ORAL HISTORY 3 TRANSCRIPT

ROBERT F. THOMPSON
INTERVIEWED BY KEVIN M. RUSNAK
HOUSTON, TEXAS – 3 OCTOBER 2000

RUSNAK: Today is October 3, 2000. This interview with Bob Thompson is being conducted in the offices of the SIGNAL Corporation in Houston, Texas, for the Johnson Space Center Oral History Project. The interviewer is Kevin Rusnak, assisted by Carol Butler.

I'd like to thank you once again for coming back to talk with us today.

THOMPSON: You're welcome. We'll pick up, I guess, pretty well where we left off last time. In getting into this time period today as I personally made the transition from Skylab to Shuttle, I think it'd be good to go back and sort of set the national picture, because, again, you don't get approval for major programs to develop new vehicles and develop new capability without the right situation existing in the nation here.

You're using resources out of the Federal Treasury, so the people responsible for spending the taxpayers' money have to be willing to spend those funds for something they think is worthwhile. You clearly have to have some purpose in mind and you have to have some capability within the government to spend those resources and accomplish those objectives.

So the time period that we're picking up on today is 1970, which in April of 1970, I finished my activities in Skylab, which we discussed last time. We had pretty well evolved Skylab from not really understanding what it should be, to having a pretty clear definition of what was to be now, and they were on a very clear path to go and commit to a flight with a dry workshop launched on the Saturn V supported by the Apollo command module launched on the

S-1B. The objectives were to fly three times, one set of three people for twenty-eight days, the second flight for fifty-six days, and the third flight for ninety days.

The real objective then of Skylab was to take essentially residual Apollo hardware with some new development and begin to fly and longer periods of time in low Earth orbit to understand how to live and work in space a little bit better, how to make it habitable for people to stay up to ninety days, how to work and live and eat and exist properly, how to carry on certain experiments.

Also, at that time, I think the national thought process and the national commitment for manned spaceflight was to shift the emphasis away from the Moon, where we'd been focused for the previous ten years. From the time the commitment to the lunar landing was made in the early sixties, until we flew to the Moon in [19]'69, the major national effort was on the lunar landing and safe return. Skylab then was sort of a little filler on the back end of that.

The country had gone through in the late ‘60s some fairly serious studies of where we should go post-Apollo. It was pretty clear that Skylab was a one-shot venture, because the hardware that existed would only support, basically, one flight. There was no real desire to continue to build Apollo hardware. The country had gone through a fairly serious set of studies and had made a decision that it didn't want to go on to a Mars trip. That would be an extremely large commitment, probably extended beyond the technology we had. And you couldn't develop a big rationale that said you ought to spend resources out of the Federal Treasury to take on something like that right on top of major commitment like Apollo had been.

So there wasn't much interest in Mars. Even today, in my opinion, in the year 2000, there's not a tremendous interest in mounting an effort to Mars that would sustain taking money out of the Federal Treasury. You can find zealots that want to go to Mars that will talk to you by the hour about how they want to go, but there's no real national purpose of going to Mars right now. You can say the same thing about lunar follow-on, there was no strong desire to continue flying to the Moon or to colonize the Moon. That was a fairly costly venture and so forth.

I think it is fair to say there was not a strong desire to completely get out of the business. There were a lot of people who argued we should stop flying the people in space, it wasn't worth it, but within the Congress, within the majority of the Congress, within the executive branch of the government, and certainly within the agency, because any agency, any bureaucracy wants to continue itself. Very few agencies plan to kill themselves and take themselves out of business. Certainly those at NASA who'd made a career of this sort of thing felt that manned spaceflight should continue.

So it left some kind of a low Earth orbital program. It was talked about and it's the terminology phrased "low Earth orbital infrastructure," that we should continue to spend at a reasonable level and develop a capability, the vehicles and the capability, of going into low Earth orbit and essentially flying the old space station kind of things that people have been talking about for years.

Now, space station had been existing in people's minds, I guess, for several hundred years. If you go back and look at the history books, people were going build brick space stations in orbit. The [Wernher] von Braun *Collier's* [magazine] articles in the ‘60s had these great big rotating wheels where you could spin the wheel and create artificial gravities so you had an Earth-like environment. It had space planes flying to and from, every hour or two. It was pretty well agreed that some kind of low Earth orbit infrastructure would be the right thing to do.

There's been a lot of discussions on how to build a space station. Should it be a great big thing launched with a huge booster, or should it be modular taken up by a smaller vehicle and assembled in orbit, built up in segments or modules? Well, by then, the practical thing that had a reasonable chance of being funded and supported out of the Congress was a modular space station that you could fly into orbit with something like what we finally got to call a space shuttle. So you could take the modules in low Earth orbit, and if you had something like the shuttle, you could transport people. You could transport modules, you could maneuver in orbit, you could dock, you could work and so forth.

So the practical program in 1970 that you could fund and support for a period of time, ten, fifteen, twenty, thirty years, was this low Earth orbital infrastructure around something like the space shuttle, followed by something like a modular space station. Then you could wrap around that a lot of arguments that we'd like to go into space and do medical research, developing new types of medicines, new types of vaccines. You could maybe separate things pure in the zero-gravity environment than you can on Earth with electrophoresis and things of that nature.

So it was very easy at that time to put together a low orbit Earth structure built around things like space station, experiments in space, even something as grandiose as a large solar-powered electrical generating station.

So NASA was pushing very hard for a space shuttle and a space station program in 1970. Well, the funding in the country in 1970 was such that we still had the Vietnam spending, there was a lot of deficit spending going in the country. At the time, peak spending in Apollo, I think NASA's budget was, it approached 3 percent of the federal budget at the peak in the ‘60s. The [Richard M.] Nixon administration was in power in 1970 and wanted to pull the NASA budget down. They still wanted to do manned spaceflight, but they didn't want to do it at 3 percent of the national budget. They wanted to do it at some lower level, because they wanted to cut down on the deficit spending. We still had the Vietnam spending going on and so forth.

So as we came out of Phase A, the early conceptual designs for the Space Shuttle, NASA still had hopes of building a fairly large completely reusable two-stage winged vehicle, wing booster and winged orbiter, and as I think I said last time, this was a good program for NASA in that there was a large booster for the Marshall Space Flight Center [MSFC, Huntsville, Alabama] to build and there was a large orbiter for the Johnson Space Center to build. Everyone was very happy with that great big two-stage fully reuseable system and it was the front end of the Space Station Program, or a low Earth orbital infrastructure.

You certainly don't want to build a space station first, because there's no way you can get it there, get people to and from it. So it was pretty obvious you build the shuttle first, if you can't afford to build them simultaneously. No one was interested in keeping the funding at the level that would let you start them both simultaneously. So it was a very logical set of A, B, C, and Ds that finally led to a commitment at the national level to build a space shuttle, but a commitment to build it at a funding level somewhat less than the agency would like to have seen.

You can read in the history books about that it was too funded-constrained and this sort of thing, we should have been more visionary and built a bigger, better vehicle that cost less to operate. Well, I think that's a lot of nonsense. That's a lot of argument about he should have married some other girl, he'd been much happier. You don't know how happier he'd been if he'd done that. It just wasn't practical to take on a very large spending program at that time.

Also from my standpoint, the two-stage fully reusable system that came out of Phase A was not a very practical system. It was extremely large, it carried the cryogenic propellants internally, which complicates the vehicle very much. It required funding beyond what you felt you could keep the nation committed to give. Any program that takes more than about eight or ten years to bring to fruition is a sick program. If you have to go ten, fifteen years before anything significantly happens, with the Congress changing every two years, and the President maybe changing every four years, and the Senate changing every six years, if you embark on a fifteen- or twenty-year program and try to sustain it without very much happening, you're beginning to fail before you get started. So we felt we'd like to have something that could come on line in no more than, say, seven or eight, nine years.

So when you put together the funding issues, you put together the practicality issues, and what kind of vehicle to build, and particularly when you have the feeling that it's going to be your responsibility to cause it to happen, it's one thing to sit around and be a visionary and write things and postulate things when you don't have to go do them. But when you have to go do them, you look at it a little bit differently.

So as we came out of Phase A going into Phase B, where we got serious about building a space shuttle now, with all this background I've just been going through, I was most anxious to see the vehicle simplified. Now, we first of all had to decide what it is we really wanted to do, because when you get ready to build a vehicle you can no longer, as I said, just draw cartoons and draw big winged vehicles doing things. For example, if you asked [Leonardo] Da Vinci what he was trying to do with his helicopter, he was just trying to show the physics of flight, probably. The same way with some of the early people who conceived space shuttles and so forth.

But we had to decide in a more pragmatic sense what it is we wanted to do. How big a payload did we want to take to orbit and why? How many people did you want to take? What kind of capability do you want the vehicle to have once you got on orbit?

So we went through a period of time where we were arguing what size of modules to take to Earth orbit. We went back and forth, and we finally settled on a fifteen-foot diameter, sixty-foot-long module. So that set the size of the payload bay.

Now, you can read in the history of the thing that people were looking at ten-foot diameter, thirty-five-foot-long payloads. We looked at different-sized payloads, but we never were very serious about anything other than the fifteen-foot diameter, sixty-foot long, because modular space station, if you get the modules too small, aren't very practical. Plus, when you looked at a reasonable vehicle, making the payload bay shorter didn't really help very much. The fineness ratios of the vehicle and the reasonable-size wings, making it short and stubby didn't do that much for you. So the fifteen-by-sixty payload bay came out to be the practical thing to do.

The 60,000 pounds, there was a lot of argument about whether your payload should be 60,000 pounds. The payload is very critical to you. Anytime you're trying to accelerate from Earth, sitting at zero velocity on the surface of the Earth up to the 25,000 feet per second you have to do to go into low Earth orbit takes a lot of energy. So you have to be careful what your weights are going to be, and you have to be fairly confident that you can achieve those weights, because if you start off to build a 60,000-pound payload vehicle and if the weight of the vehicle grows 60,000 pounds, you've got a vehicle but it can't do anything. So you can't allow your weight margins to kill your program.

You then had to decide how many people and how. If you want to dock with something, where does the docking mechanism go? If you want to maneuver in orbit, how much maneuvering propellant do you take? You've got to have attitude control propellant. You have to have a manipulator arm to help you do work when you get up there. If you're going to build a building, you need a crane or something of that nature.

So we settled, first and foremost, on what it is we wanted to do. We settled on a 60,000-pound payload, fifteen-by-sixty, ten people, an arm or a crane, maneuvering propellant. So those things kind of fixed what it is you wanted to do.

RUSNAK: Along that line, if I can interrupt for a second, what role did the Air Force have in establishing these requirements?

THOMPSON: At the time NASA said they would like to build a space shuttle, they went over and invited the Air Force to participate in the program. The Air Force said, "We would be happy to. We will not help you in the funding, because we think you should get the funding for that. We'll be happy to give you our desirements or our requirements, and if the vehicle meets that, we'll consider taking some of our payloads off of the unmanned vehicles and taking them to and from space with the Shuttle."

Now, they were doing a lot of things with satellites in Earth orbit, and a lot of the satellites wanted visual looking down at the Earth. They wanted fairly long optical path links. So they wanted something like the sixty-foot payload length, just like we did at NASA. You hear a lot of people say we did it strictly because the Air Force wanted it. That is not true. We did it because we and the Air Force both wanted it, "we" being NASA.

Now, the Air Force said, "If you build it too short and stubby, we can't put our payloads on." So we were really happy to build it to where it would accommodate their payloads, but it also accommodated the payloads we wanted. So it was a mutual friendship. Now, some people pushing their own pet ideas said the Air Force forced us to do something, we would have done something different. That's not true.

Let me make sure you know where I'm coming from. Whenever you get ready to go put a program like Shuttle together and actually literally go build it, an agency like NASA then has to put together a program structure. In other words, there has to be someone there to run the program every day. There has to be a manager who's there every day to run that thing, and he has to have an organization. He has to have a staff around him, he has to have a bunch of project people to go build the major parts of a program.

So you can sit down and have the classical organization chart of people in Washington [DC] who have to interface with the Congress and get the money and make sure the overall picture fits what the agency wants to do, but somewhere there has to be some guy with a "program manager" title on and he has to work twenty-four hours a day and make sure everything happens.

People like to run around and find the person who designed the Space Shuttle on his kitchen table, and all of a sudden, well, that's not the way it happens. The design evolves over a period of time with this organizational structure within the government making little bitty decisions every day, every week, not little bitty decisions, fairly significant. Fifteen by sixty, 60,000 pounds, ten people, EVA [extravehicular activity] arm, docking capability, delta V, decide what you want to do. Within the government there is this program organization.

Then you plug industry in to do certain things, like you contract with a company to build an Orbiter or you contract with a company to build an Orbiter and provide integration support. Another company would build a tank. Another company would build booster rockets. Another company would build rocket engines. The program manager sits at the head of this government organization and works hard for ten years and the money comes out of the Federal Treasury and feeds into this system, you'll have a Space Shuttle that you can take to launch pad some day and it will go to orbit. But no one sits at home at his kitchen table on a napkin and sketches a Space Shuttle and all of a sudden it appears. That ain't the way it happens. So if you go looking around for who invented the Space Shuttle, you won't find it. The Space Shuttle evolved out of this organization I'm talking about.

Now, as we came out of Phase A going into Phase B, the phased program planning that NASA had then, and we picked that up primarily out of the way the Defense Department managed their weapons system programs. They had a conceptual phase, preliminary design phase, Phase B, and Phase C/D, is the design, detail design development and evaluation. That's when you really start spending money at significant levels and start building something, getting down to real detail design.

I joined the Space Shuttle Program at the start of Phase B, when we moved from conceptual design to detail design. At that time we had a program group in Washington leading the overall program. There was a fellow named Charlie [Charles J.] Donlan, was an assistant to the Associate Administrator for Manned Space Flight, who was Dale [D.] Myers at that time. Charlie Donlan was essentially leading the Shuttle Program effort out of Washington. They wanted the Johnson Space Center to set up a program office. They wanted Marshall to set up a program office to manage, too, apparently, all Phase B studies.

That's when I left Skylab and came into the Program Management Office at JSC to manage the Phase B study. There was a similar office at Marshall. We wrote some RFPs [requests for proposals], let some contracts, selected some contractors, and JSC selected Rockwell [International Corp.], Marshall selected McDonnell Douglas [Corp.], but both contractors were going to study both the booster and the Orbiter for this Phase B preliminary design with this two-stage fully reusable vehicle that came out of Phase A. The government's RFP requirements specified the two-stage fully reusable vehicle, and so the contractors—if you pay the contractors and give them reasonable directions, they'll do what you tell them or ask them to do. So they started developing these vehicles.

