You probably noticed Professor Cohen is a little bit more formal and wears a tie.

And so, when he's here, I also wear a tie.

[LAUGHTER] But today we're a little bit less formal and so no ties.

But I'll probably have one on, on Thursday, again.

Just so that you knew what the code was.

Tom Moser is coming.

You know, that was the generation where everybody wore ties.

So, I'll wear a tie, too.

Anyway, despite the fact that we're a little bit more informal that doesn't imply any intellectual informality.

We are actually, I think, very fortunate that Professor John Logsdon, who is the Director of the Space Policy Institute at George Washington University which is part of their Elliott School of International Affairs -- And we have a recent graduate of that program.

He is going to talk to us today.

And this is really going to be the last in the looks at kind of the policy which led to the original requirements on the Space Shuttle.

And, as we've pointed out on numerous occasions, when you're looking at systems engineering of any scale project -- Well, anything really.

It is absolutely critical to get the requirements straight.

And we cannot really understand a lot of the technical issues with the Space Shuttle and the challenges that we had to face without understanding how it got to be that way.

Professor Logsdon has written numerous articles about the shuttle.

And do you have an electronic version of your science article?

You don't.

We'll have to dig that up.

We'll give you a version of that.

But before that, actually, I guess the work where he really achieved a national recognition was his book on the Apollo program, "The Decision To Go To The Moon," which was a history of the Apollo program.

Professor Logsdon is a recognized expert is space policy.

You will see numerous articles by him in Space News.

And he is often the first person who gets called by the New York Times or National Public Radio or one of the other media for comments on various developments in space.

And actually, depending on how the talk today goes on the shuttle in terms of time, if there is some time left over he's brought some information about the new exploration architecture which was just announced formally yesterday.

And, given that we're setting out on another large space project where a lot of the same issues that we had to deal with about the shuttle will also apply, I think it would be interesting for people in the class to start following what's going on in this new space system.

So, that's enough from me.

John, I'll turn it over to you.

And take it away.

Good morning.

What I'm going to do this morning is somewhat different from what you just announced in the sense that I'm not going to talk about the political history of the shuttle requirements as much as the political history of the shuttle and how the requirements interacted with that political history.

So, it may be the same thing.

But I'm not a technical person.

Although, you have a bachelor's degree in physics which is a well-hidden fact.

Yes.

Next Tuesday is the 100th anniversary of the publication of the equation E equals MC squared.

And my degree in physics is almost before that, not quite.

[LAUGHTER] One of the things that we've been doing at George Washington University, seemingly forever, and close to it, it started in 1990, is a project to collect the seminal documents that define the evolution of the US Space Program.

There are now six volumes of this size printed, we're working on seven and there is one more to follow called "Exploring the Unknown".

Jeff thinks that it's in your library.

I'm going to try to get an electronic version of what I'll just talk about in a moment to put on your class website.

Volume four, which Dr.

Hoffman has at his home, not in his office, deals with access to space.

And one section of volume four deals with the shuttle.

And that's what I'm going to try to get an electronic copy of for you.

What I've done is built this talk around the original documents that trace the policy history of the shuttle.

And I'll use them kind of as backdrop.

As NASA approached the end of the Apollo program, its leaders, or at least some of them were thinking about what followed Apollo.

And, at that time, the head of I'll say Manned Spaceflight and apologize for the gender-specific language.

But that indeed was the Office of Manned Spaceflight in the late `60s.

Its head was a very creative character named George Miller who is still active.

He's one of the founders and moving spirits in a thing called Kistler Aerospace that wants to provide alternative commercial access to space.

Miller gave this talk, as you see, August of 1968.

As far as anyone can tell, it's the first use of the term "efficient earth to orbit space transportation system and economical space shuttle".

Miller's concept of the shuttle, which had a lot of influence in one strain of its development, was rather grandiose in character.

Especially the notion that the shuttle would operate in a mode similar to large commercial air transports and work in and out of major airports.

Landing would be completely automated with prime dependence on spacecraft guidance with ground control backup.

And this is a long talk.

It's in the book I just mentioned.

Then its basic design could be applied to point-to-point transport.

If the Space Shuttle were used as a global transport, safety and comfort standards could be comparable to those of a large transport jet.

It was probably not like business class in a 747.

[LAUGHTER] Maybe like the Concorde.

But that's certainly what they were talking about with the National Aerospace plane.

I mean if you can develop a plane that can take off from a runway and fly into orbit.

And you remember, when we talked about the rocket equation, we tried to make it clear why that is such a difficult thing to do.

But, if you could do it, then you don't have to go all the way to orbit.

You can just go halfway to orbit and land in Tokyo after you take off from London or New York.

Right.

And this kind of holy grail reduction in cost by two orders of magnitude, that was the mental set of the guy who I would call at least the policy father of the Space Shuttle, is that you could have an aircraft-like operations, two orders of magnitude of a level of safety and reliability and operability that it could even be used for commercial

transport.

As you know, NASA was successful in carrying out its mission of getting humans to the moon in July of 1969.

When Nixon came into office in January of 1969, he had a transition taskforce on space.

And that taskforce told him that there was a need for some decisions on what to do after Apollo.

With the focus on getting Apollo done, the then head of NASA Jim Webb didn't like long-range planning.

