

From My Perspective: Post-Apollo Planning and Consequences

A lot of what goes on in the world is in the eyes of the beholder. From where I have been and where I sat, I am very disappointed with our [NASA] progress over the past 30 or 40 years. Some people think the results have been great.

I happen to think the results have not been very great. I will tell you that up front. I am not taking anything away from what has been accomplished. I would not downplay anything that was accomplished with the Shuttle, and I would not downplay the International Space Station. But when I compare it to what we had hoped to have accomplished by now—we have not achieved it.

Post-Apollo Planning thinking gave careful consideration to the future. Plans included multiple capabilities to enable the nation to explore space with an affordable system—designed with a stable foundation and vital increments to take humans to low-Earth orbit and beyond, return to the Moon, and establish a realistic path to points beyond. Again, when I compare that plan to what we had hoped to have accomplished by now—we have not achieved it.

If we want to have a productive space agency in the future, we should take time to look closely at the past three decades – since the launch of the Space Shuttle Program – and determine what should be examined to move us towards progress in the next years. If not, I believe the American people will find that NASA has no purpose and all the lessons we have learned and all the sacrifices that were made will be no more than words in history books written by those who did not live them.

This narrative is a compilation from oral history interviews, dialogue from email correspondence, and conversations with a number of individuals who all have a common goal – to ensure NASA's next journey is one that not only inspires future exploration, but achieves it.

These pages are not just my opinion; however, I have offered it at several instances. These pages are a reflection of my experiences, research, discussions, and first-hand knowledge of events and the evolution of the nation's space agency. I was there at the beginning, I helped to build the programs of historic technological achievements.

Post-Apollo Planning at the NASA Johnson Space Center led to the development of a program with a Space Shuttle and the EVA Truss Space Station along with Shuttle C. The purpose: to evolve human spaceflight. Cost per pound was not on our design objective list; however, the objective was to operate within an allowance budget of 1% or less.

The reasons for the Shuttle accidents, the transition of Space Station *Freedom* to the International Space Station, and the termination of the Shuttle Program helps to provide an accurate understanding of why the Post-Apollo plans changed – and how these events continue to impact the Agency, or how the results of the events should.

Collecting history is a very positive thing to do, but unless someone puts it into some kind of productive conversation or lessons learned, it's basically just history. I want to share what I can so those who design, develop, and implement this century's space systems can succeed.

The Appendix is a 22-page presentation shared on July 8, 2015, during a meeting of the South Western Aerospace Professional Representatives Association, a group of business development people from the different industry groups around the country, to talk about Post-Apollo planning and explain why the NASA Administrator was saying, "No Russia, No Space Station." Basically, the consequences out of Post-Apollo planning are "No Russia, No Space Station."

References to the charts from that presentation are throughout the narrative. My appreciation to Jack Frassaanito for his assistance in creating the pages of information.

Readers throughout the text will find bolded statements. These sentences are highlighted to emphasize specific messages and statements.

From My Perspective: Post-Apollo Planning and Consequences

Topics

Post-Apollo from 1966 to 1972	6
Early Shuttle – Phase A & Phase B	23
Matrix Management (Shuttle Program Management)	37
Shuttle Accidents	50
Space Station <i>Freedom</i>	55
Changing the Plan	58
Cis-lunar opportunities	63
Misconceptions	71
Suggestions for NASA	74
Lessons to Remember	80
Shuttle History ?	95
Vision for a Space Transportation System	104
Conclusion	111
Frequently Asked Questions & Answers	116

Appendix

Post-Apollo Planning, presentation, July 8, 2015
Von Karman Lecture: The Space Shuttle—Some Key Program Decisions,
January 9-12, 1984 [AIAA-84-0574]

Additional Information

Bio Sheet Robert F. Thompson
Notes transcribed from GWU – *Columbia + 10* presentation
Transcripts from Shuttle Related sessions, unedited
Requested documents
DVD from GWU program

From My Perspective: Post-Apollo Planning and Consequences



EVA Truss Space Station

I'm going to start off by showing you a picture. It's hung in my garage for 30 years.

What this picture tells you is, "You are going to go to space and do something productive. You're not just going to float through space or just go farther than anyone's ever been." That's not very productive. Portugal worked hard in discovering the world, but today Portugal's economy is not the biggest in the world. There's nothing wrong with exploration, but NASA ought to be looking for more than exploration.

Utilization, contributing to the economy, doing something productive is much more valuable than exploration.

Post-Apollo from 1966 to 1972

I joined the Space Task Group in 1958 back at Langley [Research Center, Hampton, Virginia]. I joined at the invitation of the people setting up the Space Task Group. They asked me to set up the Recovery Operations. I worked from 1958 to 1966 doing that.

In 1966 [Robert L.] Bob Gilruth [Director, Manned Spacecraft Center, Houston, Texas] called me in his office and asked me to leave Operations and become the Program Manager for what was being set up and called, Apollo Applications. My first question to him was, “Well, what’s going to happen to [Charles W.] Chuck Mathews?” He was the Gemini Project Manager and I would have thought he would just flip over and be the Apollo Applications Program Manager.” Gilruth had an answer. He said, “Chuck has agreed to go to Washington, DC, and do that for George [E.] Mueller. We would like you to take over the Gemini people and begin to work Apollo Applications.”

So, we built a system from 1966 to 1972; we stumbled around for six years looking for Post-Apollo.

When George Mueller first came in, we were in Gemini. He wanted to run things from Headquarters in Washington, DC. He wanted to run both the Program and the Operations. He didn’t want to run operations as part of the Program; he wanted to run them both. He set up an organization in DC called OSRO—Operations Support Requirements Office. He wanted everything of operational support brought to his office in Washington as requirements. His office would put them in a document, and he, George, would send them to the Pentagon. Anything the Defense Department was going to do to support us would come through him in Washington and he would control it.

OSRO was run by a colleague of mine from Virginia Tech that I knew. OSRO in doing what George says set up a document about 18 inches wide. It had columns. Anything you want from DOD went somewhere in the big sheet of paper in a column, so George could keep up with it, well organized.

I'm running Recovery [Operations] down here. I had set up an arrangement where I wrote our recovery requirements in the format the Department of Defense [DOD] wanted and in the wordage they wanted because DOD didn't want me to tell them to put a ship here, and a ship there, and an airplane there. They wanted to know *why* they were there. So I'd tell them what time we wanted here, what capability we wanted here. Then they would place the ships and send the airplanes. Their job, not mine. Working fine.

I could write this document, shoot it to DesFlot 4, the group in DOD, and they could cut an Op Order and an Op Plan, with all the ships, all the airplanes, all the people. We could go out and get the job done. I didn't need Washington. All Washington needed to know was it was going on. Both the Pentagon and Headquarters. But no, George, he's going to run it.

When he said the requirements had to go up there and go through him, I cut a deal with DesFlot 4 and said, "They've thrown this bureaucratic *** in, I'm going to give you the requirements under the table at the time you need them to do your Op Order and Op Plan, and then we'll just send them up there and they can do what they want to with them."

We went right on being on it, but I didn't want to be doing that illegally. So I chose to go to the next OMSF [Office of Manned Space Flight] staff meeting; I had to go regularly and explain what I was doing with DOD. I figured how I was going to do this. George's document, I'm not kidding, it was so wide it wouldn't fit in a government briefcase.

When it came my 15 minutes to talk to the Management Council, Wernher [von Braun] is there and George [Mueller] is there; all the people are there. I probably shouldn't have done this, but I took that document and I set it down on the podium. They're sitting there looking at it. I said, "Do you know, that thing is so big we ought to paint it and just leave it there? It won't even fit in the briefcase." The room went silent.

They began to understand what I was doing. I was needling George. I was telling George how stupid he was in front of everyone. I didn't get fired. I remember Wernher sitting there, not knowing whether to laugh or smile or what to do. I made my points and sat down, but it didn't bother George. Next thing I know, George is trying to hire me to go to Washington, telling me to "come up here. I want to make you the Mission Director." He wanted to put me in charge of the mission from Headquarters with "two jumps in promotion."

He kept, kept, kept asking, even talked to Gilruth. "Send him up here. We need him." The pressure is building. I knew what was going on. He wanted me where he could control me, keep my mouth shut. Maybe not; maybe he thought I could help him, I don't know.

But at some point, I succumbed to the prostitution and said, "I will come up there, agree to stay a short period of time. If it looks from up there like it looks from down here, I'm out of there." Talked to Gilruth; he told me, "I'll keep your job open." I transferred.

I went up there, stayed two months; then sat down and wrote a two-page longhand letter. Put it in an envelope, gave it to George, told him I was transferring back. They had my job open, I came back. Never moved the family. Should I have gone permanently? Don't think so.

Apollo Applications

What was Apollo Applications and why in 1966? I'll give you my answer. The Johnson Space Center, or the Manned Spacecraft Center as it was called at the time, did not need more work. They were busy. They were still struggling to get the LM [lunar module] ready to fly, the command module ready to fly, the Apollo missions planned, the crews trained. They had plenty of work. Bob Gilruth was very cooperative but he wasn't looking for more work. Wernher von Braun [Director, Marshall Space Flight Center, Huntsville, Alabama] was looking for work. He could see the workload at Marshall dropping because the Saturn V rocket was well into its tests, well past its design, and he could not see what the future for the Marshall Space Flight Center was. This is my perspective; I was never told that; this is my perspective.

We came out of Apollo with four pieces of hardware: a Saturn V, a Saturn IB, a LM, and a Command Service Module [Appendix, page 2]. In Apollo, we did not try to build any facilities on the Moon. We didn't go up there like they went to the South Pole and set up a hut to live in and explore the pole. On the moon, we lived in the LM. When [Eugene A.] Gene Cernan stayed there for the longest time, he slept in the LM and ate in the LM. Little bitty—I don't know what you'd call it—it was like a little dogsled he slept in. Nothing wrong with that, because the whole purpose was to go there and come back before the Russians. Not very productive, except we did it first.

Right after Apollo, as we started Apollo Applications, NASA began to have a lot of dialogue with the National Science Foundation about Antarctica, because most of the NASA senior management—and I put myself in that category at the bottom end of senior management—felt that we would go back to the Moon, which we believed was quite a bit similar to Antarctica. Antarctica is hard to get to; it's a remote part of the Earth; it's a continent that

men have been going to now for over 100 years; and there's not a commercial business that I know of on Antarctica. Far as I know, everything down there on the continent, at least when I was there, was government-sponsored. Not just U.S.—the U.S. was there, the Russians were there, the New Zealanders there. I don't know who all is there these days, because it's been 30-plus years since I was there.

For two consecutive years NASA sent senior people to Antarctica to look around. We would brief them on what NASA was doing, and we attempted to help, but we learned that to go to Antarctica it takes several different kinds of transportation. If I go from here [Houston] to Antarctica, I drive my car to the airport; I take one kind of transportation to San Francisco, then take another kind of transportation to New Zealand. I get on a military airplane to go to McMurdo [Station, Antarctica]; and I get on a special airplane to go from McMurdo to the South Pole. That is a *transportation system*.

If I want to go back to the Moon, am I going to jump on a vehicle at Kennedy [Space Center, Florida] and go land on the Moon? No, can't do it. If I'm going to go back to the surface of the Moon and do anything with it, I've got to have a transportation system. And I've got to have something to put on the Moon—a hut to build, a facility, something. So, there was a lot of systems work to be done by NASA on the way back to the Moon and we were going back to the Moon. We said, "Clearly Mars is too far. It's too costly. We don't know how to do it. We'll put it over our horizon and not even talk about it." We never gave any thought seriously of when and how to go to Mars. To this day we don't know.

[NASA Administrator] Charlie Bolden doesn't want to hear that. He gets up and says, "We are going to Mars." But I tell Charlie he's adrift—NASA has not accomplished in the 30

years what we had hoped to accomplish, because we weren't going to Mars, we were trying to go back to the surface of the Moon.

We don't have the technology to go to Mars, we don't have the money to go to Mars, we really don't have the national will to go to Mars. Charlie has got plenty of will, but he's not the nation. NASA doesn't have much money relative to funding a way to Mars. If some private group in this country wants to put together a [Charles] Lindbergh kind of mission to Mars, if they want to throw a bunch of money in just like they did when Lindbergh flew the Atlantic [1927], that's fine. NASA ought to pat them on the head and say, "Good luck," but the taxpayers of this country would never fund Lindbergh, and they shouldn't. That's where we are today, and I'll try to build what I think is a story that will support that.

But, let me go back to Apollo Applications. There is a lot that's not known. There are some things that are not in the history books.

One of the first things that happened when I became the Apollo Applications Program Manager [1967], we got a letter from George Mueller [Associate Administrator for Manned Space Flight]. I use "we" to be the Manned Spacecraft Center/Johnson Space Center. It was a letter from Mueller to Gilruth. It asked us what we thought of a proposal to use the ascent stage of the LM to support a number of experiments in space. Mueller had gotten in some discussions with Homer Newell [Director of NASA's Office of Space Sciences] about some experiments that the "unmanned people" were planning. Some of [the experiments] looked at the Earth, some looked at the Moon. But Mueller wanted our opinion because he'd been working with Marshall [Space Flight Center, Huntsville, Alabama].

Marshall had proposed to take the ascent stage of the LM and where the descent stage of the LM is, put all the experiments; then all of it would go up with a Saturn IB, because a ground

rule at that time was there were no Saturn Vs available, those were all committed to Apollo missions. They wanted to take the Saturn IB and the ascent stage of the LM and operate these experiments in Earth orbit as a use of residual Apollo hardware to prove that Apollo hardware was versatile. That letter came to me to prepare a reply.

I worked with my Gemini colleagues for a short period of time and wrote a very pragmatic but blunt letter. I usually try to explain something to someone by using a very sharp term and then explain it. The answer was, “It’s dumb,” but I didn’t say that. Then explained, if you knew anything, you knew it was dumb.

The ascent stage of the LM—and I will use numbers that please don’t hold me to, it’s been a while—seem to me like were running somewhere in the \$20 million, \$25 million per ascent stage, not the descent stage and the whole LM, just the ascent stage. We were having to chem-mill parts of that structure just to get ounces out of it. The lunar module was a unique shape so you could stand and see the surface of the Moon, and it was crowded inside. It made no sense whatsoever to apply the command module and the ascent stage of the LM to that function in low-Earth orbit on the Saturn IB.

I wrote as polite a letter as I could that said it was a stupid idea. Gilruth and his staff cleaned it up a little bit, sent it, and immediately George Mueller comes back with, “Come up here and talk to me.” I had a fair amount of trouble with George Mueller. I liked George—he was a hard worker, pretty smart guy, but unrealistic sometimes. A lot of people have that problem.

“Come up here and talk to me,” he said. Gilruth sent it to me and says, “Well, get ready to go up there. We’ll go.” I sat down, put all the logic in 12 charts, then we went up there and met George in his office at one o’clock as he directed us. We walk into George’s office, and

Wernher [von Braun] is there. We weren't surprised. We say hello. Everything gracious, friendly. At one o'clock, we move into George's little annex that had a small conference table in his office. We go in and sit down. George comes in, and just before we start to meet him, his secretary comes in and says some senator needs something.

George excused himself and walked out to take a phone call. George's seat was at the end of the table. Wernher was sitting at his right; Bob is sitting on George's left, and I'm sitting next to Bob. We're left there, the three of us. Whether Wernher had seen the letter we sent back to George or not, I don't know and I doubt if Bob knew. Obviously, Wernher knew why we were there. Gilruth, very friendly to Wernher, says, "Wernher, why don't you see what Bob has here?" Wernher says, "Sure." Gilruth says to me, "Show him your charts."

I put my briefing charts out in front of Wernher and go through them. Wernher agrees with every one of them. I began to learn; Gilruth was a very wise man. Bob said, "Wernher, why don't you give the briefing?" "Yes, I'll give the briefing," he says. Bob tells me, "Give Wernher your charts."

I pushed the charts over to Wernher. I'm sitting down there, my mouth shut. George comes in. George sits down, looks at Bob, says, "Okay, Bob." Bob says, "Wernher is going to give the briefing."

Wernher takes my charts and gives a better briefing than I could give about what a stupid idea it was. George says, "What is going on?" End of meeting. Gilruth and I get up, tell Wernher goodbye, and come back to Houston. I couldn't make that story up, could I? I'm telling you the honest truth.

What happened? Sometime later, those experiments were taken away from Marshall, sent to the Johnson Space Center, and we were told to go ahead and implement them on the rack

that mounts to the CSM like we suggested, and we did. We called that AAP-1 [Apollo Applications Project-1]. We assigned a man, that had come out of E&D [Engineering and Development] rather than Gemini to be the Project Manager for AAP-1. We ran a competition, selected the Martin Company in Denver to be the contractor for AAP-1, and Hal Gartrell was our Project Leader. We were underway, spending money, implementing AAP-1. That's where the first mission in Apollo Applications came from. It was subsequently canceled.

Marshall didn't quit. They started coming to the monthly staff meetings that Mueller ran, suggesting we use the empty hydrogen tank on the Saturn-IB as a place to do some safe EVA [extravehicular activity]. Marshall still wanted work, so they began to come to staff meetings saying, "We've got to develop EVA. People have to learn to go outside to work." We had nibbled at EVA in Gemini, and we were going to be outside in Apollo. So, now Marshall was saying, "Let's go do that in Apollo Applications. Let's go down and take the hydrogen tank out of the Saturn-IVB and make that a test area where the guy can get in there and float around and do things and he won't drift off into space and get lost." An innocent recommendation.

"Well, Wernher, there's no way to get in the S-IVB tank. There's no manifold," we told him. At the next management meeting, there was a manifold in the S-IVB tank. It's a spent hydrogen tank with insulation inside, had 70-some bolts around it and a socket wrench was needed to take them out. But oh, according to Marshall we can get all the hydrogen out of there, go down in there, and float around. The wet workshop began to grow, like Topsy, the child's story.

The wet workshop continued to grow. Marshall went from a manifold to the next thing—a floor in it. A popular structure at that time was a thing called isogrid. It's a structure in triangles. You cut the metal away in little triangular shapes, and get a lot of strength for light

weight. It was very popular. So all of a sudden, there's a need for a floor across the tank. The propellant can go right on through that floor, and then you're left with a manifold up here and a floor down here. It begins to grow.

I'm supposed to be monitoring that and being prepared for the Johnson Space Center to comment on it. I'm probably not the most diplomatic person in the world, because I like to be realistic, but anyway we watched it grow.

Gilruth began to call it the kluge, K-L-U-G-E. I don't know where he ever got that word. But I'd go brief him on what was going on, and he asked, "What is the kluge up to today?" Gilruth had a good sense of humor, not many people saw it. He wasn't a genius, but he was smart enough to use people very effectively. He was smart enough to let people dig their own grave or do whatever.

But it continued to grow, and now Wernher and George are building this hotel at Marshall [Space Flight Center] called the wet workshop. Next thing you know, they've got a commercial designer saying what color it needed to be painted, where there ought to be windows, and where the microwave ought to be, and where the dining room table ought to be, and how you can build it all and store it outside, how to let the hydrogen out—just take it there just like you were arriving at a campsite at dark and setting up this wonderful camp. It just grew like Topsy.

One day I got called up to Gilruth's office and he said his deputy wanted to talk to me. His deputy was the guy who worked at the Martin Company. They had apparently been talking and decided to send the airlock contract over to Marshall. We had the airlock contract left over from Gemini, but Bob was getting tired of getting put in this corner with this kluge. They asked me what I thought.

I said, “Well, let me go think about it till the morning.” I was pretty sure it was a good thing to do, but I didn’t want to jump on it too fast. I said, “I’ll go see if we have any contracts pending, how to manage them, and whether it’s a practical thing to do without a lot of confusion, and I’ll let you know tomorrow.” So I ran the trapline from one government agency to the other, and learned we can do that, no big problem.

I was pretty sure there were no hiccups in it. I went back up the next day and said, “Yes, let’s do it.” The people working on the airlock at Johnson Space Center had to be reassigned, but that’s life. We sent the airlock contract to Marshall. The kluge kept growing, kept growing. I kept going up to see Gilruth and telling him, “The kluge has gotten this. We’re going to take all this stuff.” It even got to the point where they were going to store stuff down in liquid hydrogen, down in the tank. Liquid hydrogen is cold, and hydrogen gas will blow your head off quickly. They were going to store a bunch of stuff down there, and they had to design it to where it could live in very cold hydrogen and then come out and be useful. It just got way out of bounds.

I’m really not exaggerating. It was a stupid idea, but it kept building. Finally, Gilruth one day says, “Put together a briefing. Put all your concerns on it. I’ll take it up to George.” I went off to put a briefing together, and it was the time in Houston when there were hurricane flags out. Newspaper says, “Get ready for the hurricane. Warning flags.”

While I was putting together all my frustrations with the wet workshop, I kept hearing about the hurricane warning flags, so I called it the Warning Flag briefing. It’s very modestly mentioned in the history books. The meeting gets scheduled for a Friday. I’m the briefer. I’m going to Washington with a Warning Flag briefing to tell George Mueller and Wernher von Braun why this is dumb with Bob Gilruth between me and them. It’s the only way I survived.

We load up the [NASA] Gulfstream—me and Bob, and I don't remember who else was with us. We go to Washington. Going to come home that night. Going up there to dump this thing right in their lap. The meeting starts, I get up, I talk. I run my mouth for an hour, as nice as I can with a stupid bowl of flowers ideas. A, B, C, D, I think I had 12 major problems—it was overweight; the astronauts had to use a socket wrench to take those 70-some bolts out, just to open the door into the stupid thing; it was a bunch of silly things.

It would be like you arriving at a campsite late at night and it is cold, and you are in your car and there's a bunch of pieces in the trunk. Now you've got to get out of the car in the cold, get all that stuff out, and build it before you can use it. Why not go up there with a trailer at least?

I didn't want to just go up there and tell them it's stupid. I wanted to go up there and tell them, "Here's another way." We had been telling them for months there was a better way to do it, because number one, the ground rule was the S-IB was the only launch vehicle available. Don't even discuss a Saturn V, because [NASA Administrator James] Jim Webb had those reserved for Apollo missions. We kept saying, "If you're going to use the S-IB and want to spend a long time in Earth orbit, build a lab—14-foot diameter, about 30-foot-long—that went in the spacecraft LM adapter area of the S-IB. Fit it out on the ground like you would a trailer when you get to the campsite. Drive in at midnight and get out and go to bed in your trailer. Then get up the next morning and fix breakfast and do what you want to. It's cheaper, and a better use of the taxpayers' money." Look up the SLA [spacecraft lunar module adapter].

The Johnson Space Center position, or my position and Bob Gilruth's position, was if we have to stick with the Saturn-IB, the SLA lab is better than the wet workshop. That was the argument at that time, because the Saturn V was off the table, no discussion.

I get up in Washington and give that briefing. I expected a big food fight, but it didn't happen. George Mueller, he's sitting at the table. I brief him, and he sits there like this [hands close together, fingertips pressed together]. He always did that. I could always tell when George was irritated because he would sit there and do that. You could see him get red. I'm up, running my mouth for an hour. He says to Gilruth, "Bob, we've decided to convene in the morning down at Marshall. Wernher has set up to show you how well the wet workshop is going to work." Bob never heard anything about it prior to that. George says, "We'll convene at Wernher's office nine o'clock tomorrow morning, Saturday morning." End of meeting.