But as we began to, or at least certainly as I began to look at the vehicle, there were things about the vehicle I did not like. As I said, it was too big, too complicated. I didn't see that much need for a big booster just to help you get on your way. The staging velocity was too high. The problem of lighting the Orbiter engines off on the back of the booster, the whole reason for the booster didn't make a lot of sense.

So while we were studying the ongoing mainline program, we also had some studies going at looking at ways of simplifying the vehicle. The studies of the vehicle that was in mainline were coming in at too high a funding requirement. To build the vehicle in a reasonable period of time, seven or eight years, the funding had to go up over $2 billion annually. The discussions between the executive branch of the government and the headquarters of NASA, the executive branch of the government was telling NASA, "You can't really have more than about a billion dollars a year peak annual funding for the Shuttle." And you'll hear a lot of people saying that was a big disappointment. That wasn't a terrible disappointment to me, because I was happy to see the vehicle under that kind of pressure because I didn't like the vehicle we had at two billion. It just wasn't the right vehicle.

So we began to look at some things, well, if you can't have $2 billion and build this big thing, what can you do for a billion dollars within, say, six or seven years? Well, one of the first things we looked at was to put cryogenic propellant inside a vehicle, it's one thing to build an airplane and put aviation fuel in it, which is reasonable to manage at normal temperatures and pressures, but to take hydrogen where you have to cool it down to minus 400 and some degrees, or oxygen, where you have to cool it down to [minus] 300 and some degrees before you can liquefy it and get it at a reasonable volume, and to build that tankage in a shape that would make a flying vehicle, which means you can't just make it a cylindrical tank, you have to shape it, and to insulate it properly and to pre-cool it and to get it loaded properly and to get all of that integrated in the vehicle is extremely complicated.

So if you can get that cryogenic propellant outside and put it in a tank, similar to what we'd done in Apollo, just build a nice cylindrical tank and put some spray-on insulation on it and build you, it also had a simple vacuum bottle, you can get a lot more efficiencies. As I said earlier, if a vehicle gets too heavy, you can't fly up to orbit. There's just a certain—at that time our propulsion was pretty well limited to what we were going to get out of the hydrogen and oxygen, because that was the best propulsion system this country had at that time. It was only practical with certain materials that were available to you to operate that engine at certain temperatures and pressures, which means it has certain performance. We use fancy terms like I_{SP} [specific impulse], but that's how much thrust you get per pound per second propellant you can use, kind of like the mileage on your car, miles per gallon.

So to design a vehicle to go to the orbit, you're in sort of a box. You're in a box of what your propulsion system can do. You're in a box of what kind of weight margins you have to have, what kind of dry weight of the vehicle compared to propellant weight, the so-called, we use a fancy term called mass fraction. That's how much a vehicle weighs as opposed to the weight of the fuel in the vehicle. You have to have a pretty high mass fractions. You have to have pretty high I_{SP}s in order to get a vehicle to fly to orbit.

Also if you're going to fly with a one-stage vehicle to orbit, you have to have extremely high performing propulsion and high mass fractions. But if you could stage, if you could help get yourself along a certain distance and drop some of that weight off, then you can get much more efficient.

So by evolving from the two-stage fully reusable vehicle to the stage-and-a-half partially reuseable vehicle, like you see the Space Shuttle, we were able to greatly simplify the cryogenic propellant issue, we actually picked the higher performance Orbiter engine because it went to high internal pressures. Apollo we'd operated 1,000 psi [pounds per square inch], we went to 3,000 on the Shuttle, we went to hydrogen/oxygen and we also went to a stage combustion cycle where all the propellant that you burn goes through the main nozzle and ends up as propellant. The propellant that runs the turbo machine, where you could pump the propellant, also is burned again in the main combustion chamber to give you thrust, where in Apollo we used a gas generator engine, where we used part of the hydrogen and oxygen to run the turbo pumps and then we exhausted that in an inefficient manner, rather than run it through the propulsion system.

So we went to very high, we went to three times as much internal pressure, we went to a stage combustion cycle engine. We used hydrogen and oxygen. So we got the engine performance about as high as we knew how to do at that time. We got the mass fractions we wanted by going to partially reusable vehicles, rather than everything reusable, because we got the propellant count and got it in a simply module where we could deal with it.

Then it didn't make sense to push the Orbiter partway without its engines running, so we put the Orbiter down on the stack and light the engines and then all we needed were some big JATO [jet-assisted takeoff] bottles, just like we had in World War II to help heavy airplanes take off. These big JATO bottles turned out to be the most practical thing we found for the big solid propellant boosters.

So we evolved in Phase B from the vehicle that came out of Phase A, the vehicle I've described to you, over—I don't remember, less than two years. Actually, the last six months of that was a very rapid conversion of that vehicle, because we finally then were able to get the funding projections to where you could support them. You could get the vehicle to where people like myself, who had to go get it done, felt it was a practical thing to do. We still had the fifteen-foot diameter, sixty-foot-long payload bay. We still had the 60,000 pounds of weight. We still had the number of people we wanted in there. We still had all of the capability on orbit. So, a pretty damn good program, looked to me like, so we were ready to go.

Now, people look back today and say, "Oh, yeah, but you didn't do it right. If you build a two-stage fully reusable, it would be one-tenth this cheap today to operate." Bull. How do you know that? I tell the people when I see them on the street, I say, "Do you know the Space Shuttle is the most expensive vehicle that man has ever built to do what it does? It's also the cheapest vehicle man's ever built to do what it does. It's the only vehicle man's every built to do what it does." So people who say I can build one to do the same thing for a tenth the cost, I just laugh at them. They don't have any idea whether they could or couldn't. Had we attempted to build a two-stage fully reusable vehicle, the program may well have spun in, and we wouldn't have had anything today. No one knows. I know this, it would have been significantly more difficult than what was done, and what was done took a lot of national effort just to get it done, get it done within the funding you could sustain and within the capabilities we had, and I think it's proven to be a hell of a good vehicle.

So having gone through that evolution in Phase B, we were now ready to fulfil it. Now, by having evolved to the vehicle we evolved to, it gave us some other fairly significant advantages, because we could time-phase the start of different elements of the program so that the funding didn't all stack up one right on top of the other. Because once you start to build something, you bring people on, you get schedules that push you, costs go up. Once you start that spending, it's there every day, it's chewing on you every day. So what you want to do is take the things that are more difficult and more complicated and start those first, and not start everything one right on top of the other one and get your funding way up high, because once it's up there, you can't get it down until you're finished. If you start the tank early and it gets up here, you still have to keep the tank people around, because you haven't flown yet.

So we started the engine first. We were pretty sure the engine was the most difficult development. We started the engine first, and I've already told you a little bit about the technology in the engine. Some details. We got a protest. The engine technology at that time, a lot of it had been supported by R&D [research and development] funding at different places around the country. In fact, the Air Force had done a lot of the funding with a company called Pratt & Whitney. But when NASA decided to build the stage combustion cycle engine with 3,000 pounds pressure at the combustion chamber throat, the turbo pumps and a lot of work had been done by Pratt & Whitney, and Pratt & Whitney felt that they were in catbird seat to win the competition.

Well, Rocketdyne [Division of Rockwell International], who had been doing the engines for Apollo, the low chamber pressure engines and the gas generator cycle combustion cycle engine, but they also had a lot of experience in building rocket engines. So you had a company like Pratt & Whitney was very heavy into R&D, you had a company like Rocketdyne very heavy in the practicality of doing things, and they were throwing competition, and lo and behold the government selects Rocketdyne. Pratt & Whitney didn't like that, so they protested, and that held up the start of the engine for about six or eight months while that protest was resolved. But then it was resolved. Rocketdyne then went to work to build the engine.

We had had a lot of debate on what the thruster engine ought to be. Collectively we all wanted to have a thrust level that would give us the ability to have at least three engines on the Orbiter, so if you had one engine out you could still most of the time go to orbit. Kind of like a four-engine airplane or a two-engine airplane today.

So we sized the engine at 460,000 pounds of thrust with three engines in the Orbiter. You can look in the history books, we looked at two-engine Orbiters, we looked at the 460,000-pound thrust engine for the fly-back booster. I think they had to have eight engines in it or something like that. But in any event, the engine program we started first.

It then came time to pick a contractor for the next start-up, and the next most complicated part of the vehicle is the Orbiter. So out at the Johnson Space Center we released an RFP and we also, at the start of Phase C/D, NASA set up a program management structure with the program manager located at the Johnson Space Center using the resources at Johnson Space Center. That's the job that I was put into that started in 1972, coming out of Phase B.

Then when we decided to go to C/D, I was made the program manager for the total program working here out of the Johnson Space Center. So we prepared the RFP for the Orbiter and for integration support.

The government was going to integrate the program using civil service resources and using the program manager, his staff and his organization. We were going to decide what the Shuttle was, program manage it and program integration. But we realized that we had to have a fair amount of support from the contractors, because the people designing an Orbiter and the people designing a tank or people designing an SRB [solid rocket booster] has to contribute to that. So in each contract we put some integration support work. So if you bid on the tank, you also bid to do some integration support work. But if you bid on the Orbiter, you bid a bigger piece of integration support work.

So in my office at JSC in the latter part of 1972, we prepared a request for proposal to build an Orbiter and provide major program integration support, those two things, and we ran a competition. I chaired the Source Selection Board for that competition. We got four bids. We got bids from North American [Aviation, Inc.] or Rockwell. We got bids from McDonnell Douglas, from Grumman [Aircraft Engineering Corp.], and Lockheed [Aircraft Corp.]. Out of those four, after we evaluated them, graded them, we selected Rockwell as the Orbiter integration support contractor, and we led a design, development, testing, evaluation contract to them to build us an Orbiter and provide integration support.

At that time I set up—I already had an engine project office located over at Marshall, now we have an Orbiter project office located at JSC. We would later on have a tank and an SRB project office located at Marshall. So three of the development offices at Marshall, one at

JSC, and, of course, we had a launch site development office at Kennedy. So I had an office that had those, plus I had integration support groups within my program management office.

The lead technical systems integrator was a fellow named Owen [G.] Morris that ran an integration office. We also had an operations integration manager. We had a program control and budget and cost and schedule integration manager. We had four major offices, we had the technical systems engineering, we called it, program control, operations and, gee, what is the fourth one? I'll think of it in a minute. But anyway, the fourth major integration activity. That's the organization we started Phase C/D with.

Then I had a staff program director that I reported to in Washington, who was Charlie Donlan to start with, and then he reported to the Associate Administrator for Manned Space Flight, Dale Myers. But it was my job to run the program on a daily basis, using staff and support out of the Johnson Space Center.

We selected Rockwell, they started on the Orbiter, and they started on the integration support contract to us. We had the engine going, the Orbiter going, integration activity going. About eight or ten months later, we competed for a tank contractor and picked a tank manager. A fellow named Jim [James] Odom was picked as the project manager at Marshall. He and his people released an RFP for a tank and they picked Martin to build the tank out of Michoud [Assembly Facility] in Louisiana.

Then about several months later—we left the sizing and the final configuration of the booster rockets open for several months on the front end of the program, and we left the final size of the tank open, because we wanted to get a better handle on how heavy the Orbiter was going to be, how heavy the engines were going to be, what kind of propellant load we wanted to carry before we finally sized the tank, and then we wanted to have all that sizing under reasonably good control before we committed to how big the booster rockets ought to be, because we didn't want to box ourselves in, make some early judgments and find ourselves wrong and have to come back and change things.

We also needed to get some integration work going so we could tell the tank what kind of heating parameters it had to design for, and how much propellant it had to carry, what kind of loads it had to be designed for and that sort of thing. Same thing then, we kept the booster rocket back so we could finally size the booster and how big a JATO unit you needed, because then you could get the weight under control.

Now, these are things you do when you really have to go build a vehicle. So we spread the selection of the contractor base over probably the better part of a year to a year and a half. Also Marshall undertook the preliminary design of the SRBs in-house, because they got contractor support to build it. So they did a lot of the early engineering design work on the SRBs in-house at Marshall using their civil service resources.

We're now in the '73, '74 time period. We settled cleanly on the vehicle. We settled cleanly on the organization that's going to run it. We've got a program that Congress is willing to put money up every year and keep funding. When we started on this Shuttle vehicle, the one that we now know when you look out and see it, when we finished our Phase B on that vehicle, we said that we thought we could build that vehicle for $5.15 billion in the purchasing power of the 1971 dollar over a period of about seven or eight years. But we also said we, the people internal to the program, my data that I took to Washington, said we want to plan the program on a success path, that we know exactly what we're doing, we'll do everything just right and it will fit together nicely, we'll build it for 5.15, but good things never happen that way, so you need to have a contingency plan for another billion dollars and another eighteen months' delay in the schedule. We had what we called a green curve theory. We'd put this funding profile versus time for the success program, then we'd put a curve with green coloring under it for just 1 billion dollars of additional funding and the other eighteen months and said, now, that's the total, the outside boundary is what you should tell Congress about.

When [NASA Administrator Dr. James C.] Jim Fletcher and George [M.] Low took that one sheet of paper that described the Shuttle and described the funding out to San Clemente [California] to talk to Nixon to get the final commitment on the Shuttle, that's what they took, and that's what their discussion with Nixon was all about. When Nixon said, "Okay, fine, we'll go with it," then they came back and submitted that to OMB [Office of Management and Budget] as the NASA commitment on the program.

Well, the best of intentions are just so good. When that got to OMB and NASA Headquarters put that budget in the 1973 budget, they didn't escalate from '71 to '73 dollars. So they took the '71 dollars and put them in as if they were '73 dollars. So we lost two years' worth of inflation. OMB says, "Oh, we never give contingency funding. We'll just make that after a while." So they lopped off the eighteen months and lopped off the 1 billion dollars and said, "You, NASA, have committed for 5.15 billion and the purchasing power is '73 dollars, and here it is. Let's go to work."

Well, we weren't going to say, "No, that's all wrong, we won't do it." We took that and went on down the pike, but we got clobbered for two years of escalation right off the front end over the whole program. The eighteen months of scheduled contingency that anyone needed was taken out and a billion dollars of regular funding was taken out. But that didn't really matter, because once it's all over, it's eight years later, the people who made the commitment have all gone and died, have gone on somewhere else. So what. In fact, we kept a constant measure of ourself, how we were doing against the 5.15 plus the billion plus the eighteen months, and I can generate a good story that says the program was brought in right on cost or even under cost, because inflation in some of those years was as much as 18 or 20 percent, and we would typically get 7 or 8 percent allowed.

