes was a terrific company in terms of performance, in terms of the people they sent us, and in terms of their attitudes. They were always completely "can do."

Best example is later on when the SYNCOM failed and we went back on Joe Engle's flight and fixed that. We did that in three months. Three months. And, of course, the satellites that were lost temporarily on Westar and PALAPA were Hughes satellites, I believe, so Hughes was involved in that operation. But they were always good. They were always extremely constructive. They were very much like the NASA technical community, the people we dealt with. They were on the same wavelength as we were, so it was relatively easy.

I've talked about how we got the upper stages. But at that time, there was additional upper-stage requirement that was primarily coming from the Department of Defense. They needed to put up bigger satellites than anything that the commercial guys were doing. They needed to put bigger satellites up at geosynchronous, 22,000 miles constant point over the Earth altitude.

There was great debate at the time as to what kind of a thing to build. Some people wanted to build liquid upper stages, liquid propulsion systems. Some people wanted to adapt the Centaur, which was a hydrogen-oxygen stage, and I only say that because hydrogen-oxygen is a little bit more dangerous. Hydrogen is difficult to handle. You've got to keep it. You can't have it leaking around. You can't have any of those things leaking around.

But there was a general disposition in the mid-70s that it was not a good time to start embarking on a development of a liquid-based upper stage. So it was decided that it should be solid, a solid rocket upper stage, which was perceived as a less risky thing. You didn't have to worry about plumbing so much and leaks and other things like that, or getting rid of the propellant if you had to land the vehicle back on Earth in case that you didn't deploy it for one reason or another, or you had an abort.

So solid was the way. And the Air Force got started on something at the time they called the Interim Upper Stage, later became the Inertial Upper Stage, and they save the acronym by using the same IUS. We got involved in that in a big way because that was

another one of these integration projects, and it had the flavor of using up all the services plus some more. It had that flavor, and it was very redundant, had a lot of requirements and a lot of service requirements and so on, but it was a suitable system. It didn't enjoy fantastic success in terms of its ultimate use on the Shuttle, but it's also been used on unmanned launch vehicles that the Air Force has for some of their missions.

But that was kind of an interesting process, and I talk about it because we deliberately started on the track of using a solid rocket motor. Later on, several years later, we got roped into really putting the Centaur on board the Space Shuttle in order to provide the higher propulsion energy that some of the new interplanetaries [unmanned robotic probes] required, and we spent a lot of time in the '80 to '85 period, maybe '82 to '85, integrating one of these Centaur stages into the Shuttle. It was very difficult. We had this big quantity of hydrogen-oxygen, and we had all these concerns about what do we do with it if we have to abort, how do we get rid of this stuff. You can't just indiscriminately dump it, because it'll catch fire. It was complicated stuff. Plus they had little nuclear devices for power for the spacecraft, which they had to have because they go a long way from the sun and they can't use solar panels. So we had all these complicated cooling mechanisms and release and so on and so on. So those interplanetaries were kind of complicated.

Let me go back to the Department of Defense. So they had this thing that they were going to work on, called the Interim Upper Stage, became Inertial Upper Stage, and we worked on that, integrating it into the Space Shuttle, and that took a lot of energy. But they also had, of course, the real reason for all this was a lot of payloads, and they had a lot of them that were classified and then a lot of them that were really classified. So we began to work with those folks.

We ran into, in many cases, the same problem. There was this general resentment in the officer corps about having to fly on the Shuttle. They would prefer to have continued to fly their vehicles on the launch vehicles, because in those cases they were the owner and they

were the clear boss. In other words, the Air Force would contract with, let's say, Martin-Marietta [Corporation] at the time for Titan, and Martin-Marietta was completely responsive to them. In our case, you had a government agency interfacing with another government agency, and it's not quite the same relationship as it is with a government agency and a contractor. It just was not the same thing. And they chafed under that arrangement quite a bit and it never really fully resolved itself.

I would say, jumping ahead some, is that when people went all the way through the process and flew, they were generally happy, but on the front end, they generally did not like what was going on and complained about it fairly regularly.

But they had a high degree of emphasis on integration. I think they had been burned a number of times on integration failures, technical mistakes, so they spent a lot of time working on it. They required inordinate attention. Compared to the communication satellites, who strove for a simple arrangement, the government users seemed to strive in the opposite direction. They loved to make things as spiffy as they possibly could, which meant complexity, which meant time, which meant money, and the paradox between trying to get a cheap flight and then all this stuff never really seemed to trouble them very much. It troubled us a lot because our budgets to service them were kind of squished down because we didn't want the cost per flight to be any higher than it should, so we had a limited set of money to do these studies and service these guys, but they had an unlimited appetite for services.

So it was a conflict from the word go, and it was a conflict also because they wanted to be in control of things, and they weren't as in control as they would have been had they had a contractor. Government to government is just not as satisfying to them.

The other thing that they worked an awful lot on was performance. By that I mean they wanted to get the maximum throw weight, payload weight, out of the Space Shuttle that they could. They had all these analysts who were always inventing things that we could do to get an extra little bit of weight here and a little bit of weight there, and it used to just drive

us to distraction. They were constantly, constantly, probably for good reason on their side, but, nevertheless, from our point of view, constantly driving us to add 500 pounds, add 500 pounds, add 500 pounds, get 1,000 pounds here, get 1,000 pounds there. It was just never-ending.