Gilruth says, "I guess we'll have to go to Huntsville [Alabama]." We didn't have any clothes, but we go. They had some rooms reserved for us in a motel there. I don't remember what we did about shaving. Next morning, we go out to Wernher's. He had set up all around the Marshall Space Flight Center little exhibits like how the attitude control system is going to work, how the environment control system is going to work, how the kitchen is going to be, how the basement is going to be, how the thermal control is going to be. About what you would set up for a high school science class.

I remember particularly they set up a little mock-up of a S-IVB stage. It was on a pivot and they could push it this way and a red light would come on; they'd push it that way and a green light would come on—attitude control system. It was like they were talking to a bunch of high school kids. They paraded us around all day Saturday. Most of us were polite, bit our tongue, we put up with it.

Then the next midmorning, we convened again in Wernher's conference room. We hashed this thing over in every direction you could. We did not give an inch. Marshall didn't give an inch. George sat there and listened to all of it. I don't want to run down Wernher von

Braun, but he was like a child, he was an overgrown teenager. He believed, by God, we can go to Pluto, we can go to Mars, we can land with an airplane on Mars.

We debated till about two o'clock in the afternoon on Sunday. We'd left Friday, and our wives expected us back home that night. Now it's Sunday. Gilruth would sit in these meetings. He always had his briefcase right down here [on the floor next to the table]. When he began to fumble in his briefcase, you knew he was ready to leave.

I'm sitting over here watching what's going on, answering whatever questions I'm asked. Finally, George Mueller says, "Well, let me sum it up." He says, "I understand the argument for the SLA lab, but we cannot do the SLA lab because it looks too much like the MOL [US Air Force Manned Orbiting Laboratory]. If we go to Congress and want to build something that looks like the MOL, we will not get it." First time we'd heard that. That was his reasoning all along.

He said, "I want to stick with the wet workshop." Gilruth then had to answer that. He said, "Well, George, it's your decision. If that's your decision, you send me a letter directing me at the Manned Spacecraft Center to support the wet workshop, because I'm on record saying it's not a good thing to do. I want the directive." George says, "I'll send you a directive."

We got on the airplane and came home. Tuesday or Wednesday Gilruth calls me; I go up to see him. He hands me the directive. It's a sheet of paper, paragraph or two, stating that the Johnson Space Center is directed to support the Marshall Space Flight Center. I don't know how it was worded but it was a directive from the Office of Manned Space Flight George Mueller, to Bob Gilruth, the Center Director, directing us, the wet workshop.

Bob gave me that letter and said, "Go do it." I then went to work. I had to direct—not I, we had to direct North American [Aviation] to do certain things to the command module. Had to

convert the environmental control system to a longer stay so the environmental control system for the command module had to stay active and work.

We had to direct the Bendix Company to build some cryogenic tankage that could keep the propellants up there for that period of time. As part of their proposal, they were going to build a special building, so we had to approve them building the building out in Ames, Iowa. I went off and turned on several contracts, started to manage them to support the wet workshop. I don't know now how much money we spent, a moderate amount. Be a lot for you personally or me personally, but a moderate amount. We implemented the wet workshop for a period of time, we, the whole Agency.

Gilruth got an invitation to come to the Kennedy Space Center [Cape Canaveral, Florida] for a Saturday morning meeting with George Mueller and was told to bring his AAP Manager. Bob called me and says, "Go down to the Cape with me Friday night. We've got a meeting with George Saturday morning at the Holiday Inn."

I do what I'm asked. I get on the airplane. We go to Kennedy. Next morning we're supposed to be at George Mueller's motel room at the Holiday Inn at the Cape [Canaveral]. Bob and I walk in the room. It's an ordinary room with two double beds, just like you would get or anyone would get. George is there in his Ban-Lon shirt and his trousers which he always wore when he was down there. All the astronauts wore Ban-Lon shirts. He had a Ban-Lon shirt. Bob and I got there on time; the time George said. When we walked in the room, Kurt Debus [Director, Kennedy Space Center] was there with his Apollo Applications Manager. Wernher was there with his manager. George is there; it's his room. Bob and I walk in.

The others were already there. Not any place to sit down, except there's a little space on one of the beds, so Bob went there and sat down. I went over and stood in the corner behind

Bob. We had no idea what was going on. George gets up, says, “Fellows, we’ve finally broken loose a Saturn V.”

Webb had retired. The constraint on using the Saturn V was now gone. Apparently, the new Administrator didn’t know what commitments had been made between [President Lyndon] Johnson and Webb; President Johnson had called Webb in, said for him to pick the number of Saturn Vs needed, and shut Apollo down. Webb went back and said, “We need 15.” Johnson says, “Buy them and shut it down.” That’s what we were doing.

All of a sudden a Saturn V is available. Then George went around the room. Said, “Wernher, what do you think about shifting to a dry workshop?” “Oh, great,” said Wernher. Debus, “Great.” When he got to Gilruth, Bob said, “No,” and then said, “George, you sent me a directive to implement a wet workshop. We relet a lot of contracts for mods to the command module, for tanks, and so forth that won’t be needed on the Saturn V. I’m wasting a lot of money.”

Gilruth twisted him for about 30 seconds, then smiled halfway and says, “Well, George, it’s probably a good move. We’ll support it.” We came home, Gilruth told me to go cancel it, turn it off, which I did. AAP-1 turned on, turned off. Wet workshop turned on, turned off. We now had Skylab—a genius of a move with the Apollo hardware. It turned out to be a pretty good program. Am I being overly critical of George? He at least found something to do with those four pieces of Apollo hardware.

In the meantime, we spent money twice, to finally got something that would work. Not very efficient, but we did it. We worked through Post-Apollo that ended up in AAP-1, wet workshop, dry workshop, study, great big Space Stations, great big Shuttles—all kinds of bull—down to what we did.

I've explained you all but one little minor thing. They found an Apollo-Soyuz [Test Project] mission later on [1975] and flew that as an independent mission to cooperate with the Russians. I wasn't involved. I stayed with Skylab till 1970. Skylab didn't fly till 1973.

Summary

In the Post-Apollo planning between 1966 and 1972 there was a vigorous discussion on the future of human spaceflight. The Apollo system of big expendable rockets and capsules was available for planning of human spaceflight following Apollo, a period of flags and footprints on the surface of the Moon. The Cold War purpose of Apollo had led to a strong support period from the Federal budget, but a long-term commitment was not possible. President Johnson directed a reduction in annual spending.

The Apollo system of big expendable rockets and capsules were limiting, and ended with Skylab and Apollo/Soyuz. President Nixon took up the task of Post-Apollo and convened the Space Council that led to no decision.

NASA planners targeted the future of human spaceflight towards a Space Transportation System to access the important regions in cis-lunar space.

Early Shuttle – Phase A & Phase B

I get a call one day from Gilruth, “Come up and see me.” He said, “Bob, I just got a call from George Mueller. They want to try to sort out all this Phase A study work that’s been going on and decide really where we want to go Post-Apollo. I’d like you to leave Skylab and become the Program Manager for what they’re going to call Shuttle.” He said, “Kenny [Kleinknecht] is available from his job over in Operations. Come back into program management; turn it over to him. You and Kenny work out who he keeps who and who you take, and who he gets from somewhere else and who you get from somewhere else.”

I set up what we called a Space Shuttle Projects Office. We are between Apollo Applications, Skylab, and Shuttle, because that’s where I was. But in the meantime two other very important things that happened in Post-Apollo planning.

I’m going to make a very important point here. The Johnson administration was not interested in planning Post-Apollo, showed no interest whatsoever. Lyndon Johnson essentially had one thing in mind, and that was to fulfill the [President John F.] Kennedy commitment to go to the Moon and back. After that, he doesn’t care much about space. “I’ve got the Great Society and Vietnam on my plate. What happens isn’t up to me.” That was Lyndon Johnson.

Now in 1970, [Richard M.] Nixon was the President. He put a paradigm shift into NASA. He said, “NASA, you can no longer just go pick some glamorous thing and decide you want to do it and we’ll pay for it. It’s not going to happen. You’re going to get down in the mud and debate with everyone else in this country for federal resources. You will debate with the food stamp people, you will debate with the highway people, you will debate with the whole spectrum in the *Bureau of the Budget* [OMB, Office of Management and Budget]. Right now I have no interest in supporting you at anything like the level you’re coming in here with. You

can set up all the committees you want to and come in here and say you ought to go to Mars, you ought to go to Pluto, you ought to take the budget back to 6 percent, and we're the most glamorous agency in the world. If you can get down somewhere 1 percent or below of the federal government, then you will probably have my support." That was my impression of Nixon.

The so-called Nixon Doctrine was developing, but Nixon wasn't stupid. Nixon was very clever. Nixon never said, "I know how to build a Space Station." But he did say, "I want the funding down at this level, I want it down in here." The Nixon threshold of 1% was emerging; the thought that spaceflight must compete for national support was born. He basically said, "We're not going to stay up here. I'm not going to run a deficit. I'm not going to raise taxes. NASA, go figure out what to do down there." [Appendix, page 9]

At that time there was a very critical change at NASA, a significant management change as we started Phase B. During Phase A, the four key players at NASA were George [M.] Low, George [E.] Mueller, Wernher von Braun, and [Maxime A.] Max Faget. The four horsemen of Apollo. They were moved aside—not moved by any strong action—but events.

Low was the Acting Administrator. He was moved to Deputy when [James C.] Fletcher came on board. George Mueller left. They moved Wernher to Headquarters and put him down the hall, with no decision making capability. They set up a program organization which took Max out of the job of representing the Johnson Space Center [JSC] on Post-Apollo discussions. Max lost this job not because he was incompetent, but he ran the Engineering Department. He no longer was a program manager; he wasn't a program manager when he was designing, and he shouldn't have been. That was the paradigm shift.

At that time, they asked me to leave Skylab and become the Space Shuttle Project Manager at the Johnson Space Center. We didn't know what the *Program* was all about, we didn't even know enough to name it the Space Shuttle Program, but we did. We also set up a similar office at Marshall [Space Flight Center] under a man named Roy [M.] Godfrey. They also then put a man named [Charles J.] Charlie Donlan as the Associate Administrator for Manned Space Flight to head up this new program in Washington, DC. Charlie Donlan happened to be a man that I knew quite well. I had worked with him for several years at Langley [Research Center]. Gilruth was still the Director at the Center here [in Houston] and I'd known Bob for several years, after I joined the Space Task Group.

Our job at the start of Phase B was to figure out where the Agency would go on some sort of a long term program. We had searched for four years on what to do with the Skylab system or the Post-Apollo system out of Apollo. We could never develop any plan we thought was affordable or the right thing to do. The things that [Thomas O.] Tom Paine tried to push through the Space Council, push in Phase A were way out in left field. The planning had been up in the blue sky, nothing but an agency hoping to continue the euphoria of Apollo.

There's nothing wrong with the euphoria of Apollo. But you might run 100 yards for a touchdown one game, next game you might start up, "I'm going to go 100 yards again," and you might end up on the back of your head. People need to understand that. I'm still hearing politicians get up and talk about the wonderful agency called NASA. NASA has been doing dumb things for the last 30 years. They've done a few good things, but a lot of dumb things, in my opinion.

Until [President] Richard [M.] Nixon came aboard, no one was worrying beyond Skylab. That's as far as they'd been committed, but Nixon in my judgment did a responsible thing. He

looked in the makeup of the Space Act [of 1958], and included was a group, called the Space Council, chaired by the Vice President. It's in the law. In fact, Lyndon Johnson had that in there so he'd have a big job.

Now Nixon uses it and puts [Vice President Spiro] Agnew as the Space Council Chair. Now we got Agnew and a new Administrator, Tom Paine. Paine had come from GE [General Electric], and had been a submarine officer in World War II. I never got to know him very well, but apparently a very capable man, with the idea of going to Mars.

The federal budget for NASA peaked when I became the Apollo Applications Program Manager. This is the NASA budget as a percentage of the federal budget. [Appendix, page 9.] Starting back with Mercury, Gemini, and Apollo—NASA did that [1967--4.5%]; peaked right there when I became the Apollo Applications Program Manager. Here's what I've done to NASA [budget percentage decreased to less than 1 percent, late 1970s and early 1980s]. No wonder no one wants to talk to me. NASA is constantly looking for some way to go up here [increased budget]. That's a government agency for you. They want to grow. Fundamental.

Lyndon Johnson had no interest whatsoever of working up to that level. But as we were coming down this budget curve, Paine wants to turn this around and build an atomic power system, a big Space Station, and go to Mars. He wanted to go. I am not sure Agnew knew what was happening; he was probably a pretty nice guy, but I'm not sure what Agnew ever did. Paine was obviously a good technical man in nuclear physics, but didn't agree with the thought of taking an agency from up here [in the budget curve to] down here.

He began to get in Agnew's mind and the Space Council, but the Nixon administration kept saying, "Oh, no, not this way [higher budget]; that way [lower budget]." Finally, after they

had all the meetings they thought worthwhile they picked three options. All three of them were out in left field. It didn't amount to anything.

In the meantime, George Mueller is sitting at NASA Headquarters as head of Manned Spaceflight, and realizes his new boss, Tom Paine blew it—he didn't turn them on to going to Mars. He thinks, "By God, I'll take it on. I can direct things. I'll set up Phase A Studies." He tells Chuck Mathews to go study Space Station; tells [Leroy] Roy Day, I want you to go study Shuttle. Have you read Roy Day's book [*Manned Space Flight: Personal Reflections with the Space Program*]? Roy is a very competent, very capable guy. There's nothing in that book that I don't basically agree with. It's very straightforward, very honest; but it's at a fairly high level, some of the details I'm sharing you won't find.

Anyway, George decides the Space Task Group blew it. They didn't take us back up [in the budget] and thinks, "I'll do it. I'll set up Phase A studies and we'll come out with something that the country will just have to buy." So he sat down and basically told Chuck and Roy what to go do.

Wernher wanted a big 100-man space Station. Chuck let two contracts, one with McDonnell Douglas, and I don't even know who the other one was with, to study this big diameter, big hotel space station. Could put 100 people in it. It had multiple stories just like the Hilton Hotel.

George sits down with Roy and tells Roy to go build a fully reusable two-stage Shuttle, so we can hook a ground support equipment test thing to it that you can fly and land. Plug it into that thing and it'll tell you whether it's ready to go again. That two-stage fully reusable Shuttle and that piece of equipment that's going to plug into it will make it cheap, C-H-E-A-P.

The Shuttle is going to be cheap. Now what is cheap? Cheap to Donald Trump is a bit different than cheap to you and me, right? George didn't know what the hell he was talking about, but that's what he sent Roy off to do. Then George started meeting with the Air Force, telling them we got this cheap vehicle and it can do these wonderful things. George tells them how it can fly every two weeks or every week. Doesn't cost much money. You can go to space, and look at what you can do, he said. Roy went to work. He started meeting with the Air Force. The Air Force kept saying, "Well, okay, NASA. If you can do that, we'll ride your vehicle. We got some pretty big payloads we'd like to send up there, so we'd like a 60 feet long, payload bay." George is trying to get Air Force to join. He said, "Sure. We'll put up a 60-foot payload, 15 feet in diameter, and fly every two days, cheap." Air Force says, "Yes, okay, fine, we'll let you fly our payloads."

George is beginning to build an argument to go build this big two-stage fully reusable cheap Space Shuttle. They go study it. Space Station, Space Shuttle, Mathews, Roy Day, for maybe nine months in 1969. Let's see, April of '69, that's when George called Roy in, took him off of Apollo, and put him on Shuttle. So it runs from April of '69 until I'm asked to leave Skylab and become the Shuttle Program Manager, which was sometime in the late spring of 1970. They had the Phase A studies—two-stage fully reusable, nothing to it, turned around (makes sound effect), cheap.

By then George [M.] Low is in Washington. The first part of Apollo is over, and he took a job to become the Deputy Administrator. Shortly thereafter, Paine left, so George Low becomes the Acting Administrator. I would not say anything negative about George Low; he generally did well. But, now he's up there in the Washington arena trying to represent people like George Mueller and Wernher von Braun in the Washington world—"By golly, it's cheap,

and we want it big, and we're going to turn that curve around. We're going to build the Agency."

He began to go around town talking about how cheap it was and how wonderful it was, talking to OMB [Office of Management and Budget] and the people in the Nixon administration. They were poker players, the Nixon people were. They weren't buying that crap. They wanted NASA's budget down. They wanted NASA below one percent and it soon became obvious that that's what they wanted.

I'm doing nothing but sitting over here watching this going on, I'm not even in all the details. Just watching it.

In 1970 some fairly important things happened. George Mueller left. [James C.] Jim Fletcher came aboard. They moved Wernher von Braun from Marshall and put him as the number three man in Washington, DC, down the hall between the Administrator and George Low. Now here's Wernher—he's left his empire; he's where no one has to talk to him; and whether that was done purposely or not, I don't know, but that's what happened. Got to be candid with you.

In Phase A, [Maxime A.] Max Faget ran everything at the Johnson Space Center. I would not say anything negative of Max except sometimes he wasn't very realistic. He would seize on an idea and that became a laser thing with him. You would have to kick him in the butt and make him look at the big picture. He could understand the big picture, but once he lasered in on an idea, he wanted to sell it. He had represented the Johnson Space Center in Phase A, but now he is back in E&D and I'm representing the Johnson Space Center.

NASA put a man named [Charles J.] Charlie Donlan at Headquarters as the deputy to the new Office of Manned Space Flight leader, Dale [D.] Myers. So now in 1970, there is a

complete change of leadership, trying to do Post-Apollo. Most people back then didn't call it Post-Apollo because Post-Apollo in retrospect was the period from 1966 to 1972. The Skylab Program and Apollo-Soyuz [Test Project] were just using some residual hardware but these didn't lead anywhere. The Apollo hardware never led anywhere. Big rockets and capsules never led anywhere.

Now NASA decided we are going to go forward primarily emphasizing the Shuttle and studying the two configurations that came out of Phase A. What were the two configurations? One had a delta wing on the orbiter and the flyback booster. One had a straight wing—that straight wing was there because of Max Faget. There was a little bit of justification for his argument, but not very much. I'd say Max was about 2 percent right and about 98 percent wrong on the Shuttle. He didn't even spend much time worrying about the other 98%, he was so latched on to that big straight wing to help with the landing velocity that the rest of it he didn't worry about. It was huge, so it was impractical.

I'm asked to go to Shuttle in the late spring of 1970. Charlie Donlan is running the Program from Headquarters. He's just getting ready to release to industry an RFP [request for proposal] to pick up on the Phase A studies and continue to fill out the details on these two big flyback booster configurations, fully reusable configurations.

Here is the configuration for the delta wing [Appendix page 10, far left]. Here's what we built [Appendix page 10, middle]. Just the physical size tells you something. This is one of the configurations. The other one had straight wings on it.

I have a job. I'm being told to help Charlie Donlan write an RFP for studying this configuration. So I go to Washington and help him write the RFP, and then I'm told NASA is going to select two contractors, and I will manage one contractor from Houston, and another

program manager, Roy Godfrey, at Huntsville will manage the same two configurations with another contractor. I'm set up in Houston, Roy Godfrey is set up in Marshall, we're going to take these two configurations, take them into more detail, and decide what to build. That's where I joined Shuttle.

One more thing you need to know. Charlie Donlan had worked in the same research division that I was assigned to when I went to work at Langley right after World War II, so I knew him quite well. He was maybe six, eight years older than I am, and was a section head there right in the same office group that I was put in when I went there. In fact, the first day I interviewed with him and another section head, and the other section head got me for his area. I never did ask Charlie whether he turned me down or lost the flip of the coin. But Charlie was a guy I could pick up the phone and say, "Charlie, this thing is dumber than ***." And he would say, "Oh? Why is that?"

I'm not doing all this alone, because I've got some pretty good people. We're all looking at this thing. People like Homer Dotts, John Roberts, Barney Evans, people that had been around the business a long time. We began to say, "What in the—? We've got another kluge."

After picking the two winners, NASA made a brilliant decision—give level-of-effort contracts to the losers so they can stay knowledgeable and when we go to critical design where we are actually going to build the thing and let an RFP, they can bid. At Johnson [Space Center], we have Grumman [Corporation] and Boeing, on one contract. Boeing I think had subbed to Grumman, but we got one contract, Grumman—and I called them the "booby prize" contractor. I didn't mean that in a demeaning way. It just meant that they were the loser, but can stay in and maybe win next time.

I don't even remember who Marshall got. They got two, we got one. But, we got the best one, I think, because I now have to tell Grumman what to do as well as manage what Rockwell [International] is doing, because I got Rockwell for this vehicle.

I tell Hal Gartrell, the guy left over from AAP-1, "Hal, you're going to be the Grumman project manager. Go see what they've been doing, and let's talk about it." Meantime, I'm helping people start to manage this thing with the straight wing, because we're going to manage those two things and get it down to something to build.

At the beginning of all this, when I would talk to Hal, I would sit in my office on the fifth floor. I asked someone the height of the flagpole, because I thought it was about 90 feet tall. I would sit there and look out the window at that flagpole, and that flagpole would come up to about here [points to picture of original Shuttle configuration, [Appendix](#) page 10]. This thing is huge; I mean this is bigger than the 747. This [proposed] orbiter was about twice as big as the orbiter we built, and the orbiter we built is pretty big. Even without an engineering degree, if you just sit there and look at this thing, it's stupid.

So I'm looking for some way to make this realistic. Meantime, Max Faget is in the same building, still thinking, "By God, I want a straight wing." He'd go into Gilruth's office and whisper in Gilruth's ear. Gilruth would call me up and I'd have to tell him what to do with all that. I finally told Max one day, "Look, Max, I'm going to come to your office at 11:30 every Monday morning and I'm going to sit in your office, and you tell me anything you want to tell me, and I'll tell you what I think about it. Then we'll go to lunch, and then you go your way and I'll go my way." I cut that deal with Max. I began to cut down my visits to Gilruth's office.

I'm telling my side of the story. Max is dead and can't tell his side of the story, and I like Max—I thought of him either as my younger brother or my older brother. He was older; he had

gone through [World War II] Navy officer training about six months ahead of me. I used to tell him that he was dumb because he was in submarines, that I was smart enough to go to destroyers; I used to tell him that and he'd just say, "Ah." We got along fine. Never had a minute's trouble. Somewhere I have a letter he wrote me at my retirement, two sentences, that said, "Bob, the Shuttle really flew like you said it would. I'm glad you invited me to the launch like you said you would." At [Configuration] Change board meetings, I used to say, "Max, if you don't quit running your mouth about straight wings, we're not even going to let you come to the launch." He came to the launch.