So if you come back and put what we were arguing with all the real things, I can show you the Shuttle was developed close to cost, pretty close to schedule. But, so who cares? And who you going to talk to at that time? Because the program had already been identified as "You said you'd do it for 5.15. Now you've spent 8." So you're way over, right? No one takes the 5.15 and escalates it and does that, they just take the 5.15 and compare it to the actual spending and put that in the newspaper and paint you with it. That's part of the game, and you get used to that after a while.

But in any event, by 1972 we were ready to go, we got the engine under way, the Orbiter under way, integration support under way, we got some preliminary design going on on the tank, and some early thinking going on on the booster rockets, and the program is moving along pretty good. One of the things that I think that I'm pleased about on the Shuttle Program is that the program management structure, the person, myself, who was picked as the program manager, the integration managers, the Orbiter manager, the tank manager, the SRB manager, and the engine manager, those people all stayed there for the whole ten years it took to develop that vehicle. So the management continuity was extremely good during Shuttle.

I think that's important in that as I look back now at Space Station, the way Space Station happened, they changed managers every three months, they changed configuration every time someone dropped a pencil. Next thing you know, the Space Station Freedom design is thrown in trashcan after a lot of time and effort was spent, and we get up on this political kick with the Russians on the Space Station that exists today. The next thing you know, two or three or four or five years is dumped down the drain. Once you get the program going, the spending is there whether you accomplish anything or not.

Now we've got this highly politically integrated program that I'm sure glad we didn't get Shuttle wrapped up in that kind of thing. We kept our management stable, we kept our design fixed. Now, by fixed, we had to evolve a lot of things in design. When we first started, we thought we would maybe want some escape rockets to lift the Orbiter to clear the pad. As we looked at what those would cost, what they would weigh, the complexity of them, and for what it did for you, it didn't work out, in my judgment, to be worthwhile, so we took them off.

We had air-breathing engines on there to give the Orbiter a fly-around capability. When we looked at the weight of those engines, the cost of those engines, the complexity of carrying that propellant all the way to orbit and back just to give you a one-time go-around capability, it didn't make any sense. We thought we could navigate, put the Orbiter in a position where we wanted to and put it on the runway the first time, so we took them off.

Once we took them off, we then had to find a way to fly the Orbiter around, so we put it on the back of a [Boeing] 747. We bought a 747 from American Airlines, used at a very good bargain, and spent some money to convert it to carry the Orbiter on its back. We were able to shorten the landing gear on the Orbiter and save weight. So we made those kinds of decisions.

Now, those things, they don't happen, again, by someone sitting at his kitchen table sketching on a napkin. They happen by a program manager and his organization of people worrying about, "Why do we have those abort rockets? They really don't do that much for us. Let's look at taking them off." So you go study that. You come into a meeting and the people who want to keep them argue for keeping them. The people who want to take them off argue for taking off. You sit there and listen to both those arguments, and then you say, "Keep them or take them off," and put out a paper and say, "Take them off."

Then someone says, "But to take them off, you have to go buy an airplane and do this with it." So you take them off and start people to go buy an airplane and put it on the back and figure it out.

So from '72 to '74 we went through all of those things. We took off the abort rockets, we took off the fly-back engines. We started off, we didn't have a good plan of where to dock the Orbiter. There were people who wanted to dock it up on the nose, you know, ought to take the nose and dock like that. Well, we looked at sticking it up in the nose, and if we were going to fly the Orbiter back and land it on a runway, complicating that whole front end of the Orbiter with a docking cone didn't make a lot of sense. So we finally decided to put it in the front payload bay and put a set of controls up in the back of the cockpit so you could dock it the way it's docked today.

Those kinds of details evolved in the day-to-day working and functioning of the organization. So who designed the Space Shuttle? The Space Shuttle was designed by government-led organization evolving over a couple of years, and, again, not because some early physicist sketched something on a piece of paper a hundred years ago. It evolved because you wanted to build something that would carry a fifteen-foot by sixty payload, 60,000 pounds, ten people, do certain things, and the knowledge base of how to fly a vehicle in the atmosphere and land it on a runway came out of a lot of other people's work, and you put that together. The launch things come out of other people's work.

So you collect all this information and you evolve it over a period of time. If the people in Congress and the people in Washington keep feeding money in the program at the tune of $5 million a day peak spending, then the next thing you know, if you do that for seven, eight, ten years and keep a good stable organization, you got a vehicle you're ready to go to the launch pad with.

RUSNAK: Do you think the previous programs at NASA were designed the same way, or was this the first for Shuttle?

THOMPSON: Well, this particular organization and this particular vehicle creates the first. As I think we talked earlier, if you look at the Apollo vehicle, where you've got a launch vehicle in a fairly clean interface and with a spacecraft up here, you can work by having people at Marshall go do the thing that's fairly independent from the people at JSC. A small group at headquarters can kind of keep order. That's the way we worked up until that time.

Mercury and Gemini were essentially all located at JSC. We just got boosters from the Air Force or boosters from the Army to do certain things.

Skylab was a little bit more integrated, and I talked to you last time about how long it took us to really decide what to do and how we argued and scrapped over Skylab. Once we got to Shuttle, now you've got a highly integrated vehicle. You couldn't just hit it with a meat cleaver and say, "Marshall, you go do this," and, "JSC, you go do this," and expect it to go together. Because the loads that the tank had to be designed to were influenced a lot by the loads the Orbiter fed into it and the aerodynamics around the Orbiter. So you have a lot of integrative kind of issues. So you had to have a program manager leading the activity at those centers and also at KSC [Kennedy Space Center, Cape Canaveral, Florida].

So that's when Charlie Donlan and Dale Myers decided to set a “lead center” concept, which means they would pick a program manager, they would give that program manager a piece of paper from Headquarters saying, "You've got the overall job, but you will locate at the Johnson Space Center where you can use the resources." The structures engineers, the flight control engineers, the operations engineers, the integration engineers, the budget managers, those kinds of people out at the Johnson Space Center to staff the program and use those resources in this lead center concept.

Now, what that does with the program manager, that gives the program manager two bosses. But my feeling, having two bosses is a great thing. It could be bad, it could be good. Then you've got a center director who is your administrative boss and you're using his resources, by "his resources," the government resources, but that he's responsible for justifying and getting budget to use. You're also managing project managers at Marshall where they're using Marshall resources where the center director over there is getting budget. So this center director is essentially ending up at headquarters on a board of directors, if you will, overlooking what you do.

But you have a program boss that goes right straight to Washington and a center boss right in the center you're working on, and you can do anything you want to as long as you keep them both happy. That's really the program manager's job to do. But the program manager at NASA has a lot of power, but he also had a lot of people watching what he does every day. So you can do most anything you want to, as long as people are happy with what you're doing and you have a lot of resources to call on.

Then you can also call on—we got a lot of help from other NASA centers. Got a lot of help from Ames [Research Center, Moffett Field, California] in high-speed wind tunnel work.

We got a lot of help from Langley [Research Center, Hampton, Virginia] in structures and structural dynamics kind of work. You can call on universities. You can honestly call on all the contractors that are working for you. So you end up, I've often argued, there's nothing better than a good bureaucracy. There's nothing worse than a bad bureaucracy. If you put together a good organization, structured properly and you go there and work every day and work to where people know what you're doing and why you're doing it and so forth, you can accomplish pretty remarkable things. That's where I found myself as the program manager from 1970 to 1981, come on through with the first flight.

Now, as we got into developing the Shuttle, as you would expect, we ran into a lot of difficult things we had to ultimately solve. Early on, we decided to build the Orbiter as a basic aluminum airplane. Simple build, build it very much like you're building the other airplane, and the industry knew how to go build aluminum or aluminum and titanium airplanes. But then you had to protect it from the heat of entry with an insulating thermal protection system that was not so heavy that it took all your payload. So to pick the hot spots on the Orbiter and put one kind of thermal protection system, say, on a nose where it gets real hot, another kind on the wing where it doesn't get quite as hot, but still pretty hot, compared to the back of the Orbiter where it's relatively cool, say in the first place it's 3,000 degrees, here it's 2,000 degrees and here it's 700 degrees, so you had to figure out what kind of protection you have in those different areas and stay within the weight budget. The thermal protection system ended up weighing somewhere between fifteen and 20,000 pounds. We used at least three different, three to four different kinds of thermal protection system in different places. First time we'd ever put that kind of thermal protection system on a vehicle as big as the Orbiter.

The Orbiter, even cut down to the size that we cut it down to, it's still a pretty big vehicle. You go look at it, it's not a little tiny thing. It's still pretty big. Now, you can imagine how big it gets if you put all that cryogenic propellant in it, right? It gets to be real big.

But in any event, we covered it with the thermal protection system, and to develop the materials, prove to yourself the materials would do what you wanted them to do, called material characterization work, figure out how to attach them to the Orbiter in such a way they would stay there, and then do the test program to prove to you that they would stay there, was a fairly significant development program.

We got a lot of help out of industry. Lockheed had the contract as a sub to Rockwell to build the lightweight thermal insulating tiles. Other contractors built the carbon material that's on the nose cap. Rockwell developed the blankets that go on the after part of the vehicle. So we called and we got a lot of help out of Ames in thermal protection work. So we had a lot of people around the country doing a lot of things, and that's just the thermal protection system. We could talk for hours or days on all of the engineering issues in the vehicle. Structural dynamics was a big issue.

Before the Space Shuttle we would have generally built launch vehicles that I call stacked like telephone poles, they were all in line. The reason you do that is you get the efficient aerodynamic efficiency, you pushing the thing through the air in a pretty efficient way. You've got a good thrust vector that goes right up the center of the backbone of the vehicle. You can drop off parts of the vehicle as you stage and go on pretty clean there. So an axial-oriented vehicle is a pretty efficient vehicle.

There were lots of people who wanted to have the Shuttle as close to that as they could. So people wanted to put the booster rockets behind the Orbiter and push it along the axis, but that wasn't very practical if you wanted to burn the Orbiter engines at liftoff. See, the Orbiter engines were efficient engines and we very much wanted to turn those engines on before we lifted off to make sure they were working, plus they were the most efficient engines. So we wanted the Orbiter down in the fire pit there where we could light off the engines.

So then you could put the tank in front of the Orbiter, but that didn't make a whole lot of sense because we wanted the tank down, just part of the structure backbone to put the booster rockets on. You had to have the booster rockets so they could light off for you. So we ended up stacking it in a way that you see for the Orbiter now.

But now that brings—when you hang those four big masses together, you get a lot of low-frequency vibrational modes. It shakes and rattles like a bowl of jelly. In other words, it's got a lot of structural modes that can fed into the propulsion system or can fed into the flight control system.

One of the things you really worry about in a launch vehicle is a thing called pogo. Pogo is just a name, pogo stick. You've seen them jump on pogo sticks? Well, if you've got a rocket engine pushing on a vehicle and you got the vehicle shaking so that it's interrupting the flow of propellants or causes the flow of propellants to be like you're walking with water, a pail of water. If that propellant gets to sloshing and the vehicle gets to shaking and that influences the thrust, they can feed on each other and they can cause this thing to build up and it can destroy a vehicle. It can shake itself apart.

So there was a lot of worry, if you take and put these four masses this way and you got the SRBs burning and you've got the Orbiter burning, you got the propellant sloshing around the tanks and those big things structurally tied, it's going to shake itself apart and people would come, "Oh, you can't do that, it'll tear itself apart. You can't have the Orbiter down there in the fire pit, it'll burn itself up. You've got to get it up here," and so on.

As program manager, what you'll really doing is you sort of sit there and say, "Well, what set of problems do I want to live with for the next four years? Do I want to stack it like a bunch of telephone poles and take on all of those problems, or do I want to stack it in parallel and take on all those problems?" So you have to make a judgment call, what do you want to do. You then decide based on your experience or based on what people tell you, "I'm going to stack it this way and take on these problems, and I will keep that from being a problem by doing certain things." So you sit there and kind of put the program together and buy into whatever problems you're going to have for the next four years.

Stage combustion engine. "Oh, you can't have two burners on an engine. You can't have a bunch of free-burners and their pumps interrelating with a bunch of other burners and their pumps. You'll get propulsion instability and they'll tear themselves apart." Yes, but if I can do all of that, I get the highest I_{SP} out of the engine, so I'll just take on those problems, even though we've never done it before, and get the higher I_{SP} out of the engine." But now I have to start a development program and make sure that I don't get any propulsion instability because of the structural modes of the engine.

So we embarked on what we called a pogo prevention plan, put together some key systems engineers, got help from industry, got help from universities around the country, did a lot of analytical work, a lot of test work, made sure we understand the structural dynamics. We found we had some marginal problems, we put some accumulators in certain places to keep it from being a problem. Probably the most pogo-susceptible vehicle we've ever built is the Shuttle and it's the only vehicle we ever built that's never had a pogo problem. And it didn't because we went in and solved all those things and put some accumulators where they belonged and kept it from pogoing.

There are fifty of these things I could talk about here for X hours, and that's probably not very productive. But we were able to pick the set of problems we wanted to live with, thermal protection system, pogo propulsion dynamics, flight control. We decided that the Shuttle was the kind of vehicle—when I first went to work at Langley right after World War II, I went into the stability and control group there. At that time, NACA [National Advisory Committee for Aeronautics] had to have two stability and control subcommittees because there was so much disagreement. There were people who wanted to have artificial stability and control by putting gyros on airplanes and thinking that I'll put the gyros and feed them in the control system and so forth. Then there were people who said, "You never do that. You give the pilot a stick, hook a cable to the aileron, and he sits there and flies the vehicle. You're not putting a dumb gyro between my aileron and my stick." So you had the people who wanted a plain natural stability and control system, and the people who were willing to hook up a bunch of electronics and computers and so forth.

Well, we looked at the Space Shuttle and it didn't make any sense to do anything other than what we call a control-configured airplane. That is, you put the pilot in sending signals to a computer. That's all a pilot does; he sends signals to a computer. The computer takes those signals and mixes them with signals it's getting from sensors located around the vehicle, gyros that are helping him navigate, or sensors doing different things around the vehicle coming into this.