He wanted the politicians to tell NASA what to do, rather than the other way around.

NASA was woefully unprepared for what it wanted to do after Apollo.

And the country hadn't discussed it at all.

Nixon appointed a so-called space task force, Space Task Group and asked it for definitive recommendations on the post-Apollo space program.

That task group was chaired by the vice president who traditionally has had the space portfolio in most administrations.

At that time was a well-known space expert named Spiro Agnew.

You're all too young for that to even be a joke.

He was later caught taking bribes in the White House and resigned in shame.

He was a typical Maryland politician, which means corrupt.

[LAUGHTER] That's my home state.

The Space Task Group was captured by NASA, by its then administrator Tom Paine who was a very bravado character.

He told NASA that they should be swashbuckling.

And by Miller, who had developed a long-range plan for NASA.

And, ultimately, by Wernher von Braun who was brought up to Washington to add the charisma to the plan.

The report that was submitted by the Space Task Group to the White House two months after Apollo 11 had these

recommendations -- -- for what NASA should do.

This was what NASA really wanted to do, mars starting in 1981, a hundred man space base in the mid '80s.

The program that was recommended ultimately was Program 2 which had mars in '86.

And you see these comparative accomplishments.

And in here was an earth-to- orbit space shuttle for some time between '75 and '77.

That's where the shuttle entered into national policy, was in Nixon's reaction, or in the country's reaction to NASA's post-Apollo proposal.

Again, just to give you a sense of this kind of thinking at that point, I'm not sure where this came from, to be frank.

But you take the station, the space based and other stuff in this maximum program and you're talking total space shuttle flights a year peaking in '83 with 66 flights a year, including 34 to service a six-man base and a six-man orbiting station at the moon.

So, these truly grandiose ideas of what might be done.

I don't think it was ever clear why you had to go to the moon every other week in order to maintain a six-man base either.

[LAUGHTER] No, I think it was not every other week.

Thirty flights a year.

I think it was a three month rotation of a crew.

But they've got 30, 40 flights a year.

Maybe logistics flights, I don't know.

Logistics.

And you're doing two things.

You've got a six person station in orbit around the moon.

Why? I don't know.

And a six person base.

The architecture, it was announced yesterday, culminates in the buildup of a four or more person lunar base with a passing mention that, oh yeah, we might go to mars.

By the way, if anybody has comments or questions, interrupt me.

Otherwise, I'll just drone on.

Yeah, Larry.

To what extent was the Space Station's existence importance for the shuttle back in the `70s?

It was the reason for its existence.

At this point, the reason to have a space shuttle was to take crew and supplies to the station, period, at least in the core NASA planner's ideas.

You had people like Miller who left the agency in September of '69 with these very grandiose ideas.

He was succeeded by Dale Myers, who I understand has already talked to you.

And Myers was very instrumental in the negotiations that led ultimately to the decision to go forward with the station.

I remember the first time I heard the word space shuttle.

As Jeff said, I've been at this a long time.

I finished the book "The Decision To Go To The Moon," published by MIT Press, but out of print, in late 1968.

We tried to market it as a paperback.

We were going to put a rocket and a girl on the cover, and the inside story of why Kennedy sent us to the moon.

It didn't work.

It had footnotes and all because it was a PhD dissertation.

[LAUGHTER] Talking to an audience like this, they understand what a PhD dissertation looks like.

I went down to attend my first launch, which was Apollo 11, and for some reason hadn't rented a car so I was

figuring on hitching a ride from Orlando to Coco Beach.

And the person that I ended up driving to was a man named Leroy Day.

Did you know Roy Day?

Roy was, at that time, running the Phase A studies of the Space Shuttle.

And he told me what he was doing.

It was the first time I had heard of the concept.

See, I don't know where this came from but it's the kind of thinking of the need for this.

So, to go to your point, Larry.

When NASA first presented its post-Apollo plans to the Congress in the spring of 1970, the program was called Station Shuttle.

And they were coupled at the hip.

And so it was the integral justification from the NASA side.

Although, people like Dale Myers were already negotiating with their counterparts in the Department of Defense for potential military use of the system.

Although, almost clearly this is before any military involvement or really commercial involvement came in because, when you look, there are only two unmanned satellites per year.

This is the manifest to implement this.

And that was purely as NASA program.

There was not much consideration of other users of the shuttle at this point because this was enough to justify the investment in a new vehicle.

Again, the logic was that you could put these big things in space like space stations but the logistics costs would drive you crazy if you were doing it with expendables.

And so the only way to operate a permanent outpost in orbit or beyond was to have reusability in the supply system, in the transportation system.

That was, in essence, the number one requirement.

Unfortunately, well, I don't know whether it was unfortunate but in reality the Nixon administration was not having any of this.

Nixon made a statement in response to the Space Task Force report, as you'll see, March of 1970.

So, it took him six months to respond to the report.

Meanwhile, NASA's budget was getting chopped to pieces.

But it was essentially a fundamental 180 degree change in policy from Apollo.

Now, Apollo was separate leaps requiring a massive concentration of energy.

Space must take their proper place within a rigorous system of national priorities, must be planned in conjunction with all the other undertakings.

In other words, space has to be compared in its priority to all the other demands on the federal budget.