And they did a lot of their own analytical things, and they would always come back in, and usually what they had done was either complicated or something that we didn't want to go regularly. There were reasons why we didn't want to do some of these things. It required a lot of special analysis for every flight and on and on. So this was another one of these money-eating things. But they just were fanatics on the subject of getting the most possible performance out of the Space Shuttle as they possibly could.

We had a great deal of difficulty with that because most of what they were trying to get performance for was out at Vandenberg [Air Force Base, California] on the West Coast. In the NASA community, NASA had this fixed point of view that the Shuttle could throw 65,000 pounds out of the East Coast. That was our spec. We know how to do that, etc., etc. So people were comfortable with that.

And there was a general perception that stuff that flew out of the West Coast, because of the orbital mechanics, was about half. Okay? So the Air Force used to always talk about 32K, half of 65, flying out of the West Coast, but they wanted full tanks of this and full tanks of that on the propulsion system and on the cryogenic system and on this and that and the other thing. And we always had trouble explaining to other people how the basic requirement and then all these other requirements added up to more of a requirement than what we were facing with on the East Coast, and our management in Washington would get these complaints from the Air Force that we were being uncooperative all the time. I mean, it was a very closed loop and it was a very tight loop to Washington, for the Air Force guys, because they were hooked into all the highly classified circles and could make a lot of foot-stomping noises at NASA.

So NASA was always calling me, saying, "Why are you guys being so difficult?" So Leonard and I, Nicholson and I, said, "We've got to figure out how to explain this to people." So we finally took all the rules that we were using for Vandenberg and said, "Let's apply them to the East Coast and turn the 65,000 into a new number that would be an equivalence performance number for what they are trying to get us to do on the West Coast." And instead of 65, it was 72K. In other words, we were driving the system. We were trying to get 10 percent, or thereabouts, more payload, in other words, push it harder, push it harder with either engines' thrust going through the atmosphere, whatever, that all the NASA community had come to accept as acceptable at 65.

So when we finally made the transposition from if we did on the East Coast what we're being asked to do on the West Coast, we would have to fly 72,000 pounds' worth equivalent payload. Then it was like the light went on and we started to get some help. But until that time, it got lost in all the mushing around of the numbers and what was in, what was out, and on and on.

But, nevertheless, that didn't stop it. It continued. But at least that was a breakthrough in terms of illuminating for the NASA community what we were being asked to do on the West Coast. It was quite a bit more in terms of driving the system hard, harder, through the atmosphere and with the engines and the loads [unclear] and everything else. It was quite a bit more than we were asked to do on the East Coast. So we made a dent with that, finally.

Classified payloads. We also had to start dealing with this idea of handling security, and that was a long-term issue for Johnson Space Center and our office and the people at Space Division, which was the name of the Air Force unit at Los Angeles that took care of all this stuff for them.

Now, security. Handling security is an interesting problem, because it depends on what you assume the threat is to try to penetrate your defenses, and therefore it gets to be

how much do you want to spend for this. You can put a big fence around the place or you can wire-cage the building, you can figure out all the wires and you can cyber-lock every door and on and on and on. Most of the expense was electronic security. But it was ongoing for a long time.

Now, the Air Force community came to us with these requirements, one, didn't want to be here in the first place, and, number two, they wanted to make a point that we civilians could not take care of—my take on this, Glynn's take on this, and all of the NASA people, was they wanted to show that we civilians could not handle the security requirements that they had. So they just used to kind of drive us in circles with one requirement after another, after another, after another, about how we could run missions out of here, and they would give us requirements, and we would try to figure out how to do them, and then we'd tell them what it cost. Then when we told them what it cost, it would drive them crazy and they wanted ten dollars' worth of security for a buck's worth of price. I'm exaggerating, but it was that kind of argument.

Now, one of the crux things that happened was, in the late seventies, General Henry, Dick Henry, who was running Space Division, the Air Force unit out in Los Angeles at the time, and who had been here when he was a young captain or major in the sixties, so he had, as opposed to everybody else who had this resentment attitude towards us institutionally and even to some extent personally, General Henry had kind of the opposite opinion. He was kind of partial to having been part of the Apollo era, and he was partial to the people. He knew us.

So he came to Houston one time to review a number of subjects, including this security business and why it was costing so much. So we had this briefing for him, and I'm there telling him about it, about the security. I go through all the requirements and here's how we're going to implement it and here's what it costs. Complicated, multi-chart presentation, but that was the simple version of it. I showed him a number that was, let's say,

35 million dollars, and he looked at that for a while and he says, "Just a minute, Glynn. What is that number there?"

I said, "It's thirty-five million dollars. We will do all these requirements this way, and it costs you this. You'd have to pay for it. It costs you, General Henry, 35 million dollars."

Well, that turned out to be a bombshell, because the colonel who had been interfacing with us had been telling him that we were telling him it would cost 100 million dollars, three times that. This is no kidding. It sounds like you can't believe this is the truth. But what he had been doing is, he'd been taking all of the things that the Air Force wanted to do for this and other programs, IUS and a bunch of other stuff, he took all the kitchen sink and the bathtubs and the commodes upstairs and he threw them into the budget for security by JSC. Okay?

So instead of honestly representing the security cost at 35 million, he was representing the security cost, which he used as a line item, and included all this other trash, two times as much as 35 million, and he had been telling all the people in the Air Force chain of command, including General Henry, that it was 100 million dollars. After that meeting, he never showed up again. [Laughter] He resigned, left the Air Force.