Within the flight computer you've got a set of software that's flying the vehicle. It's got a bunch of software and memory and they're telling you where to guide the vehicle. A pilot's sitting here putting some commands in, but he's put them in at the outer loop and in the inner loop the vehicle is flying and stabilizing itself based on its sensors around the vehicle.

So we had to put together what we called a control-configured vehicle. Now, that's great, but it means you've got to have a highly reliable set of computers and flight control systems, because a computer, if it breaks down, the pilot can't fly the vehicle. So we did a lot of work early putting a highly redundant avionics system on the Shuttle.

Then we got around the problem of having some generic software problems by putting a relatively simpler, not simple, but a relatively simpler backup flight control system in a fifth computer that would give the ability to fly the thing if these four bombed out. These four worked by comparing what each one of them was doing with each other, so if you got three of them doing one thing and one of them is doing something wrong, you'd throw the one out and take the three. Every now and then you'd get two on two, and you had to have a way to solve that as well.

In fact, the first time we got ready to launch, we started the computers and lo and behold we got two on two. It had only happened on very rare occasions. We'd seen it a few times in the avionics development lab. But we had to scrub the first launch for a day while we went in and set a way for the computers to start so they wouldn't get two on two voting right up front. But we put a lot of effort in the avionics, a lot of effort in thermal, a lot of effort in structural dynamics, a lot of effort in all of these kinds of technical things.

Got a good set of contractors. Ultimately, Marshall went out on a bid and got [Morton] Thiokol [Inc.] to build the boosters and got a different contractor to help them integrate it and put it together down at the Cape. There was a lot of debate about whether it would be a solid propellant booster or a liquid booster. We finally settled on a solid propellant from a cost and late development and a recover and reuse we figured.

Another thing that's fairly interesting, in looking at the Shuttle and justifying the Shuttle to the Congress and to the country, and when you looked at everything the Air Force wanted to do and everything that NASA wanted to do, you could look around and, gee, we're going to fly this thing forty, fifty, sixty times a year. Every two weeks, maybe. Lo and behold, the more you flew, the cheaper it got per flight. So all of the budgetary kind of stuff that went between the agency and the Congress always biased toward a high number of flights. Now, no one really got serious about asking where all the money was going to come from to create all the stuff to do all that stuff, because, you know, people are hoping for bigger budgets in the future.

But internal to the program, we never structured anything that gave us any capability beyond twenty-four flights a year. That's what sized the tank fabrication capabilities that we put together. So if anyone ever wanted to go above twenty-four flights a year, they would have had to up the tank production capability of what we put in in the fundamental program, and they haven't gotten anywhere near twenty-four flights yet.

Another thing we had a fairly significant debate on was whether to make the first flight unmanned. There were a lot of people in the agency that grew up, including myself, in the time period of Mercury, Gemini and Apollo where we always went unmanned. Put an animal in, then put the people in. I personally felt that by the time we got to Shuttle, it was as much an airplane as it was a launch vehicle or an orbital vehicle. We had a lot of experience under our belt of how to build things. It made it a lot more straightforward and a lot more simple just to build a manned vehicle, not build an unmanned one and then build a manned one, or build an unmanned one and have a manned overlay or unmanned overlay. It just complicated it. I felt that it justified risking a couple of people to make a test flight, that the country knew how to spend the money and design and build it and man it right up front. You never had any trouble getting people to go fly. The astronauts fought each other to see who would go first and so forth.

So very early on I favored going up manned. Some people I have a lot of regard for still wanted to go unmanned. So we made a judgment that says, "We're going to baseline it for manned. We're only going to build a manned configuration. If, as we approach a first flight we make a thorough review of it, if we aren't comfortable with it, then we just won't go. We'll shift back over and try to go unmanned at that time," which we did. We went manned all the way. We held a review, we were comfortable going manned. A lot of the people that didn't want to go manned had either retired or gotten tired of arguing or finally agreed with it, and we went right on manned and went on from there.

We did go through an approach and landing set of tests where we launched the Orbiter from the back of the 747 and tested the tail end of the glide slope and the touchdown on the runway. Historically, airplanes had had taxi tests, where you would take an airplane out before you fly it and run up the engines and run up and down the runway to make sure you didn't have any shimmy on the wheels and so forth. People came in and wanted to taxi test the Shuttle, for example, the Orbiter.

After listening to all that, I felt that that really wasn't necessary, that we knew enough in this country to design a vehicle that probably would land all right, and the cost of putting jet engines on this thing and trying to taxi it didn't make a lot of sense, but that putting it on the back of the 747 and air-launching it and gliding it down and landing on the runway was a worthwhile thing to do. First of all, it gave us a look at the landing gear and the controllability of the vehicle and the approach and landing tests. It satisfied a lot of our taxi test requirements. It also gave our operational people kind of a thing to get back used to doing something before we went to orbital flight, because it was about an eight- or ten-year period where we weren't flying very much. Between the time we finished Skylab in, say, '73 or '74 until '81, the Ops [Flight Operations] people hadn't been doing a lot. So it gave us a chance to force the Ops people to face up to planning some things and putting some people in the vehicle and doing some things.

So we decided to make four approach and landing test [ALT] flights, two of them with a tail coming on, which reduced the drag the Orbiter made a little bit more shallow glide slope, and then, too, with the tail coming off, which gave us a steeper glide slope. I think that's the way we go. I'm beginning to get a little fuzzy in my memory now, because I'm going back. I think we made two of each, but I can't remember.

The approach and landing tests went quite well, except for we had one major glitch that came out. We found some flight control problems with the last, and they manifested themselves in the last flight. The Orbiter is a relatively crude aerodynamic vehicle in the landing mode, crude in that it doesn't have high lift to drag, like a glider lands pretty controllable and it's kind of hard to make sit down because it wants to fly. You don't have any trouble getting the Orbiter to sit down, because it's relatively low L over D [lift over drag]. But you're coming in fairly fast and fairly steep compared to traditional airplane kind of things, which means that good news, bad news.

The good news is, it's not very sensitive to gusts and that sort of thing, because it's not a good aerodynamic vehicle. So if a gust hits it, it doesn't respond a whole lot. It's got fairly high wing loading and fairly low lift to drag ratio. So if you set the Orbiter up at the right place up here, it's a fairly simple task to glide it down and then change some of the kinetic energy of the glide slope to what we call flare, to change it so you can flare and kind of kill your vertical velocity so that you're within three or four feet per second vertical velocity when the wheels hit the runway and you run out.

So if you set it up carefully up here with fairly limited boundaries and fly it nice and gentle down through here and flare it gently, it'll fly in and land real nicely. In fact, if you watch all the landings, they look pretty good. It flies nice and steady. But a lot of people worry about that, because they were used to building and flying airplanes, which have a lot—this is kind on the end of—We didn't go as far as the lifting bodies, which are even worse than the Shuttle, because their L over D and aerodynamics is worse than the Shuttle. So Shuttle's a little bit better than lifting bodies, but not nearly as good as an airplane.

But on the fourth approach and landing test, the pilot flying the vehicle, sort of unbeknownst to us, had made some bets with his buddies that he was going to hit the numbers on the runway. Well, where we launched him up here and where we set him up and the glide slope he followed, he shouldn't have put it on the numbers, he should have glided on past the numbers and let it do its natural thing and set it down. But he decided he was going to win the bet and he wanted to try to force it on the numbers, so he tried to make it land before it was ready to land. So he put some pitch control in.

The control system we have in the Shuttle is a rate command system, so you put some pitch in, it says pitch at a certain rate. Then you take that rate command off when you want to stop that rate. We had a logic in the flight control system that if you put a lot of pitch in, the hydraulic system and the controls would give you the pitch you wanted, because at the same time you put some roll in, a little bit of roll and a lot of pitch, it would try to meet your pitch rate before it picked up on the roll rate. That was the logic we had in the software in the flight control system.

We also had the flight control system relatively high gained, and that means that a little bit of motion of the control stick gives you a lot of response in controls. That's a high gain kind of a high response. So we had the gain set fairly high, because that's the way the astronauts had argued that they wanted it. The people who designed the flight controls went to moderately high gains. Then the logic between pitch and roll was such that if you were asking for a whole lot of one, the system gave you that before it gave you a little bit of the other one.

When Fred [W. Haise] tried to set the thing down on the numbers, he called for a lot of pitch. Well, in the Shuttle you're way up above the principal axis and the only pitch controls are those trailing edge flaps. They also give you lift, in addition to pitching moment. So when you ask for pitch, your first sensation is you go up, then the nose comes down. Well, he asked for pitch and he started going up, said, "I'm not getting enough," so he asked for more pitch. Well, then the wing dropped a little bit, so he's asking it to roll, but he asked for so much pitch he wasn't getting his roll. So next thing you know, he's putting more in there and he gets into a classic pilot-induced oscillation [PIO].

Anytime you're trying to fly a vehicle and the control system is such that there are some adverse time lags between the time you ask for something and you get it, then you start asking for too much, and then when you get it, you pull back. The next thing you know, you're doing this [gestures]. Well, he started pitching and wobbling and was beginning to build up some attitudes and some rates that looked like he was going to really prang the vehicle, because he was getting pretty close to the runway.

Well, fortunately the co-pilot knew that if he'd just take his hand off of the control, the computer, which was running the inner loop control system, would quickly stabilize the vehicle and bring it back to a reasonable glide slope. So he told him to turn the control loose. He turned the thing loose and the thing settled down and then it came on down, got on the runway and made a good landing. Everything was all right, but we had some scary moments there.

Well, we got on top of that, look at it, decided we could degain the flight control system a little bit, change the logic between pitch and roll, run through some simulators. At Ames they have a motion-based simulator that you can do a lot of that kind of work. We didn't do another ALT test. We just fixed the flight control system and took the pilot out of the loop a little bit by degaining the loop and changing the logic and went on the flight and it's worked fine.

So the approach and landing tests gave us some things we wanted, plus gave us the confidence that from 10,000 feet on down we knew what we were working with. Of course, once we went to orbit, we had to then manage from orbit down and pick up the top glide slope here at about 30,000 feet. As long as you got it all set up in the right place there, we put a lot of capability in the Shuttle for being in the right place. We put a very accurate microwave system on the runway that upgrades where you are, so between the onboard system, the TACAN [tactical air navigation] system you use once you get down farther in the atmosphere, and the microwave landing system we put on the runway, we were pretty sure to have the Orbiter in the right position. If you have it in the right position and if the pilot didn't have too many bets to try to make it through what it's not supposed to do, he's going to be on the runway every time.

So the landing, even though there were a lot of people nervous about the landing capability of the Shuttle, as you compare it to an airplane, we stuck to what we started with. We stuck to the aerodynamic configuration we started with. We didn't try to get real fancy with the shape of the vehicle to get aerodynamic stability all the way down through. We just put a reaction control system in it and brute-forced it and made it just take a muscle to make it stabilize.

If you look at a lot of the configurations in the history books and so forth out at Langley, you see these fancy contoured-shaped HL-10s and M-2s. These are all vehicles where the aerodynamicist is trying to make them fly bare bones stability and control all the way from orbit down. But in a practical sense, you don't have to do that, you just put muscle on there. You put a reaction control system and a navigation and control system and just brute-force your way through, because the aerodynamics up there at that high, the air densities aren't so high that you can just—you can take some poor aerodynamics and just force your way through it. And that's what we did on the Shuttle. We didn't try to get too fancy all the way through. Made a lot of aerodynamic friends unhappy with us. They said, "That's a crude-looking vehicle," and we said, "We're not trying to be fancy aerodynamically. We're just trying to go to orbit and back."

But it was an interesting time period. We got through the ALT Program. As we got down close to first launch, if you'll remember the eighteen months and the billion dollars, it turned out we needed the eighteen months and the billion dollars. So we had been talking about 1979 as the first launch period, and that's what a lot of the newspaper people and so forth had been counting on. When we got to 1979, we weren't ready to fly. We still had some thermal things to do, some engine things to do, some avionics things to do, the typical things that we knew would build up. We needed about a billion dollars and about eighteen months.

So people began to get a little bit nervous. A lot of the newspaper people that had been running around waiting, that hadn't flown since Skylab, they were ready to fly. Skylab was up there getting ready to come back down. They wanted to hurry up the Orbiter and go up and save Skylab. Well, that was a bunch of crap. No one was ever serious about taking the Orbiter up. The Orbiter couldn't do anything with Skylab. We weren't at all configured to go up there and take a hold of Skylab and save it. I don't know why anyone would want to save Skylab. It was useless. We designed Skylab to do just exactly what it did.

But anyways, we got down to the late 1979 time period and we began to get a lot of pressure. "Gee, is this thing going to ever fly? Will it do this? Will it do that? Will the tiles stay on?" And so forth. We ran into a problem on the tiles. We had done some reasonable development work, but in retrospect, we had not characterized the material as thoroughly as we should have. By characterize the material, let's say you're trying to build these lightweight insulating tiles. What you really need to do is build several thousand of them, test the strength of several thousand of them, statistically get all of that data, draw a statistical boundary around it, and then pick a number off of there to make sure all the tiles are at least that strong.

We'd also decided to put the tiles on the aluminum surface by putting some rubber glue, RTV—room temperature vulcanizing—it's a rubber glue, aluminum rubber glue, a felt pad, rubber glue in the tile. We'd done limited testing to make sure how strong that was and the characteristics of the material, but when we got ready to put it all on the Orbiter and begin to test the tiles, we found some tiles coming off at less pull weight than we thought. So it wasn't as strong as we thought it was.

We began to look around, well, maybe we hadn't characterized the material as well, and maybe there was something about that bond we didn't understand. So now we're already down at the Cape with the vehicle and we were gluing the final tiles on and finding they were not as strong as we thought they were. So now we're in a big scramble.

We found out that this felt material that we put on there, the way in which it was manufactured caused some little short strings of felt to be put in the vertical plane rather than the horizontal plane. So that when you glued it on there, when you thought you were pulling a long string parallel to the structure, we put a little short string that stuck right up into the bottom of the tile from the aluminum. So you'd pull that little string and that little bit would pop loose, and the next little bit would pop loose. So it would come off at less [unclear] because the way we made the felt with some needles to glue these long strings of rayon together, ended up these little short strings that had a little short pull, that would pull a little section of the tile out at less weight.

So we had to go in and take the tiles off and densify. We took liquid glass and densified the lower layer of the tiles to make that little string stronger, and then glued them back on and then went through a very elaborate pull test to make sure they were strong enough to where we got ourselves in a boundary of the strength of the tiles.