And at least for the Nixon administration, but in reality for every administration since, the answer has been essentially the same.

When Kennedy made his speech saying we should go to the moon in 1961, the NASA budget jumped 89% the first year, 101% the second year, 38% the third year.

And it's like a rollercoaster that gets to the top of the first hill.

And the program has been living on that momentum every since.

And you came down that hill very quickly.

You see by '73 or '74, this value was percent of the federal budget, so it's kind of a constant measure.

As the budget goes up, NASA gets essentially the same share of the federal budget.

About seven-tenths or eight-tenths of one percent.

And has gotten that share for 35 years.

And this, I would say, is the way the democratic political system makes policy choice, is through budget allocations.

And if you have the same budget allocation essentially for 35 years, I would say that's where space ranks in the scheme of national priorities according to the political leadership in the White House and Congress.

Just to flip ahead to 2004, one of the fundamental premises in the Bush Vision for Space Exploration is that NASA will stay at this level of expenditures.

And that everything you want to do, going back to the moon, eventually to mars, has to be within that budget envelope, which means you have to design to that.

And remember the fundamental systems engineering triad we talked about on several occasions, cost, schedule, performance.

That clearly demonstrates cost is a fixed parameter.

We don't have the freedom.

Either for the shuttle or in this future program, cost is going to go up by very much.

Just in case anybody asks what these two blips are, this one is the replacement of Challenger after the 1986 shuttle accident.

It's a one-time cost of building another orbiter.

And this was Bush 41, you may remember, or no, who announced a space exploration initiative on the 20th anniversary of Apollo.

And he provided an increase in budget resources to carry out that initiative which, when Bill Clinton was elected, quickly got undone.

And you see the result in the past few years.

In a sense, that decision that space had to be planned in the context of all other priorities has had multiple impacts over 35 years.

The first thing is NASA has never accepted it and has always tried to do more than it has resources.

And one of the things Jeff didn't say was that I was a member of the Columbia Accident Investigation Board after the last accident.

One of the things we said in our report was that NASA had, for too many years, been trying to do too much with

too little.

And it created the kinds of stresses in the organization that led to some of the organizational sloppiness that was at least a contributing factor in the Columbia accident.

It told NASA that it could not pursue in the `70s a post-Apollo program that was anywhere near its ambitions.

And so NASA had to reinvent its program from what it had proposed in 1969.

And, by the end of 1970, this is how budgets get done.

This is a letter from the then head of NASA, Jim Fletcher, transmitting NASA's recommendations for the next year's budget.

This happened last Monday, September the 12th this year, NASA submitted its formal budget proposal to the White House.

Every year this starts the process.

Well, you can read all this rhetoric later.

NASA had decided that the key element in the program for the `70s was not the Space Station by now but the Space Shuttle.

It supports the last four of the presidents' six objectives, these four.

And reflecting that decision, NASA announced, "We have made a major decision to defer development of a space station to a later time and to orient the space station studies towards modular systems that can be launched, as well as serviced by the space shuttle." Again, a fundamental change in plans.

The station that NASA was planning in 1969 would have been launched by the Saturn 5.

Would have been 33 feet across, have lots of habitable space, be big, a 12 person minimum building up to 50 person, maybe eventually 100 person outpost.

This represented a major shift that said, number one, the shuttle becomes our number one priority, not the station, and the shuttle has to be designed to launch space station modules.

That was the overriding NASA goal.

And so I would argue or suggest that this decision made in late 1970 only separated in time shuttle and station

that the intimate link between the two programs remained.

It was just going to do them in sequence, rather than at the same time.

And here we are 35 years later.

And the major issue in getting started on exploration remains, what do you do with the shuttle, what do you do with the station?

They are now seen as mortgages that have to be paid or obstacles to the next systems or however you want to characterize.

What this also meant is that the traffic model that was justifying the shuttle of all these launches to space stations and lunar bases that you saw was no longer operative.

And so beginning at the start of 1970 and all the way through this two-year complex decision process, the Office of Management and Budget kept saying well, how do you justify this investment?

You're talking about a multi-billion dollar investment in the future.

What is the justification for it?

This was the first time, in the early '70s, that the White House, through its Office of Management and Budget, used cost-effectiveness analysis, cost-benefit analysis as a tool in budget allocations.

It had not been done, certainly not been done in the space program of the `60s.

But OMB insisted that NASA show an economic justification for this investment.

And in order to make it come out the way OMB wanted it to come out, which was that there was no justification, how much economics do any of you get in this environment?

I have never had an economics course, except at Jesuit undergraduate college called Christian economics, which may be a contradiction.

Never mind.

[LAUGHTER] But I'm going to say something, I don't have a clue of what it means, which is that OMB insisted that NASA use a 10% discount rate, which is the future value of current money.

And that's much higher than the discount rate applied to many other investments, because this was a long-term

and risky investment.

And so that meant the economic justification for the shuttle had to be very strong.

And, throughout this process, there was this constant pressure on one hand to justify the shuttle economically.

The only way that could be done, absent a space station or an ambitious NASA program, was finding other users.

And this goes back to your comment earlier.

NASA became not just a kind of suitor of the military as a user of the shuttle, but the economic justification for going ahead with the shuttle became totally dependent on the military willingness to use the vehicle.