Let me go back and pick up. We're trying to figure out what to do with this dumb thing that came out of Phase A. Chemical propellants are limited in the energy release you can get. Even hydrogen and oxygen which are about as efficient as you can get, to build a vehicle that can fly to orbit, it gets big, because it takes a huge amount of hydrogen and oxygen, it takes big tanks. That's what causes this thing to get so big. So why keep it? Why not put it in a Dixie Cup and throw it away?

I called Charlie Donlan and said, "This thing is stupid. If we take all the propellant out of it and throw it away, it can get smaller, we can maybe build it." I told Hal one day to tell this Grumman offline. I told Charlie what I was doing. He said, "You can do anything you want to with Grumman, but I want you to keep Rockwell studying these two vehicles, because that's what we're going to do." I said, "Okay, I understand, we'll keep Rockwell focused so they can compete, and whoever Marshall is managing, but I'm going off on a tangent." He said, "Fine, just keep the two main vehicles your mainline effort."

I told Hal to talk to Grumman. Grumman had looked at taking one of the propellants out and putting it in some wing tanks. I told him to tell Grumman to take all the propellant out and

put it in a belly tank. I'm just playing with the orbiter. The booster, this great big flyback booster, I'm leaving alone. So we do that.

Now we find the staging velocity comes down because the orbiter is more efficient; it's smaller. I got a throwaway tank, so it can start at lower velocity and go away to orbit. I'm beginning to push Marshall out of the room, right? So the more we study it we just keep pushing them out of the room. Not deliberately. But to make a long story short, we went from that to that [change of configurations, [Appendix](#), page 10].

We have to extend Phase B, because we are going to go change configurations, and this is all from the Johnson Space Center. Marshall [Space Flight Center], I'm not even sure knew what was happening. Roy Godfrey, he would be in program control on a program; he wasn't a conceptual engineer; he wasn't an aerodynamicist. We essentially left Marshall in the dust, but I don't mean that derogatorily, because they came back and did great things on the tank and engine booster rockets.

By 1971 late, we'd essentially cut the development cost of this thing in half. To go back to the funding curve [[Appendix](#), page 9], we had gone from having to turn this curve back up to proving we could come down below this curve, if we built the Shuttle and the Space Station in a series.

Also while we were going from that big Shuttle to the smaller Shuttle, we were still carrying in our minds a Space Station design. We weren't told to do that, but **there was no reason to build the Shuttle if you weren't going to build a Space Station. There was no reason to build the Shuttle if you didn't have a way to build the Space Station.**

With the Space Station, if you make the same kind of modules we made in the SLA lab, all that was needed was to have some place to work the electricity and thermal control and hook

them together to make the Space Station. You didn't need a great big Hilton Hotel. So in the back of our minds we're designing a Shuttle *and* a Space Station.

We did not document all this. We did not design a Space Station and put it in people's face and say, "There's the Space Station twenty years from now. Shut up, go build it." You can't do that. You can't reach out twenty years and tell people what to do. The President is gone in four years. You don't know what's going to happen to NASA. If you can plan 10 years out, you were lucky; five years is probably better.

We mentally brought the Space Station along while we developed the Shuttle. We brought this along in our minds, and we brought this along in our minds. [Appendix, page 8] It put the country in a good position, but unfortunately it got screwed up.

I've taken you now through Apollo, Apollo Applications, into Shuttle. All my talking so far has got me to here [Appendix page 5, far right, bottom]—we are now in late 1971. Fletcher did a couple things that were very significant. He said, "Number one, we need a new program start for the Agency next year. In the next budget cycle, we have to get the program in. Number two, we cannot commit 10, 20, 30 years of activity. I don't want to hear any more talk of Space Station."

He didn't tell me that. He told the people at Headquarters that, who came to Charlie Donlan—everything I'm saying came from Charlie Donlan to me. Charlie Donlan ran Post-Apollo planning; he was my interface, mostly over the telephone. I spent no time with Fletcher or Low or Myers. At the time, Myers was off running Skylab and [Apollo-] Soyuz.

A lot of what I told you was never written down and put in formal documents because Fletcher says, "We're not going to try to sell a 30-year program, you can't do it, and if we try to sell it, it'll just be a good excuse for not doing anything next year. They'll say, 'Well, let's work

another year or two and figure it out.’ ” He said, “I want to get Shuttle committed. So we will commit to Shuttle in an isolated argument.”

This meant he never did go back and clean up all the crap that others had laid out there: “It’s going to be cheap. Oh, man, it’ll fly just like an airliner. Only cost \$150 a pound to fly.” So we didn’t go clean up our garbage.

Matrix Management (Shuttle Program Management)

I'm going to bring up a very critical subject. *Management structure*. I don't even know at this point in time whether it will help NASA; I don't even know how well they're managed, but I know it's part of the problem that kept us from going where we should have gone. I'm going to try to explain what I think Post-Apollo planning intended and the consequences.

As we got into 1971, Charlie Donlan was at Headquarters, having spent a lot of his career at Langley; he had a very good feel of what you ought to try to do in Washington and what you ought to leave for the Center to do, or leave out of Washington. In Apollo they built up a big 500-man contractor base in Washington to help Apollo, and Apollo was much simpler than Shuttle in a systems sense. Charlie apparently introduced the idea of setting up what he called a *Lead Center*. Now that's bad terminology. We never corrected it, but looking back, it's bad terminology.

What it should have been called was ***Matrix Management***. Now, all that means is you've matrixed a technical organization or a program organization to develop and fly a vehicle, and geography has nothing to do with it. What happens in Houston and what happens in Huntsville and what happens at Kennedy [Space Center] is irrelevant. **It's what happens in the Program that's important.**

The center directors all had the same job in the Program—they were members of a board of directors on the Office of Manned Space Flight staff and could offer any advice on what the Program was doing. But they *cannot* make any decisions in the Program. The Program is basically none of their business, except they're supposed to help the Program do what it has to do that's assigned in their center.

I was working at the Johnson Space Center, so most of them addressed their thoughts to Bob Gilruth, and then he sent those to me. Like it was asked, “What organization can we set up to minimize the contractor staff in Washington and give the systems level in the Program the muscle they need to run the Program?” These questions or issues would come down to me to work, to answer.

I had been through a couple years in the service [during World War II], and as part of the time there you learn chains of command and how to run things. Sometimes on a ship, you’ve got a Type Commander who helps you keep the ship clean and equipped; and you have a Task Force Commander. When you go to fight, you go to work for the Task Force Commander. All of a sudden he’s your boss and if he tells you to go do something, you go do it. When [Admiral William F.] Halsey took a task force out to the Philippines, the Pacific commander [Admiral Chester W.] Nimitz wasn’t the commander. Now Nimitz could go to the Secretary of Navy and say, “That Halsey shouldn’t have gone in the storm, he was stupid.” That’s fine, but Halsey was there, and Nimitz was back in Pearl Harbor.

With the Matrix Management of the Shuttle Program, the Center Director was a Type Commander; the Shuttle Program Director was the Task Force Commander. There wasn’t a lead center.

My job— go put an organization together for the Shuttle Program and go build it. That’s what they told me. That’s what we did. Also once we got to the final Shuttle configuration, it came down to me.

They had a big meeting in Williamsburg [Virginia]. Dale Myers chaired the meeting, not Charlie Donlan, but Charlie was there. They said, “Here’s what we’re going to go build, not that [Appendix page 10]. Thompson from the Johnson Space Center is going to be the Program

Manager. We're going to dump on his back the thing he's been talking about. We're going to set up a lead center and he's going to be at the lead center. He's not going to move to Washington."

This had all been worked out prior to this meeting between ourselves and with letters—these are probably in a file somewhere. At Williamsburg they told me to go clear it up, go get a contractor and get started.

We had already committed a contract to build the engines even before they stuck me with the job [of Program Manager]. I'm not using "stuck me" in a negative sense, I'm using it in a positive sense. I came back to Houston with two jobs from that Williamsburg meeting. I'm trying to set up an organization and write an RFP for two functions. The RFP would be a major integration support activity and build an orbiter. Two very different jobs.

The RFP we wrote—Hal Gartrell and his secretary actually coordinated and wrote the RFP, and then I had Homer Dotts and John Roberts take on the job of helping me put together the organization.

There was no prime contractor. We deliberately set up the organization where the government was going to design and manage and integrate the Shuttle. Now by design I don't mean decide how thick the metal has to be at some place, but we [NASA] made the decision on what kind of orbiter to build, what kind of tank to build, what kind of booster rocket that was needed. Whether you had go-around engines or didn't, whether it went manned or unmanned, whether you did this or did that—the government did that, NASA did that.

Frankly, my office at the Johnson Space Center led that. So for all those who want to know who was so stupid and did not put ejection seats in the orbiter, come ask me. That's the way we set it up.

I was essentially an employee of Washington [Headquarters]. The Johnson Space Center was providing me a desk and air conditioning and the people that I wanted on the Program. If the Center Director wanted them cutting grass or helping somewhere else, we had to work that out. But, I assigned them [Shuttle] Program duties. I wanted Program data and so began to pick people and put them in the Program Office, but there were other people we didn't want to transfer into Program Office, because I wanted some people from Marshall, and I didn't want to transfer them from Alabama to Texas, because if I did I would get the weak people. I wanted the good people. ***You can't run an operation with two bureaucracies.*** It's the smart thing to do. You don't have to transfer people around. I learned this in the military, or I learned it in college, because I went to a military school. There's a chain of command, and there's a chain of responsibility, and they match. They match.

The Program Manager is supposed to keep the \$6 million a day doing something. If he can, in about 10 years you can get a Space Shuttle and go fly. Or ***you can run a bureaucracy and do it forever and never have anything to fly.*** I was not a lead center; I was a Program Manager reporting to a Program Director in Washington, DC, who was on the staff of the Office of Manned Space Flight at NASA Headquarters. That was the ***Matrix Management*** structure.

What we did first of all is to ***take the program and break it down into*** what we used to call ***a work breakdown structure.*** We had a big program to accomplish and that program had no geographic identity—it wasn't a JSC program, it wasn't a Marshall program, it wasn't a Kennedy program. It was the nation's program.

Then we ***created a management organization to make that work breakdown structure happen.*** Then identified the ***certain things that have to be anchored in Washington, DC,*** such as the budget. You cannot take the budget out of Washington and survive. You're not smart

enough; you can't communicate [with Congress] well enough. Even if you did today, four years from now there's a new bunch of people up there who don't give a damn what the people said yesterday. The people in Washington have to stay there and constantly work the budget interface and stay stable. If you told them you needed \$10 but you negotiated with them and they gave you \$9, you have to remember that and go back when you're asking for two more dollars, say, "One of them is your fault and one of them is my fault," but let's keep the Program going.

If I take the budget down to a local level, I have two people in Washington looking to fire me—the budget people and the [NASA] Headquarters people—because it's not "our" problem. We gave it to them.

I had at that time two very experienced people who'd worked both in industry and the government—a fellow named Homer Dotts and a fellow named John Roberts, both had worked out of the Gemini Program Office. I asked them to sit down and do a work breakdown structure, and began developing a Shuttle just like they would develop an airplane, but a very complex airplane. They had worked in industry and worked in government, and they knew what the government could do and what industry could do. I worked with them. They were doing all this in a room near my office. I'd go work with them part of the time. Off in another room, I had another group writing an RFP, because we were going to contract with industry to build an orbiter and help us integrate the Program.

We broke it down in typical layers of what all has to be done. We began to think, "Well, we need to break this thing down into layers. What's simpler than layer one, layer two, and layer three, and layer four? Layer four is where you put industry. Layer three is where you put the primary interface between the government and industry. Layer two is where you put the top-

down watching what's going on. Layer one is where you put the people who just direct—that's Washington.”

We took all the work that would have to be done to build that vehicle, put it in a work breakdown structure, then decided what things ought to be done in Washington—Level One we called it; what things ought to be done by the Program Manager at Level Two; what things ought to be done by project managers at Level Three.

I began to take the results and put the information in briefing charts, because shortly after they asked me to run the Program, immediately people began to come down and say, “You can't do this. It's got to be done from Washington. How are you going to do this?” I must have had four, five different people ask. I just kept building on these briefing charts; that's the Green Book. I'd take those briefing charts and I'd say, “Look, here's what we're trying to do, here's the work breakdown. Here's what Washington is going to do, here's what I'm going to do.”

We developed that organization over a fairly short period of time. We had numerous people come from Washington and say, “How you going to run it from here?” I'd have a briefing chart. They'd come back and ask, “How you going to run from here?” I'd have a thicker briefing chart. And again, “How you going do it?” All these charts, this collection, became what I called the “Green Book.”

I've been looking for a copy of the Green Book. I did not take it with me. I found a copy of an organization meeting we had and I have about two-thirds of the Green Book in these briefing charts I had. The Green Book was not a well written book, we never made it an official book. It was really the forerunner of what became the 07700 series of documents, which is the series of documents for the Shuttle. But, it structured the management and responsibilities. Then, we plugged industry contracts into that organization.

As the Program Manager, I ran no contract. I had no direct interface with any contractor. I had direct interface with NASA project managers and I wrote directives. I didn't just say, "You go do what you want to." You can't do that, but you can't go over there and tell them every detail of what to do.

I had watched some program managers at the Johnson Space Center load their briefcase up over the weekend, jump on an airplane and go all around the country for a whole week and come home, then grab things and go and do the same thing the next week. Stupid. You got to stay in your office and work through your people. You have to make clear between you and your people what you're doing. You have to move quickly, not irresponsibly, but you have to keep uncertainty at a minimum and move.

We set up the organization with Level One, Level Two, Level Three. We also wrote an RFP and ran a competition and I chaired the Source Evaluation Board. We already had Rocketdyne moving out on the engines. We got responses from four contractors to do the integration support and the orbiter. There was a clear winner in our mind, it was Rockwell. The other three, one of them who scored the lowest, wrote us a proposal that essentially said, "You guys tell us what you want and get out of our way. We'll run it. We know how to do it, you don't know how to do it." That was Lockheed. Had to decide whether to declare them unresponsive or grade them. We decided to grade them way down.

Second from the bottom was McDonnell Douglas [Astronautics Company]. They were in the process of integrating McDonnell and Douglas, and they said, "Hey, we're big guys, we can do it. We'll build half of it here and half of it there. We'll put it together right, and you guys get out of our way." They got graded next bad.

Grumman gave us a reasonably good proposal, but the Grumman Corporation was coming apart. They said, “We’ll go to Florida and open up a big new plant and boy, we’ll do a great job for you. Here, look at our structure, look how smart we are.” Some of our structures people liked it, graded them high. But when you looked at the total picture, Grumman was not ready to take on the job. We would have had to build up Grumman to where they could take it on.

Rockwell was sitting there in the residual part of Apollo primed and cocked, ready to go. They did a fine job. We sat down, set up an organization, a government to integrate it, and then carefully plugged the integration part of the contract with Rockwell into Owen G. Morris’s office at Level Two under me. The orbiter part we put under a project manager Level Three, Aaron Cohen, both of whom we brought out of the Apollo Program, because by then Apollo was shutting down.

We brought Owen in and put him over Gartrell; Gartrell left and went to Martin, because he had built up a relationship there, so away he went. Owen was, of course, a very capable man to take over the Systems Integration Office. I had four staff offices—one for budget, one for operations planning, another office for what we called management integration, and then one we called systems engineering integration. Then we had the projects spread down here [Houston]. All the contractors were plugged in. In each contract there was a piece that Owen managed, so a piece of the tank contract had some integration support that Owen would tell the Tank Project Manager what to do and he would get him that data. Owen managed directly the big part of Rockwell that helped write the ICDs [Interface Control Drawings] and do complex analysis work.

So if you look at it, it was structured with industry that bumps up against a government organization which is on top of it. There are ways it works through projects into integration and ways it works through a staff office into integration.

I sat right at the top of it, and reported to a program director in Washington, DC, who's on the staff at NASA's Office of Manned Space Flight. The center directors were like a board of directors. It was a very good matrix organization for the government to use for industry to go build the vehicle.

We set up what I would call a semiformal or formal way of organizing. A lot of the program managers I've watched made mistakes by going to the plant, wandering through, and making remarks; that's not advised. First of all, the people that listen to the remark are not sure what it means. He's wasting his time, that program manager. Now if he wants to just go there and have them familiarize him, go there and keep his mouth shut and let them tell him, then if he has something he doesn't like, he can go tell the staff person who's responsible for that or the project manager who's responsible for that, explain it to him, and then get out of the way. Unfortunately, some people who get pretty high jobs never learn that. Sometimes the best thing the top guy can do is keep his mouth shut, have his staff come in and explain to him the pros and cons, get the data well understood, discussed, and then make a decision.

The Shuttle organization that was established to develop the Shuttle was structured to put NASA in the critical decision positions, controlled at Level II. I recall turning down a waiver request from the Orbiter project at a control board meeting. We had a spec calling for containing the debris from explosive bolts. The contractor decided that it didn't need to be done and requested a waiver. The Orbiter project approved and forwarded the request to Level II. When studied at Level II the requirement could be readily accommodated. The debris could possibly

have caused mischief but not likely. Upholding the spec improved the design and had no significant effect on cost.

I can give you several examples of how the organization was set up. The Green Book explains how each office is responsible for A, B, and C. Some of the history books talk about the “trouble” we had, like this book called *Space Shuttle Legacy: How We Did It and What We Learned,*” Chapter Three. It’s number one conclusion is not correct—the development program failed in management because Bob Thompson couldn’t run Marshall [Space Flight Center]—that’s absolute BS. Marshall cooperated with me probably more so than the Johnson Space Center.

I, as the Space Shuttle Program Manager, wasn’t supposed to be a genius and think about all, but I was supposed to be a manager and pick items and assign them to the organization and use it. Let me give you an example.

My background in research was called stability and control, but there’s a phenomenon that goes on in flying airplanes called flutter. Flutter is the kind of stability that occurs at certain times but it’s a very high frequency kind of thing, like a flag flutters. Stability and control is usually a low frequency kind of thing, but you can relate those two things. For some reason I got diverted into working some flutter thing. Now I’m working both a slow thing and fast thing.

When we started Shuttle, I set up the *matrix management organization and set up key panels that were supposed to work all round it [the Program] and bring all the experts together* from the Agency, from Johnson, Marshall, and Kennedy. On one of those key panels I hung a subpanel; that subpanel was called pogo prevention. There’s a man lives over in Pearland, Texas, to this day, was a young PhD out of University of Houston. We put him as head of that. He worked it for several years. They came in to me at Level Two and said, “We’d

like to build a one-fifth scale dynamic model.” I listened; I knew what they were talking about. They were hoping to convince me to build a one-fifth scale model. They were worried that we didn’t want to spend the money and I knew that. When they finished I asked them one question. I said, “Would your facility accommodate a quarter scale model?” The quarter-scale was bigger and easier to build, plus gives you better data. When they said, “Yes,” I said, “Go build a quarter scale model.”

They worked and worked and worked and worked. Finally, they came back to the Control Board one day and said, “We’ve found a condition between the two pumps on the two engines, between the low pressure and the high pressure LOX [liquid oxygen] pump. If one of these pumps gets into a cavitation speed, it’ll put some pulses in the system, and those pulses may couple, and the vehicle will begin to shake.”

They couldn’t prove it absolutely. I could have said, “Unless you prove it’s going to happen, I ain’t going to put it in there.” It’s the kind of thing that’s not black or white. It’s judgment. They couldn’t prove it, but their analysis, their mathematics, their testing, everything told them it was marginal, it might happen. I listened to that and I said, “Okay, we’ll put it in.” I wrote and sent a directive to the Engine Project Manager that put a component right in the middle of his engine. So, could I tell him what to do or not? I never had a single directive refused from Marshall. [The statement in *Space Shuttle Legacy*, Chapter 3, page 71] is about as malicious a charge as I can think of.

Unfortunately, two weak design features came into the Shuttle design and survived the development program—seals in the solid rocket boosters [SRB] and foam on the tank. Very early in the development program when I looked at both of those things, I was convinced they were doable. We put two seals [in the SRBs] where the Air Force had one. We said both seals

have to be working before you fly and made it a category 1R. That's what I accepted and put my name on.

Also we wrote a spec[ification] that said nothing but very minor pieces of foam will come off. That foam didn't fall off the tank [*Columbia* accident]. The foam hung on till it got up to very high speed and high dynamic pressure. Now that was a relatively subtle thing. But, had the Program Manager at the Johnson Space Center, when those two things—the seals early in the Program and the foam later in the Program—in flight indicated they weren't doing what they should do, he should have created an action item, given it to his Engineering Department, and told them to go across the entire Agency—JSC, Marshall, KSC, industry—anyone they could find to work those problems, and bring them to the Control Board. This is the way it was supposed to have been done. The way we set it up, industry had one layer of government oversight called Level Three. A second layer of government oversight went down to individual problem areas or dealt with things that come up. If NASA had followed that when the joints started leaking—

From Level Two, I got problems two ways. They came up from the bottom or I sent down and got ahold of them. Or a flight anomaly is something that I own. Once I see something in flight, I don't give a *** where it comes from. Can be level 20. If it's not doing what it's supposed to do it was my job to go fix it. JSC didn't do that [with the O-rings and foam]. JSC management thought that was Marshall's problem. They [JSC] were the systems people, not Marshall. It was a system problem--two of them; over a period of 30 years it happened twice, same thing.

There was a general thought in the country that Marshall and JSC would not work together. That was the popular thought. The idea of putting a guy out of the "lead center,"

telling the other centers what to do, wouldn't work. Yes, it will, and it did. If you set up an organization structure and say, "Look, I'm going to send you a directive. If you don't like it, tell me. Otherwise do it."

That's what I did, and then I'd check often enough. Had they refused to put that accumulator in [refer page 60], for example, it would have taken me about an hour to go grab that Project Manager by the butt and straighten him out. He would have put the accumulator in or we would have been in the Program Director's Office in Washington. If you don't want to run a program that way, don't take it on.

Everything that came out of industry was managed below me in the Program, was managed by a project manager or one of my staff people. I did not directly manage any of it; didn't want to. I was not capable of going running everything.

A lot of NASA managers think they're so good, they grab their briefcase, jump on the airplane on Monday morning, go all around the country bloviating. It's not right. Assign people something, let them *go get the data. Bring them back into the right kind of forum, discuss it, then make a decision. Right or wrong, make a decision. If it's wrong, it'll probably get corrected down the way. If you don't make a decision, you're wasting money, by definition.*

Shuttle Accidents

Now why NASA didn't manage the system right and had two accidents is fundamental. No one wants to understand it. No one wants to point a finger to say what happened. I could have come out of retirement and in two days told them why they had the accidents.

That organization broke down. The minute I left after the first flight [STS-1, 1981] the *management structure* began to come apart. It *went from a program-focused organization to a flight-focused organization and weakened the program oversight of the vehicle*. They no longer very carefully watched the vehicle. It became, "We built this thing to fly, let's go fly it." That's fine except until you have an accident.

Those O-rings as we designed the vehicle were a category 1R critical failure point. What that means as you design is, while you are flying this vehicle you watch that point, and if both O-rings aren't working right, fix it. Or you write a spec[ification] that says, "If anything's coming off the tank in this area that can hit the orbiter, fix it." They started flying and continued with the thought that because it did all right the last time, that meant it's okay for the next time.