That was one of our victories of sorts in this process of dealing with that, if you can call that a victory, but it was, I wouldn't say typical, but it was somewhat characteristic that people were painting us, who were trying to do this for them, really in the worst possible light. I don't know what all the motivations could be for that, but there was a tendency for them to paint what we were doing in the worst possible light, and there was a tendency for people, when they were unhappy with the integration process or anything else, like security, to call Washington headquarters. They'd call the administrator, deputy administrator, and I'd be on the carpet for it, like performance. Whenever they wanted 100 more pounds or 500 more pounds and I couldn't deliver it, I was on the carpet for it, and why was I being uncooperative, and on and on.

So bless his soul, you know, bless his heart, General Henry helped us in this one case, where we just would have been beaten up regularly for having such an expensive—it's almost like political discussions. Nobody talks about the real facts or the real numbers; they talk about "it's too expensive" and "they're too high" and "these bad guys this" and so on and so on. So we ended up getting tarred with that brush, and then everybody just painted it and painted it and painted it and waved it at us then.

So we were a little bit in the middle of a difficult situation, probably more difficult than we even realized, because a lot of what the Air Force was trying to do was very real, like on performance. They really did need performance, and that was fine. It's just that it was trying to be disguised as normal-normal when it wasn't. It was extra normal, and we were just trying to be sure that everybody understood that and we had to do the things that it would take to get there. So we got tarred with the brush on that score.

But control mode is what we ended up calling the solution for the security protection here at JSC, and we ended up using it then on a number of flights, and it went very well, and the people who worked on it did a good job.

BUTLER: If we could pause here for a moment, we'll go ahead and change our tape.

We're back on.

LUNNEY: Okay. So I think that the experience that we had with the Air Force, which, by the way, had its high points and its successes, but it was years of difficulty in getting to some of those successes, is really probably another case study, because here you had the two government organizations that were being asked to, in effect, depend on each other. We depended on their payloads for traffic and for our rationale for being, and they depended on us for transportation. But either the way in which it had been coerced within their chain of command or just the fact of it in the first place gave them considerable cause for resenting us

and acting it out. And we probably responded poorly at times, so I'm not saying it would all be just that they behaved somewhat improperly. Probably we did too at times, because it got to be a fairly testy relationship.

Now, in retrospect, the fellows—the men, primarily males—in the Air Force, they have a different kind of a mentality also than we in NASA did and do. They are very sensitive to command and control and chain of command. I mean, we deal with it in NASA for executing programs, but they're even more sensitive to it in terms of controlling things that they thing should be under their command.

I think they just had a longstanding difficulty with trying to have something that was very important to them, their payloads flown, executed by this other government agency called NASA, and they didn't really have the control. The DoD does not control NASA. So the loss of control, or the degradation of control, just was against their grain. It was against the way they've been taught to think and operate all their careers, and therefore gave them a great deal of difficulty, and it manifested itself in this resentment and this constant positioning us to look bad, this constant set of that. But it derived from their loss of control and lack of control, lack maybe more than loss. It wasn't like they lost it, but they didn't have the control that they used to have in the past, and it just upset them a great deal.

Frankly, it ought to be a lesson for people who try to do something like this, of this nature, at least, again. I don't mean Shuttle, but anytime one agency is dependent on another for vital function and so on, it's grounds for things to become difficult. They were very interested in low price. They always wanted to get the low price, but they always wanted the high-end services. They were always interested in much more analysis, much more this, much more that, much more testing, much more proof, much more insurance, than we provided, for example, than the communication satellites. So they liked the low prices as much as the comsat guys, but they were hard over on high servicing.

They had this tremendous emphasis on performance of the Shuttle and how much it could throw, and we went through lots and lots of hoops which require analysis, studies, all translates into money. Everything I'm saying here is money. High services means money, cost. So however much you engage in, you're spending money to do these things, and the high performance estimate, the high performance emphasis was a constant thing that cost NASA money.

To some extent, in some cases it was NASA performance, real abilities, actuals, eroding from their specs, so in some respects it was valid. In other respects, it wasn't. So it was a mixed bag and nobody was completely pure on the subject, but it was a constant source of irritation and so on.

The other thing that characterized our relationships with the Air Force was that there was a very short loop in the Air Force for going to Washington, D.C., and, in effect, calling us here at JSC on the carpet for not doing something, whatever it happened to be at the time or whatever. And that became an irritant. It's hard to work with somebody when you know that as soon as he leaves the room he's going to call your bosses and run you down. So that became an irritant and made it difficult for people to continue to act in good faith and be constructive and so on. They just react emotionally to that in a human way, and they get kind of angry about it.

We also had people involved who probably should not have been, and on a number of occasions we removed people who were involved in the process. Either they didn't behave the way they should or they asked too many questions about classified things that they didn't really need to know, because, frankly, we wanted to know as little as possible about that stuff. [Laughter] As little as possible to do our job, but some of the people that we had in NASA just sort of had a penchant for curiosity about it. As soon as we stumbled on that, we could get them out of there. We wouldn't have them in it.

They being the second community that I've talked about after the communication satellites, the last was NASA, and NASA had a variety of payloads, scientific and otherwise, we were going to fly on the Shuttle, and for the most part that went pretty well. The NASA guys were probably in between the communication satellites and the DoD in terms of their demand for services. They were more than comsats but less than the DoD, generally speaking.