And military is a euphemism.

Many of the payloads that were being discussed there were intelligence payloads operated by the organization called the National Reconnaissance Office which, at that time, the existence of the National Reconnaissance Office itself was classified.

So, you could not say NRO satellites.

You can say it now.

NRO's existence was declassified in 1992.

But, at that point, was all called Air Force or DOD satellite, many of which, including the most demanding were intelligence satellites.

The primary determinant of the size of the shuttle's payload bay, the width was the ability to launch space station modules.

Professor Young may be able to comment.

If I understand it right, the kind of human factor studies at the time said that people would be unwilling to live in tubes less than 14 feet across for long durations.

And so the shuttle had to be able to accommodate a 14 foot wide module.

The length could be adjusted.

But the military payloads, I think Hubble pointed down rather than pointed up.

I think there's been enough discussion of it that I'm not revealing classified material.

The reconnaissance equivalent of Hubble was the next generation reconnaissance satellite.

And that was basically 55 feet long.

And so the decision was that you needed a payload bay 60 feet long in order to capture many military and reconnaissance payloads.

And that was a determinant of the size of the payload bay, which again drove the size of the shuttle.

The other military requirement was the desire, well, there were two.

One was a desire to be able to go into polar orbit which meant a west coast launch site.

You cannot launch into polar orbit from Cape Canaveral Air Force Station or Kennedy Space Center without flying over Boston.

Actually, I guess you'd launch south flying over Miami and Cuba which, for range safety, is not a great idea.

If you launch from Vandenberg Air Force Base out in California, you've got several thousands of miles of open ocean in front of you.

The Air Force was in a nice position here because it could make up any requirements it wanted.

We've actually talked about the cross-range.

OK, you've talked about it.

That's where the cross-range came from.

And so you've talked about cross-range leading to delta wings, leading to heavier orbiter because of more thermal protection, but all of that came from the requirement of getting the Department of Defense to say they would use the shuttle as a way of justifying to the economists the large upfront investment.

Have you looked at anything like this?

This is kind of from the outcome of the Phase A studies in the last `60s and early `70s.

As you see, Phase B proposals, a bunch of studies.

And then, in June of 1971, a rapid shift so that in six months the configuration evolved to what was finally built.

And I presume if you've talked about cross-range and that sort of thing you've talked about the difference between the preferred shuttle of Johnson Space Center and its chief designer Max Faget, which was a straight wing minimal cross-range shuttle, probably technically simpler to build and less expensive to build into a delta wing configuration that matched the Air Force cross-range requirement.

What happened in June of 1971 was critical to this whole process.

At this point, in its studies, NASA had concluded to build a two-stage fully reusable shuttle that would match the cross-range requirement and the big enough to launch space station modules it would cost in the order of $10 billion to $14 billion in investment cost with a peaks funding of $2 billion a year during the `70s.

OMB, in May of 1971, said that's fine, but you can only have $5 billion with a peak spending of $1 billion a year.

If you want a shuttle at all, it has to fit within that budget curve.

And I presume Aaron and others are going to talk about the kind of hectic trades that got from a fully reusable shuttle to first moving the liquid hydrogen tanks outside the orbiter air frame and throwing them away.

Then coming up with the idea that you could put both the external oxygen and hydrogen fuel tanks on the outside and throw them away to the notion that you could use strap-on solids to assist in takeoff and move the orbiter down to the bottom so its engines could be used as part of the take-off thrust to the final configuration.

At that point, June to December 1971, there were not zillions but hundreds of different variations of shuttle design being floated around and other designs to do something that was approximating but not totally -- What's the right word I want to say?

Totally meeting all of the payload requirements that had been laid out.

I'm sure you're going to be talking a lot about the engineering choices that were involved in this.

And I'm not capable of talking about them.

But as apprentice young system engineers, the notion that you could go from here, totally different concepts to here in six months and know what you're doing should make you a little nervous.

Why was the shuttle ultimately approved?

OMB, the Office of Management and Budget was on one spectrum of the participants in this debate.

It really didn't believe, its staff, in the value of human spaceflight.

Its staff was, and is, the guardian of the federal budget, believed it was under the policy guidance of the Nixon administration to cut federal expenditures dramatically across the board.

And so OMB, through this whole process, through a variety of interventions and changing demands on NASA and political interventions, getting leaked information from the aerospace industry and asking NASA nasty questions that it didn't want to answer -- The career staff of OMB, they say, in retrospect, went too far in trying to kill the shuttle.

So they were at one end of the spectrum.

NASA was at the other end, obviously, because by now, 1971, the shuttle was a survival project for NASA as it viewed itself as a large organization built around human spaceflight and developing new large scale systems.

Yeah, Larry?

[AUDIENCE QUESTION] OMB, not Congress, is what I'm talking about.

Well, ask your question.

Well, the fact that non-elected AUDIENCE: staffers, I was thinking of congressional staffers?.

LOGSDON: Yeah, but OMB is the same thing.

AUDIENCE: Have enormous influence over not only implementing but making policy.

And they stay long after their term [UNINTELLIGIBLE].

LONGSDON: Any of you heard of Paul Shawcross?

I wouldn't think so.

Paul is an MIT graduate.

He's the Examiner for Human Spaceflight in OMB right now.