Compare it to this -- it's like if you get in your car and start down the freeway. Just because you went there last time okay with a big cut on your tire, it doesn't mean this time it's not going to blow out on you. That's called in-flight anomaly. Whenever there's an in-flight anomaly that's out of spec or shows a weakness in a critical point, you better stop and think. You better assemble a bunch of good capable people and discuss it and examine it.

The O-ring—we had never tested at that cold temperature. It had been leaking. Why would you go fly on a cold day? Marshall didn't report it was bad, but it wasn't just Marshall's job. It was JSC's job.

That's what I mean when I say, *Management Failure*. I don't want to throw rocks at my colleagues, but do we want to learn or do we want to sit around and run our mouth?

Challenger occurred relatively early in the Shuttle Program, even before Space Station got very far along. The *Challenger* accident board [Presidential Commission on the Space Shuttle *Challenger* Accident] came fairly close to putting their finger on the problem, but they stopped short of being specific. They didn't say, "You did it. Or this organization did it." They stopped short.

I've been told since I was a child, if some guy in a plant throws the wrong switch and blows up something, you don't fire that guy, he learned; he's the one guy that'll never throw that wrong switch again. You don't have to necessarily punish people. I'm not saying anyone did anything intentionally wrong. But when you start saying, "The hell with it, I'm going to go fly," and *not paying attention to what the vehicle is telling you*, you're not going to accomplish what you set out to accomplish. That is how to work the relationships between a program organization and a flight operations organization.

Flight operations of the Shuttle should have been a Level Three function under the Shuttle Program. You'll find people who will not agree with that; there are people who want to say operations is a separate entity unto itself. The reason I say that is [an operations person] cannot sit in the Mission Control Center and worry about checklists, worry about how much propellant is left, and be the same person who worries about whether a system is working right.

I was retired at the time of the *Challenger* launch. When I left there, that O-ring was identified as a Criticality 1 Failure Point and had to have redundancy, so it was Criticality 1R. That means there should be two functioning O-rings before you fly. If either one of them is

showing any leakage you had better fix it. If it fails, you're dead. That's Criticality 1; R means there needed to be two.

Those leaking O-rings at launch should have worried Level Three, Level Two, and Level One. They should have been thoroughly studied and understood at all levels, well before it failed and killed people. Starting with flight two [STS-2], it was showing weaknesses regularly. I was not there, but I have been told that the Program Manager who succeeded me at the Johnson Space Center gave Marshall a waiver not requiring redundancy—I have been told, that he signed the waiver while standing out in the hall, never discussed it. If that happened, someone didn't understand what they were doing. I could be wrong, that's all I know. I would like to have someone correct me.

We had a spec that said nothing will come off of the tank in a quadrant that would affect the orbiter. We didn't say "nothing" – we said that little tiny bits can come off, but nothing of any significance. They were violating that rule. They didn't study it; they didn't really understand it, didn't worry about it, and it flew all right, so they figured, let's go.

Twice. There were two accidents so some said, "Shuttle is bad, get rid of it."

The CAIB, *Columbia* Accident Investigation Board [CAIB], I don't know quite what to say about that. The Board had good people on it; I'm sure the leader was a competent man. The college professors who were there didn't belong there, but they were there. The CAIB walked into an environment where the Shuttle had killed 14 people; the thoughts were, "It's got to be bad. How, why didn't the government replace the Shuttle? It was old." You know, NASA started the Shuttle the same time the Air Force started the F-16. The F-16 is still today one of the best fighter planes in the country or in the world. It's all over the world. It was believed that the Shuttle would be operated for several decades similar to the F-16.

The Shuttle musings of the CAIB should have been corrected and the cause of both the *Challenger* and *Columbia* accidents better understood and corrected. **The basic cause for both accidents was lack of proper system level management.** This led to poor response to in flight indications of potential system failure. Specifications and critical failure points, created during development, should have been kept under close management during operations of space systems. The accidents prevented expected Shuttle long term evolution.

JSC can sit here till the cows come home and throw rocks at Marshall for not fixing the O-rings. They can sit here and throw rocks at Marshall till the cows come home about not fixing that foam. Didn't hurt the tank, didn't hurt the booster, but it blew the *** out of the total vehicle. These were both *systems level failures* and that *was Level Two's responsibility*. Why didn't they [JSC] go down, find the problem, and fix it? Their answer: "Well, no one told me."

Didn't they look at flight anomalies? They run the flight. Don't they know the O-ring was blowing past? When they pulled the booster up, there was soot marks there. They'd known for years foam was coming off. There were plenty of fixes to foam. They just didn't do it. The bureaucracy sat there and played bureaucrat to each other.

Now who do you blame? I have thought a lot about this. The foam failure I would give Marshall 40% of the blame, I'd give JSC 50% of the blame, I'd give Headquarters 10% of the blame. I told this to Kraft one day. Said, "I'm sorry to hear you say that." He wants JSC to be zero on both of them. [William] Lucas was the Center Director over there [Marshall SFC]; I didn't know him very well, but I had some problems with Lucas. But I knew I would have problems with everyone—when you run the Program you have problems with everyone. Some of it is a good problem, some of it is a bad problem. But that's just how it is. You have to sit there and listen to one man tell you one thing, and one man tell you something else, and a third

one tell you a different thing. Sooner or later, some judgment factor has to go in and you have to go on. Or you can sit and say, “Well, let me stew on that for a while and come back, discuss it next week. And then say again, well, let me stew on that a while.” When the meter is running, it’s like the national debt. We just sit here and debate and there it goes.

The Shuttle was not a mistake. Shuttle was probably terminated because of the two accidents and a lack of focus in accident investigating. Both accidents were caused primarily by poor NASA program management at Level II. Levels I and III contributed.

We still should be flying the Shuttle. The O-rings should have been fixed. The foam on the tank was easily fixed. The country lost its nerve or its brains, I’m not sure which it was. But, I lived through Apollo Applications and once you dumped the Shuttle, you dumped the entire Post-Apollo planning—it was built around the Shuttle.

Space Station Freedom

We designed the Shuttle and the Space Station in the broadest sense at the same time, and understand that Apollo, Post-Apollo, Apollo Applications was the start of it.

The Shuttle and the Space Station together with Shuttle-C [Appendix, page 8] gave the country a basic start towards a space transportation system in cis-lunar space, back to the surface of the Moon. Shuttle C—Shuttle cargo, the C was for cargo. We could have taken the manned part of the orbiter away and launched good big heavy payloads with Shuttle-C.

The Air Force wanted a 60-foot-long payload bay, 15-foot in diameter. We looked at it. Fine. It met our needs and their needs. We could put an airlock in the front, our modules in the back. It was just the right size for that. We would build the modules on the Space Station and hook them to a truss structure.

I'll use a term called EVA Truss Space Station, because I'm now getting into implementing all of this. On that truss structure, we would put solar panels and radiators. We would build that truss structure with EVA, like Tinkertoys. We'd go up and hook it together. The truss structure would have been put together with EVA out of the Shuttle payload bay. You could go up there and build that truss structure and hang a radiator on it or hang a solar panel on it. Build that truss structure and put a hangar up there. Put a vehicle in it to go on up to higher orbits.

We told this generally (not specifics) to Richard Nixon in 1974 when he came down to Houston. He had approved the Shuttle [January 1972]. Fletcher was supposed to tell him about Space Station when he went to California, but apparently never got around to talking about Space Station. I'm not even sure Fletcher ever got around to going back and trying to explain the total picture. The total picture wasn't important. Until we had the Shuttle working, the rest

of it was never going to happen. Nixon was going to be gone by then anyway. [Ronald W.] Reagan came along; the Shuttle was working. He approved the Space Station, and *Freedom* was the name given to the EVA erectable truss Space Station that he approved.

Once the Space Station got approved, I had left the government. I went to work for McDonnell Douglas to help build the EVA Truss Space Station. That was McDonnell Douglas's proposal to NASA. We won the proposal hands down and we were building it.

Now when I say EVA truss, that's what I'm talking about. It's like land, where you can build. Up there it's easy to build; a heavy component, two people can move it around. They just don't want to move it too fast. We had developed a way to do all of that at McDonnell Douglas, after I went to work there. We checked it all out in the tank [neutral buoyancy laboratory].

Then the government came to me one day and says, "Change it." When they told me to change from that EVA truss, I went and told them it was the wrong thing to do, that it would cost them a lot of money and would screw things up. I went to Reston [Virginia] where they were running the Space Station Program. I said, "You're dumb as ***. Don't change it."

McDonnell Douglas built a facility out here in Houston, because John [F.] Yardley and I went to the McDonnell Douglas corporate office and we explained to them why it was important for McDonnell Douglas to build that facility and move a lot of the Space Station work here. We could train the astronauts right there how to build it. We could load the equipment needed to build a truss structure in space, put it in a box, ship it to the Cape [Canaveral], and they would put it on the vehicle, and they never had to play with it down there. They go up there and put it together. If it didn't work, so what? It wasn't a launch vehicle. It wouldn't kill anyone. They'd go back out and fix it the next day.

But NASA said, “No, change it.” Too much EVA, they said. Too much EVA. Later, we went up there with Hubble [Space Telescope] and did twice as much complicated EVA. It was bad judgment by honest people, hardworking people who were afraid. They said to put it all together. Engineer it perfectly. We’ll take it to the Cape and play with it for weeks and then send it up there. It was just stupid.

So, I changed it. I was in industry trying to run a work package; I finally got so disgusted with them. I talked my government boss into letting me put a list of recommendations for the government. When they would come out to review us, the first chart I put up was things I want them to do; never got any results. I set up a software control board—that was number one. We had the software to develop, we could not, *could not*, get the government to stabilize that program. Everyone and his brother kept coming in saying, “I want this, I want that, I’m going to do this, I’m going to do that.” Kept it completely chopped up.

The program manager from Boeing had the Huntsville work package, came to see me one day in [McDonnell Douglas] Huntington Beach, California, said, “Why don’t we form a backroom partnership and straighten this program out?” I said, “Well, that’s a good question. But we cannot do that.” Industry cannot go behind the government’s back and straighten out the government’s problems. If you don’t have a reasonably good government bureaucracy, then you have to do something else.

Changing the Plan

During Post-Apollo planning, zealots were in charge during the early years. The very difficult debate between MSFC and JSC relative to the use of the Apollo system finally resulted in Skylab and Apollo/Soyuz; Bob Gilruth influenced the zeal.

Zeal prevailed again later during the Space Council and Phase A study periods, but the move from Phase A to Phase B in the Post-Apollo planning in 1970 was accompanied by management changes in key NASA positions. The Phase A foursome of Low, Mueller, Von Braun, and Faget were replaced.

During Phase B, zeal was dampened and an affordable system concept of Shuttle, EVA Truss Space Station and Shuttle C was developed at JSC. The shift away from the systems in the Phase A studies began in late 1970 and led to Shuttle approval early in 1972, starting development of the Space Transportation System [STS]. This led to the concept of a STS for use in visiting regions in cis-lunar space to include the surface of the Moon.

At that time zeal was further dampened by a decision by NASA Administrator Jim Fletcher to seek only approval of the Shuttle. Therefore, the **full spectrum of Cis-lunar Regional Development that was in the Post-Apollo concept was never recorded.**

Approval of the EVA Truss Space Station in 1984 was the next logical step in the STS; however, the *Challenger* accident in 1986 started the demise of the Space Transportation System and NASA lost direction.

Challenger had happened before we'd gotten into building the Space Station very much. Once we were in the Space Station development, the *Columbia* accident happened. That's when the country lost its nerve, with the George Bush administration and [Sean M.] O'Keefe as the Administrator. In my opinion O'Keefe was caught in a very awkward position. First of all, he

was not well versed in space. Then almost immediately he was hit with the *Columbia* accident while the Space Station was being built. And with the mood of the country, he was overwhelmed. No one could sit back from all that noise and smoke and say, “Let’s not panic. The vehicle is okay. We just did not manage it well.”

We could have fixed the foam. We could have fixed the O-ring [on *Challenger*]. We should have fixed those. If we would have thrown away the F-16 the first time it failed, or the F-14 the first time it failed, we’d never have a first-class fighter plane. Early in the F-14’s life they were landing one day and a hydraulic line fatigued in two. The pilot lost his flight control, had to jump out, the airplane was destroyed. They didn’t shut the program down, they just fixed the hydraulic line to where it wouldn’t fatigue off again.

When you design something, you’re not smart enough to realize in-flight how much the engine is going to shake, if the airplane is going to shake a little bit, and if that line is going to. You try to analyze that; for example, we set up a very critical subpanel trying to understand pogo. If you don’t know what pogo is, pogo is a situation on a rocket engine usually where the propulsion activity is putting pulses into the structure. Then those two things start interacting in such a way that they build up rather than stay low or disappear. It can finally shake you apart. You have to be sure there’s not something in your propulsion system that will shake your airframe in an unstable direction.

Pogo was just studied from a kid jumping on a pogo stick. A launch vehicle will start chugging like that and instead of it damping down—see, when you’re a car, if you drive and you hit a bump, the wheel tries to jump. It has damping in there. So the wheel doesn’t sit there and vibrate very long. It has shock absorbers so that when you hit it it doesn’t shock the whole thing.

So you can hit a bump and the wheel will jump one time and shake once and then stop and you're okay again, because they've got shock absorbers and dampers.

A solid rocket fundamentally shakes just because you can't make it burn perfectly smoothly, and with liquid rockets you're having to pump fuel in there with extremely fast rates, and it's got to all burn. You try to make it burn very efficiently, but every now and then—so that's shaking and the structure tunes into that. It can shake you apart.

Knowing that was a problem, we set up a very critical group to do nothing but analyze the Shuttle. To pick up on pogo, at the systems level, we started studying pogo very early in the Program. We set up people from government, people from industry, even people from academia and other places, and analyzed what were building from a pogo prevention standpoint. Did we need to add some damping somewhere? Or add an accumulator somewhere to decouple things so the vehicle wouldn't shake? We didn't ask the engine group to study that or the tank group to study that or the rocket group. The government and their integration support from the contract studied that at Level Two.

We then finally decided we need to put an accumulator on the engine. After reviewing that very carefully at the systems level, we directed the engine group to put an accumulator in. They did. They didn't come back and say, "You can't tell us what to do." They accepted it, put it in. We've never had pogo. There's no guarantee that that was perfect. There's no guarantee that you would have had pogo if you hadn't put it in there.

But you have to make those judgment calls—like when we made those decisions on whether we were going to launch manned first time, or whether we were going to keep air-breathing engines which we decided not to, instead decided to put the orbiter on the back of a 747. We did that to keep from having to deal with air-breathing engines. We didn't want a

250,000-pound airplane sitting dead at the end of the runway. We had to have some way to move the orbiter around and some way to go test it. We just worked those things every day and worked through them.

The government should have evolved the Shuttle, not terminate the program. Actually, we didn't want it replaced, we wanted it to evolve. We wanted to have Shuttle for 100 years, or Shuttle and its derivatives because it would be part of our *space transportation system*.

We didn't throw the steam engine away first time it had problems; if we had, we wouldn't have railroads today. It went from a crude steam engine to a big old locomotive to a diesel-powered thing to electric-powered machine, and now it's a 150-mile-an-hour train. I'm sure along the way some people were killed.

The Shuttle was a work vehicle—a transportation and work vehicle. It wasn't a capsule to go to orbit and back. [Former Administrator Michael D.] Griffin, you know he wanted the country to build something to go to Mars. He was running around saying, “We spend more money on bubble gum than you're giving to NASA,” trying to shame the country into giving NASA a lot of money. He didn't want to talk to anyone. I sent him a letter, said, “I'd like to talk to you.” He had one of his staff people call me to say that he didn't want to talk to me, he speaks his own mind. He knew what I was going to tell him. So he didn't talk to me. I sent a registered letter, so I know he saw it.

Norm Augustine—he led the group that recommended to shut down the Shuttle [October 2009, Review of United States Human Space Flight Plans Committee]. The Obama Administration established the Augustine Committee to advise on the options available for human spaceflight. Senator [Kay Bailey] Hutchison asked him at a hearing, “Could we continue

to operate the Shuttle?” Augustine gave her an honest answer. He said, “Yes. But we wouldn’t have money for other things.” He didn’t say why, didn’t say what other things were.

The Augustine study effort failed to recognize the need to continue Shuttle and terminate Constellation. Augustine gave very poor advice in my opinion. Senator Hutchison did not ask the second question. She should have said, “What are the other things?” President [Barack H.] Obama must have selected an option for “other things” and the Senator got conned into supporting SLS [Space Launch System]. Shuttle and Space Station as best I could see were using somewhere around two-thirds of the funding from human spaceflight—there was a third of the funding available for other things, like these vehicles that go on up to the other part of space [Appendix, page 19].

The termination of Shuttle after being underway with the ISS as a program within the Vision for Space Exploration further diverted the planning in an unfavorable direction. Constellation further complicated the affordability issues with a very foolish attempt to return to the big rocket and ablating capsule days of Apollo. Transportation beyond low-Earth orbit became confused and Constellation was a further example of over zeal.

Constellation failed for several reasons. Among the reasons are concept, design, funding, and management. Constellation added two more throw away stages than Apollo and had a poor design concept called Ares 1. When Constellation was later properly terminated by the Obama Administration the dependence on Russia for support of ISS significantly increased.

The decision to develop SLS and Orion further aggravated the confusion from a productive cis-lunar program. Technology and funding must match your zeal. Unfortunately, I feel that the Agency is still confused and in over zeal. This is where we find the Agency today.

Cis-lunar opportunities

What we were trying to do when we planned Shuttle and Station together was give the nation a capability to utilize cis-lunar space. Let me explain cis-lunar space from my definition. I consider cis-lunar space to include the volume of space encompassed by a sphere centered on Earth's center and extending in a radius that touches the Earth/Moon libration point known as L2.

Cis-lunar space is a geographic definition of a volume of space. If you take the Earth and draw a big circle around it and that circle runs around the Moon, that whole volume, that big sphere of space is cis-lunar space. It's a volume of space centered at the Earth that reaches out far enough to include the Moon, but it's not very far. It's only 250,000 miles. Compared to 250 million [distance to Mars], it's not much. Cis-lunar space is where everything that's going to really develop in the next 100 years for humans is going to take place. It's not going to be at Mars. It's going to be somewhere in cis-lunar space.

So we wanted to build a *space transportation system* that would allow you to go from the Earth to the regions that were important. That's what this chart says [Appendix, page 6]; I simplified it by with rows showing everything to escape velocity.

Escape velocity, if you're traveling fast enough and in the right direction, you will escape the Earth's gravitational pull and just leave the Earth. Not sure where you'll go, but you'll head out into space and the Moon will pull on you a little bit and Mars will pull on you and you'll wander through space. Deep space can be effectively explored by current unmanned machines.

Remember I told you that to get to Antarctica, I'd drive to the airport, then fly to San Francisco, and so on? When we leave the Earth, we go to low-Earth orbit. That's the first region. We're there now fiddling around. Then we go on up to geosynchronous [GEO]. Then we go to what's called the libration regions. Then we go down to the surface of the Moon, and

maybe begin to do like they do in Antarctica, put a research station. The Russians will have one there, Chinese will have one. But we're not going to get together with the Russians and the Chinese and go to the Moon. They won't be able to put a group together and agree on the time of day.

Utilization and support to Earth was primary in our Post-Apollo discussions. Post-Apollo envisioned **cis-lunar regions as *using grounds***, not for the primary purpose of developing the systems for a journey to Mars. Deep space exploration by humans beyond the Moon was over our horizon, left for machines and later consideration.

What we were trying to do is start a **Space Transportation System and a Space Station that provided the ability to go to low-Earth orbit, establish a facility, and then begin to travel back and forth to there and from there to do something.** When that got to work, we'd figure out some space-only vehicles to take the people. First of all, you'd go there, get off that vehicle, take a shower, spend the night, get on another vehicle and go up to the next place. Then get on another vehicle and go up again. There'd have to be some facilitation at each place. So you take some Space Station pieces and put them there. You'd build, travel, and hub, travel and hub, travel and hub. We expected the low-Earth orbit facility to serve as a transportation hub; GEO, L1 and the lunar surface regions would be developed in due course. That's what NASA should still be doing.

If you go to low-Earth orbit you're about 55-56 percent of the way to escape velocity. Takes another big jump to get to GEO[synchronous orbit]. Once you get there, it doesn't take much energy to go on up. In my opinion they will not go back to the Moon until they have a vehicle at a libration region that they can refuel that can take them down to the Moon and back. If you try to haul everything from the bottom of this gravity well of the Earth to the Moon and

back with big rockets, you ain't going to do it. **We still haven't changed our thinking. Everything is not a launch vehicle.**

Yes, you should thoroughly check out before you launch everything that's a critical launch vehicle. But if I'm going up there to build a house, and it isn't going to kill anyone if the roof leaks a little bit, I can go back and fix the roof. I don't have to put the roof together down here and let it rain on it for six months to prove it's good.

Right now they're setting up the ability to build about one of these big rockets every 18 months. What they going to do with it? One every 18 months. It can't put in orbit but a small part of what you need to go to Mars. Another 18 months, you put another little piece up there. By the time you send the next one, you've already eaten all the supplies that are up there. The SLS [Space Launch System] and Orion have a dubious purpose at this time.

They should still be trying to climb up those green squares [Appendix, page 6]. NASA should deliver steady progress to the taxpayers. **The exploration program in NASA will require evolving productive missions.** Perhaps the current NASA "Proving Ground" concept should be fully utilized with each significant region in cis-lunar space developed and utilized for its own merit.

The surface of the Moon has strategic value, also GEO and Earth/Moon libration regions. Since we have never flown a human mission to GEO, I would suggest that strong consideration be given to conducting a mission to this region early in the exploration series. GEO is the next significant region past LEO on the path to deeper regions of space. A program to GEO similar to a program called Mercury should be planned and explained to the public. In support of this mission NASA could coordinate with industry and determine any joint interest for

having long term human participation in this region. Similar comments for the libration regions and the surface of the Moon.

Human utilization of these regions should be primary—utilization rather than exploration. In our Post-Apollo planning we found strong interest in communications, electric power generation, earth viewing and other activity of industrial and strategic value. A space station like facility was also visioned at both GEO and the Earth/Moon libration regions. Fuel depots and storable propellants were visualized but not studied in any technical depth.

Incremental steps were thought to be very important. We were anxious to proceed with Shuttle and Space Station Freedom in the low-Earth orbit region.

Human spaceflight efforts in the next several decades should be committed to Cis-lunar Regional Development. NASA needs a different systems approach and a focus on Cis-lunar Regional Utilization. Space only vehicles and refueling in space should be developed.

Programs having an explanation of where, when and why should be explained to the tax paying public; this will develop the level of budget support for the Agency. The timing of programs must be carefully considered. A journey to Mars can be on the back burner. Mars is a bridge too far for current planning.

This [Appendix, page 19] shows these five regions up through the Moon—and you can do certain things around the Earth, certain things at libration points, certain things at the Moon. That's cis-lunar space. Now, NASA's trying to call cis-lunar space anything that orbits the Moon.