But NASA got involved in a couple of things, one in particular that really put a strain on us. NASA got involved in a very special way to contract for the Tracking and Data Relay Satellite System [TDRSS] that Goddard put up. When they first contracted for it, it was very much like a service contract. They're contracting with—I think the outfit was called Westar or Western Union. Westar satellite. I think it was called Western Union originally.

So they wrote this sort of service-oriented contract about how they're going to provide this communication stuff, but they weren't involved in satellites or any of that stuff. So it was a very complicated contract, and the organization that was running it on—I think it was Western Union at the time. I may be doing them a disservice, but I think that's who they were at the time. Their office, as we saw it, was populated with lawyers, as opposed to engineers. [Laughter]

They came down here a couple of times for a meeting, and they basically told us—they told us this. They walked in the room and said, "Look. We don't even know if we should be here. Our lawyers have told us that they aren't even sure that we need to talk with you people or even listen to you people. But we're here, so we'll listen to what you have to say."

So we had a couple of exchanges like that with a bunch of people from the Tracking Data Relay Satellite. The Goddard people were all embarrassed about it, of course. They're too professional to have any truck with that. But this contract had been structured in such a strange way, it was one of these innovations that NASA got carried away with, and they

created something that created more of a problem that it did any kind of a solution, and probably cost them just as much in the end, anyway. But it created this monster, this legal monster that chose to view all of us with great disdain. [Laughter] As a matter of fact, not even sure they should condescend to speak with us.

So we had a couple of rounds of discussion with those guys, and it eventually resolved itself. I can't remember anything specific that caused it to resolve itself, but they came into it with a bunch of lawyers saying they didn't even know they had to be there to talk with us. "So how the hell are we going to fly you on the Shuttle?" [Laughter] But that didn't bother them. They were free of that.

So on the NASA side, we also interacted with JPL, who, by the way, is also a very high-performance organization, did a lot of very—still do—a lot of very great things, but they really also wanted high performance to shoot their probes to the planets. They wanted to be able to have as much mission capability as they could. They reconstituted the argument about having a liquid-fueled stage called the Centaur, hydrogen-oxygen stage in the cargo bay. I can't remember when. Probably '80 or '81, thereabouts, after the IUS, the solid kick stage that had been in work for quite a while by the Air Force and Boeing. JPL, in effect, having gotten them to build this thing, some of which was devoted to meeting their requirements, in other words, NASA got the Air Force to build this thing and meet some NASA requirements, all of a sudden NASA's requirements were being pulled away from this Air Force development called IUS.

So we started to work on this Centaur. Frankly, we were in the position here at JSC of, in effect, having to prove that we could not do it. It wasn't, "Hey, can you make all the technical arrangements to put the Centaur," like how do you dump it during abort and safety, sensors in the cargo bay to tell you if any hydrogen is leaking, and all that. A lot of complicated stuff. So it wasn't a question of "Can you do this?" It was a question of "Can you prove that you can't?" Not expressed in those terms, but executed in those terms. That's

the way the thing was dealt with. And basically we could not prove that we could not, so we set about trying to do our very best to get it done.

At the time of the *Challenger* accident in January [1986], after I had left the program, we had two Centaur missions scheduled in May of that year. The accident in January. The following May, we were to have two interplanetary Centaur missions flown on two different Orbiters. An example of perhaps some degree of unreasonableness within the NASA hierarchy of trying to—this is a big bite technically to make, and here we were not only launching one of them, we were going to launch two of them in a one-month period, about a month period. That was part of the loading that was going on in NASA at the time of the *Challenger* accident.

By and large, we found JPL, as an organization, to be very professional, very good at what they did, amazingly good at what they did and what they do today. Probably the biggest difficulty we had with them was this whole idea of putting a Centaur stage in the cargo bay and all of the attendant problems that went with it. But it was constructive, for the most part, for them. And the rest of the NASA payloads were not too demanding, so it wasn't too unreasonable and it went along all right.

But we found ourselves driving back to the communication satellite industry as a model for how to do business. Their whole attitude was one of, "Give me the simplest way to do this, with the simplest number of meetings, the simplest number of discussions, the smallest amount of paper, and I'm happy." The government people on the other side were, in varying degrees, much more on the other side of the gulf on that score. But it was very helpful for us to be able to deal. We learned more from the communication satellite industry than they learned from us, but it was helpful to us to have that as a model, to see that people could successfully run satellite programs without all the attendant hurrah and extra analysis and spending of money that some of the other government users required, government customers.

So it was an eye-opener, and we came to love working with the communication satellite guys. They were just great people to work with. They learned a lot, they were very open, they would tell you what things were going on, explain things to you, and if at times what they wanted to do was not quite understandable in our frame of reference, they would explain why, for business reasons or insurance reasons or some other reasons that they wanted to do something like this. They usually had a very good reason for what they wanted to do, and once understood, it was easy to see their point of view. Although we got to the point where we would accept their point of view without even understanding it, because we knew they always had a reason for it, so we didn't have to understand it. So that was that.

Now, in the course of all this, so we had all these different kind of users, customers, with all these different kind of mental attitudes and desires and requirements and so on and so on. It's just a wide range of opinions about what they wanted and how much and so on.

So we began to try to generate a generic process for handling them, a generic way to take them from approximately three years before launch, approximately, down through a series of technical reviews that would culminate in a successful launch. Leonard Nicholson and Larry Williams were great at this stuff, and Leonard especially.