He did a TPP masters up here ten years ago or so.

And he is leading the fight to ground the shuttle.

Now, nobody knows his name unless you're inside the beltway.

One of the things I'll say, Larry, in reaction to where you were going is at least the career staff on the Hill are relatively accessible.

So, if you're an aerospace industry operative, you know who they are and you can talk to them.

Particularly back in this period 35 years ago, the OMB staff operated under a cloak of anonymity, weren't open to talking to industry people.

It's changed a lot over the years.

And were able to operate behind a wall of secrecy and push their agenda into national policy.

It is my belief, after starting my 40th year in Washington.

God, that's a long time.

Most people outside of Washington think that Congress matters, but almost all the decisions that matter are made in the Executive Branch and Congress just snips at the margins, 2% or 3%.

Yes, sir.

How much did industry lobbying affect the design of the shuttle?

I mean you look at it and every aerospace company had a piece of the shuttle, you know, they were getting money from it.

I assume they also were probably lobbying their senators for places like [OVERLAPPING VOICES].

I mean how much did industry [OVERLAPPING VOICES]?

Well, if you look at this, all of industry had study contracts.

This is Grumman, which was a separate company at the time that had built the Lunar Lander.

And Boeing, before it bought Rockwell, this was North American Rockwell that had built the Apollo Command Module.

This was McDonnell Douglas.

So, the major aerospace companies each had a concept.

And they were lobbying or contending for the adoption of their concept rather than what you see now which is work shares of a single concept.

But this was a decision totally inside the Executive Branch at this point.

Congress was more or less supportive with the exception of one senator, Fritz Mondale, Walter Mondale who kept asking some difficult questions.

And NASA had its preferred concept.

MSC is Manned Space Craft Center, what's now Johnson Space Center.

And it was Grumman and McDonnell Douglas that came up with the idea of putting rockets on the side, at that point they weren't necessarily solid rockets, to enable a cheaper configuration.

What you ended up with was the preferred orbiter of the Manned Space Craft Center and the NASA Orbiter after all these design requirements.

With the Grumman McDonnell Douglas concept of an expendable external tank and recoverable strap-ons.

I don't want to say solids.

What came out of this was an amalgamation of everybody's ideas.

And I said in passing, I will say again, one of these industry firms, and all evidence points to North American, had a relationship with the OMB that was feeding OMB questions that would embarrass their competitors.

Or, result in not doing the shuttle at all and continuing on with the existing systems where North American was building at least the Apollo Command Module.

Players in this included the economic analysis.

Here is a report that was given, as this debate heated up, to NASA in October of 1971 done by a company called Mathematica, which was founded by Oscar Morgenstern, an economist at the Institute for Advanced Studies in Princeton.

And his young colleague, Klaus Heiss, was and is an Austrian somewhat crazy economist.

Again, that may be the same thing, crazy and economist.

And they had the contract to do the external economic analysis for the shuttle.

And they came up, through their analysis, with the conclusion that a reusable system is economically feasible at the current level of activity.

And that a thrust-assisted, that's the strap-ons, shuttle is the economically preferred choice.

This is economists designing technical systems, another thing that would make me nervous.

And this goes back to your comment earlier, the demand for space transportation by NASA, the Department of Defense, but particularly by commercial and other users is the basis for economic justification.

The economic analysis had, as an input, a demand model that was totally unconstrained.

It's everybody's wish list of things that might be launched but weren't funded for the next 15 years.

And that's where the next round of shuttle launches, 50 or 60, which was part of the image at the time the decision was made, came from this demand model which was done by the Aerospace Corporation given to Mathematica to play with in its economic analysis.

It's not clear how influential this set of recommendations was in the final decision to proceed.

Klaus Heiss, who is still very active, claims it was very influential.

I tend to think, well, you'll see my explanation why the shuttle was chosen.

These are the kind of economic comparisons that were talked about.

The launch vehicle investment costs, nonrecurrent, were clearly much greater for the new shuttle system, but the recurring costs of operations were much less than using the current system.

What is that?

Almost $6 billion.

This is 514 space shuttle flights over a twelve year or eleven year period.

Eleven, I guess.

That is, what, about 48 or 49 flights a year, the model that was being used at this time.

It always interests me when people do modeling like that.

You notice they chose the number 514, not 513 or 515.

I mean it sort of gives you the impression that they know what they're talking about.

[AUDIENCE QUESTION] If they had just put approximately 500, that's really as much as anybody knew at the time.

But that's the number that will make it work, I suppose.

[LAUGHTER] Now, that would be rigging the analysis, wouldn't it?

Look at how round the numbers are at the bottom, too.

Well, one of the things to watch here is that a lot of the costs were payload savings.

There was this illusion at the time, proven to be an illusion, that because of the characteristics of the shuttle you could make the payloads much less expensive.

You didn't have to design them to space program standards if you want.

Here are the payloads.

Instead of costing $18 billion over this period, we're going to cost $12 billion.

That's a $6 billion savings in payload.

And it's that combination of operation cost and payload savings that give you the $7 billion advantage in the economic argument for going ahead with the shuttle.

Bush 41 later used the term, which I think is properly applied to this analysis, calling it voodoo economics.

And I think most of the people involved in this decision recognize that.