NASA's want to send the next flight [Orion EMT-1] on a great big loop around the Moon so they can go farther from the Moon than Apollo 13 did. When we had the accident with

Apollo 13, in order to make it come back to Earth, we went farther from the Moon than anyone else. They hold the record in that failure for being farther from Earth. So what?

They [Orion EMT-1] aren't going to do a thing but look out the window and say, "Gee whiz." It's not going to help the economy, it's not going to justify NASA in the future. The country is going to get tired of paying money for "gee whiz."

Planning three successive missions similar to Apollo 8 strikes me as poor planning. What are we trying to accomplish with these costly flights? Apollo followed [the Apollo] 8 mission with a different mission. Orion has already done its "Apollo 8" so make the next flight to GEO. I would hope to see a mission to GEO replace one of these currently planned missions.

We need to go to low-Earth orbit like we are. We need to go to GEO. We need to go to the Earth/Moon libration region. Orion could spend a few days in one or the other of these cis-lunar regions and conduct some research. We have never visited either region with humans. I believe that they have strategic value.

We need to go to surface of the Moon. We maybe need to begin to benefit the people on Earth by sending electricity down to them or helping communicate or doing research to help them when they get older. Or to go back to the Moon, if we find some way in the future to do fusion—where we're trying to fuse atoms rather than split them. In that fusion hydrogen-3 becomes a very valuable commodity. We think there's a lot of hydrogen-3 on the Moon captured, that came from the Sun. It doesn't much come to the Earth. It's a wild idea right now, but 50 years from now it may be important who has control over a certain region on the Moon and producing hydrogen-3.

Maybe we don't want the whole Moon, but we don't want China to have the whole Moon. We don't want Russia to have the whole Moon. We don't want them to sell us hydrogen-3. We don't own all of Antarctica and they don't.

I had the luxury of going there one time when NASA was studying Antarctica compared to what we were going to do on the Moon. The continent of Antarctica, the land is down about sea level, but the South Pole, you're up at 10,000 feet, because there's a cake of ice 10,000 feet. It's built up down there. Never melts. They can core down and with atomic timing tell you when that ice came. So when you get there, they give you a drink with a piece of ice in it from your birthday. It's a big deal when you're a 40-year-old guy and you're making a drink cooled by ice the year you were born. So there are lots of strange things down there, and there's some things that happen down there that help us understand the environment of the Earth. We've done research now for quite a while, but no one's ever made much money. There are no stores down there. There are no housing areas. There's no colonization.

There may be some benefits of going to some of these [cis-lunar] regions, and that's what the transportation system that we conceived in 1971 would do. We conceived it so we could maybe do it down in this [lower] funding level. Because if you're not going to do it down there, you're not going to do it. You can try to embarrass Congress all you like, but there are hundreds of them, it's hard to embarrass all of them to give you money when you don't have a good reason.

NASA hasn't done a very good job. They're going to go out of business. NASA must recognize its capability limits and plan accordingly. The funding level that the nation will support has however been established. It appears to be below 1% unless a strong purpose for human spaceflight develops.

In my opinion until you have a refuelable lunar module [LM] or refuelable vehicle at either L1 or L2, either the libration region between the Earth and Moon or just the other side, until you have a truck stop there, and a fueling station, and a way to get in the vehicle to go down on the Moon and back and go over here and back and over there and back, you can't have Antarctica. If I went to Antarctica today I would go to McMurdo [Station]—that's the libration region. I could get in a helicopter and I go to the station there, and take them groceries.

You cannot go back and do anything useful on the Moon or beyond it until you have that space transportation system. That means resources. That means systems capabilities. NASA is not working on it.

What does SLS do? It just throws a big massive weight at a certain velocity and in a certain direction. That's all it does. That's the capability. But what are you going to do with it? Until you can go plan something useful with what you are trying to do, why do you want it? Someone ought to look out the window at the flagpole.

The term "Journey to Mars" is a very broad describer. For example, it could start with a rental car ride to LEO. A government vehicle could travel to an assembly area at EML1. A space living vehicle could travel from EML1 to an orbit of Mars and then return to EML1. Government vehicle back to LEO and rental car back to a runway landing on Earth. This describes a Journey to Mars from Earth and back—somewhat zealously. Time period several months, some risk, costly and why go at this time and hurry back? There are many important regions in Space between the Earth and Mars.

There's no doubt in my mind if you're going to use the total capability of the Agency on some future endeavor—something on the scale of the Space Shuttle and Space Station

programs—you are going to need to set up a management organization very similar to what we *set up at the start of Shuttle.*

Misconceptions

The *Columbia* Accident Investigation Board [CAIB] had a lot of what I call musings. A musing is when you sit around and speculate and talk and don't really know a lot about what you're saying. They had people come and say, "Well, they shouldn't have had the crew and the payload on the vehicle together." But, why do we have trucks with drivers? They're supporting the payload and the payload is supporting the driver.

History as far as I'm concerned is me and the hundreds of people that helped me, thousands of people. ***You have to use the technical competence of the total agency.*** You have to get through the petty politics is about as nice a term I can use to explain it. People use politics to mean lots of things. You put a bunch of children in a room, include a couple of bullies in there. These two bullies fight for who's going to boss the children. So in NASA, a bully is at Marshall, a bully in JSC, do you let them fight for who's going to run things? What you ought to do is take those two bullies and smack their heads together, so we can use the talent at Houston and the talent at Marshall and the talent at Kennedy [Space Center] without petty jealousies.

Let me tell you about the [Space Shuttle Program] organization. It was ***not Lead Center.*** Kraft as the Center Director in Houston had the same function as the Center Director at Marshall and the Center Director at Kennedy. Once a month they could go to the Board of Directors meeting in Washington. Each month I went there and briefed that Board on what I had done and was doing. They were free to criticize anything I did or comment on anything or ask me why I did it.

I answered them. If they didn't like it, they could decide what direction they wanted to give and give it to the Program Director [Charlie Donlan] in Washington. Then he could try to convince me. I would sit down across the table from him and we'd probably have a fistfight,

we'd probably have a shouting match, and one of us would win, and the other one would have to leave. Or we could maybe compromise and go on.

You cannot spend \$6 million a day and have a month debate on everything. I'm not trying to blow my own horn here, but someone had to sit at the head of the table and make those decisions. You have to make sure they hear you. You have to write it down.

Let the family argue all they want to. Then someone has to say, "Okay, here's what we're going to do." You have to make sure they hear you. You have to write it down. Because if you don't, the little seven-year-old will go, "Mommy said I could have cookies." "No, you didn't. You said you could have one cookie a month." "He said I could have cookies. I want cookies." See? What he heard and what you told him, miles apart. He was right. You told him he could have cookies. Silly argument, isn't it? That's the way adults work.

Frankly, the matrix management organization we put in place was to use the bureaucracy and prevent the bureaucracy from fighting or pulling against each other. In that book, [*Space Shuttle Legacy: How We Did It and What We Learned*] this is what it says:

The pure lead center approach as formulated at the outset of the Shuttle Program might have made sense from a rationalistic standpoint. However, approach failed to take account of discrete field center interest and rivalry among JSC, KSC, and Marshall. Sister centers were not about to take orders from JSC, the designated lead, and JSC's key decision makers for the Shuttle were neither willing nor able to enforce their will. ["Managing the Space Shuttle: Leadership, Change, and Big Technology," Chapter 3; author W. Henry Lambright, page 71.]

It is absolutely wrong. The writer, a professor at Syracuse University, is trying to explain the popular culture that the centers won't work together. He had heard that rumor somewhere. What is he writing about? He doesn't know a thing about it. He came to Houston. He didn't come and see me. Never talked, never seen him. How can a man come to Houston, Texas, study the history of the Shuttle, not even talk to the Program Manager who was there for 11 years?

I never once had anyone refuse to do what I asked them.

In *Wings in Orbit [Scientific and Engineering Legacies of the Space Shuttle, 1971-2010]*, Griffin says how stupid the designers of the Shuttle were. According to him, we should have built a little test vehicle and seen whether it would work or not. It was barely doable. What is barely doable? You can barely stand up. But you're standing up, aren't you?

The history of the Shuttle –I have not found what I would consider a proper history. I don't expect history books to be 100 percent accurate, but it ought to be 80-90 percent. *Wings in Orbit*, when you go to a chapter where they're discussing a subsystem the people who knew something about it wrote it, and it's good. That's our history.

Suggestions for NASA

NASA better learn to be a space agency. They better learn to take advantage of what a human can do. Now you have to carefully put him in a suit, you have to provide him air, cooling, but he can go up there and push a one-ton object around. They ought to be on that path. They ought to be building space-only vehicles. They ought to have refueling stations.

We had said, if we built these things—things like Space Station, Hubble, solar power systems, satellite servicing, science—all of that would open up all of that economic spectrum. Back then we talked a lot about building a big solar power collection system. That was one of the regions for the EVA truss. A big solar collecting system up there maybe ought to have a collector a mile long. You go up there, build it, put solar panels on, then send the electricity down.

It's not cost-effective right now, but we worry about burning coal, burning fuel. If NASA was telling the public, "We're looking at building a solar collector to collect energy from the Sun and use it here on Earth," people would begin to relate to that. Or I could go up there and put a big communication station in place. I don't have to keep people there all the time, but I can put better equipment up there and go up to service it. I can do broadband communications all over half the world from one station up there.

NASA is not working those things. I don't hear anything where they're collecting and arguing the merits of being here, here, here, here, and here [Appendix, page 6]. They're talking about a little rock out there 50 million miles away, where we've got robots out there today telling us more than we need to know about it. I think this is dumb. That's what I'm saying.

There were times when we almost did some really dumb things. This [Appendix, page 10] is the big Saturn V daddy that Wernher wanted to build to go to the Moon, called Nova.

Some engineers at Langley, most of whom I knew, told NASA they were stupid if they used that; they ought to do lunar orbit rendezvous. NASA finally woke up, went to lunar orbit rendezvous, downsized to the Saturn V, successfully completed lunar orbit rendezvous, and went to the Moon and back.

For the future, we're going to go back to 1950s capsules and send our people up by taxi. Nothing wrong with that, but I hate to see us go back to the 1950s when we had a truck [Shuttle] that could take 10 people. You don't want small cars. You want big trucks with a cab in the back for people and a crane. You want to go service your tower or do something. With it, you could go do something. A little capsule? Yes, that'll get you up there, bring you back and dump you in the ocean and hope you don't drown. I'm telling you the way I see the world.

One of the first lessons is ***you have to fit the activity in the Agency to the budget because you never know what the budget will be the next year.*** The Agency has to do a certain amount of projections. When I was there you had to do this year's budget and five-year projections. I don't know whether they still do that or not, but they ought to have a budget for this year and five-year projections and ought to show how their activity, programs, social programs, whatever the Agency has planned for has got to fit that budget.

The Agency completely blaming the OMB for all the shortcomings is silly. Why are we bloviating about Mars when we have no budget that fits it?

I'm going to talk to you in the very biggest sense. We searched from 1966 to 1972. What I learned in 1966 was that Marshall [MSFC] needed work; JSC did not need work. But Headquarters and Marshall were worried the number of people they had in that Center over there [Alabama] and the design work and the manufacturing of the two launch vehicles that were left was getting mature. Point one.

Point two. They [MSFC] always wanted to expand their role. They always wanted to encompass some of the things that were focused at the Johnson Space Center. Nothing wrong with that, except it's got to be controlled. Country can't afford two astronaut groups. They can't afford two space vehicle groups, but they now have two—one is ambitious and the other one is doing dumb things—my version.

Go back to terminating Shuttle. Why did we terminate it? There was never an official government statement of why we terminated the Shuttle. I have an opinion why we terminated. There were lots of people who said it was a dumb thing to do. Fine. But we did it, and it worked to a certain degree, and it had certain limitations, it had certain capabilities. When they terminated the Shuttle, we lost a lot of capability for the future. They didn't understand it and build on it, keep it, and evolve it – that was the original plan.

I can say the same thing about Space Station. In Phase A, Wernher wanted to build a 100-man space station and launch it on a Saturn V and Huntsville would become the Trump Hotel of the world. You couldn't help but like Wernher, but he was so unrealistic. A visionary is fine. You can sit here and postulate a second human race on Mars or half of our human race on Mars, but between now and when that happens is probably several centuries, not 20 years.

The space station with the EVA truss design was 10 years away; it wasn't a 200-year vision. When I left Skylab and went over to become the Shuttle Program Manager, I didn't just think of the Shuttle. Phase A had tried to figure out Space Station and Shuttle so we could go to low-Earth orbit and begin to do things. That's what the Space Transportation System was about, not the Shuttle. The Shuttle was just part of it. The Space Station was part of it. Shuttle-C was part of it. Other things should have come in and been part of it. We should have kept that [plan] and built on it. That's where we should be today. We're not there.

[Appendix, page 20] One of these is “utilization rather than exploration.” I don’t quarrel with trying to bring industry deeper into space involvement. I question a little bit the way NASA is doing it. But, if we ever accomplish anything of real value strategically, industry will be involved.

Now frankly, all NASA is doing is contracting with three contractors to build a capsule; or recently they added *Dream Chaser* as a cargo carrier—they ought to be the number one. It can accommodate several humans, and as well as being a people carrier, runway landings when possible are preferred. NASA got that backwards, but it’ll work out.

There’s nothing wrong with NASA as a government agency helping stimulate industry using the new space environment. I don’t want to go on record being against it. I want to question sometimes how they’re doing it, why they’re doing it, and what they’re doing.

NASA uses the word commercialization. I don’t know what SpaceX would be doing if NASA wasn’t putting money in it. Let me tell you, I don’t think Boeing would build it to sell it to the average man on the street. They’re building a capsule to sell it to someone like the government or selling the use of it.

What we did on Shuttle was very much like what this country did in World War II to get ships built. They did it in cost-plus contracting. They went to shipbuilders and said, “We need Liberty ships. They need to do this. You build us Liberty ships and we’ll pay you the total cost of building them and allow you a certain profit.” Later on we’ve learned to say, “We’ll allow you a certain profit and then we’ll give you a certain award fee that gives you more if you do well and less if you don’t do well.” It’s a way for government to incentivize industry to do what the government wants.

That's the way we did Shuttle. We did it in cost-plus contracting, but now that puts a burden on the government to manage right, manage efficiently, and get what they want for a reasonable price. It does not allow you to set up a dumb organization like they did on Space Station and sit there and argue and talk and waste money until someone has to butcher it and partner with the Russians and lose control of it and stick it somewhere you don't want it. We had to stick it up at 51.6 degrees, which makes it hard to work with. It's got the advantage of looking at more of the world and an advantage to the Russians. Otherwise they couldn't get to it.

But it [inclination] decreased our payload to it probably 20 percent. We can't sit at the head of the table and decide what to do; we're sitting over there in the corner; we don't even have adequate control. We can't even send people up there and back.

All I want to say is, commercialization is fine, but call it what it is. This use of commercialization is another way for the government to contract for something. It's a way to hide the government's poor way of getting what it wants.

Is the government going to go to SpaceX and make sure they're worrying about pogo? Are they going to go there and make sure they're worrying about critical failure points? Are they going to go there and make sure they got the right safety factors on everything? If they are, they ought to put it under a contract and be responsible for it. You can't go out there and say, "Mr. [Elon] Musk, are you looking at this thing?" One of these days he might say, "Get out of here." I don't blame him. If the government doesn't want to stand up and be accountable, say so. Say, "We'll dangle this money out here and hope he does something." That's what they're doing, and I hope he does well.

Personally, I don't think we ought to be building 1950-era capsules. We ought to be landing on a runway. I spent my first six or eight years [with the space agency] picking people

up out of the ocean [as Chief, Landing and Recovery Operations, 1959-1966]. You can do it, but Gus [Grissom] nearly drowned and we were lucky, we fished him out before he drowned.

Right now this big capsule they're building, they don't know what they're doing out in the ocean. If they land that thing in rough seas, they're going to have a time getting it. They can avoid landing in rough seas, but if it leaves somewhere coming, and it gets very far, it can't go anywhere but where it's going to go. If the weather turns bad, it's going to go there, and they better well be prepared for it. We were prepared.

When I was running Recovery [operations], we decided to put people in the water, put additional flotation around it, put a 20-man life raft there. Maybe it would have helicopters to get the people on out of there, and then carefully pick it up. Now they're going to go flood-down a big ship and draw the capsule into the back of the ship, and the ocean is going to sit there very nicely and let them do all that? Who's learning? We went through all that. They well better be prepared for some rough seas. You can't always avoid them.

Lessons to Remember**WHEN WE WENT FROM A *DEVELOPMENT* ORGANIZATION TO AN *OPERATIONS* ORGANIZATION PEOPLE WEREN'T VERY SMART.**

Why are we in a mess? Let me talk about number one, management. It looks to me like when we went from a *development* organization to an *operations* organization, people in Washington weren't very smart. The people at Houston weren't very smart. They went back to the Apollo mode—Marshall, you do your thing; Houston, do our thing; Washington, you tell us what to do.

I understand Houston even told Marshall, "You don't have to tell us even what's wrong with your things. We're not interested. That's your problem." Houston had the [*Challenger*] systems level responsibility. They should have been telling Marshall, "Tell me everything that's wrong with your system, and let's join up and work it out." When issues came up like the leaking O-ring and the foam, no one worked it. Houston says, "We're going to go sit in the Control Center and run things, run them right in the ground." Management, that's number one.

After the accidents, the investigation boards came in, but they weren't thorough enough or smart enough to say, "Houston, you screwed up for these reasons, and Marshall, you screwed up for these reasons, and Headquarters, you screwed up for these reasons. Now straighten it out." They weren't that smart, because they hire people; they didn't even understand what was going on.

I appeared before them over here for four hours [*Columbia* Accident Investigation Board]. I tried to tell them some of these things. But, a professor from George Washington University [John Logsdon] kept interrupting and wanted to talk about the cost per pound. Had nothing to do with the accident. Kept asking, "How come you told us it's going to be \$150 a pound, we never told them it was \$150 a pound. George Low shot them a bunch of crap and

they interpreted it as such. That's where the cost [estimate] came from, but what did that have to do with the accident? How did he get on the accident board?

Go read my testimony to them. I'm trying to tell them what happened. Sitting on my side is a guy named [Milton A.] Milt Silveira. He's dead now, but every time I tried to tell them the truth he tried to override me. Why? He was trying to protect Max Faget. I understood that, but the Board didn't. I'm telling you things that are my opinion.

IN A PROGRAM ORGANIZATION, THE DISCIPLINE OF THE ORGANIZATION, THE MANAGEMENT RESPONSIBILITIES, AND THE PEOPLE THAT WORK IT HAVE TO WORK THINGS OUT.

Let me tell you a couple of incidents that'll help you understand all this. In 1974, in the first budget cycle from John Yardley, [Associate Administrator for Manned Space Flight] we put together a Level Two recommendation for the budget, sent it to Washington. It was the first year we started the [external] tank contract at Marshall. Sometime during that process I got a phone call from Yardley saying, "I see you have marked the tank down from X million to Y million. They asked for X million. You marked them to Y. Why'd you do that?"

I explained why. He said, "Well, [Center Director William] Lucas has talked to me and I think they need that higher money." I said, "Well, John, you're the final authority on it. Do what you want to." He gave them the extra money.

Sometime later I'm sitting here looking at what the tank [group] is planning, because they sent their schedules to us on a regular basis. I see a wind tunnel test at Tullahoma [Tennessee]. I had never approved wind tunnel tests at Tullahoma, never heard about them. I pick up the phone, call the Tank Project Manager, and said, "Tell me about the wind tunnel tests at Tullahoma."

“Oh, we have to go up to Tullahoma and run the complete configuration to get the interface loads to our tank so we can go ahead.” I said to him, “Do you understand A, B, C, D?”

“Well, yes.” I said, “There is where your loads come from. You knock that off until we get to D. We’ll give you the loads.” He said, “But I need something for my people to do.” I said, “We shouldn’t have given you the money.” I made sure Yardley heard that. He later apologized to me for marking Marshall that high that year on that tank. Now Yardley was within his bounds of overriding my budget, but it was wrong. I’m sure I did some wrong things.

Another one. Late in the Program, we had made a static firing. You set everything up just like you’re going to fly, you load the tank, and get everything ready, start the engines, and shut them down. Start the liquid engines for four seconds and shut them down. You don’t light the boosters. It’s like scrimmaging your team before the game on Saturday.

We had done that. Then we found a problem with the tiles on the orbiter, so we had to take a longer time. Finally fixed this. I had the Program go study whether we should do another static firing since so much time had passed. Owen Morris from the Systems Office went out and talked to everyone, got all people’s opinions. This came back to the Board; I chaired the Board. We discussed it for two hours. We couldn’t find any single thing that said you ought to do it. We didn’t see where anyone had done anything wrong. People had stayed within the configuration responsibilities, but there’d been lots of little things going on.

I made a decision and announced it. I said, “Look. It’s just prudent for us to do another static firing. Therefore, I’m going to direct another static firing.” Monday morning, I put out a directive, “There will be another static firing.” A few days later I get a phone call from John [Yardley], who said, “I’ve been talking to Lucas. We don’t think you need another static firing.” I said, “Well, John, you’re certainly well within that opinion. What do you want to do about it?”

No answer. I said, “Well, John, you can do one of two things. You have fired the Program Director; he’s gone, so you’re the Program Director. You can send me a directive signed as the Acting Program Director and tell me not to do it. Or you can even send me one as the head of Office of Manned Space Flight [OMSF], tell me not to do it. Either one will work.”

He said, “I’m not going to do that.” I said, “Well, I’m not going to change my decision. What do you want to do?” Then I said, “What you should do is have an OMSF Management Council meeting. Call your board of directors together, and I’ll tell you about it.”

That’s what he did, but he went bigger. When I show up in Washington to brief them, it’s not the OMSF totally. It’s the OMSF plus the Administrator. Fine. I’ve got an hour, so I got up and talked for an hour. If you give me an hour, I’ll talk for an hour. The theme was prudence. I got through, sat down. There was a little bit of discussion. Then a vote all around— one hundred percent support for a static firing. Bill Lucas sat there and never opened his mouth. Yardley sat there, chaired the meeting, and never once said, “I called him and told him not to do it.” What’s my point?

IF YOU’VE GOT AN ORGANIZATION, IT OUGHT TO WORK A CERTAIN WAY, AND PEOPLE OUGHT TO UNDERSTAND THAT.

Let me emphasize a couple things. I’d like to put emphasis on management. Now my terminology of *matrix management* means different things to different people. The terminology of *lead center* management means different things to different people. Sometimes when people even try to talk about it, they talk past each other. I think it’d be very important if you can find the Green Book. As I told you, the Green Book came about because I started building up briefings for people who kept coming down saying, “How can you possibly do this?”

There are some very subtle important things there. What should Level One do? What could you do effectively in Washington without a huge staff of contractors?

And, a Program Manager shouldn't make a decision he's not willing to have the newspaper in Houston, Texas, know about, and he's not willing to get up and tell the church why he did it.