They and I and the office at the time, we created a document called Shuttle Payloads Integration Activity Plan. It was basically a road map for "Here's what we do. When we meet you, there's this paperwork and here's what needs to be done. Then we'll meet you again in six months and then we do this stuff." Then about halfway through the process, about eighteen months—it's different now; it's about twelve months—halfway through the process, we had what we called the Cargo Integration Review, where we played back to the customers, "Hey, on your flight you are manifested with so and so and so and so, and here's what you all are doing to each other and here's why we think it's okay. Here's what the deployment sequence is and here's how we're going to meet your requirement for this and that and the other thing."

So it was a technical playback of how do we meet. On the front end we invented this thing called Payload Integration Plan. The center guys all called them PIPs. It's a form of document, it's a standardized thing. You could literally fill in the blanks. If you were willing to fly a completely standard thing, redesign it so a communication satellite could fill in the blanks and hand it to us, and we could fly them. Then it had some annexes that had more detailed information depending on whether they were doing EVA this or whatever.

But we had a very nice system, and today that's still the way they handle payloads. Then we had this Cargo Integration Review and then we had several other assurance reviews as we approached the Flight Readiness Review and eventually the flight. And we created this kind of three-year set of milestones. In three years we do this, and this is how we document it. In two and a half years, we do this, and here's how we document it. Here's what we'll do, here's what you have to do, etc., etc., all the way down.

We also had a safety process. Now I'm back to the fact that we owned and were responsible for the Orbiter and for the crew. Therefore, we had safety requirements that we wanted the satellites to live within, which, in fairness to them, were more than they had to deal with when they were on the unmanned launch vehicle. So it was another set of requirements, and we had three phases. We gave them a book of requirements, then we had three phases of reviews to be sure that those requirements were met and that we had extracted from them, solicited from them the information that we would require to be sure that this thing was okay.

When we first started that, it was just a hodge-podge mess. I'm going to say a name here I don't mean to connect with hodge-podge mess, but Bobby Miller was one guy running the safety thing, and they had compiled some requirements, but it was almost like random. They would have the mechanical requirement and an electrical requirement and a radio frequency requirement, then a mechanical requirement, and then something else that wasn't a requirement. It was a hodgey-podgey thing.

So we organized a document into logical groupings of subjects, and we basically then documented that and evolved it over a number of years, providing it to customers and then going through these phased staged reviews to be sure that they were compatible with the intent. Sometimes their solutions would be more innovative than we had imagined, so we'd have to go through a discussion and be satisfied with the intent.

The safety process also brought great screams from especially the government people. Never had a screaming from the communication satellite people about it, but the government people, government customers, would rant and rave about the safety process and so on. We never could find anything to take out of it.

But all this took time, and we didn't invent any of this stuff in the abstract, and we didn't invent it before we met the first customer. We met and interacted and dealt with a variety of people, and then we began to evolve some way of dealing with all this that would be logical and reasonably uniform and generic so that anybody could understand it. We did that. Sometime in the second half of the seventies we published all that, and then basically the center today runs on that system. Probably some things have changed a little bit, timing and so on. They can do it at fifteen months rather than eighteen months or whatever, but it's the same system that we put in place twenty-some years ago to do that, and it has served everybody very well.

As I was explaining to you earlier, people would grumble about this and grumble about that, the process was too cumbersome. Mostly the people who wanted more and more services, where the people grumbled it was too cumbersome. So on several occasions the volume on this grumbling got so high that on at least two occasions I had to do something about it. So one time it was coming from the Air Force, all this unreasonableness on the part of us here at JSC, which is peculiar, by the way, because we had completely opposite motivation. Our motivation was to be as simple as possible.

But anyway, so I had a letter written and got it through the right channels to the Air Force and to some under secretary, that says, "Look. All this griping is going on and all this grumbling about this process. Fine. We accept that you're unhappy with it. Therefore, we want you to chair a review and we will come in, you come in with whomever you want on your team. We will tell you what we are doing and why, and then you can tell us, based on your experience, what we should change." Okay? It was like "Put up or shut up."

And they had an under secretary or some title like that named Plummer [phonetic], who ran this review, went through several months listening to all this stuff. When all was said and done, they changed absolutely nothing. They changed absolutely nothing. As a matter of fact, the basic attitude was, "Well, if we were running this system, that's about what we would do. That's pretty close to what we do in the launch vehicles today," etc., etc. That's what they did.

A year or two later, within the NASA community, same sort of stuff, yapping about the process and cumbersomeness of it and so on and so on. So I did the same thing, and we enlisted a guy who was in some position at Lewis [Research Center, Cleveland, Ohio]. His name was Andy Stofan [phonetic]. He had worked on Atlas Centaur, Andy had. He was project manager for Centaur for a while at Lewis. And Andy was relatively hostile towards the Shuttle as a concept. He was not a friend of. He was not a NASA friend of the Shuttle. He was an adversary, I guess I would say, of it. So we said, "Fine. Same deal. Put up or shut up," nicely put in bureaucratic language, and suggested that somebody—I can't remember if we suggested it or somebody else did—that Andy Stofan run it.

Andy Stofan ran one, came in. When he got done, I could not get him to give me a report. He would not give me a report. He had no recommendations for change, but he would not document that fact. I mean, so it sort of validated a lot of our experience and, frankly, what had developed by that time into something of an attitude about it that these people are just griping for the sake of griping. I mean, two high-level commissions, under

secretary and might have been the center director or deputy center director or something like that at the time at Lewis, when we asked him to do it, which was probably in the early eighties, but it was one of those "Put up or shut up. You guys think this is so bad, come in and review it technically, tell us what to change," and you get no answer. He would not write a report. He would not write a report on months of effort.