In a technical decision, the White House often, at this period in time, depended on its Office of Science and Technology, now called OSTP, Office of Science and Technology Policy, and its President Science Advisory Committee called PSAC.

What does PSAC mean?

President Council of Advisors on Science and Technology.

And so the science advisor who was actually an engineer, not a scientist, named Ed David, commissioned a

PSAC, President Science Advisory Committee study to look at NASA's proposals as a basis for the position he would take in White House debates.

Head chair of that study was Alexander Flax who was President of the Institute for Defense Analyses, a think-tank in Washington.

And this was a kind of summary report that Flax sent in about the panel.

Doubt that a viable shuttle program can be undertaken without a degree of national commitment over the long-term analogous to that which sustained the Apollo program.

It may be attainable but is certainly not apparent at this time.

This is a long letter, and I'm just going to show you a couple of things.

In retrospect, I think this advice was sound advice that was provided.

Maintaining the program is large and risky with the long-term prospect of fixed budget ceilings does not bode well for the future of the program.

Some decisions had been taken which introduce additional hazards to the success of the program technically, operationally and economically in order to reduce projected peak-year funding requirements.

At that point, I think the strap-ons, firing the main engines at liftoff.

I can show you the analysis in the letter, but I think that's what he was talking about.

And basically what the PSAC panel recommended was postponing the decision for a year or more while some of the uncertainties were studied.

General view.

No significant role for manned spaceflight in military and civilian or science.

Didn't believe NASA's suggestion that the shuttle would allow experimenters to conduct their activities in spaceflight.

Evoke no enthusiasm from the scientists.

You can counter that obviously.

The shuttle was not a wonderful laboratory for most applications.

The scientific community in large doubts the potential benefits of the space shuttle.

Manned spaceflight should be considered contributions in terms of national prestige, international cooperation, exploration and unforeseen future needs.

Basically, the justification was really kind of arm-waving intangibles, some of which I think are very real like prestige and cooperation.

[Jump back a little bit to the?] science enthusiasm or lack of it, because I think there was a clear division in the science community then between the "real space scientist" and [OVERLAPPING VOICES]

which sort of came into its own with Skylab when it was realized [OVERLAPPING VOICES]. But Skylab was two years after this, Larry. But at this point the life science community was better that interesting things were going to be happening.

But without any real data Skylab was the first long duration exposure.

And the life science community did not have the high step in the space science community at that point.

Space science was dominated by physicists.

And, in fact, even within the NASA hierarchy.

I think at that point it was still part of space medicine.

Right, crew medicine.

So, yes, that split was there.

It must be noted that new approaches have often not been recognized or appreciated by the putative users until after they've been demonstrated.

Yeah, Mark.

Didn't Hubble then conveniently make scientists excited about the shuttle?

Some.

But, again, only after.

We don't want to talk about why.

We'll let Hoffman talk about whether the tradeoff of putting Hubble in the shuttle orbit compared to it being serviced was a good tradeoff compared to where you want a telescope.

If you would have been designing this large space telescope in 1970, would you have made it shuttle launched?

Well, everything had to be shuttle launched then.

I mean given the history of Hubble, obviously, had it been put in an inaccessible orbit, we wouldn't have a space telescope now.

So what can you say?

Again, the shuttle cannot be justified on a purely economic basis for the unmanned portion of the program so it's a position directly opposite the thing I showed you before.

It must be justified on the basis of new capability, contribution to leadership and prestige, its unique value if we're going to have intensity of infrequent manned spaceflight.

And you have to postulate expanding rather than level space budgets over the next ten years.

And the Nixon administration said that wasn't going to happen.

Again, the somewhat bottom line of the PSAC position -- -- led to the conclusion that if you had to make a choice in 1971, you had two choices.

Either proceed with the shuttle program now or soon or drop manned spaceflight after Skylab.

And nobody likes binomial choices like that.

But, in the large degree, that was the consideration or the mental set as this debate came to a head towards the end of 1971.

Actually, that brings into sharp relief.

Remember the comment that Professor Cohen made when he was talking about what should a systems engineer do when presented with requirements that you're not really happy with and don't know if you can meet?

But, on the other hand, recognizing as they came to that basically if they didn't build the shuttle that was being specified they probably were going to end up with nothing at all.

And I think what John just showed was justification that that, in fact, was the political environment at the time.

It wasn't the shuttle or something else.

It was the shuttle or nothing.

Well, except at the end people like PSAC and OMB kept suggesting alternatives.

This was a chart drawn in November of '71 by George Low who was the Deputy NASA Administrator and kind of the technical strength in this thing, showing the investment costs versus, this is in billions, this is in millions, the cost of operations for various things.

The two-stage fully reusable, $10 billion investment, low operating cost.

The baseline 15 x 60 foot payload bay could be done, he's saying, for $8 billion.

Within three weeks it was $5 billion.

A phase development, develop a simpler one first and then a more complex orbiter later with the large payload bay and various rocket assists developing a smaller one, smaller payload, smaller bay, or developing a Titan 3 launched glider sort of thing.

And the argument was in this curve it made sense to pick something along this line, the knee and the curve on that basis.

NASA made its last best case in a memo to the White House.

This is dated November the 22nd.

I think it shows up at the top.