IT'S A BIG DUMBO, IT'LL NEVER FLY. (BUT IT DID.)

One more story. *Houston Chronicle* had a science writer back then who didn't know a thing about space or physics, but he had the job of writing articles in the *Chronicle* on what was going on in the space program. I got to know him typically because he'd come by and want an interview. I found him to be a real amusing kind of a guy, because I think every time before he came, he had had a couple drinks. In my opinion, he was always flushed, and a little bit inebriated, because it was usually 4:30 or five o'clock before I talked to him.

He came with one of these little spiral notebooks like you had in high school, a half size one, with little wire spirals. He'd come in and sit down and open it up to his blank page and get his paper out and sit down. It was up to him to say what he wanted to talk about.

So he'd bring up some subject he had thought about. I got to explain to this guy what he's asking. I know he's not very smart technically, but I didn't try to make him think I was a rocket scientist. Every now and then I would say, "It's just this simple, $F = ma$."

What is $F = ma$? That's the so-called rocket equation at the very basic. You push on something hard enough, long enough, it'll go fast enough and high enough to be in a position where it can float around the Earth. That's all it is. That's the rocket equation.

So every now and then I used to say, " $F = ma$." Every now and then when you're trying to explain to someone, you just got to go to the basics. He kept coming and says, "How do you know this thing [Shuttle] is going to work?"

I said, “We’re pretty sure it’s going to work, because $F = ma$. As long as we can make F [force] and you know what m [mass] is, we’ll get a [acceleration]. But if F quits or m is too heavy, we won’t get there. We’re very careful. We’re trying to keep our weight down, keep our propulsion force up, keep it from breaking up, and we’ll get there.”

We kept reading articles about what we were developing: “It’s a big Dumbo, it’ll never fly. The orbiter, the Shuttle is a big Dumbo. It’ll never fly.”

We heard this again from the admiral [Harold W. Gehman, Chair of the CAIB]. He wanted to know, whatever made those stupid people build that dinosaur of a vehicle? He didn’t know his head from a hole in the ground as far as rockets are concerned, probably knew a lot about submarines, a lot about the Navy. They should have had someone chair that Board who knew something about space vehicles. They shouldn’t have had college professors in political science on there either.

THE *COLUMBIA* ACCIDENT DID NOT OCCUR BECAUSE “FOAM FELL OFF THE TANK.”

Foam couldn’t fall 20 feet and hurt the orbiter. I still read about foam falling off the tank. Anyone who writes about foam falling off the tank does not know what they’re writing about.

That piece of foam came unattached and got in a position where force wasn’t still pushing on it. It tried to fly in parallel without a rocket. It slowed down. The orbiter ran into it, tried to knock it out of the way. It hit it with a 500-foot-per-second difference in velocity. This foam slowed down enough and the orbiter speeded up enough where there was 500 feet per second difference. Kinetic energy is the square of the velocity. Square 500—you get a big number. Even though it only weighed a pound, you had 20,000 foot-pounds of kinetic energy.

That's equivalent to taking a 100-pound cannonball 200 feet in the air and dropping it on your head. It'll kill you.

But it's light foam, people said, pick it up, that won't hurt. Why does a piece of straw or grass go through a barn door? Ask people in Kansas where tornadoes come through. You have to keep people looking at the vehicle who understand tornadoes. We didn't do that.

“GIVE ME MORE MONEY” IS NOT THE ANSWER TO EVERYTHING.

I got to know [N.] Wayne Hale by watching a television replay of the “*Columbia + 10: Lessons Learned and Unlearned*” symposium, held at George Washington University on the tenth anniversary of the Shuttle accident. A friend of mine called me and said, “You better watch that.” It had been recorded and was on television, so I took the advice, went in, sat down, turned it on.

Most of the symposium was a replay of the funeral procession, or about picking up the pieces. But then they got to the last section. The real wrap-up of the day was with the chairman of the *Columbia* Accident Investigation Board, Gehman, and Wayne Hale, a Shuttle Program Manager from the Johnson Space Center. They were going to wrap up the session.

The admiral goes first and states how stupid we were to build the Shuttle. Wayne Hale begins to chime in, “Yes, they didn't give them enough money. The program managers weren't smart enough to tell them that they can't build it” with that budget. Both said, “They tried to build it and built the wrong thing.”

I'm sitting here, and I'm ticked off. Sometime later, I had Wayne here. I had never met him. Sat him down right in that chair, talked to him like I'd talk to my child. He was a

gentleman about it, he took it. I think he's learning—give me more money is not the answer to everything.

NASA keeps saying, "Give me more money." They better take the money they got, spend it effectively, spend it reasonably, and they may eventually get a little more. Or they will at least survive.

A lot of my colleagues around here tell me they want a robust space program. I say, "What is robust?" And they answer, they don't know, but it's got to be robust and want to go up here [on the budget line, Appendix, page 9]. I said, "Why don't you have a robust one down here?" It's all in your meaning of what robust is. We can take this money and have a robust program in my definition. It's the only program we're going to have, or go out of business, one or the other.

You ain't going to go to Mars. We are not going to go and land on Mars and start colonizing Mars in anything like 20 years. You would have to be building the hardware today to do that. They can't even show you a picture. They don't have any idea how much money it'll take. They have no idea what kind of propulsion system to use, what kind to put where, how to land, how to eat until it comes time to come back, how to come back. They don't have any plan. They're being told by virtually every responsible group they don't know what they're doing.

ONE OF THE MOST IMPORTANT THINGS IS THE BUDGET INTERFACE WITH OMB.

To explain to OMB why you have predicted that kind of spending, and what you expect to accomplish in that year or that two years or that five years, and what you've done versus what you talked about. They have to feel a responsibility for that. Otherwise they're second-guessing you on everything. It's easy to do. It's easy for them to sit up there, let you work with all the

problems, and then fire you because you didn't do what you said you were going to do. Human nature. You want them to feel responsible, certainly at the budget level. Because you cannot sit down here.

When we set up the Shuttle organization and showed what responsibility we had down here, OMB decided to monitor us. I got a call from Charlie Donlan one day. Said, "OMB has come over and said they want to put a monitoring group in Houston." He said, "They will be very disturbing. They'll give you a lot of problems. Do you want us to cut them off?"

I said, "No. Absolutely not. Send them down." He says, "You know what you're doing?" I said, "Fine, send them down." He sent them. They came down. Said, "We'd like to come down with several accountants, five or six." I said, "Fine. I'll give you offices right here on the floor with me. You're free to go to any meeting we have and ask any question you want to ask. You have total freedom of everything, every meeting." Fine.

The [OMB] guy was stationed up in Dallas; he's going to commute down here. Brought a staff, I think about five or six of them. We put them right down the hall. Said, "It's all open. Everything that's said at the water fountain out in the hall and meetings, you're free to hear."

Man, they were in heaven. They were running around and writing notes every meeting. End of each quarter, they had to write a report and send to Washington. They'd write the report, send it to Washington. OMB would send it over to NASA Headquarters. NASA Headquarters sent it down to me. Answer it.

So now I'm answering questions from this guy right down the hall from me: "Bob, why'd you do that? Cost this much money." I'd answer, "We did it for this reason." Send it back up; they'd clean it up a little bit and send it over to OMB. They'd send it back down here.

The guy could have walked to my office and I could have told him that. So he began to do that. In fact, he even started bringing me his report for me to look at it. It would take me two days to straighten it out—he had all this garbage in it. I'd correct the bad things and send it. After two years, they said, "We don't want to do that anymore," and left.

YOU CANNOT PUT ACCOUNTING PRACTICES ON AN R&D PROGRAM.

When we decided to take the engines off the Shuttle configuration and use the 747, they came in and said, "You took some engines off and you buy a 747. How much money did this save? How much did this cost?"

I said, "I don't know, you figure it out. We took the engines off because we know it cost a lot in performance to take them up there. We know that to keep them up there and keep them healthy is bad. We know we don't need them. Why do it? Throw them away. This is a better way. As far as I'm concerned it's equal trade. You figure it out. I didn't do it on cost. I did it because that's what we should do." Then I was asked, "But what am I going to say? I'm looking for a cost number. I don't know whether that's what you should do or not."

I said, "Go figure it out. That's your job." They couldn't. So after a while they came back and said, "We're useless, we're going to get out of here." I said, "Well, we've enjoyed having you. Goodbye."

Let me give you another story. We're well into development. We've got a series of documents called 07700. One of those documents is the payload interface—explains if you're going to ride in the Shuttle this what you have to do, where you have to have mountings, what kind of shaking you're going to get—tells any payload what they need to know to design their payload. Volume 13.

The Europeans decide they're going to build a module to fly on the Shuttle. They're going to take their money and build a module to fly on the Shuttle. Fine, it's a manageable program. They appoint a program manager for the European Spacelab from Germany. Shortly thereafter, I got a message he'd like to come visit me.

He comes to my office. I meet him. He said, "Look, we're spending our money in building the Spacelab. I want to make sure you don't do anything on your side that hurts me. So I'd like to become a cochairman of your Control Board with you."

No, that's dumb. I explained carefully. "Young man." He was older than I was. "You are a payload. This [document] tells you all you need to know. If we do anything that really begins to hurt you, let me know. We'll try to work out with you. But you're not going to sit at the head of my Control Board and say no, which is all you could say. I'm not going to waste my time fooling with you."

Now I didn't use those exact words. I said, "Now if you don't like that, you ought to go to Washington, talk to someone up there, and tell them your problems." He did. He went to Washington. He told them his problem. They solved his problem. They set up an office in Washington and picked a pretty senior man as head of it. Put a staff of people there. Then three or four times a year that group went to Europe, to Noordwijk, and sat down with the people designing the payload, and made sure they understood what was in Volume 13.

I don't know what that cost the U.S. government. Those people who went to Europe four times a year probably enjoyed their job, but as far as I was concerned it was a useless bureaucracy. I did not tell the people doing that for NASA, because they had an assignment from NASA, had a bureaucracy they had to support, and they were competent people. They

never bothered me, I never bothered them. I never traveled to Europe. I never had someone sit at the head of the table with me to say no. I was much more efficient not having him there.

I can't imagine running Space Station today. [NASA] left Space Station spinning doing nothing until the country was ready to cancel it. Then the Clinton administration said, "Gee whiz, that's a lollipop, let's go hold it up in front of the Russians, and maybe they'll be our buddies." Now, they are our buddies—as long as we keep throwing money, they'll be our buddies.

I don't know what's going to happen when we quit throwing money. It's that simple. You can't tell those people what to do; you've got the Japanese, and Europeans. Maybe try to persuade them, but one day if the Russians want to shut the furnace down they'll shut it down. People say, "Well, look at the money saved." Money you're saving?

NASA is working with no positive control in the International Space Station Program. Because it is a partnership, no one has positive steerage.

YOU'VE GOT TO KEEP A PROGRAM OF TECHNICAL PEOPLE FOCUSING ON TECHNICAL THINGS.

In the old NACA agency, NACA never built a vehicle. They took vehicles being built by the military or commercial and tested them, or did fundamental aerodynamics in wind tunnels. The product we had then were reports. The first ten years I worked in the government I produced nothing but reports. I didn't design any vehicles, didn't fly any vehicles. But we had a flight test organization, and they took vehicles from the Air Force or from somewhere else and put together flight tests to help understand certain things to help the Air Force fly the vehicle better or manage the vehicle better. It was a useful thing. But NACA was basically a test

organization and an R&D organization developing information. The only product from NACA was information.

The people who grew up in that NACA, people like Chris Kraft, he was in flight operations. He took Air Force vehicles and planned flight tests and wrote reports. Or Walt Williams, who went out and set up a place at Edwards to help test the early subsonic and supersonic airplane. They were flight test people. They're used to being handed an airplane and they test it.

They may not understand the specs on that airplane as well as they should, because they didn't grow up with it. They didn't design it. They didn't develop it. But they could go fly it and do useful things. When we first set up the Space Task Group that's what that picks up on.

The day I was asked to join, I was asked to go talk to Chuck Mathews, who was looking for some staff. Chuck had been given the operations job for Bob Gilruth. Max had been given the engineering job. Those were Gilruth's two principal deputies. I had been suggested to Chuck Mathews as a person to run recovery. I don't know who made that recommendation.

But I agreed to go talk to Chuck. Chuck was trying to set up someone at the launch, someone to be flight controllers, and someone for recovery. He finally got a fellow named Merritt Preston from Glenn to be the launch thing. He had Chris to be the flight control thing. He had me to be the recovery thing.

That's the way we started. Chuck was a research guy basically. He did not have the experience to go down to the Cape and interface with the Cape and beat up the Air Force and make them give him all the stuff he wanted. Bob Gilruth went out and got Walt Williams from Dryden Flight Research Center [DFRC] to do that, and finally pushed Chuck out of operations

back over into E&D. Then they brought him back to run Gemini and then he went to Headquarters.

I spent most of my time working with DOD and the Navy and Air Force and scattering them all around the world for recovery. Kraft goes and grows flight control to what you now see. Preston goes down to the Cape and grows what is now KSC. When Walt Williams came in, we had a little party over at our house in Timber Cove one night. Bob Gilruth and Walt Williams were there. They were sitting at the bar while I'm mixing drinks. I'm listening while I'm mixing drinks, so I pick up pieces of conversation.

Walt Williams was trying to get Bob Gilruth to cut the Space Task Group into two pieces and have Bob run the development part and Walt run the operations part. That's the way it worked at DFRC. Someone else developed the vehicle and brought it to Walt and he operated it. Walt said, "That's what you should do."

Walt tried for a long time to chop the Johnson Space Center into two pieces, an operations piece and a development piece, and let Gilruth run development, he would run operations. Gilruth, very wise, very quietly explained to Walt why he wasn't going to do that.

That mindset is still in a lot of people's heads out there. One of them is Kraft. It could be done if you made it perfectly clear what you're doing, but it's dumb. You're setting up two bureaucracies instead of one. That's why I would not go to Washington and become a mission director. I told George he can run all he wants to through the Program Director he has.

We were competing with the Russians, and I think we defeated them very badly with Apollo. Apollo put us clearly as the world leader in manned spaceflight. We intended post-Apollo to continue that lead. We found out the way to continue it—or we thought the way to

continue it—was not with big rockets and capsules. Now, we are trying to do it with big rockets and capsules, and I think we're completely wrong.

Shuttle History ?

These 12 things—I can show you somewhere in written history every one of those negative things about the Shuttle. I put this list together [Appendix, page 22] because people say these things and the truth needs to be told.

(1) *Shuttle should have been fully reusable.* That was George Mueller's concept; he didn't know that to make it fully reusable, it would get too big, too complex. Chemical propellant has its limits. Takes big tanks. Big rockets.

(2) *Shuttle should have been two-stage fully reusable with straight wings.* That's Max [Faget]. What Max was trying to do was slow down the landing speed. When you launch something like the Shuttle, you'd like to have no wings on at launch, but you'd like to have enough maneuvering when you leave orbit to get to the runway. If you leave a little late or a little early, you have to have enough adjustment to make sure you get to the runway or things don't go exactly right. You have to have enough maneuver volume, so having some wings and a control system to maneuver you makes sure you get to the runway.

You would like to fly like an airplane through the air. If you try to fly an airplane that's stalled through the air, the thing is liable to spin like a pinwheel. We have no experience of flying something like the Shuttle the way Max wanted to do it. All he was trying to do was put a big straight wing on there, which would make good aerodynamics for landing. He was focused hard on an important thing but blowing it way out of perspective. The Air Force kept trying to tell him that. Max didn't like the Air Force to tell him anything; he was a Navy guy.

The straight wing argument from JSC was stupid in the total spectrum, once we found out that ablative heat shields weren't going to be required, a [refractive] heat shield, one that would allow you to survive the peak temperature, how long the heating goes on doesn't matter, because

it's not ablating. So I'm hot while I'm flying 5,000 miles? I don't care. Once we knew the ablative heat shield wasn't a requirement and we could meet the weight with a refractive heat shield, the argument was stupid from there on. His [Faget's] worry that things were going to happen aerodynamically here and heating there but I want to land slowly was wild. I kept saying, "Max, straight wings have nothing to do with what we're talking about." He finally stopped.

Interesting story. He came in one day and said, "We need to get rid of the APU [auxiliary power unit]. Go to all-electric control system. Man, how nice that would be." He says, "And I've set up over here in building so-and-so how we can do it. How about going over there with me?" So I go over there.

He's got this idea but we're well into development. We've got a 3,000-psi hydraulic flight control system. Have to have an APU to generate pressures to run the hydraulics, just like airplanes or fighter planes. We knew what to do. He wanted to get rid of all that, go to a new electric system. There was a company up in Virginia that could build little electric motors with tremendous torque, and all you needed was a battery and some electricity to run those big powerful little motors that you put all around and fly the Shuttle, get rid of that fuel and that APU.

We're well into development, building parts, but I go over there. They brief me all about this great thing. I said, "Max, how do you get those motors?" "Oh, they're all ready," he said. I asked, "Well, who builds them?" He tells me it's such-and-such a company. I said, "Well, I'll go think about it a little bit."

So I go back to the office, look up that company, and call them. I think they were located in Blacksburg, Virginia, where I went to school. I called the president of this company, told him

who I was, and said, “Tell me about your motors.” Rare Earth motors. He had a rare Earth feature in the motors that gave them powerful torque for their size. I said, “When do you think those things will be ready for application?” He says, “Oh, we’re almost there. Within ten years I’m sure.”

I said, “Well, ten years from now you think you might have one with that kind of capability?” He told me, “Yes, we’re working hard.” I said, “Thank you.” Went back to see Max and said, “Max, sit down.”

(3) *Shuttle and Space Station were mistakes.* That’s Griffin; let me tell what he was saying. He wanted to trash the Shuttle because he wanted a big rocket because he also wanted to go to Mars. He knows the Space Station at high inclination is more difficult to support than at low inclination. So he didn’t want to say, “I’m against Space Station.”

It’s at high inclination because the Clinton administration cut it up so the Russians would join us, and the only way the Russians would join us, if it went to the high inclination. So the Clinton administration took something that existed, threw away the power system and attitude control system, and a bunch of stuff that we’d already paid to build, so the Russians would join us. Then we had to send it up where they wanted it. Is that good or bad? I can argue both ways. Yes, we’re having a love affair with the Russians in space, but [Vladimir] Putin, he just cut his space budget 30 percent.

Griffin wanted to trash Shuttle in a hurry to get that money, because he wanted to go back to “Apollo.” Let me tell you what his Apollo system was—the basic Apollo system even more expensive. The basic Apollo system had a certain number of throwaway elements. He added two more throwaway elements. He had a launch vehicle for a capsule and a launch vehicle for another part. So he had two launch vehicles; on Apollo we had one. He had two components of

that launch vehicle. So he had a throwaway, a whole new launch vehicle, had to launch two things into orbit, mate them, and send them, and started off managing and spending money on a program before he ever knew what the weights were, before he ever knew what he was trying to do. He was just a wild man running around. The Administrator running a program.

The Administrator cannot run a program. He cannot stay there twelve hours a day and run a program. He's in Washington doing what Washington tells him to do. He had no business trying to do it that way, but his ego was so big, he thought he knew what he was doing. No one grabbed him by the ear and sat him down and talked to him. No one asked me to do it; I'd have been happy to do it; I tried to do it. I sent him a registered letter. Sent it in such a way he had to sign for it or his secretary had to sign for it. He got it. He had a staff man call me.

(4) *Shuttle was barely doable.* There's no such thing. It's either doable or not doable. The Shuttle was designed to launch 65,000 pounds due East from the Kennedy Space Center and also carry 10 Astronauts—all of this in one flight—while also supporting useful work in orbit, then landed back on Earth on a runway. That's doable.

(5) *Nixon canceled Apollo and put NASA managers in a cruel position with an underfunded Shuttle Program.* Nixon did not cancel Apollo. That's Griffin's essay in *Wings*. Go read it. It's absolutely wrong.

(6) *Shuttle managers were technically dishonest.* That's also Griffin. He thinks, "You should have built it in little parts and make sure it worked before you could build it." Go waste money for ten years and then try to build something. It's tougher to build a little vehicle to go to space than it is a proper size vehicle. Building a scale model of something sometimes is harder than building the real thing. If you are not pretty sure you can build the real thing, don't start building it.

People ask me, “How did you know you could put an orbiter on the back of that 747 and it would work?” It’s basic aerodynamics. We never had any doubt that it would work. I had worked on hooking airplanes together wingtip to wingtip. Now that gets more dicey, but it can be done. When I was at Langley as a research engineer, the Air Force came in there one time. They wanted to hook some F-86s on the wingtip of B-47s and carry them on bombing missions. Then if fighters came up, the fighters could take off, defend, land, and come back and hook up. Wingtip to wingtip. They wanted a fighter on each wingtip of a B-47. But they were worried about the lateral stability of it.

How do you make it stable laterally? So they came to Langley, came to the Stability and Control Division. I’m a project engineer there. They ask me in the meeting. Tell me what they wanted to do. I told them what I thought we could do. They said, “We’d like you to do it.” So I did it. Flew the F-86 in a wind tunnel on the wingtip of a B-47 with the structural characteristics properly simulated. Worked fine.

In the meantime, they were flying an F-84 on the wingtip of a B-50. Straight wings, before they went to the swept wing, but they had a failure in the aileron system on the F-84 and it rolled over and tore the wing off the B-50. They killed 10 people. Meantime ballistic missiles were coming along, so we don’t need B-47s flying over Moscow. They stopped the program. But I had worked hooking airplanes together in a much more complex way than just sticking an orbiter on the back of the 747. I never had any doubt it wasn’t going to work. This thing was not a complex aerodynamic issue. We did that so we didn’t have to take air-breathing engines and a whole bunch of gas tanks to space and back.

It worked just like we said it would work. It cost us \$29 million to modify the 747. We found a 747 used and only paid \$18 million for it. It happened because we were scrubbing down

the things that George Mueller wanted to build that you didn't have to have. You didn't have to have go-around engines. You didn't have to have great big straight wings. It doesn't make sense to have everything reusable. If it made sense, there wouldn't be any Dixie cups. Do you know why we have Dixie cups? It's cheaper to throw the things away than to sanitize them. Sometimes throwing something away is okay, so we put all the propellant in the tank and threw it away.

The Shuttle configuration was not NASA's desired choice. It wasn't George Mueller's; we got rid of that. Wasn't Max Faget's straight wing; we got rid of that. **But we built it and it worked.** It was the payload bay the Air Force wanted, the payload bay we wanted. **It wasn't an accident and no one made us do anything we didn't want to do. Even Richard Nixon.**

(8) *Shuttle could only go to low-Earth orbit.* Right, that's what we built it for. But, it could build a *foundation* to go all the way to the Moon if we'd just been smart enough to do it.

(9) *Shuttle did not need wings and engines.* The Admiral [Gehman] said the Shuttle shouldn't have had rocket engines in the back end of it—it was a glider, those engines were unnecessary. I guess the mere fact the engines took you to orbit was incidental.