So, take that for what it's worth. What would you think if that happened to you?

BUTLER: I'd say about the same thing.

LUNNEY: So anyway, we did that a couple of times. Then internal to NASA, the Shuttle program was in development and one of the natural things that happened in development is the weight of the vehicles keep creeping up, the performance keeps creeping down. We were on the front line of the performance question in terms of trying to satisfy especially the Air Force and the interplanetaries who, by the way, had very high performance requirements, even from the Shuttle and the upper stage.

So we were always struggling with that, and our headquarters, John [F.] Yardley and so on, they would view us as, "Why are you guys having all this problem?" Because within the development program, although the weights were going up, people would say, "Well, the weight is going up, but we're going to do this or that to offset it," blah, blah, you know, this performance trick. Well, some of those could be done and some couldn't, but John was getting, from the development team, a kind of—he was not getting a red alarm that the performance goes down. He was getting some other sort of message, or maybe it was lost altogether. I don't know what.

We got called to Washington a couple of times because people thought we were misrepresenting the performance of the system, when, indeed, we weren't. We were completely tied in and it was very accurate in terms of what we were portraying as the throw

weight, the performance of the system. But we were caught in the middle. We were caught in the middle. We were caught in the middle with all these customers, because we had a limited budget, we'd invented this standard services, optional services. "Here's what you get, standard price. If you want some more, you pay some more." And in the safety process we were constantly under criticism for that, and yet nobody could ever recommend anything to do other than what we were doing. So it was really a frustrating thing for us. I mean, we just sort of went on with it, but it was kind of a constant source of conflict and irritation for us and for everybody else, I guess, too.

I talked about manifesting up at headquarters, because that was their role. We had a group here that technically supported them, but Chet Lee's office did a lot of the negotiations with the customers, which included price and included where they fit on the manifest, which flight they're on, which payload. And Chet did a hero's job on that score. I mean, he was involved in more scrambling to try to provide a price to people without breaking the generic policy ground rules, if you know what I mean, because our competitors would be in saying to other people they can do this and that and the other thing. So Chet was always trying to maintain Shuttle's market share, which he should, that was his job, without giving away the store. But the other thing that was constantly doing this daily change, hourly change, was this manifest thing. It was a joke. I don't mean a joke, but it was a matter of some humor that we had so many variations of manifest floating all the time.

But they were, I guess, a manifestation of how dynamic everything was at the time and who was going to fly and who wasn't, somebody delayed, somebody had to move up, this, that, and the other thing happened, and so on. So it was quite a time. But Chet did a hero's job for NASA in those years, I think. We always had a good relationship with Chet from previous programs, but through this whole four- or five-year learning period and after that, even, when he was continuing to do that. He finally left NASA at some point.

But it was difficult. It was difficult for the Washington headquarters people in the Office of Space Flight, because they were trying to keep this thing whole and keep it the best they could, and they often found themselves struggling with interpretations of what they should or shouldn't do in terms of pricing. You know, the controller's office, for example, would often find that they shouldn't do something. They were trying to do something for the right reasons, but sometimes they would run afoul of a rigorous view of what should be offered and what the Air Force should be doing, and so on. So they struggled a lot with that issue, and I think they did the best that they could.

Now, looking back on all that stuff, by the way, I was in doing that until 1981. We flew STS-1, and then I got into the Shuttle job. Looking back on that, it was quite a high-energy time. Most of the NASA people here at the center had relatively little to do with it. We had kind of dedicated teams. We had a program office that was probably thirty people, and then we had dedicated people from each of the major directorates that would work with us on these things. We had loads guys from the engineering directorate, mechanical guys, and we had some ops guys from flight ops and so on. We integrated crew into that process as they were assigned to flights and so on.

So it really ended up being a pretty good process for what we were trying to do, but it was complicated. It's not a simple matter. As a matter of fact, there was a fair bit of attention paid to whether there was a breakdown in the safety requirements and the safety system at the time of the *Challenger* accident. It became clear that it was not a payload problem, but rather an SRB [Solid Rocket Booster] problem. But people reviewed what had been done there, and this is not always the best thing you can say about it, but they could find no fault with it. That doesn't mean it couldn't have been 10 percent less work than it was, but they could not find any fault with it and again could recommend no reduction, simplifications, or decreases in the kinds of things that were being done to be sure that the payloads wouldn't cause something that turned out to be *Challenger* in January of '86.

So again, to the credit of the people who persevered in terms of doing their job through all those years of kind of being called on the carpet, which I was all the time and they were with me, this system that we derived and the integrity with which it was basically executed were good. They were good.

The Air Force/DoD connection, I've always talked about that. Anybody who wants to do something like that again, where one agency is major dependent on another for a significant part of their real role, needs to think through that and be sure that they've mitigated the fallout that will automatically and naturally come from it. We didn't do that in our case. It just fell out and we had to deal with the fallout.

The problems that we had with cost, with the Shuttle, there's this continuing passion and speeches and etc.'s about how we need to make space transportation cheaper. I don't have any argument with that. Yes, we do. To some extent, though, it's going to require some degree of breakthrough and/or better stuff coming along.