Well, people were impatient while you were doing all that work, because they wanted to go fly. The newspaper people said, "Gee, you don't know what you're doing." Well, we knew what we were doing, but we just had to put up with all of that.

In the meantime, we were doing some testing in our avionics development laboratory to be sure we were comfortable with the flight control system, the avionics system. All of that hadn't completely matured. The engine, we were still doing some of the final certification testing. So even if the tiles hadn't been a problem, the software wasn't quite ready, the engine wasn't quite ready. In fact, the tank, even though we started late, it ended up ready early. The SRBs, we started those late, they were ready early. The thermal system, the avionics system and the engines were the things that really paced the program.

But we didn't get the program too badly out of balance. The tank was ready maybe six months before we were ready to fly, the SRBs more than three or four months. So it all came out on the back end pretty well. Had we been able to stick with our original eighteen months and one billion dollars, we could have been heroes, but no one was interested at that time anyway, because the people we talked to had long left office and gone on to somewhere else and so forth.

RUSNAK: If we can take this opportunity to stop and change out our tape.

THOMPSON: Sure.

THOMPSON: …part of 1970, when we were dealing with issues like the thermal systems, is it ready to go? The engines, are they ready to go? The tank, is it ready to go? SRBs, we'd had three or four static firings of the SRB by then. We're now getting ready to bring this thing all together and have a couple of people get on board and fly it to Earth orbit.

There were several things that were unique to the Shuttle that we had to worry about. One was, we worried a fair amount about icing. We were worried about the ice that would build up on the cold hydrogen tank and come off in the early part of the flight, maybe in chunks, and do some damage to the thermal protection system on the way out. I always felt moderately comfortable with the thermal protection system in that the way we designed it, it was pretty forgiving for any one entry. Even if you knocked a big chunk of tile off, it still worked fine. In fact, you could lose a whole tile in many, many places and the glue and the felt and the aluminum, you'll get some local damage, but you can still come in and land.

It was just a simple enough system and a crude enough system to where it had a lot of forgiveness. In fact, I remember an early test on the thermal protection system we were doing in either a tunnel at Langley or Ames, I can't remember now, a blow-down tunnel, and one of the copper heating elements in the tunnel failed and melted, which meant they put a bunch of copper pellets in the air stream that hit this test sample, looked like you'd shot it with a shotgun.

They brought the sample in my office and said, "Look what those pellets do to this thing." I looked at it and, sure enough, here the thermal protection system is all chewed up. But then I asked them what the temperatures were back in the thermal couples where they were made, and the temperatures were such that it would have survived. I said, "Well, gee, okay, there's a huge amount of damage, but on one entry it's fine and we'll just figure out a way to repair it and go fly again."

So the fact that you had that failure on that test was great. That's the kind of test that told me what I'd like to know. So if something does that kind of damage, the chances of losing a vehicle are still pretty low. But we still worried about stripping off large segments of the tiles, of course, the first time we'd flown, and you may have had some kind of structural response you didn't understand or some aerodynamic loading you didn't fully allow for, even though we'd put pretty good margins in all of our design.

We had the usual number of design reviews where you would bring experts in from academia or other companies and do design reviews, flight readiness reviews and these kinds of things. We were able to work our way through all of the concerns that people had and all the issues. We were able to satisfy ourselves that we were comfortable flying the thermal protection system, because we took a whole bunch of tiles off and densified that lower level and glued them back on and tested them. It was time-consuming, but it got done.

In the meantime, we did a lot more testing in the lab of our avionics system to where we were comfortable with that. We got some more engine tests under our belt to be satisfied with that. One of the issues as we approached first flight, we had had the Orbiter at the Cape for a fairly long period of time and we had done one flight readiness firing. But then we ran into this thermal protection system and it was several months before we were ready to go again. So the issue came, do you need another static firing of the engines? Well, as typical on a major issue like that, you had a bunch of people who said no, and a bunch of people said yes.

So we had a lot of soul-searching. I took the position we should do another static firing. A lot of the folks at Marshall said they didn't need it. I said, "Well, I know you don't need it, but we're going to do it just to make sure everything's ready. You've made a lot of changes to the engine since last time. I know they've all been carefully looked at, but we're just going to do it. If nothing else, it will make our ops people a little bit ready." It's kind of like the scrimmage on Thursday before you play the game on Saturday.

Well, that got bounced around quite a bit, a lot of argument, but we finally decided to do a flight readiness firing, so we had the second flight readiness firing, and everything went fine. A lot of the people said, "See, we told you everything would go fine."

I said, "Sure, I knew everything would go fine. We've had that practice. Now let's go fly." So those were the kinds of things you had to deal with as you approached that first flight.

We did everything that we felt we wanted to do. I hear a lot of people—it's amazing how many people you bump into that had nothing to do with the Shuttle that know something about it. People say, "Oh, gee, if they had more money, they would have done something different." I don't know of a single thing that money forced us not to do, that we really wanted to do. Now, I phrased that maybe where you couldn't—money was no excuse for anything. We did the things that our judgment said needed to be done, or we wouldn't have flown. We didn't do a lot of things that people had done historically because we didn't think it was cost-effective or worthwhile or necessary to do that.

So when people say the Shuttle is a dumb design driven by dollars, I don't think that's right. It's a dumb design, if you want to call it dumb, driven by common sense to how you like to go build a vehicle to put fifteen-by-sixty, 60,000 pounds in Earth orbit in a practical way, with something that's reasonably affordable to develop. Is it expensive to operate? Yes. But any vehicle you build that's going to fly to Earth orbit and back is going to be expensive to operate.

It's pretty interesting to me that all these people coming out, they say, "I can build one that's an order of magnitude cheaper to operate." When anyone tells me something's an order of magnitude something, I knew right away he doesn't know what the hell he's talking about. All he can remember is some algebra class somewhere where some professor told him, you know, there's a factor of ten here. It's a nice term, "order of magnitude." So if all he knows is an order of magnitude cheaper, he doesn't know what he's talking about, because he hasn't done anything other than pick an engineering term and throw it out there. So I say, well, that's kind of like naming your restaurant the low-cost restaurant. Every meal is low cost, right? It's a low-cost restaurant.

So what is practical today, in today's technology, twenty to thirty years after the Shuttle? The Shuttle started in 1972, thirty years ago, roughly. I would venture that if you were to start off today to build a Space Shuttle, you'd meet some of the same kind of things I've talked about, and I think it would end up being very close to the vehicle you see today, if you wanted to do the same things.

You'd want to put a fifteen-foot diameter, sixty-foot-long payload into Earth orbit, I mean, fifteen-by-fifty or whatever, sixty. Same payload size, same payload weight, same orbital maneuvering capability, the same crane capability, the same passenger capability, the same docking capability, I think it would end up looking a whole lot like what we've got, because we don't have anything better than hydrogen oxygen, and the I_{SP} out of the Shuttle engine is pretty high, even today. I don't know how you'd build one much higher. The practicality of putting the cryogenics in a throw-away tank is still there. The staging efficiency you get are there, otherwise you're fighting a terrible mass fraction problem.

All these people who go around saying, "I'll build a single-stage to orbit that will be an order of magnitude cheaper to fly," are napkin designers running around.

RUSNAK: I think the experience with the X-33 that they're having bears that out.

THOMPSON: The X-33, in my opinion, is silly. The X-33 is a little bit like eating a watermelon before you go to a watermelon-eating contest. I mean, why would you set out to build a scale vehicle to prove you could do something? We didn't build a scale Shuttle to prove we could build a Shuttle. Why would you invest two or three billion dollars to build something that can fly 400 miles? That's what X-33 is. X-33 can fly 400 miles from somewhere in New Mexico to somewhere in Utah. That's all it can do.

Now, they say, "Oh, but we're testing technology." The place to test technology is not in building a flying vehicle, in my judgment. First of all, that aerospike engine is extremely integrated into the airframe of the vehicle, so you complicate two very difficult things, where we separated them purposely so we could get a design path that can go on effectively. We put a computer on the engine so it could go off and do its own thing independent of the computer on the Orbiter. We went off and could build the Orbiter as a basic airframe, insulate it, have its own avionics system, and here's the engine, and those two development programs can go on, then you can bring them together. Because once you start the program and you start spending five million dollars a day, boy, the costs go up in a hell of a hurry.

Now, if I'm going to stick that engine inside the Orbiter, now I've complicated two very difficult development paths. Now, with that aerospike engine I don't have any idea how much controllability you got over it. On the engines we built, if you want the yaw out of the thing, you tilt the damn nozzle over there and you get a lot of yaw. Here, you have to move the whole base of the engine, whole base of the vehicle some way.

So they've stuck the engine into an airframe that's very complicated in a scale model that doesn't do anything but go 400 miles. They've tried to put cryo [cryogenic] tanks inside this thing and shape it like an airplane. The very things I said and made judgment calls that I don't want to mix that and that, I don't want to complicate this and this and separate them so you could get at something you could go build and fly to orbit, they've put them all in one great big hodgepodge and stirred them up and gone off here and built a little scale thing to go play with for a while. I'm off on a tangent. But it's silly. It doesn't make any sense to me.

Now, should we be doing R&D on a cryo tank? Nothing wrong with going in a laboratory somewhere and seeing how to take a tank shaped like a wing and see what it takes to insulate it, to handle liquid hydrogen, what it takes to condition it and load it. But then to try to integrate that into a single-stage orbit vehicle for the mass fraction problems you have, propulsion problems you have, all the problems you have, and then you call up a station and say, "X-33 is the replacement for the Space Shuttle," that's nonsense. X-33 is nothing but a little toy that people want to go to play with and try to do research and development and, in my judgment, that's not the way to do research and development.

There's nothing wrong with doing research and development, but to pick a program manager and put all that stuff and start funding it like a program, and then start getting the vice president and the head of the agency to pull a little cartoon off of a table, or a little model on a table, and say, "There's the replacement for the Space Shuttle," that's nonsense. This country ain't going to take money out of the Federal Treasury and build anything like the X-33 tomorrow, the next day, ten years from now, in my judgment. But maybe when some people like myself pass on, maybe you smarter, younger people will do it better, quicker, cheaper, better. [Laughter]

RUSNAK: That's right. [Laughter]

THOMPSON: Don't want to get off on that tangent.

RUSNAK: No, I didn't mean to misdirect you, I guess, from your original line of thought.

THOMPSON: The things leading up to the first flight were fairly straightforward. I said we had a date, finally got ready for launch date, fired up the four computers, and damn it if two of them didn't vote one way and two of them vote the other way. We had to shut it down and separate that out. It took us twenty-four hours. Came back the next day, loaded up again and flew.

The first flight was relatively trouble-free. Flew in orbit. What did we stay, a day? I can't remember. About a day, I guess. Came back and landed at Edwards [Air Force Base, California]. There had been a lot of worry about the landing, as I talked about. We could have improved the landing capability vehicle by putting canards on it, for example. We'd have made a little better aerodynamically in landing, but the canards were really terrible for launch. You didn't want them there for launch. To stow them somewhere and put them out was complicated. I always felt if we put the vehicle in the right position and flew it properly, it would land very well, so we didn't do anything to try to make it a whole lot better aerodynamic vehicle. So we very carefully landed out on the dry lakebed [at Edwards Air Force Base, California] where we had plenty of room.

We built a nice big runway at the Cape. We built it 300 feet wide and 15,000 feet long, with a couple thousand foot of overruns on either end. It's only a single strip, though, so you had a little bit, maybe if some cross-wind problems. But as I say, the Shuttle is heavy enough and less responsive enough to things aerodynamically that if you set it up right, it's going to come down and land pretty well.

But the whole flight, the launch into orbit, I was getting ready to talk a little bit about our icing concerns. We were a little concerned about ice building up on the tank and shedding off when you launch. There was a school of thought that says it's really not going to be ice, it's just kind of frost, but we ran some tests and we could get some weather conditions where you could get clear ice. Most of the time at the Cape you would not get those conditions. But we had an ice review team very carefully structured and took visual, went up and down and looked visually at the vehicle, places where ice would build up and made sure we didn't have any ice built up on the vehicle. They still do that to this day.

There were a lot of arguments, maybe we should build a big structure that covers the whole vehicle and keep it conditioned. But we could never quite convince ourselves that that expense was worthwhile or necessary. Later on the Shuttle got into some trouble on that flight where we lost the vehicle because of cold weather. I'm not sure to this day how much of it was purely cold weather. It turns out that the joints we designed for the SRBs were not as good as, in retrospect, they should have been. We should have been smart enough to have sorted that out and found it without a major accident, but it didn't work out that way. That didn't occur until, what, twenty-five, thirty flights, something like that. In fact, that's the one design weakness that has really hurt us. I guess we had to shut down a year to fix that and so forth. It really was not that complicated a design issue. We should have really done a better job of worrying about it earlier.

But in any event, the conditions on that April when we got ready to fly at the Cape were good. No icing problems that worried us. The launch was a clear, blue day, and the thing went off in great shape. Good crowd there looking at things and cheering things on.

The landing, we landed out at Edwards, went very well. Went out and looked at the vehicle and you could see some heat effects in certain areas, but all the tiles were pretty well in place. The whole thing flew quite well.

I had decided to retire from NASA sometime earlier, so that June I retired from NASA and did nothing for a few months and then to work with McDonnell Douglas.

RUSNAK: Before we move on to that point, I did have one or two questions, particularly about the first Shuttle launch. I guess the first four flights, really, had ejection seats for the two pilots. I wanted to ask you about the inclusion of those.

THOMPSON: We decided to put ejection seats in for those flights, particularly for the ALT approach and landing test, where with only two people on board, and with a fairly reasonable expenditure, and when you weren't worry so much about weight yet because you weren't flying to orbit, you could take almost existing ejection seats out of military airplane programs and put them in the Orbiter in such a way that you gave the crew a capability of getting out. It made no sense at all to put ejection seats on there for ten people. It made no sense to put ejection seat for the pilot and co-pilot when there's eight people in the back that didn't have seats. In fact, I didn't want the pilot and co-pilot to have ejection seats if the eight people in the back didn't have ejection seats. It didn't make any sense.

So is there a risk in flying the Space Shuttle? Yes. You can't fly to Earth orbit without incurring some risk. There's a certain amount of risk when you get in an airplane and fly from here to Dallas. Those risks are generally managed in such a way they're acceptable for what you want to achieve. You make the judgment that the risk of flying from here to Dallas is acceptable, because you want to be in Dallas and you know that the odds are one in several million that you're going to lose your life in it. Well, if you want to fly in the Shuttle, there are some odds that says you can get hurt or you can lose your life in it. Is it worth that risk to fly? There's no way you can guarantee 100 percent of the time that there isn't some risks somewhere.