And look at these reasonings.

This is really NASA's best case.

Number one, the US has to stay in the human spaceflight business.

That's not subject to analysis.

That's a belief.

And NASA argued that this should be a policy premise that the United States had to have humans in space.

And the shuttle is the only meaningful new manned space program, the operative word being "new".

You could have kept launching Apollo capsules and Saturn 1bs or something.

Saturn 5 had been cancelled by then.

The shuttle is a necessary next step for science applications, military position in international competition and cooperation.

The cost and complexity is one-half of what it was six months ago.

Again, as engineers, that statement ought to be very nervous that in six months you can cut cost and complexity in half.

And starting the shuttle now will have a significant positive effect in aerospace employment.

Not starting will be a serious blow to both the morale and health of the aerospace industry.

Let me talk about that last one.

Those, I think, were NASA's five best reasons for going ahead.

Employment impact was one of them.

This is an undated memorandum from somebody within OMB.

Peter Flanagan was Nixon's top person right at the intersection of policy and politics who was overseeing the space program.

And Flanagan had asked for impact of the shuttle on the aerospace industry.

And this is what came back.

What the program is.

Here is the additional employment impact on the engine program space shuttle.

Main engine.

Not very much in early '70.

This is '71.

But in '72 fairly significant employment impacts in either California or Florida.

And on the airframe, depending on when the decision was made to go ahead with the shuttle, the impact in '72 not very big, but big enough.

Peak of 70,000 jobs might ultimately result.

The number of actual jobs by the end of 1972 would be relatively small.

Why do you think 1972?

You have to recreate the environment of the time.

This was 1971.

The supersonic transport had been cancelled.

Defense spending on Vietnam was ramping down.

NASA had no new program.

And, in doing the article that Jeff mentioned on the space shuttle decision, I ended up one afternoon in, of all places, Santa Fe, New Mexico talking to John Ehrlich, one of Nixon's top guys.

He said they sat down in the White House and mapped NASA jobs on key election states and said if we want to win the 1972 election, again this is political history well before your time.

At that point, the leading candidate was Ed Muskie of Maine who was viewed as a serious candidate.

It wasn't George McGovern who was, for better or for worse, not a serious opponent.

So that the political people were worried about winning places like California and Florida and saw in the Shuttle Program a way of providing the indication of future jobs in key electoral states.

Some of the people I have talked to over the years say that, at least for the top political levels of the White House, that was the major reason for going ahead with this program.

Was in order to have aerospace employment impacts for the '72 election.

You can judge whether that's a good reason or not.

The decision kept getting postponed until very late in the budget process.

OMB kept asking for more studies.

This was a letter to the Deputy Director of OMB, Caspar Weinberger, later Secretary of Defense, which NASA said we've concluded the full capability still represents a best buy.

But, in recognition of budget problems, we are recommending a smaller vehicle, 14 x 45, because that is the smallest that will still be useful for manned spaceflight, Reid Space Station.

It won't accommodate many DOD payloads and some planetary payloads.

And here are the numbers.

I don't know whether you've seen these numbers yet.

Attached to this letter, this is what NASA was telling the White House last business day of 1971 what the cost of various shuttle configurations would be.

You notice very little difference in the development cost of the configurations, eight-tenths of a billion dollars between a very small and less capable and the full size fully capable.

And the operating cost relatively low across the board.

Look at that number, $7.7 million a flight for a payload cost of $118 a pound.

I think one of the points of your course, if I understand it, is to understand maybe where these numbers came from and where they ever possible?

I shouldn't bias the answer.

Were they ever a possible realization?

I mean here are the heads of the leading technical organization in the US government presenting these figures to the White House.

Did NASA lose its technical integrity in this process, was there any foundation for these numbers or where these total salesmanship, are all, I think, valid questions.

You said you took a two-minute stretch break.

Yeah.

Let's do that, and then I'll come back with the answer of why they ultimately went ahead with the shuttle.

I'm going to argue that the decision to go ahead with the shuttle was made before all of this last six months or so of 1971 back and forth when it occurred.

And the basis for that is primarily this memorandum written through the Director of the OMB, George Shultz, by Cap Weinberger to the President in which he is talking about the staff proposals for reducing the NASA budget, which included eliminating the last two Apollo flights and eliminating Manned Spaceflight.

And Weinberger said in this memo to the President, I believe this would be a mistake.

The reason for reducing NASA is because we cut it because it's cutable, not because it's not doing a thing.

That the uncontrollable programs that offer no real hope for the future, this is remember a republican administration, are eating up the budget.

We do need to reduce the budget but we need to do it on a reasonable basis.

There is real merit in the future of NASA.

And, if you took NASA apart, it would be very hard to put it back together again.

And he says stopping Apollo and not starting new programs would be confirming a belief, I fear, is gaining credence at home and abroad.

Our best years are behind us.

We are turning inward, reducing our defense commitments, involuntarily starting to give up our superpower status and our desire to maintain our world's superiority.

[LAUGHTER] America should be able to afford something besides increased welfare.

Notice the underlining.

And this came back with a handwritten note, I agree with Cap.

That's Nixon.

My view, the decision was made with those four words.

Yeah?

Just out of ignorance, who is Weinberger?