The rocket systems that we fly today are controlled explosions for about five to eight minutes. There's an explosion going on that you are trying to control. The explosion is looking for a way to get out, and it's very, very energetic. If it gets out, you're done. So that implies a lot of engineering analysis of dense cracks, this thing, that thing, etc. It's not like you can just look at it and wave your hand and say it's going to be okay, like you get in your car and you've got a scrape on the bumper. Well, you don't think about that; you drive. Right? Well, you get into something like this, and depending on where the scrape is, it's nowhere near as easy to decide to go drive it.

Plus, the other thing that's true of rocket systems, as differentiated from aircraft, and people tend to make a relationship or analogy at times, rocketships are tested full up with their tanks and all their plumbing and their engines, almost only when they fly. We had some tests. I'm exaggerating.

We had some tests, of course, in the Shuttle system, but they've long passed. So we're basically gaining eight minutes of experience eight or ten times a year with the Shuttle system, experience in terms of what's happening, how to make it better, etc., etc. I contrast that with jet engines. I mean, when I was a boy and co-op student in Lewis, we were running jet engines in laboratories for hours, days, I mean as long as the fuel supply would last, and basically that's why jet engines are reliable. People have run them for immense amounts of time by now, and they've run them in not only test stands, but in full airplanes, and they get just millions not of hours, but of days on jet engine systems in aircraft.

What happens is, as soon as they find something that doesn't work, well, they make it stronger or better, hopefully, and then that fixes that problem. So then you run for quite a bit more time before the next problem manifests itself, and when it does, you make that one stronger and so on. So the reliability of flight systems in aircraft derive from the fact that you get this enormous amount of time on them and that you can continue to improve them as you go along. As you do that, you're extending dramatically the amount of service time that you can get out of the system.

In our case, we fly the Shuttle system or any launch vehicle, but the Shuttle system we fly eight minutes eight or ten times a year. That's eighty minutes in a year. Do you know how much aircraft jet engine interaction time we get in the world? I mean, it's measured in the millions of days, I expect, compared to eight times ten, eighty minutes.

So my point is, we've got this controlled explosion, we have a relatively small amount of test time, flight time, which tells us what's getting weak or what might be a weak point that we could make stronger. So the analogy to aircraft time and so on is quite a bit different. Therefore, launch vehicles, as presently conceived of being controlled explosions, are going to be delicate creatures that we never fully understand because we never really do operate them long enough to fully understand them. We understand how well they work in this narrow band of performance parameters as they go up, but we don't understand them outside

of that, and how hot can you make this and how hot pressure can you make that, what gives first, and what could you do to make it stronger, and what would be the next thing and the next thing. That's the way you build confidence in jet engines, by doing that. You run them to destruction and then make whatever destroyed itself stronger. You keep doing that, and eventually you end up with a pretty long-lived system.

So it's going to take a while. If somebody came up with a breakthrough that is something other than a controlled explosion, then we may get on a different path. But as long as we're dealing with these controlled explosions, there's going to be analysis to be sure that it's okay. So it tends to be a system that is supported by analysts, engineers, and so on, and that's true also of the launch vehicles, unmanned launch vehicles. They do as much, I think, damn near as much, to assure the quality, integrity, and reliability of their systems, and they get caught. Their reliability is probably 90 percent. One out of ten fail for them. Shuttle's done better than that, but it's done better than that by dint of people being very, very careful with it.

There's a main propulsion ducter lying at the Cape that's got a dent in it. Well, you know, there's a whole set of work going on to say, is that dent okay? Has it gotten worse since the last time we said, etc., etc. Do we have to replace it? And so on. That kind of work takes talented people who you have to pay to do that, and it isn't like they're off building something else that you can call back. They tend to be kind of dedicated to it.

So that's going to be the case for a while, and NASA and the country will continue to struggle to find cheaper methods of getting to space, and I hope we do. But I think people have to be careful not to fool themselves about what they're dealing with. It is not something that lends itself to jet engine kind of analogies because of the nature of the beast.

I talked about the Air Force. I think that there's some need for lessons learned there. Somebody ought to do a—now that enough time has gone by—a thoughtful review of that

and see what could be learned just for guidelines in terms of government agencies working together again.

But when all is said and done, the process for integrating payloads and being sure that they're safe, being sure that we know how to manifest them, and being sure that they fly right and so on and so on, maybe could be shaved here and there. I haven't experienced it in recent years, but maybe they could be shaved here and there. I don't think you can make drastic fundamental changes to it. Therefore, the system that we invented almost twenty-five years ago, twenty years ago anyway, is very operative and has served the center over here very well, and generally is probably not understood, because the bulk of the people work on the development side of it still, keeping its—let me call it the operational side, but it's the development kind of work associated with the vehicle. And they don't have much of a sense of what goes on in the smaller world that is represented by this activity.

But I have to give credit to the people like Leonard and Larry Williams, who has now passed on, by the way, Larry has, but Leonard, who's still over at the center, and so many other people that work so hard to make this a good, solid system. They and we endured constant criticism and complaints from people, and we tried always to respond to those as best we could, and we evolved the system over time and it is what it is. We have sought advice on how to make it different, and generally don't get much in the way of recommended changes. We have not gotten very much. I don't think we've ever gotten a recommended change from the outside. I think the recommended changes we had have all been internally generated.