When you look at the envelope the Shuttle flies, the ejection seats cover a very small percentage in some highly selected areas. Now, on the approach and landing tests where you were horizontal and you'll pop off here and glide down, you were at a pretty good attitude, if the vehicle started doing something funny, it wouldn't get upside down or do too much before you could get out of it. It was reasonably cost-effective to put the seats in, but it was never our intention to have an escape system for the ten people that we'd launch separate from the Orbiter.

Once we put those people in there, they were going to stay in the Orbiter until the Orbiter landed. That's the way we designed it. We took the calculated risk. You have to make those judgment calls, and that judgment call was made, and I still think they're going to do it again today. If you want to get to orbit with any kind of payload, you won't put an escape mechanism, other than the basic vehicle you've got them packaged in.

The same thing when we first designed the Space Station. We didn't insist that everyone on the Space Station had a way to come home all the time. Subsequent to that, when they got the connection with the Russians, they keep some kind of escape module up there, and I notice they're working now with an escape module to bring people down. There's nothing wrong with that, but I would point out that today we, the United States, has operated a research program in Antarctica for fifty years now. They've had people staying over down in Antarctica for several months and they can't leave there. They get a fire down there that burns their building, they can't get in an airplane and come home. The weather is such, there's no airplane down there. You have to go down from Christchurch [New Zealand] and get them and bring them back. You can't go down for six months.

So people are willing to take those kind of risks, and we felt that if you want to go and live and work on a space station, you didn't have to have an Orbiter there all the time, that most of the contingencies, if your food got low, you could send an Orbiter up and get them. We had four or five vehicles, and the odds of having an Orbiter grounded to where it couldn't go in some reasonable contingency time and get people, and if you've got an explosive decompression up there, you're dead in thirty seconds anyway. Why do you have to have a transport vehicle to come home?

Now, if you can afford it and if it's fairly straightforward to do, do it. But I didn't see that we were taking that much of a risk to not have ejection seats in the Shuttle, and I didn't think we were taking that much risk to not have a come-home vehicle docked at Space Station all the time. But ultimately that's the judgment call of the people that run the program. The people putting the money up out of Congress, the people in the agency at the head, in the administration level, and at the people at the program level are running it. That's a judgment call as to what they want to do. But you don't do these kinds of things completely risk-free, and if you set out to do them risk-free you'll find sooner or later you just can't do them. You can't cover everything.

The spectrum of problems you're dealing with to escape from the Orbiter over the whole launch spectrum, a few tens of seconds after liftoff you're going too damn fast to get out of the vehicle anyway. Best thing you can do is stay with that Orbiter and try to turn it around and bring it back. You can't turn it around in all cases. If you've got a couple of engines out at a critical time, you're going to end up in the water somewhere. Or if you have something happen like the *Challenger* [51-L] accident, even if we'd had had ejection seats on that thing, the odds of those people getting out of that thing were nil. I can't even envision ten ejection seats coming out of that Orbiter. [Laughter]

Years ago when I worked at Langley, we did a lot of work on escape pods for airplanes. When airplanes first started going at real high speeds, people would design ways where you'd bring the whole front of the airplane off and then you'd pop out some stabilizing veins to keep it from tumbling, then you'd pop out a couple of stages of parachutes to slow it down. They were borderline practical. To my knowledge, we've never really built an airplane where you tried to bring a pod of people out and save them.

RUSNAK: I think the F-111 has a crew compartment, I guess, for both the two people in the front that pulls them out as a unit, but not quite the whole front end of the vehicle, though.

THOMPSON: That's sort of a derivative of some things we looked at years ago. They just decided it's better to package the two people and get them out, rather than bring them out in a series.

But escape seats for a vehicle like the Space Shuttle, the more we looked at it, the more I was convinced it made no sense. We considered it, and we had a lot of people argue to do it, people that would come in very emotional. "You can't put people in there and not give them a way to get out." I said, "Sure you can. If they don't want in there, they'll know it. They don't go." But those are things you have to deal with as the program manager every day as this thing evolves.

RUSNAK: Certainly the men who are flying these, the astronauts who used to be test pilots and such, are used to taking a risk of some sort. As you said, they were standing in line to fly this thing. Do you remember if the astronauts had any reservations about the vehicle or any particular input in any regards?

THOMPSON: Well, I don't recall any serious disagreement. All through the design evolution of the Shuttle, the Flight Crew Division had an individual who came to all of my major design meetings where the decisions were made that we've been talking about, and this individual was a person I had a lot of respect for. He was an ex-NASA test pilot that was assigned in the Flight

Crew Division, and he came to all the major Shuttle Program meetings and represented the crew and the crew's thoughts and would take things back and discuss it with individuals or groups of individuals.

Some of the things that they argued for that we never put in the vehicle for them, this particular individual at least, I don't know how many of the astronauts felt the same way, but he always felt that we should have a thrust termination capability on the SRBs. He argued—in fact, he's retired. He would still argue that you should have thrust terminators on the SRBs, which would give you the ability to kill that thrust so that if some problem developed somewhere along the way, you could thrust-terminate those, which would maybe help you separate the Orbiter a little bit, although I was never convinced of that, because the way you terminate the thrust of SRB is you blow the nose off of it. So you've got this cylinder with all this solid propellant burning. You can't snuff it out, can't turn it off. So you've got a bunch of hot exhaust coming out this end. I could never convince myself you were that much better off to blow the nose off and have exhaust coming out both ends in kind of an uncontrolled fashion.

Then I was never sure how you'd make the judgment you wanted to blow the nose off. Where do you get the data that tells you? Would you do it because your attitude started skewing? Maybe that would be the dumbest thing you could do.

So when you take those things and study them, and what we would do typically if this fellow came in and argued, say, for thrust terminators, because we'd baseline, the way I had the program going is we had a baseline, and what the baseline said, "Unless someone convinces me to do something different, here's the way we're going to build the vehicle. Now, everyone's invited to come in and recommend any change they want to at any time. But until I make a change and put out a written directive, this is the way we're going to build it. This is the way we're spending our money and this is the way we're going to build it."

So people from time to time would put in a change. They'd say, "Put the thrust terminators on the SRBs," and they would submit that to my office.

I would say, "Okay, we'll send it out for a comment."

So you'd take that recommendation and send it to all the pertinent people in the program, give them an appropriate amount of time to decide the pros and cons of thrust-terminating. You'd have the structures people study the structures issue, you'd have people study how you'd decide when to use it and that sort of thing.

Then I would schedule that subject for a design meeting on a Friday. I'd have those meetings every other Friday and we'd treat fifteen or twenty items. So thrust terminators on SRB would come in. We'd send it out for study. It would come back, it'd get on the agenda, and at two o'clock on a Friday afternoon that agenda would work its way to the top, and so now for the next forty-five minutes we all discussed thrust terminators. "Warren [J. North], you've recommended it. You get up and tell us why you think it ought to be done." So he'd get up and give you an impassioned argument for thrust terminators for five minutes.

So then you would then start talking to the SRB people, or the flight control people, or the system engineers and cost people, and you'd sit there and say, "Well, but suppose this happens. It won't do you any good. Well, suppose that happens. It won't do you any good. Suppose it goes off accidentally. Now, you've really shot yourself in the foot."

So you'd sit there and listen to all that pro and con, and you'd then turn to Warren and say, "Warren, I hear your argument. I understand where you're coming from, but for this reason, this reason, this reason, this reason, we aren't going to put thrust terminators on it. No change in the baseline." And we would dispense that recommendation with no change.

Three months later he'd come back again if he wanted to and put the same thing in the system again, and you'd deal with it the same way. If something changed, you'd change it and put it in the baseline, or you'd throw it out again. And you'd just sit there for eight or ten years and grind along that organization that way, and, lo and behold, the vehicle comes out the other end, and it doesn't have thrust terminators on the SRBs. Was he wrong? Not necessarily. He had some good arguments, he had some bad arguments.

Canards to make it land better. The people who knew a lot about canards knew a lot about landing, and we did the flying qualities and evaluation and this thing was a relatively poor landing vehicle. We knew it was going to be a poor landing vehicle. So they'd come in, "Put canards on it, make it land better."

So you'd go out and study it and come back, "Well, if we put canards on it, you're going to have them on out at launch or not?"

"No, let's stow them."

"Where you going to put them?"

"Well, let's just fold them in the nose of the vehicle."

So you'd go off and do a rough design. They only weigh 1,000 pounds. We'd have to take something out of the nose and move something around and move some structure to make a place to move them in. Then we'd have to have a mechanism that pops out. That mechanism has to be reliable enough that they come out together. We don't want one out on one side and not on the other side. It makes the vehicle fly this much better. You had to quantitize that because it's not a very measurable thing.

So you'd sit there and listen to the arguments, the pros and the cons, the pros and cons, and maybe about after thirty, forty-five minutes, if it was properly staffed and people have had plenty of time to understand it, you're on telecon [teleconference] and people all around the country are listening to you, because we didn't bring all the people into one big meeting, we hooked them up a telephone. We had the people we wanted in Rockwell, the people we had in Martin, the people at Marshall, the people at Langley, the people at some university somewhere. I ran the meetings that way so that we could bring the people in for that subject, and then they could go back to work, and bring the other people in for another subject. That's the way we ran the program.

So I'd sit there and listen to all that and then say, "Well, I understand, but we're not going to put canards on it."

So the directive goes out and says, "This recommendation to put canards on is—"

And then I'd go to a monthly meeting in Washington and I'd explain to them, to the center directors all around, and the Associate Administrative in Washington, and all the people in the staff in Washington, say, "We had a recommendation to put canards on, but for the following reasons we're not going to put canards on." And they sat there quiet and we didn't have canards on.

Or if they'd say, "You dumb son-of-a-bitch, get out of here, you're fired," I was gone. [Laughter]

RUSNAK: Which seemingly they never said.

THOMPSON: That's right.

RUSNAK: When it came time for the first launch, STS-1 is going to go up, where were you for that, and what were you thinking as this was about to take off?

THOMPSON: Well, first launch I was over at the Cape in the launch control center. The Associate Administrative for Manned Space Flight, a fellow by the name of John [F.] Yardley, who had taken Dale Myers' place, he was there. He's my immediate boss in Washington. The launch people, Bob Gray, who was the launch project manager from Kennedy, was there, and the launch director, the people at Kennedy who got the vehicle ready for launch. You're all in a cubicle during the launch. You've seen it on television.

So you sit there with a headset on at the console, and when the computers didn't match up just right, and we listened to a discussion back here in Houston on the computers and so forth, and made decision to scrub. We made the decision to meet the next morning and review everything, see if we were ready to go that afternoon. So I was down there doing that sort of thing in the launch control center, and had my immediate boss in Washington, they were with me. Johnny Yardley was there in the seat next to me. Deke [Donald K.] Slayton by that time was on my staff as the ops coordinator. He was there. So I was at the Cape on launch.

I went out a few minutes before launch and met with the ice team when they came down off the gantry and said, "Well, what'd you find?"

"Nothing. Ice looks fine. We've looked at this, this, this and this, no ice."

So then you get on and say, "No icing problem. We're go for that."

Any little issues that came up during the countdown, most of them are handled down in the launch organization, but occasionally a policy kind of thing would come up and you'd be sitting there taking care of that. Like the scrub and whether we go the next day, whether we had time to sort out the computers, and for that launch the people who were second-guessing me in Washington were sitting right there with me, so we were there together.

Then after the launch, we got on the airplane and I came back to Houston here and we stayed in the control center here at Houston during the flight. I went home that night, had a good night's sleep, came up the next morning for the landing.

After landing, I went out to Edwards to look at the vehicle, but I didn't go out there for the landing, I stayed in the control center here, because this was a better place, really. If you go to Edwards, all you do is see the final flare and touchdown.

So went through that, and then, of course, you go to the press conference and tell them all the great things that happened and answer all the questions. Then packed them up and left.

RUSNAK: As you said, you left only a few months afterwards and you went to work for McDonnell Douglas.

THOMPSON: Right.

RUSNAK: So if you could tell us some about your experience there.

THOMPSON: Okay. I left after the first Shuttle flight, and John Yardley also left at that time. I decided not to talk to anyone about going to work in the aerospace business for a few months. I didn't want any conflict-of-interest kind of problems. So I moved up north of Houston, built a house up there, and considered going into business with my daughter and son-in-law. They were in the home building business up there. But the home building business was having a down cycle at that time, plus I didn't know anything about the home building business.

After a few months of inactivity and golf, you can only play so much golf, I decided I'd still go on and work some more. I was, I think, fifty-seven at that time. So I talked to a few of the aerospace companies, and McDonnell Douglas decided they'd like to have me come on board and work with them, particularly if Space Station became a real program, to then manage their Space Station activities within the company. So I joined McDonnell Douglas. John Yardley was the president of the company within McDonnell Douglas that had the responsibility for Space Station, the space part of McDonnell Douglas.

When NASA decided to release an RFP for Phase B Space Station studies, I moved out to California to head up the Space Station bid and proposal activity out there. So that was my first real experience within the industry, looking at it from the other side. So I was really on the receiving end of an RFP coming from NASA, where prior to that I'd been on the sending end of RFPs going to industry.

But it helped quite a bit to know both ends of the business, to know what the government is looking for when they release RFP, how they go about evaluating it, how they go about grading it, how you go about communicating with them, what you put in the document, what you don't put in the document and that sort of thing.

So we bid on the Phase B studies and we won one of the studies. We conducted those studies from probably [19]'82 and '83 is when that bid and study time. I can't remember when they released the RFPs for C/D on the Space Station originally, '84 or '85, somewhere in that time period.

When they did, they released RFPs for four work packages. NASA decided then to break Space Station into four work packages and they decided to manage them out of Washington, although they set up a lead center here at JSC somewhat similar to what we had on Shuttle originally, but for several reasons that never did quite work out very well, partially because the people in Washington didn't want it to work out, and it'll only work if the people in Washington want it to work.

Then secondly, I'm not sure the people at JSC knew quite how to make it work, so it was kind of rough. The work packages were somewhat complicated, but no more complicated than the four projects we had in Shuttle. In fact, I would argue the Shuttle projects were probably more complicated to integrate and put together than the Space Station was, because you had more difficult things to deal with. Space Station is in a fairly passive environment. You don't have to launch it. You don't have to protect it from entry and all that sort of thing, but it's not without its complications.