At the CAIB, I sat here and I thought as a little JG in the Navy I shouldn't tell a four-star admiral he's dumb, should I? You will find me trying time after time after time to criticize the CAIB—I'm not criticizing how hard those people worked; I'm not criticizing the individual capability of those people. However, they criticized NASA for groupthink and they [CAIB] were the most guilty group thinkers I've ever seen. There were people on that board that were there to trash Shuttle, and they did. They trashed Shuttle in the CAIB proceedings, such that after their trashing and two Shuttle accidents, there was no longer any confidence for Shuttle.

Shuttle had been refurbished, put back on flight status and was flying. That's when [NASA Administrator] Charlie Bolden came on board, and said he was going to lead NASA to deep space. That's where we are today.

(10) *History/Nixon caused the accidents.* That's what Gehman says.

(11) *Shuttle was poor national policy.* They all think we should have kept our big rockets and gone to Mars, and that [funding] curve should have gone up to 10 percent.

(12) *Shuttle was unsafe, too costly, and got too old.* Was the Shuttle unsafe? What does safe mean? You have to figure out what the risk is, figure out why you want to do it, and if why you want to do it is worth that risk, ride it. It's safe to you. "Shuttle was unsafe"—it couldn't be. People rode it all the time, were glad to ride it. Was it risky? You can't go to space unless you take risk.

People ask me, "Why didn't you put an escape system in there?" I picked up a book written by an astronaut named Mike Mullane [*Riding Rockets*]. Now I never met him, don't know anything about him. He's making money now going around the country with an astronaut jacket on telling big corporations how great astronauts are and how stupid the designers of the Shuttle were, because we didn't even give them ejection seats. What should I tell him?

I should tell him, "Number one, take your jacket off and sit down. If you're going to go around the country wearing an astronaut jacket and letting them pay you for talking, they're paying you because you took risk. Unless you knew what you were doing you shouldn't have gotten on that rocket. No, we didn't have a bedroom switch in there for you."

You know what a bedroom switch is? A lot of people wanted a bedroom switch—you're sitting in the vehicle, it starts shaking, you begin to get a little scared, so punch a switch and it will put you back in your bedroom. Someone else will be in your seat.

Did we put the two pilots at unacceptable risk when we put them in the vehicle for the first time [STS-1] and flew? I didn't think so. Did we put them at risk? Yes. I thought the risk was maybe 1 in 100. Other people thought it was 2 in 100. Other people thought it was 50-50. If you'd asked me, I'd say 1 in 100, because I knew the vehicle.

I knew trying to put a rocket on that big orbiter and separate it from the booster stack and put those guys back in the bedroom was a stupid thing to try to do. We took that off and threw it away.

On his design George Mueller had escape systems and air-breathing engines and everything fully reusable. George Mueller didn't know what he was doing, frankly, at that level. It was fine for him to go around Washington and sell the Shuttle, but you could have never built *his* Shuttle. He wanted to run the mission and the Program from Headquarters.

Let me tell you what's wrong with that. ***One channel of bureaucracy is enough in a program; you don't need two channels of bureaucracy.*** A mission director sitting over there in the Control Center bossing the Flight Director is useless. The Flight Director is only useful for certain things. If it's a quick time thing that they've thought about, maybe they can help the crew, but the real decision has to be on scene.

When Neil [Armstrong] got ready to fly over that crater and land somewhere else, he didn't ask the Flight Director whether he could do that. He didn't have time. He knew he couldn't land on that rock; he had decided to go over there. The Flight Director and the mission controllers have a job, but it's limited. If it's moderately quick and they've thought about it, they can be helpful. They can also keep up with lots of things and get a lot more done during a mission.

Or if you have something like Apollo 13, you can replan a navigation plan and come back home and manage the expendables. It saved our neck on Apollo 13, unquestionably. The three guys in the capsule couldn't have figured out everything to do that. It's like an insurance policy or a mission amplifying policy, but they're not in a position to understand the subtleties of the system like the O-rings or the foam.

Vision for a Space Transportation System

As part of Post-Apollo Planning, we had a vision for a ***Space Transportation System***. It was never looked at. Never looked at. It was basically a concept, because once we [designed] a Shuttle that the people in Washington were pretty sure they could get approval for, they put out the word, “quit talking about Space Station.” Quit trying to sell the whole cis-lunar regional development thing.

Cis-lunar regional development was never fully understood and fully debated. Fletcher said, “If we open that Pandora’s box we’ll be debating two more years. We need to get going. We’ll get the Shuttle and the Space Station. Then we’ll figure out where to go.”

There’s a big jump between low-Earth orbit and geostationary, energy jump. NASA is flat not working on that, haven’t worked on it. ***NASA has not analyzed the propulsion systems that are required to do the steps for cis-lunar, and the vehicles that are designed to fit that propulsion capability.***

We designed the [Space Transportation] System so every time you came back to Earth you’d come back in an “airplane” and land on a runway, but you were coming from low-Earth orbit. So low-Earth orbit was to have a Space Station, be a great big assembly point or great big gathering point, a great big hotel. Then to go to GEO, you first go to low-Earth orbit and get in something else, go to GEO, then get in something else to go to the libration region, and get in something else to go down to the Moon. Then when you come back you go return to those places, and then get in your airplane and come home, landing on a runway.

Gehman, who ran the CAIB, asked, “Why were there wings on the Shuttle?” You put wings on a space vehicle so when you re-enter, you don’t have to be dumped in the ocean, you don’t have to come down with a parachute. Parachutes were designed to be emergency landing

systems. Are we going to open hotels up there and have people jump out in parachutes when they come home? I don't think so.

NASA is spending money now having people build "rental cars" [to go to space] and both land on parachutes. Why aren't they funding the [Sierra Nevada Corporation] Dream Chaser? Dream Chaser can perform both the rental car task and the modest delivery service. No, they threw it away and picked two capsules with parachutes. Why?

This so-called Commercial Program is half government and half nongovernment. We won World War II with all government. We told the contractor we wanted some Liberty ships. We said, "We'll pay you for all the cost of the Liberty ships you build. We'll tell you how we want them built and we'll give you an award fee and we'll monitor what you spend. Then your award fee will be fixed over here before you spend." Then later on, they took part of that fixed fee and made it award fee for incentive. So they tried all kinds of tricks between taking money out of the Federal Treasury and getting something built.

This is definitely a totally different working arrangement with industry than the arrangement NASA used for Shuttle, and does not give NASA complete system insight or responsibility comparable to Shuttle. Supposedly, the Shuttle was replaced with commercially provided (cheaper) services. NASA has negotiated 5 agreements—2 for rental cars [crew transporters] and 3 for modest delivery service [cargo] to the ISS. Rental cars and light delivery service does not replace the Shuttle capability.

These capabilities when developed enable only a portion of the capability provided by the Shuttle. We have no convenient capability to add to the facility. Heavy maintenance, modification and add-on are all required for the health and prosperity of a National Laboratory and a National strategy for utilizing space. It represents our capability in a very important region

of cis-lunar space. We should carefully study this need and the merits of human presence in all of the important regions of cis-lunar space and plan accordingly.

A well-managed cost plus award fee contract worked for Mercury, Gemini, Apollo, Skylab and Shuttle. What have we changed and why is it a different world today? The method of working with industry utilized during programs up through the Shuttle Era including the development of Shuttle should be reviewed. **Turning low-Earth orbit over to private interests and undertaking the development of a human presence on Mars is not a sensible or realistic plan.**

WHY DID WE BUTCHER SPACE STATION?

WHY ARE WE STILL PLUMPING DOWN IN THE OCEAN?

WHERE ARE WE GOING AND HOW?

That's why I've been pestering Charlie for several years, but I've been doing it now for 10 years, even before he became Administrator. I never wrote anything about what NASA was doing until I heard [President] George [W.] Bush give *The Vision for Space Exploration* speech. Instantly someone with my background knew that was wrong in this sense—yes, we can go back to the Moon and on to Mars maybe in 100 years. But that's not the solution after two Shuttle accidents and a Space Station that's been butchered and joined up with the Russians with a big international program.

He announced in that same announcement to terminate the Shuttle, which [Dr. Joan] Johnson-Freese from the U.S. Naval War College immediately saw that if you are building a house on an island, you need to have boat to get there. It was stupid.

The first thing I did was fuss about it with my family. Everyone said, "Well, why don't you do something?" So I wrote my senator did. I sat down and wrote a four-page letter to Senator Kay Bailey Hutchison. Before I sent that letter, I really thought about it for a long

time—do I want to swat this tar baby or not? Because it was a tar baby. I knew when I hit it here, I was going to get stuck. That's where I am. I hit the tar baby.

I didn't send the letter immediately. I left it on my computer. Congress comes in, and agrees with the Vision for Space Exploration, "Oh yes, we'll go back to the Moon and on to Mars. Here's a nickel."

They get the Shuttle fixed and it starts flying. It's being put under some pretty good managers, who realize that it is a dangerous vehicle, so you have to be careful how you fly. It looked like it [Shuttle Program] was maybe going to recover.

The next thing you know, here's a guy named [NASA Administrator Michael] Griffin. This guy believes, by God, he can do anything. He didn't know his *** from a hole in the ground. Not saying the man couldn't go to college and get degrees. He's smart, intelligent, but his judgment? He believes he can make the country bring money. To this day he's trashing the Bureau of the Budget [OMB] for causing NASA to fail.

Bureau of the Budget tells NASA every year what to expect. His [Griffin's] job was to look at that curve, and ask himself, "Can I put it up there?" So he starts trashing the people who built the Shuttle. It was the wrong thing to do; read his essay in *Wings in Orbit*. Most self-serving. If you want to self-serve, you tell someone, "Don't pay attention to what I say, but how smart I am. Man, I was building the payloads for Shuttle. But those ***, they should have built a scale model and made sure it worked before they built it."

The Shuttle worked, and worked well, and still would if they'd taken careful watch of it. The Shuttle was the launch and orbital support vehicle that enabled the U.S. to undertake a cis-lunar program. But, the country became afraid of the vehicle. After two Space Shuttle accidents, we lost our nerve. We wanted to find some reason to trash the Shuttle, and we found a

reason. We had a bunch of planetary kids come forward and say, “Throw the thing away, let’s go back to the Moon with great big rockets and capsules, and go on to Mars.” The leader was a guy named Mike Griffin.

Big rockets and capsules create a debilitating overhead. The Constellation Program that was proposed to take us back to the moon and on to Mars was mainly a costly demonstration of existing technology. The one flight in Constellation with Ares 1 and the last development flight with Orion were both of questionable value.

Then, the Obama Administration upheld the termination of Shuttle. Also embraced the International Space Station as home for a National Laboratory in low-Earth orbit. We now have an international bureaucratic jumble. NASA should analyze this jumble and consider contingency planning. There is the possibility that the International community will op-out and the U.S. must have a plan. Perhaps, the International Space Station is not a good example of how to approach international cooperation in space. Our financial arrangement for ISS should be carefully studied

You take the Shuttle and the Space Station, \$200 billion. That’s what the country has invested. We’ve thrown them both in the trash can. All we have left is pieces of Space Station *Freedom* joined with the Russians, and we can’t even get [our astronauts] there.

NASA did an absolutely horrible job of setting up the management structure for Space Station. Space Station was mismanaged. I can’t imagine a dumber organization. They chopped Space Station up into four work packages but did not put leadership in place. They attempted to fix it two or three times and never did. For a long time, those four work packages wandered, because we had certain responsibilities under contract to JSC. Boeing had a contract with

Marshall. Someone else had a contract with Glenn [Research Center, Ohio]. Someone else had contracts trying to figure out what experiments to run.

Could never get it focused. Suffered major setbacks in calendar. The government did not set it up right and focus it right. They didn't have some jerk like me, sitting there every day making sure all four [work packages] went properly. They finally came back and tried to do that and let a contract with Grumman to integrate it. Grumman tries to integrate four packages, but they don't know what is in any package. You can't set up four contracts all around the country and let them go do what they want to. It was fouled up.

That's the way they managed Space Station. They chopped it in four pieces, put it all around the country, and then sat back in Washington and wondered why a debate was going on.

The federal government, NASA, screwed up.

We intended to have a Space Station at 28.5 degrees that NASA ran, but the only way they finally saved Space Station was to butcher *Freedom* and take the residual part and pay the Russians to join us, and we're still paying. Now we don't even have a way to get to Station except to pay the Russians and we're working like hell to try to catch up with a Project Mercury capability. We're bloviating what a great job "industry" is doing trying to catch Project Mercury. Pretty sad.

So here's where we are. We are back to big rockets and capsules and we don't know what to do with them.

SLS [Space Launch System] and Orion have a dubious purpose at this time. Right now about all you can say for the SLS and Orion is—it's a capability of some sort. What they're going to do with it they cannot tell you; however, the current exploration strategic plan involves

three straight Apollo 8 type missions—drifting out around the Moon and landing in the open ocean in the Orion capsule is merely repeating the Apollo 8 mission.

And I have concerns relative to the Orion recovery and sea state—the open ocean can be contrary at times. You can take that big rocket and you can send people back and forth with that capsule, but you *have no business whatsoever taking all the weight in that capsule to Mars—that [Orion] capsule is marginal for landing out in the ocean.*

If they land a day when the seas are rough, under their current plan of going about it, they are going to have all kinds of trouble and they don't want to hear that. We had trouble with the Mercury size [capsule] in rough sea. Inside a capsule in a rough sea is a real seasick generator. They have spent more money on Orion than they should by several factors. I picked up the newspaper and read, "Order of magnitude safer than Shuttle." How do they know? They have never flown it. They don't know what they're talking about.

You sure cannot go to Mars in Orion. Right now it's not even apparent to me they're even thinking about what it takes to land on Mars, stay a year, and come back. I don't think they're even doing that, but they are throwing words like "colonize."

Conclusion

- The Shuttle and EVA Truss Space Station was the Post-Apollo foundation on which the future of human spaceflight was based.
- Terminating Shuttle and Space Station *Freedom* and attempting Constellation has severely damaged our human spaceflight program.
- NASA as an agency failed in the stewardship of this decision.
- It was an agency failure not a lack of resources or the fault of OMB.
- NASA must fit their programs and other activity to the appropriated funds.
- Current planning is “over reach” and destined to fail.
- NASA must recognize its capability limits and plan accordingly.

What were we trying to do in Post-Apollo? We were trying to position the country to where it could begin to **utilize what we had learned, have humans go up and do something worthwhile in the regions of space.** What are the regions in space? This chart [Appendix, page 8] was put together to tell a crowd we really hadn't accomplished very much on what we were trying to do. There's very little left of that, because Shuttle was crucial to the plan, and Shuttle has been trashed because it had two accidents. They shouldn't have been eliminated the Shuttle; they should have fixed it, kept it, just like the F-16s.

The Agency right now is bloviating about something happening in 15 or 20 years that is virtually impossible. If the current goal to land on Mars in 20 years, there is no creditable plan; no single cost or schedule chart; no useful vehicle configurations or any discussion of mission approach or how to land on Mars; and no plans to launch from Mars and return to the Earth. Even if you were working on some of the hardware very actively today you probably couldn't get it ready in 15 or 20 years to go to Mars. If we could mount a responsible government

program to Mars in 50 years, I would be surprised. You aren't going to do it unless you turn the funding way on up.

NASA is not even working on the answers, and big rockets and capsules are not the answer. I can't get my message across. The Apollo euphoria people don't want to hear it. They want a big rocket and a big capsule: "We did it in Apollo. It just needs the will of the nation." That's nonsense.

While doing Shuttle, Space Station, we were hovering at or below 1 percent [funding level] and there was room to do some other things. We could have had a good capability in low-Earth orbit. We could probably have had a good capability at GEO[synchronous orbit] today and could probably be working on the libration regions, because eventually in the libration regions you're going to have to have a hotel, going to have to have a machine shop, going to have to have a garage, some fueling stations. If you're going down on the surface of the Moon and doing an Antarctica kind of thing, **you got to have a transportation system. You got to have some way to go there and back.** You can't keep blasting out of the gravity well of the Earth and blasting down in the gravity well of the Moon and do anything productive.

Right now the Johnson Space Center has no future if the Russians pull out of the Space Station. First of all, they'd probably have to bring it out of orbit because essentially the Russian's have the key parts of the Station. It's just like if you brought your neighbor into your house to run the furnace and the water, and then your neighbor says, "The hell with you," and turns off your furnace and your water. What do you do? You move out.

Congress asks Charlie [Bolden], "How is Space Station?" He answers, "No Russia, No Space Station." He is right. They pull the plug, we ain't got a Space Station. It has no future if

they pull the plug. That's where we are. Right or wrong, that's negative to people of my generation.

Now what should they do? I don't know. There's no real good answer. The Moon is probably the limit of realistic planning for human spaceflight at this time. Reaching out to deep space exploration and bloviating about Mars is simply over reach. The Agency has the task of spending the human spaceflight portion of the Agency's budget in the most productive manner that it deems possible. This task must receive proper approval including public understanding and support. Our current funding, technology, purpose and planning is not adequate. A bridge too far in planning.

**WE HAVE BEEN DRIFTING FOR SEVERAL YEARS.
A SIGNIFICANT CHANGE IN PLANNING IS NEEDED.**

What we were trying to do [with Post-Apollo Planning]? This is a chart that I have used for many years [Appendix, page 6]. I've never seen anyone else use it. Maybe it's too simple, but this is distance. I could put it on a log chart, but unless you understand logarithms you don't really understand how far Mars is. You know where Mars is? Let me explain. Here's the Sun. The Earth is here. It's going around the Sun at a certain rate. Mars is out here. It's going around the Sun at a different rate. Sometimes the Earth and Mars are only 40 million miles apart. Man, that's close. Sometimes they're 250 million miles apart—two hundred fifty million miles. And we're going to go build a colony there?

What I'm trying to express to the Agency is what I think has happened since 1972 and before; and why we are where we are today, because I personally think we're in a very difficult situation today. During Post-Apollo, we were moving away from big rockets and capsules.

The two Shuttle accidents should *not* have reversed this decision, but the two Shuttle accidents and the transition of Space Station Freedom to the International Space Station started a radical change from the Post-Apollo planning “affordable path” of 1972 planned for human spaceflight. I use the term affordable path carefully because no one knows that will be affordable with public funding. Budget will always be an annual task. Shuttle senses a level of around 1% of the nation’s spending for the agency as an affordable path.

We have lots of people in this country who are exploration buffs—we want to go to Pluto and open a Walmart—and there’s probably nothing wrong with that, except it’s fantasy in today’s world. In my opinion today Mars is even a fantasy, unless you’re very careful what you say about it. Even the Moon is a fantasy unless we change our direction. We cannot go back to the Moon today; we haven’t been working on it now for some time.

NASA should plan to the available funding level, not try to force the funding higher by overreach in planning. We should plan to the five-year budget projection—not to some plans without cost, schedule, purpose and sketches of vehicles.

My time in NASA was mainly productive, I thought. I don’t know what responsibility I have to try to help today’s generation, but I am disturbed and concerned about the bloviating that’s going on. I don’t mean it as a terribly negative word, but it goes on all the time. In fact, it’s almost a science in our political system.

Also I cannot look back and point out problems or failures and shortcomings without criticizing close friends of mine, and I’m willing to do that. I would welcome comments or counter-comments if anybody wants to point out where I’m wrong. I’m big enough to take it. If I’m wrong, I’ll admit it. But I am very disturbed, because a lot of my friends just want me to

shut up. I'm not going to do that. I'm not going to do that primarily because that doesn't help the Agency.

When there's something wrong and you shut up, you're not helping. You may help someone cover their butt, but that isn't worth hurting the Agency. Flying in space is risky.

Oral history sessions conducted in Houston, Texas, on January 22, 2016, and March 11, 2016, with Robert F. "Bob" Thompson for the NASA Headquarters Oral History Project. Interviewer was Rebecca Wright, NASA Johnson Space Center History Office.

Frequently Asked Questions & Answers

1. *What led to the two Shuttle accidents?***A significant failure in technical management and oversight by NASA.**

Two weak design features survived development testing and got into the flight program. *Challenger's* weak design was O-ring seals. *Columbia's* was foam. Both were readily correctable if the Program Management had worked as planned. When these potential fatal failure features became apparent during flight, the management system that NASA established for the Shuttle program failed.

In-flight anomalies are a very key indication of pending failures. They often provide a clue to a more damaging anomaly in a subsequent flight. Anomalies were not handled properly during the operations of Shuttle. The accident investigations did not clearly point out the reasons within management that led to these two Shuttle system level failures. NASA should understand these failures and the two accidents in full detail.

Weak accident investigation recommendations failed to carefully correct this management responsibility failure after *Challenger* and *Columbia* occurred several years later for a similar failure in NASA management. Some responsibility for the failure can be allocated to each of the three layers of NASA program management and the Headquarters oversight at the Administrator's level. Morton-Thiokol for the SRBs and Martin for the external tank were also to blame.

Following the *Columbia* accident, the CAIB was especially misdirected and heavily contributed to Shuttle termination by getting into issues remote to the accident. Shuttle termination greatly altered our human spaceflight plans.

Both Shuttle accidents violated specifications established by the development team.

Having wings on the “barely doable vehicle” was not the cause of either accident. The CAIB findings should have been fully vetted by NASA.

Failures must be used to improve the performance of the Agency. NASA must learn from mistakes. The premature termination of Shuttle has set us back. We need to carefully plan an affordable recovery in human spaceflight.

2. Why was Space Station Freedom converted to the ISS?

Space Station Freedom failed because NASA organized and lead the program poorly. Weak NASA program management led to cost and schedule growth. The program was facing cancellation and at significant cost was factored into an international partnership and led to the International Space Station.

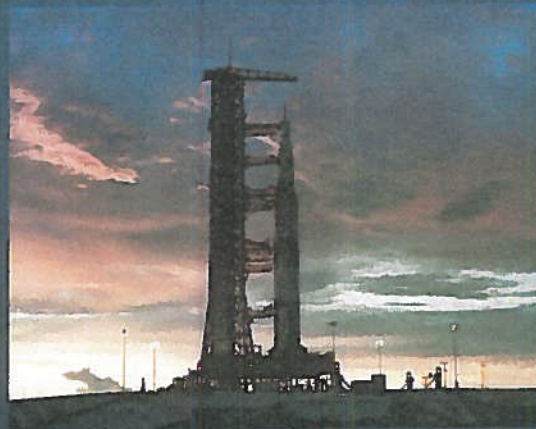
The Clinton Administration's correction was to create the ISS. A noble gesture but an inefficient way to organize a complex/risky program, especially when the U.S. subsequently terminates the enabling Shuttle.

3. Why did the Shuttle have wings?

This question was postulated by the CAIB Chairman. The purpose was to create maneuver volume during entry through the Earth's atmosphere and enabling a runway landing. (a major objective of the Shuttle Program.) Refer to page 95.