So it's served everybody well. As I said, when we walked into this in January, let's say, of 1976, we had no idea of what we were getting into. We didn't know anything about the Air Force satellite system, which, by the way, is a story that some day ought to be told so that the country knows how much good has been done in that regard, because most of it is classified. But they have served their country well in terms of what they have done with that

mission for satellite work for defense and security purposes. They've done the country a great service.

We enjoyed the communication satellites. I wish they were still flying on the Shuttle. That industry, by the way, is booming, is booming. Today more than half of the money being spent on space systems is in the commercial field. I mean, it used to be like 5 percent or some. When we were doing this in the seventies, it was probably 10 percent. It was mostly government spending either by us or the Russians or the others for government programs, relatively little on the commercial side. Now the commercial expenditures exceed those of governments in space activities. It's quite something, isn't it, in twenty years, and they're putting all kind of systems up. It's just exploding, and it looks like it's just going to continue.

BUTLER: Hopefully that will lead to more support for the space programs.

LUNNEY: Oh, I think it will. I think it will. But it tends not to be support for the Shuttle program and the manned space program itself. It could have been. It could have been. And we've even had some recent opportunities to do that, but right now the Space Shuttle is involved with the [International] Space Station, so the human space flight is back to where it was in the sixties.

It's a self-contained program that's run internal to itself with its own goals and purposes and so on. They service other payloads, but by comparison to what we were trying to do with Shuttle in the 70s, so far it looks like a smaller-scale activity with less national and commercial significance. We may find some, but today, from what you know about them, there's not quite the same significance as there was in the payload community that the Shuttle was about to fly and undertook to fly four or five years' worth up till the *Challenger* accident.

So I look back on that time and what we went through and what we learned and how we translated that into processes for handling people and what we went through in terms of making it as reasonable as we possibly could, and I look back on it as a big success. If you went out and talked to people in the rest of NASA and so on, they would probably give you the other side of that story, and probably even a lot of other minds are still being painted as a very troublesome, complicated, irritating process, but I look back on it and think that it actually was done reasonably well. Could always have been done better, but it was done reasonably well, and ended up with something that served NASA very well over twenty years of flying.

BUTLER: Sounds like it has.

LUNNEY: Twenty years of flying. So that's my story about those years.

BUTLER: Great. Great. We've covered most everything I had down about those years. Of course, you did move on to a few other things with Shuttle, and I don't know if you want to go ahead and continue on today.

LUNNEY: I've got to do kids here in a little while.

BUTLER: Okay.

LUNNEY: I'd like to come back.

BUTLER: Okay.

LUNNEY: Is that okay?

BUTLER: That would work fine.

LUNNEY: Because then I moved into the Shuttle Program manager job, and, by the way, I brought all those guys over with me at that time. We made it all—probably not immediately, but soon thereafter, so we made it all in one office. But there were a lot of guys who did great work in those days, and it was such a small community dealing mostly with outside people who were in some cases negative towards us, that they probably didn't get the recognition or the reward for it that they should have gotten. But I think they know what they did. They know what they did. It was quite a story. It was quite a time, quite a time. It was sort of big bureaucracy's grinding along tectonic plates and we just happened to be at the plate where we kept getting ground on. [Laughter] But all in all, the people handled it pretty well and did a good job.

BUTLER: Accomplished what you were setting out to.

LUNNEY: Yes, did a good job. And we didn't know at the beginning, we didn't really know what the dimensions of this thing we were getting into called payload integration really was, but we sure learned. Took us a while, but we learned and turned it into something that was workable. If you go over and talk to people today, they'll still talk about the same things. It's amusing to me when I hear them talking, because I listen to it now and then, or I hear it now and then, and it's like these things were written in stone by the ancients, you know, passed into the shrouded mystery of time, and they don't even know where they came from. But they all talk about these events, the CIR and the IHSR and the FOR and all this stuff. They

do, they talk about it like it's chiseled in stone and came down somehow from some alien civilization that gave it to us. [Laughter]

BUTLER: I guess it has a longstanding impact, then.

LUNNEY: I think it does. I think it does. The interesting thing about that, and I'm not suggesting that it would be different, but it's interesting because we built that system for high flight rate, lots of different kind of users. We were trying to build a system that could handle this kind of a funnel out here and get it through down here.

It's interesting that, to my knowledge, they haven't done a fundamental rethink of how they should do that when they are now working with Shuttle and Space Station. I think they do it in about the same way. They probably have made some modifications to it. But I have never heard—and by the way, that doesn't mean it didn't happen, but I never heard that they did a fundamental rethink of how to do that, how to do Space Station integration into the Shuttle in order to get it on orbit. I suspect they're using the same methods, and the methods may be fine. They may be just convenient ways of documenting things and documenting requirements and so on.

I think you could go look at it fundamentally and you might not change it very much, but to my knowledge I never heard of anybody taking another look and say, "Okay, we're not flying thirty times a year with all these different people. We're going to fly seven times a year of the Space Station. How should we do that?" You might end up with the same answer, but you ought at least have asked the question, and I haven't heard it being asked.

BUTLER: Hopefully we'll have the opportunity at some point to talk with some of these people that are working on Space Station and talk about some of that history.

LUNNEY: And maybe they've modified it a great deal. It may be modified much more than I think. My impression is, it's sort of a very recognizable child of what we started with twenty years ago, derivation of. But it's probably very recognizable to me if I saw it all, and maybe it should be.

Well, there you are. It's always nice to go on with you guys.

BUTLER: Thank you.

[End of Interview]