One of the work packages was mainly things that fly on the Space Station experiments, so really there were only three work packages. A management structure similar to Shuttle would have worked quite well, but they never quite got into that mode.

But in any event, at McDonnell Douglas we decided to bid on the work package out of the Johnson Space Center. Rockwell bid against us, so there were two bidders. It was a fairly comprehensive RFP. RFP was well done. We worked hard and submitted a proposal that was the winning proposal. So we were awarded the contract for work package two, I believe it was called. Work package two had a lot of the critical elements of the Space Station on it. It had the avionics system, the propulsion system, the electrical power distribution system. The generating system was in Cleveland, nothing out of that work package. But it was a very good package of work.

We put together a good team of engineers that bid on it and a good team of people to implement the program once we started. We went into Phase C/D for what was called Space Station *Freedom*. It was a modular space station with an EVA-erectable truss. One of the issues that had been worked for several years at NASA was as you went into this low Earth orbital infrastructure, what should you do about big structures on orbit. People at Langley did a lot of work, people at other places did a lot of work, and a lot of work was how to go into Earth orbit and assemble a truss to give you a big structure.

I always used to argue that the truss was a little bit like if you were going to build a factory here on Earth, you'd go buy several acres of land, right? Well, you're going to build a space station in orbit, the first thing is to go up there and build a big truss structure to hang everything on. You hang the electrical power generator out in the boondocks on either end, you maybe put a thermal distribution system in the center somewhere to take the heat and radiate it out and so forth. Then you put your house in the middle of it somewhere. So I think the EVA-erectable truss made a whole lot of sense. Not only that, but it developed a national capability of taking the Orbiter and going into Earth orbit and opening the payload bays and building nice big structures, because we'd worked out the details of how you build the joints and how you snap them together and how you build graphite epoxy structures to make it lightweight and you can just put in a bundle in the payload bay and don't have to worry about launch loads. You just put it in a box, take it in orbit so you can put together a nice big structure up there, and then here's a place to put your solar panels for generating electrical power, here's a place to put your radiators, here's a place to put the house you live in and so on.

Frankly, I think it was a great design. We spent probably the first eighteen months on the EVA-erectable truss Space Station *Freedom* design, NASA changing program managers and changing things a lot. Somewhere along the line they decided the EVA-erectable truss was too risky. Someone came in and proposed putting ejection seats in and they bought it. So they came out with a direction to go away from the EVA-erectable truss. We'd already finished all the design work, all of the work of going into orbit and doing that, had contractors building truss elements and so forth.

So we had to cancel all of that and go to an integrated truss, where you had to build a truss here on the Earth within the sixty-foot length of the payload bay, mount all of the stuff on it, mount them in such a way that they could stand a launch load, so the weights went up. The complication, you had to release a lot more drawings and all this kind of thing.

So the program begins to go through these bumps in the road. Once you kind of start that, next thing you know, you've opened a real can of worms, because this thing leads to that, and that thing leads to something else. So the program began to run into concerns about whether they could meet their cost, meet their schedule, meet anything along. But in the meantime, they were still struggling along.

Going to the pre-integrated truss, per se, would not have necessarily killed the program. It just slowed it down and made it cost a little bit more, where you had to release a lot more drawings. You had more weight and all of these kind of things, but the program was still stable going along in that regard.

NASA attempted to set up a program management and program integration function in Reston [Virginia], right outside of Washington, that had a job similar to the job I had on Shuttle here at the Johnson Space Center, but where when I got the job I had a mature center to draw from, when I wanted structures engineers, they were there, and they were in a laboratory where they could do structural test work and they could integrate what the contractors were saying and they had capability. If you're in a shopping center in Reston, Virginia, with people you're just picking up and hiring here and there, there's no real capability there. They were trying to start from scratch and build that up.

So the next thing you know, the detail kind of things that we handled here every Friday began to be problems. They'd hang around. No one was doing anything with them. People would say, "We want to do this," and they would just sit there and hang. So the program began to stall out, or not move as effectively, and next thing you know, we had a change in this manager and change in that manager.

So the program was drifting along, but still doable. Still Space Station *Freedom* was a credible design. The work packages were still going along. And lo and behold, [President] George [H. W.] Bush loses the election. We got a new President in. Well, next thing you know, we got a new Vice President. And next thing you know, they're reviewing what NASA's doing. "Gee, that's a Ronald Reagan Space Station. The Republicans did that. That can't make a lot of sense. We've got to be able to do something better."

So the next thing you know, the Russians are in the picture. "Let's join up with the Russians." Then you've got a new Administrator. He wasn't there when this Space Station was conceived, so he didn't have any real feeling of commitment to it.

So in the meantime, I'm sitting, running a group of people, releasing drawings and building things. We're actually, we have the propulsion modules built and then hot-fire test out at White Sands [Test Facility, Las Cruces, New Mexico]. We've got the avionics system ready to go in test out here at the new facility we built at Ellington [Field, Houston, Texas]. Program's moving along. Space Station *Freedom*, whether you like it or not. The only big change is to go from the EVA-erectable truss to the pre-integrated truss, which we got through that hump without major damage.

But the next thing you know, there's a big stir with the new President, big stir with the new people in Congress, big stir with getting in bed with the Russians. The next thing you know, Space Station *Freedom* isn't very popular anymore. The next thing you know, you throw that in the wastebasket and now we're off, it's going to be cheaper to have the Russians do this propulsion module, right? So the Russians produce the propulsion module, so they canceled the one that we're building and the Russians now are building one.

So to help the program along, the Russians volunteered to build a module. The next thing you know, the fellows in Congress ask NASA, "Well, how do you know the Russians are going to build that module and get it to you on time?"

"Oh, we'll go away and study that." So they come back and say, "Oh, we'll tell you how you can do that. We'll pay for it. That way we're guaranteed to get it."

"Oh, that's a good answer." So NASA sent the money over there. Does the money go to that module? I don't think so. The money goes somewhere else. The next thing you know, they look and there's no module there, and NASA says, "Well, hell, we're going to build one ourself." They canceled a perfectly good one for Space Station *Freedom* two years ago.

The next thing you know, they're off building a propulsion module. I don't know where it stands today. So next thing you know, I look around here and it's the year 2000, I think, and there ain't no Space Station up there yet. There will be one there some day.

But in any event, McDonnell Douglas had a policy that if you're at the VP [vice president] level at sixty-five, you're supposed to leave, which is a good policy, I don't have any quarrel with that. But they were generous and asked me to stay on for a couple more years. When I got to be sixty-eight, I decided that there were too many people that were leaving at sixty-five, they were being asking questions, "Why is he staying till sixty-eight?"

By then we'd moved here and built a facility out at Ellington, they'd moved Space Station activities here from McDonnell Douglas. But now they're beginning to take the program and turn it topsy upside down, so it was time for me to retire. So I left the Space Station manager job at McDonnell Douglas in [19]'93 and I worked part-time with Eagle Engineering here locally for a couple of years, just to phase down. But I really haven't worked actively since '93.

But I wish Space Station a lot of luck. I think eventually, as you see, we're getting it up there. We've got triple modules up there now. Give them enough time, enough effort, it will end up being a good thing to do. I wouldn't want to argue whether it's been effectively done, cost-effectively managed. What we get out of our relationship with the Russians I'm not in a real position to evaluate. I think certainly we need to work with the Russians in some way in space. I personally would have liked to have seen this program structured in such a way they were not in too critical a path.

I think if the Russians would have been willing to take a position somewhat like the Europeans or the Japanese, and NASA had stuck with something very close to Space Station *Freedom* and left them putting a module somewhere toward the center of the thing if they want to spend some money on the space, or let them use maybe their unmanned carrier to take some things up and back, put them in that role, and then if they found they couldn't afford it, just not have it show up, but leave NASA controlling the main core.

I can recall when the Europeans decided to build the vehicle or the pressurized module that goes in the payload bay. I forget what they call it now. Spacehab. Not Spacehab.

RUSNAK: Spacelab?

THOMPSON: Spacelab? When they decided to Spacelab, the program manager from Europe came to see me and said, "We're going to now take our money and build Spacelab. You people are taking your money and building the Shuttle, and these two things have to interface. You and I need to be joint program managers." In other words, you don't change anything on your side and I don't change anything on my side till we both agree.

I said, "Thanks, but no thanks. I mean, you're a payload. We're under way. We're building a vehicle. We have Volume Thirteen that tells what all our interfaces are. That's all you need to design your Space Lab. I don't need you in a single meeting I'm having from here on. I don't need to come to Paris [France] for a single thing, and you don't need to come to Houston for a single thing. These things are manageable if we keep them apart. We put them together like this, I'm not sure they're manageable and I'm not interested in getting in a voting society." And that was the last meeting we had of that nature.

I frankly think that some of those kind of things should have been done on Space Station as well. Having joint meetings in Moscow and Houston and joint flight control centers and joint this and joint that, I don't see how they get anything done. But I said I wasn't going to get into that very much. You can climb a mountain many different ways, and they'll eventually climb the mountain.

I enjoyed my ten years in industry. It was very rewarding to see how you work on that side to interface with the government. I wasn't as frustrated as I thought I might be. It's one thing to sit on the government side and do things, it's something else to sit on the industry side and do things. There is obviously a very effective role for both sides, and as long as both sides understand what their roles are, it can be very productive.

Frankly, taking money out of the Federal Treasury and building something like the Space Shuttle, the responsibility has to lay in the hands of some people with government badges on, and those people have to have the capability to make very detailed day-to-day decisions to make things happen. I don't believe you can turn those kinds of things over to a contractor and expect him to do them.

First of all, the contractor's in business to make a profit. He's got a board of directors, he's got some shareholders, and he has to do things in a responsible way, but still turn a profit. It's unfair to ask him to make some of the decisions that affect that profit mode with taxpayers' dollars. Someone with a taxpayers' badge on has to make those decisions. Therefore, you have to put together a management team in the government with enough technical capability and enough management capability to run one of these things on a daily basis, and you have to admit that's what you're doing and insist on that's what you're doing. You can't say, "I'm turning it over to the contractor and I'm going to beat him up if he doesn't do it right." It's a joint thing and you don't want anyone to get beaten up, because when you're beating up people, you're wasting taxpayers' dollars. If you have to beat up people, you're wasting taxpayers' dollars.

RUSNAK: So what then do you think of the greater role of contractors in running the Shuttle Program, for instance?

THOMPSON: Again, I'm not that close to the details of the way it's done. Now, you can fragment contracts too much. For example, when people around here were talking about taking forty Shuttle contractors and making it one, I said, "No, you're taking forty Shuttle contractors and making it forty-one." And in many cases that's what happened. All you did was give that integrating contractor part of the government's role, but it's not clear how many of these other forty went off the payroll or what was changed. Now, some of them may have fallen off, and there may be some efficiencies that finally emerge. I'm not saying you can't fine-tune these things, but it's an oversimplification to say, "I'm going to take forty contractors over here and I'm going to make it one." The one contractor has got to be the government, and I think it is extremely important that the government understands it and the government recognizes that and the government's willing to say that and the government's willing to be held accountable for that.

I don't believe it's in anyone's best interest to turn the detailed day-to-day responsibility to run the Shuttle over to a contractor. I'll bet you if you get behind the closed doors and look, it's not happening. I'll bet you there's some government people right in the middle of things, and they should be, and they should be in enough number and enough technical and operational and management depth to really feel responsible for what's going on.

So when I meet some guy on the street and say, "We're going from forty contractors to one," I say, "No, you're going from forty to forty-one." And I'm probably not all right and he's probably not all right.

Taken to the extreme, you can ask yourself what's the purpose of NASA. You see, the money comes out of the Federal Treasury under the supervision of the Congress and the executive branch of the government and comes over to an agency working for the executive branch of the government called NASA. There's an Administrator up there. An Administrator has to have in place, if he's going to spend a big part of this money for something like Space Shuttle, he has to have in place a management team of government people that can really be held accountable for what goes on in Shuttle. Every dollar spent on Shuttle, someone in the government ought to be held accountable for it.

That means that there has to be enough government people in place and enough capabilities penetrating deep enough to do that effectively. Now, you can overdo it, but very few government people sat at drafting boards and drew structure for the Orbiter. Rockwell had structures people used to designing wing layouts and picking material thickness and so forth. But I guarantee you we had someone in the government who knew those drawings were being made, who knew what kind of load factors it was being designed to, who knew what kind of safety factors were being put into that design, and who could come to my meeting and argue about whether that was a reasonable weight bogie or not and argue about whether that was a reasonable design factor to be designed to, or could argue about whether that wing was going to give a reasonable lift characteristics.

That's what we had in place in the organization I've been trying to describe to you that had a government program manager and a staff of 300 people in these four integrating offices and an Orbiter project office with two or 300 people in the project office, and then had over here a Structures Division with a couple hundred structures people and a lab out here to play with, as we watched structurally what was going on in the total program.

Now, you can argue how much of that government is needed. You say, "I'll give [The] Boeing [Company] a job and pull all of this back." Someone ought to be careful. When they give Boeing a job, if you don't pull this back, all I'm doing now is spending money twice. I'm paying for this over here and I'm paying for this over here. So instead of one contractor, I've got forty-one contractors, and NASA's still doing it. I still see a hell of a bunch of cars parked over at the Johnson Space Center. If they're parked there, they ought to have a very responsible job, they ought to be doing something. I'm not saying they aren't. I'm just saying they should be.

So I think the management structure that evolved around the Shuttle would have worked extremely well around the Space Station had people in NASA at that time, from Washington right on down, understood it, put it together, supported it and made it work. They didn't do that. So they had a lot of starts and stops and trials, and then the political events overtook it. I think had Bush won the election, Space Station *Freedom* would still be on track. It would not have been run as efficiently as it might have, and I think the EVA-erectable truss would have been a better long-term investment than the pre-integrated truss, but that's a detail.

The McDonnell Douglas role in Space Station when they went to the one they have now with the Russians, I'm not even sure what they call it, the role was eroded to some degree. The things that they were doing, some of those things were taken and "given" to the Russians, because the Russians would do it free. The pre-integrated truss is still a part of the McDonnell Douglas contract, owned by Boeing now. Boeing has overtaken that. The propulsion system, I guess, went to the Russians. A lot of the avionics and software went to the Russians, but a lot stayed here. That all happened after I retired, so I'm not sure how that finally broke out.