POST-APOLLO PLANNING

JULY 8, 2015



Bob Thompson

POST APOLLO PLANNING – 4 PHASES 1966-1972

- Apollo (Moon): S1B-SV-CSM-LM – No Facilitation – Spending at 4.5% of Nations Budget – Flags and Footprints – Capsule Thru the Atmosphere and Parachute into Water return to Earth – All Vehicles Expended
- Post Apollo objective after 4-phases of planning: Reusable Work Vehicle – Regional Facilitation – Reasonable Transportation Steps – Spending at 1% or Less of the Nations Budget – Useful Utilization of the Space Environment – Future Use of Other Space Regions – Earth Return to Runaway – “A Long Range Future” at an affordable budget level. MARS/Over the Horizon

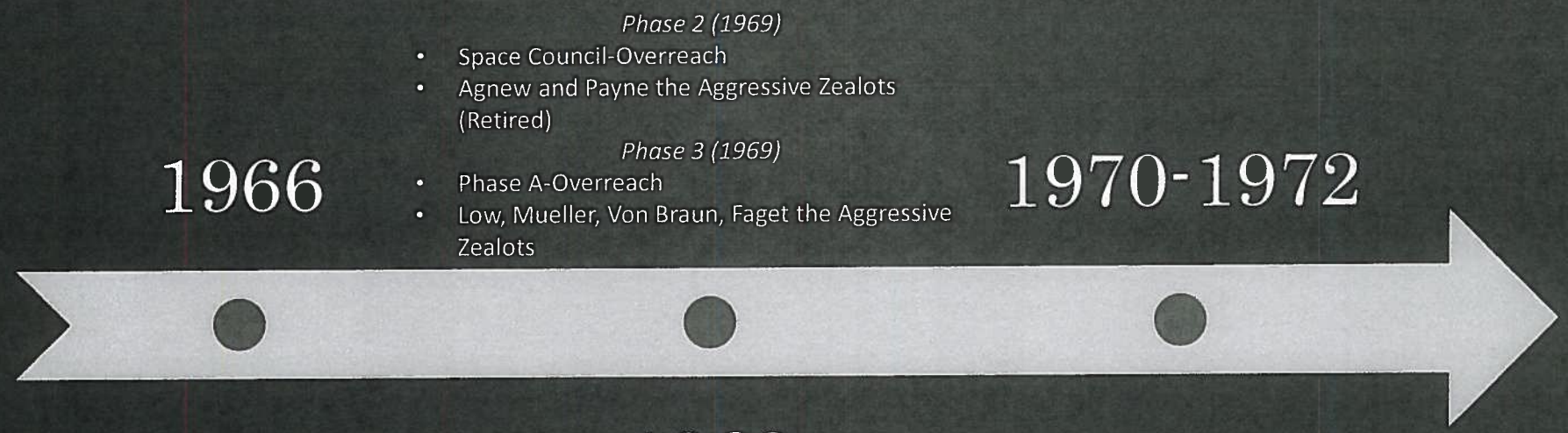
WHAT ARE REGIONS IN SPACE?

- What progress have we made in response to our post Apollo planning?
- Very little left
- Bottom Line – Current status disappointing. – Major setbacks encountered
 - Two avoidable accidents eliminated Shuttle
 - Poorly focused management eliminated Space Station Freedom
 - Poorly focused management eliminated Shuttle C

“NO RUSSIA-NO SPACE STATION”

- NASA Administrator's recent status report
 - Should have volunteered – “No Shuttle-Space Station difficult to maintain or replace”
- NASA is currently promising too much!
- ISS and Pioneering Mars in 20-years? – Overreach/Hoax!
- Four tenth's of one % of budget and falling!
- Expendable rockets and capsules/Mars?

CONTROLLING THE ZEAL



1966

Phase 1 (1966)

- Apollo Applications –AAP1 (cancelled)
- WET Workshop (cancelled)
- Dry Workshop (Skylab)
- Apollo/Soyuz add on
- Mueller and Von Braun the Aggressive Zealots (Retained)

1969

Phase 2 (1969)

- Space Council-Overreach
- Agnew and Payne the Aggressive Zealots (Retired)

Phase 3 (1969)

- Phase A-Overreach
- Low, Mueller, Von Braun, Faget the Aggressive Zealots

1970-1972

Phase 4 (1970-Shuttle approval in Jan 1972)

- Phase B – Space Transportation System/ Infrastructure for the Future

What was the Space Transportation System?
 Previous: What are regions in Space?

6

Energy vs. Distance Map of Near Solar System

Choose an affordable path



Step by Step



- Shuttle/ISS evolution - Shuttle C Was affordable (Utilization)
- CxP was NOT Affordable

No Russia, No Space Station

Bob Thompson NASA Shuttle Program Manager 1970 – 1981 (1974 Briefing)



“Infrastructure”



No Russia, No Space Station

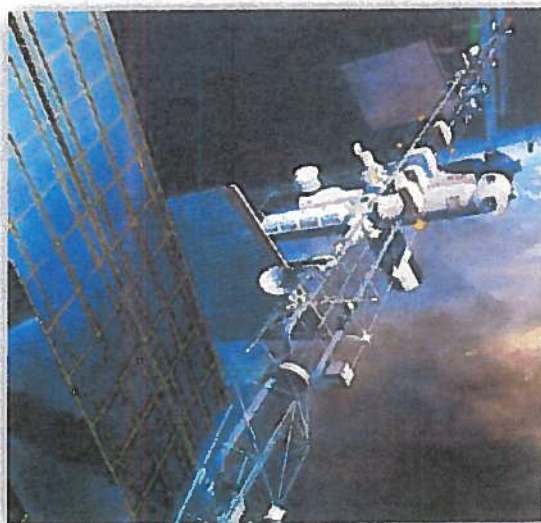
Low Earth Orbit Infrastructure Elements

Space Station

Shuttle

Shuttle C

Capabilities



- Truss Assembly
- Internationals



- Current
Status
- Gone



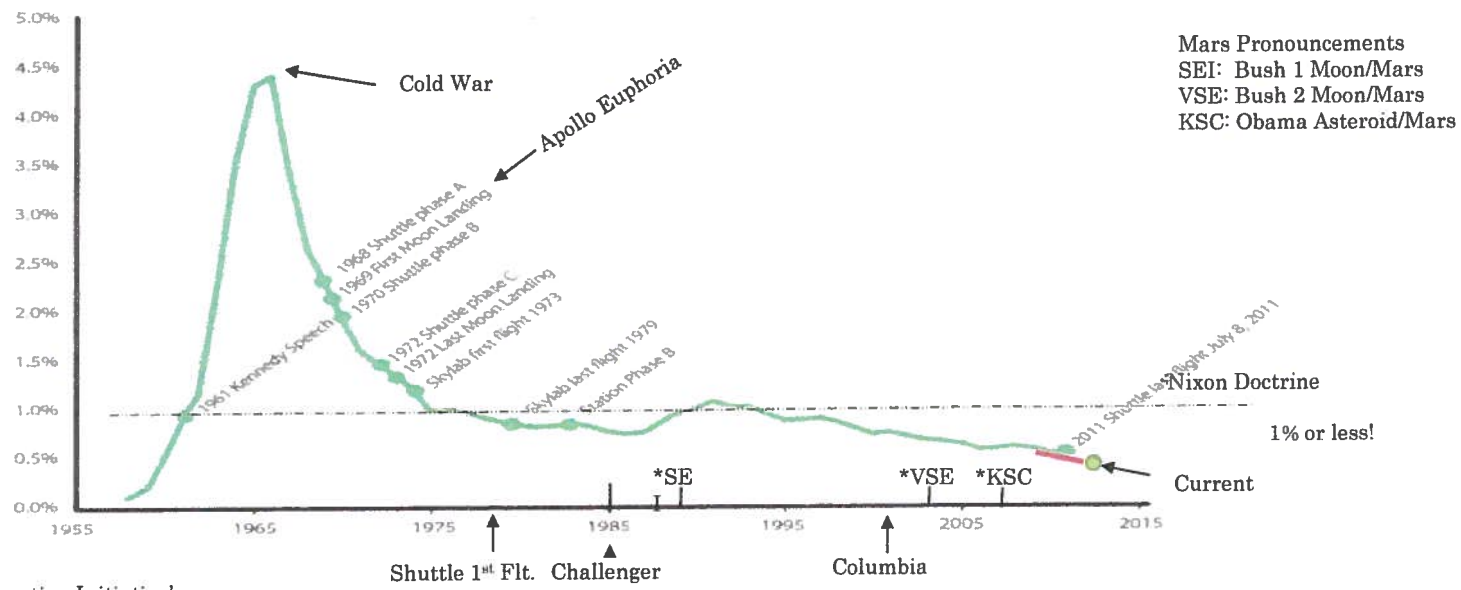
- Gone

=

- Space Station
- Hubble
- SPS
- Sat Servicing
- Science
- Etc.
- LEO
- GEO
- Libration
- Points
- LLO
- Moon Surface
- Etc.

No Russia, No Space Station

NASA Budget as a % of Federal Budget



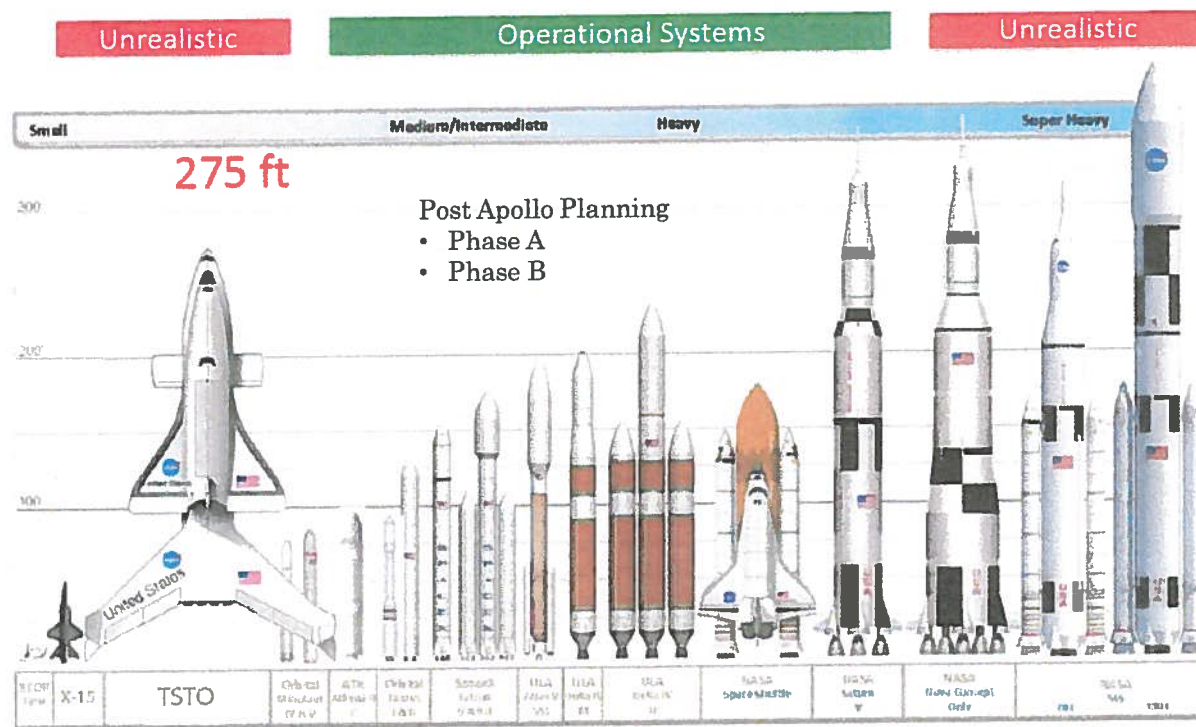
Mars Pronouncements
 SEI: Bush 1 Moon/Mars
 VSE: Bush 2 Moon/Mars
 KSC: Obama Asteroid/Mars

SEI = Space Exploration Initiative's
 VSE = Vision for Space Exploration
 KSC = Kennedy Space Center

1% or less!

No Russia, No Space Station

Size Comparison (Big is not always Better)



HISTORY AS SEEN FROM HOUSTON

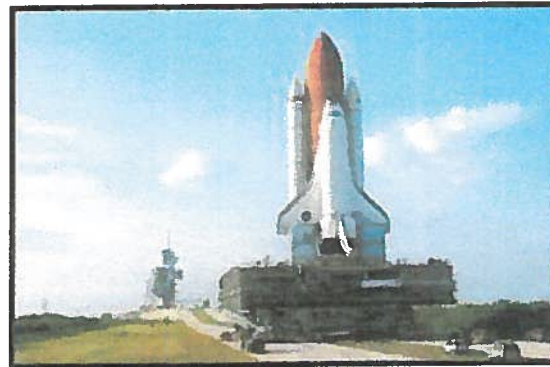
- **After Apollo?** Apollo Applications. AAP-1—Martin Contract (cancelled)
- After AAP1, WET Workshop, JSC/MSFC Stand-off; Warning flags briefing, directive to JSC
- After Webb, Saturn 5. Dry Workshop. Skylab/Apollo/Soyuz. End of Apollo vehicles
- After Johnson/Proxmire/Mondale/Kennedy; Nixon: What to do with human spaceflight?
- After Space Council/Phase A. Phase B established a program management structure
- After Agnew/Paine; Low/Mueller/Von Braun/Faget: Phase B and new players
- New Management in NASA : Fletcher/Low/Myers/Donlan/Thompson; MSFC lost momentum

HISTORY AS SEEN FROM HOUSTON (CONT'D)

- **PHASE B.** Shift away from big rockets and capsules to LEO infrastructure; JSC design lead
- Nixon doctrine became policy. Shuttle approved for development, saved human spaceflight, good policy
- Shuttle development on time and on cost. Flight operations began in 1981
- Space Station Freedom approved for development. EVA-Truss from Phase B
- Challenger accident. NASA management failure, accident board shortcoming
- Space Station Freedom. NASA management failure, shift to International Space Station
- Columbia accident. NASA management failure, accident board shortcoming
- Vision for Space Exploration. Griffin overreach, poor technical and cost planning; cancelled
- Back to big rockets and capsules. Overreach of the Nixon Doctrine, failure possibility!

HISTORY AS SEEN FROM HOUSTON (CONT'D)

- **Terminate shuttle and start "drifting" in our human space flight activity**
- **After shuttle?** NASA has a plan – Go implement the plan – ISS and Mars!
- Nixon doctrine prevails, good national policy, Shuttle/Space Station Freedom
- Griffin: Wrong
- Gehman: Wrong
- Augustine: Wrong



14

Admiral Hal Gehman (ret) Columbia + Ten, 3/8/2013



- Chapter 8 history caused this accident. Why does the shuttle have wings? No other re-entry vehicle in the past or in the future had wings.
- Why does it have engines? It's a glider, why does it have three (3) of these 25,000 (pound) engines?
- In our opinion, the organization of the space flight program was not safe. The organization allowed this accident to happen. They didn't contribute to it, they caused it.
- The political decisions made by the Nixon administration created this dinosaur and caused this accident. That's our opinion.
- After the Apollo program, NASA came up with a plan. The plan was orbiting space stations.
- After the Viet Nam war, inflation was raging so the OMB and White House asked "...how much is this going to cost." NASA comes up with a number and they get thrown out. The agency could not afford even a quarter of that. So the White House goes back to NASA and indicates it will fund the truck to go back and forth. But NASA has to capture the DoD and commercial launch business to make the cost revenue neutral. This would require going into orbit above DoD spy satellites to retrieve film. They then land at a landing site more than 600 miles removed from the launch site.
- NASA got the business but not once did they go to a satellite and recover film. But now NASA had a vehicle that had wings.

No Russia, No Space Station

COLUMBIA ACCIDENT INVESTIGATION BOARD FINDINGS

- Recertification
- Separate crew and payload
- No wings
- No engines
- History caused the accident
- Organization was not safe
- History caused it
- Political decisions made by the Nixon administration.



The external tank was painted white for the first two shuttle launches. From STS-3 on, it was left unpainted.

Shuttle declared "Guilty"!

NASA Administrator Says Space Shuttle Was a Mistake (USA Today 9/27/2005)



- “The Space Shuttle and the International Space Station-nearly the whole of the U.S. manned space program for the past three decades – were mistakes”.
- Griffin says NASA lost its way in the 1970s, when the agency ended the Apollo moon missions in favor of developing the shuttle and space station, which can only orbit Earth”
- “It is now commonly accepted that was [shuttle and space station], was not the right path.” Griffin said. “We are now trying to change the path while doing as little damage as we can.”
- He told the Senate earlier this year that the shuttle was “inherently flawed” and that the space station was not worth “the expense, the risk and the difficult” of flying humans to space.
- Asked Tuesday whether the shuttle had been a mistake, Griffin said, “My opinion is that it [shuttle] was....It was a design which was extremely aggressive and just barley possible.
- Asked whether the space station had been a mistake, he said, “Had the decision been mine, we would not have built the space station we’re building in the orbit we’re building it in.”

Norman R. Augustine, 5/12/2011



- Augustine's answer to Senator Hutchison's question during the Senate hearing:
- Question: "Could we continue to operate the Shuttle"?
- Answer: "Yes - but there would not be money for other things".

- **RT: If we plan to spend \$19.7 billion on NASA activities in 2011, and say 40% is devoted to human spaceflight, then about \$8 billion is available. This should be sufficient for both shuttle and space station after cancelling Constellation, with enough left over to stimulate commercial interests and search for new technology.**

No Russia, No Space Station

Dr. John Logsdon



Subject: Re: Generalizing budget talk
From: John Logsdon <logsdon@gwu.edu>
Date: 4/22/2015 1:07 PM
To: Robert Thompson <dotandbobt@comcast.net>
CC: Norman Chaffee <chaffee.norman@att.net>

Bob,

Norm Chafee has committed to me that he will allow me to complete my 45-minute presentation Monday without interruption, then open the floor for comments and questions. I hope that you will agree with that approach, since it is the condition under which I have agreed to speak to the NAL. I do not want the session to turn into an extended debate between the two of us. Other will want their say. I am never going to be able to satisfy all your concerns, and an extended discussion of why the government did not follow the Shuttle, space station, shuttle-C approach you believe so strongly was the appropriate course is really not germane to what I have to say in the book.

I think Glen Smith is correct. You should get your perspective down in a book-length version for the world to consider. I am not going to comment on CAIB, the Augustine report, or Mike Griffin's tenure as NASA administrator, None of this is germane to the book, which is what I am coming to discuss.

JML

John M. Logsdon
Professor Emeritus of Political Science and International Affairs
Space Policy Institute
Elliott School of International Affairs, George Washington University
Suite 403, 1957 E Street NW
Washington, DC 20052
phone - (202)246-7292

Cis-lunar Opportunities for Indefinite Future

A Compelling case for Developing Cis-lunar Space Next and Soon:
Realize Economic, National Security, and Scientific advantage for the United States and our partners.



Full utilization and servicing of the ISS with international partners and commercial providers across the in-orbit beyond Low Earth Orbit

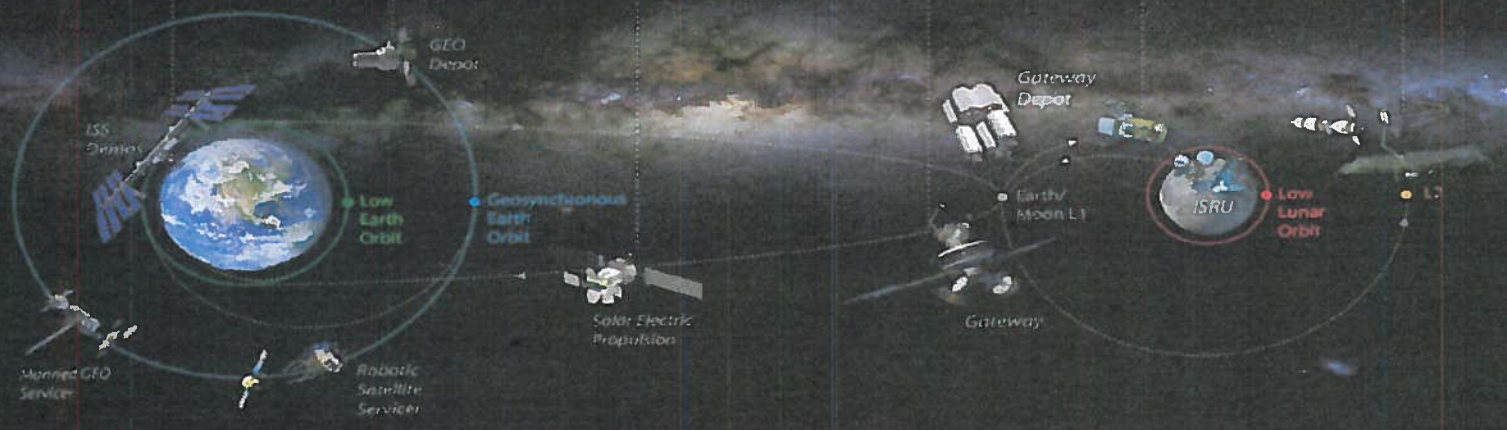
Reusable deep space lander capability of ascent and return Launch vehicles and refueling of vehicles for space transportation

Hybrid reusable transportation infrastructure support for LRS, L2, crew and cargo for lunar exploration and satellite deployment & servicing

L2/L3 Gateway transportation hub location for permanent deep-space access to and from the Lunar surface

Lunar in-situ resource utilization and water extraction for surface operations and for sustain life surface operations with air and water

Construction and servicing of advanced infrastructure and other in-space assets



No Russia, No Space Station

SUGGESTIONS FOR NASA

- Cut back significantly on the hype of pioneering Mars in the 2030's
- Join with industry and re-establish a LEO capability
- Decide on GEO or the liberation regions as the next step in human space flight
- Accept an allowance budget
- Utilization rather than Exploration
- GEO – Earth
- L ½ - Moon

Questions?



NASA ADMINISTRATOR'S STATUS

No Russia, No Space Station

“No Russia, No Space Station!”

- **Yes—We Managed Our Way to This Situation**
- **Why?**
 1. **NASA Management Failure**
 2. **Accident Investigation Failure**
 3. **Political decisions**
- **NASA Management: Center Focus or Program Focus**
- **Center Focus *is* the Management Issue:**
 - **A Primary Reason for the two shuttle accidents (Design weakness; Infant mortality)**
 - **A Primary reason for the cost and schedule growth of Space Station Freedom!**
- **Accident Boards Were Not Comprehensive in Corrective Recommendations**
- **Political: We Gave Up Too Much To Form The ISS Endeavor—Value Difficult To Evaluate**

WE ARE WHERE WE ARE!

22

No Russia, No Space Station

Shuttle History

Questionable "common knowledge"

1. Shuttle should have been fully reusable
2. Shuttle should have been two-stage with straight wings
3. Shuttle and Space Station were mistakes
4. Shuttle was barely doable
5. Nixon canceled Apollo and put NASA managers in a cruel position with an underfunded Shuttle program
6. Shuttle managers were technically dishonest
7. Shuttle configuration was not NASA's desired choice
8. Shuttle could only go to low orbit
9. Shuttle did **not need wings and engines**
10. History/Nixon caused the accidents
11. Shuttle was poor National Policy
12. Shuttle was unsafe, too costly, and got too old

Result – Retire the venerable vehicle!

ANY QUESTIONS?