Boeing, when they picked up the lead contract on Space Station, they moved a bunch of people here, and they're over here in an office building with probably several hundred people. We didn't have that sort of thing in Shuttle. We did that with civil service people, although we had some support, either support contractors or we had the prime contractor bring some people in.

For example, when I would run a Friday meeting and deal with these fifteen or twenty items, and you had to write up the directives and collect the data, what was done, that was a combination of government people and Rockwell people working in an office that put those packages together that I would sign on Tuesday and send out. So we brought the contractor in at that kind of way and jointly did the integration and the management. So I'm not trying to say the government does everything, but by the same token, the contractor doesn't do everything. There's got to be a very well thought out and a very structured way of working effectively together. You'll have a tough time finding that one guy sitting in his kitchen and designing Shuttle. [Laughter]

I'm not sure what else I can—it's five o'clock, I guess, and I think we've maybe run it out, unless you've got some more questions. Let me cut a deal with you. I'll be very happy, because I don't play golf that often, anytime you want to sit down and have a follow-up for a couple of hours, if you make up a list of questions, I'll be happy to come over and sit down. I don't know whether you do anything to write this kind of material up.

If there are any other people that I've mentioned that you want me to describe to you, if you haven't talked to these people, they'd be a valuable asset to you. They're people like Owen Morris. I don't know whether you've talked to Owen Morris, but Owen would be a very valuable person. Aaron Cohen. [R.] Wayne Young. If you haven't talked to Wayne Young, Wayne was essentially our cost and budget and schedule man, integrator. Reg [Reginald M.] Machell was essentially our program control or management integration. He was the fourth box I couldn't think of a while ago.

We had four boxes. Management integration was Reg Machell and a fellow named Bert [James B.] Jackson [Jr.] that worked with him. Bert was his assistant and Bert had the unholy task of doing all of the staff work for those design meetings that occurred every other Friday where we'd deal with the subjects I've described to you. He had the job of getting all the minutes written up and all of the preparation to make sure everyone was ready to argue their case, and then write it all up and get it ready for me to sign by the following Tuesday. We'd have a meeting on Friday and the directives went out the following Tuesday.

RUSNAK: As far as the management integration, what does that involve exactly?

THOMPSON: Management integration was that configuration management. In other words, you baseline a vehicle. We had a documentation system. It was called the 07700 Series. There were eighteen volumes in that thing, all of the requirements of the program, all of the this is what it's supposed to do, this is how it's built, this is all the safety requirements here, the schedules, the whole hierarchy. Bert Jackson in the management integration office was the deputy there.

Reg, his background was mainly EVA. So we had things like the suits, pressure suits, and all the food and all of that was managed out of that management integration office. Reg ran that, and Bert ran the program control, program management scheduling kind of things.

Wayne Young ran the budget schedule. It was Wayne's job to make sure we got all the dollars out of the system that you needed every year to run the program.

We had an Ops Integration Office that was a small office that interfaced with the Flight Ops Directorate at the Johnson Space Center. The Flight Ops Directorate actually did their thing of doing the mission control and mission planning and flight planning and flight control, all this kind of thing, but had a small office that made sure all of the things around the total program, the things that the contractor had to do to support that, the things they had to do at Kennedy to support that, and the things they had to do at Marshall to support that. We had people in our control center at Marshall to have that integrated with. So I had a group that integrated that.

Then once we got the ALT, we brought Deke Slayton in and put him into that area. A fellow named Don [Donald C.] Cheatham had it for a long period of time. Don is dead now and Deke is dead, so you can't talk to any either one of those, I guess.

I'd say Owen Morris, Wayne Young, Reg Machell, and Bert Jackson would be four key managers to talk to at the integration level, if you haven't talked to those. Bert Jackson left the government, went out and went into private industry, then went back to work for the government and was working over at the Cape last time I knew anything about Bert. He may still be working over at the Cape, although he's probably getting close to retirement by now. Reg Machell lives up north of Houston, you could get him.

RUSNAK: He's on our list to talk to.

THOMPSON: Okay. Owen Morris you say you've talked to. My deputy through those years is dead, Homer [W.] Dott. Scott [H.] Simpkinson, who was one of the key staff people I had, Scott was a kind of—he was a trouble troubleshooter. Scott was the kind of a guy you didn't really put in charge of too many things, but as a one-man band to go out and work a problem and bring you a good concise report on it. So I used him and he did a lot of the—if you had some issue that the system wasn't working very well, you could set Scott on that issue and give him an ad hoc group of people and he'd go work it a couple of weeks and bring it back to you with the pros and cons of it pretty well. But he's dead, too, now, can't get to him.

We had a bunch of committees. We had an Aerospace Safety Advisory Committee made up of people from outside of government. That was set up after the Apollo fire, and they were active all through Shuttle. They used to come every quarter or so, and I had to spend a day telling them what we were doing. They'd ask you each time, "Why don't you have ejection seats?" Or someone would key in and say, "Why don't you have canards?" [Laughter] Scott was my representative to that group when they would meet somewhere else outside and I didn't want to spend the time going to the meeting. Scott went to that all the time with me. They were very valuable.

Now, there are people—if you're going to do this thing right, there are people at Marshall you ought to talk to. There's a fellow named Bob [Robert] Lindstrom, Jim Odom, J.R. Thompson. When we brought J.R. in as the engine project manager, he was known as Bob Thompson at Marshall. I told him, "Look, I'm Bob Thompson in the program, you're J.R. in the program from here on." So he got to be J.R. and I got to be Bob. He ran the engine program. He ended up being a Deputy Administrator of NASA at some point along the way. I think he's still in Huntsville. I think he worked for Space Hab or one of those companies, or he did for a while. And George Harvey, the SRB project manager.

Marshall did a hell of a good job. They took on the task of being integrated into the program office out at Houston without bitterness. Bob Lindstrom had the job of looking over the three projects at Marshall, kind of a pseudo program manager. He showed on the organization chart. If we wanted to do some budget, play around between the three projects at

Marshall, I'd give him that job and he'd go do that. Much better to have him do it than to have me do it from over here. He was extremely valuable. He'd be a good person to talk to on Shuttle if you're going to document those levels of details.

Jim Odom's still around. J.R. is still around. George [B.] Hardy's still around. So I'd say a trip to Huntsville you could justify here in the future if you wanted to find those three people. Bob Gray, who was the project manager down at Kennedy, is still around. He was very valuable, because we had to take all these facilities down there and get them ready for Shuttle and get their organization ready to accept the vehicle and build the new facilities down there we needed.

For example, late in the program we found that we were getting too much reverberation off the launch pad structurally on the back of the vehicle, so we decided to put a water barrier. We had to, late in the game, build a big 300,000-gallon water tank. If you look at the launch structure, you'll see that water tank there. That dumps water down and puts a water shield at the base of the Shuttle so that pressure waves don't bounce back and do some things on the back of the structure we didn't want to have done. Then you had to do a late scramble.

Then also the icing thing you remember, worrying about the cold hydrogen exhaust coming out and mixing with the air and icing up the front of the vehicle and put that little beanie cap, we called it. You see the thing they take off the top, the rotating structure for payload. At one time in the program we had people arguing that you don't want the capability to put payloads in at the launch pad. Make them go in the Orbiter back in LNC, don't let them open the thing.

In fact, our Deputy Administrator, George Low, who had been the Apollo program manager, he argued very much to not put a payload change-out capability to pad, but I never did buy that. I said, "You can't force the payload people to finish whatever they're going to do thirty days before you launch and lock themselves up. If they've got animals or something like that, you can't do that." So we put in the rotating structure that rotates around, you can put payloads in and rotate that out of the way to launch.

You go down and talk to Bob Gray, he'd bend your ear for a while, and that history probably ought to be gathered. Certainly the history at Marshall ought to be put together. I'd certainly recommend you going over and talking to Bob Lindstrom. If you call him, he could lead you to Odom and Hardy and J.R.

One of the things, as I reflect, NASA was in a good position to take on the Shuttle in 1970, because it had a bunch of people that still had ten or fifteen years of work ahead of them, but they had worked ten or fifteen years in the business. We had a bunch of support organizations, like the Johnson Space Center with all of their divisions, Marshall Space Flight Center, Kennedy Space Flight Center. Those things still exist today. What capability is there today compared to twenty years ago, I don't know. Thirty years ago now, I guess.

But coming off of the Apollo Program in 1970, within NASA there was a lot of capability that if you would put it together in a reasonable functioning organization and you were pretty careful about who you put where, it had a lot of capability, and, I think, allowed us to take on building something like the Space Shuttle in a reasonable time period for a reasonable investment that has worked quite well with that one exception.

If NASA were to take on building another Shuttle or a Shuttle replacement tomorrow, I'm not sure just what exists there today that you could put together to do that. A lot of the people today that are in key management positions did not come out of the research environment or the Mercury, Gemini, Apollo environment that most of the people I've been talking to you about came out of. There are people that have come in from other walks of life, military, other places. I'm not sure what kind of a team you would be able to put together today within NASA to take on that kind of a technical development job.

Things like the X-33, I was invited several years ago now, three or four years ago, to go to a meeting out on the West Coast and review some of the things they were doing on the X-33. I did that. They weren't at all pleased with the things I said to them. I knew they wouldn't be pleased when I said them, and they obviously didn't do anything with what I told them. But I found them to be a different breed of people than I was used to working with. The training, both the formal educational training and the experience, didn't match with what I was used to seeing. As I recall, the key man in Washington had some kind of a non-engineering degree and his experience base had been a staff member over in the Congress somewhere. Well, I don't criticize those roles, but that's not necessarily the person to take on a job of being a major technical development.

When you ask them, "Why are you doing the X-33? What is your objective?" they weren't able to answer that very effectively, except, you know, "We're going to prove we can build a vehicle like that."

I said, "Well, what kind of payload are you designing the big vehicle for? Because that affects the mass fraction of the vehicle and affects what you have to scale down to this one."

"Well, we don't know yet."

"If you don't know that, how can you decide what you're doing down here?"

"Well, we'll solve that problem later."

"Why do you want to use a single-stage to orbit?"

"Well, it's cheaper."

I said, "Well, are you sure you can get enough performance and you can get the mass fractions to take a reasonable payload to orbit without the benefit of staging?"

"Oh, yeah, we can do that."

"Show me your numbers. Show me your calculations. What kind of mass fraction do you have down?"

"Oh, we'll figure that out."

Again, it's easy for a person like myself to come in and one day throw a bunch of rocks in the machinery. They didn't want to hear that. They had their program approved, the administrator that held up the box, "There's the replacement for the Shuttle, and it's cheaper, quicker, better, and it's going to work great." So you just shake your head and go back to playing golf.

If you had to build something to do what the Shuttle does, I'm not sure you'd build it a hell of a lot different. I'm sorry they didn't stick with the original design on the Space Station, and I hope whatever we finally get out of what they're doing now is reasonably worthwhile. I wish the Russians well. I really think they ought to be building roads and sewers and infrastructure. Maybe I don't see the whole picture.

Will there be a manned mission to Mars? Probably not in my lifetime. Will there ever be? Yes, I think probably, maybe fifty, a hundred years. I don't know what the answer is. It's going to take something I don't see right now to even motivate 250 million people to put up that kind of money and stick with that kind of thing for ten or fifteen years. The motivation that sent us to the Moon was unique. The Shuttle and Space Station are kind of living on that commitment of doing manned space flight, and it's probably the only practical thing to be doing.

Colonizing the Moon isn't something you can really justify. Going to Mars with a couple of astronauts is hard to justify, in my opinion.

Something to stimulate the technology. I'd say the number-one stimulus to technology we've had up to now is our military programs. Probably the number-two stimulus is NASA's programs, although a hell of a lot of the electronic things and so forth are stimulated by commercial products, you know, kids' toys. They put pretty good requirements on electronics these days.

But I think, in my mind, you can certainly justify NASA at somewhere close to 1 percent of the national budget. It's gotten down to where it's now three-quarters of a percent, about three-quarters of the annual budget. As I say, at the peak of Apollo, it was nearly 3. Most of the time we were in Shuttle it was 1. It's dropped down to maybe three-quarters now.

The infrastructure, the bureaucracy that demands money is as big as it's ever been. If you go back and look at the start of Apollo, the infrastructure to run NASA on a daily basis was a hell of a lot smaller percent of the budget. Now the bureaucracy is there, so any program has to be over and above what it takes to have the Johnson Space Center or have the Marshall Space Flight Center. The real problem of squeezing down the overhead as you make room for new program dollars is tougher every day in the agency, much tougher than it was thirty, forty years ago.

The concern that the Russians were doing something we couldn't do really motivated us through Mercury and Gemini, and then the gauntlet that [John F.] Kennedy chose to thrown down got us through Apollo and Skylab and got us into, "We don't want to quit, so we'll do low Earth orbital kind of things with shuttles and space Stations." But, boy, what would bump us back up to 2 or 3 percent of the federal budget and off and running to Mars and that sort of thing, I don't know. I don't see it anytime soon.

The promise that you can do things better and quicker and cheaper will only go so far. If you can do things radically cheaper and better, then the previous people must have been doing something radically wrong. You know, to just come in and blatantly say, "I can do it quicker, cheaper, better," is in some respects saying, "Those people before me were stupid and I can do things a lot better." Well, that's not a very good way to start. If you want to postulate technology has allowed us to maybe make a paradigm shift of a sort, experience base in previous programs allow us to learn and do better, if you really learn to do better. But just to build a model and put it under a box and lift it off and say, "There's a replacement for Space Shuttle," that just tells me those people don't know what the hell they're talking about.

Will the Congress support a new Shuttle? You ought to have a reasonable answer to that before you say that's a replacement for Shuttle. To just arbitrarily say it's going to be a single-stage to orbit kind of begs an understanding of eighteen layers of issues that you have to be prepared to deal with. So I'm at the point in my life and career where I think I'm going to go play golf. [Laughter]

I hope it's been some help to you, and I don't know what you really want to do with all of this. Put it in the archives somewhere. Right now I'm not motivated to write a book, mainly because to really write a book that does honesty to all of these kinds of things is a real challenge. It'd be tough to do. You'd get into so much detail. And people are looking for the glamour things of, you know, astronauts write books, flight controllers write books. Program managers that run detailed programs don't write too many books, I guess. I'm not sure they'd sell. Only people like you will sit and listen to all this.

RUSNAK: People with certainly an interest in the historical aspect of all these are not just looking for a good story. There are people who would be interested in that.

[End of interview]