Weinberger at that time was the number two person in the office of Management and Budget, long-time California associate of Nixon, became Secretary of Defense under Reagan.

Who he is, in a sense, irrelevant, except he was a political appointee and a trusted associate of the President.

And basically he was telling Nixon that the reason for continuing the space program was image.

I mean, again, read those words because they're interesting words.

Not having the strongest space program would confirm our lack of desire to maintain our world's superiority.

I should you this December the 29th memorandum where NASA went to the White House and said we would recommend the full-size orbiter usually but, with tight budget, will go with 14 x 45.

That was a Friday, the 29th of December, or maybe earlier in the week.

Anyway, over that New Year's weekend, '71, '72, somehow somewhere Nixon and his inner circle decided to approve the shuttle and approve the full-size shuttle.

And they decided if we're going to approve it, we might as well approve the one that NASA thinks is best.

And there was a meeting scheduled between NASA leadership and the President in the San Clemente on January the 5th.

This is written by George Low.

For a historian, Dr.

Low was wonderful.

He dictated his notes every week on the events of the week and then backed it up with the documents.

That's like a treasure load for somebody that's trying to write the history of this.

Met for 40 minutes.

Here's what the President had to say.

We should not hesitate to mention the military applications.

Routine operations.

Quick reaction times.

Solar power satellites.

These kinds of things tend to happen more quickly than we expect.

Nuclear waste disposal.

He liked the fact that ordinary people would be able to fly in the shuttle.

Preserve the skills of the people in the aerospace industry.

In summary, we do not know of the things the shuttle will be able to do.

It will open up entirely new fields.

Did we think it was a good investment?

We, the top two leaders of NASA.

It's not a $7 billion toy.

But he indicated even if it were not a good investment, we would have to do it anyway because spaceflight is here to stay.

Men are flying in space now and will continue to fly in space, and we best be part of it, which was essentially what Weinberger had said six months earlier.

And, to me, that link in doing research in this area, I've talked with both Weinberger and Ehrlichman and others around that.

It's that link of human spaceflight to national image of the United States, plus the employment impacts in the '72 election that were the fundamental reasons for going ahead with the shuttle.

You may make a judgment that those aren't great reasons, but there they were.

Finally, the decision was made, say, January 3rd, we would develop a shuttle with the big shuttle.

And the only major open issue was whether to use a liquid or solid strap-on.

And that was studied for three months.

Trade-off between future benefits and earlier savings.

Liquid boosters have lower operating cost, solid boosters have lower development cost.

Conclusions here are heavily dependent on the mission model.

The basic concern was keeping within the development cost of the shuttle and somebody else worry later about operating costs.

All of that argument led to a decision in favor of the solid booster.

The rest of this is kind of irrelevant to that.

Basically with the OMB acceptance of this letter and the choice of the solids, the configuration was frozen.

There were some things in it that I'm sure you'll talk about later.

There was at that point it had abort capability on the solids.

I'm not quite sure how that would have worked.

And somewhere along the line, and it's not clear to me, at one point the shuttle was going to have jet engines so it could fly to a landing rather than glide to a landing.

And those were taken out.

And I think it was after this, but I'm not sure.

As I said at the start, the technical requirements of the shuttle, I want to say it a little differently.

The reason for approving the shuttle had very little to do with the specific technical characteristics of the system.

If my argument that the main reasons were national prestige, national image, aerospace employment rather than the actual performance characteristics of a particular configuration.

As long as the shuttle could be developed within a $5 billion a year peak funding profile and as long as the shuttle could do things for the Department of Defense that made it useful to both civilian and military users.

Those were the drivers of the shuttle decision.

And the technology was derivative of that rather than the other way around.

That presented challenges, as I'm sure Aaron Cohen or Jeff have talked about, of developing thermal protection, developing a main engine, developing a vehicle that could operate in multiple flight regimes.

But those were secondary to the policy decision that the country should go ahead with this capability.

Questions?

Comments?

Reactions?

Yes, sir.

One quick question.

I saw, in one of those earlier things you put out, that it was around '71, it talked about first flight was '77 and fully operational by '79.

It seems to me that you could really reduce things like heat cost and you could spread out your development cost if you just said we're not in a hurry, let's do it right but let's take our time.

Because there wasn't the race anymore.

I mean we had done the Apollo.

We had beaten the Russians.

And I was wondering what kind of time constraints played into this, why they were trying to finish it by the late `70s and why not say let's launch it mid `80s?

Well, it ties into the current situation rather nicely in the sense that there was then, and I think is now, a perception that an extended gap in US human spaceflight is not politically acceptable.

And, at that point, at the end of '71, the only human spaceflight missions on the books were three flights to the Skylab Space Station in 1973.

The thing that followed that, the Apollo-Soyuz Test Project, had not yet been agreed on.

That wasn't agreed until May of '72.

There would have been from '73 to whatever future date a gap in American's flying to space.

And I think the general sense was that that was not acceptable.

Also, you had a workforce issue of maintaining the workforce with something to do at Johnson, by then not yet Johnson, but Manned Spacecraft Center, Marshall Spaceflight Center and Kennedy.

And so you needed a relatively rapid development program so that you didn't either disassemble the teams and have to reassemble them later.

And the same for the capability inside the industry.

This was a program that was paste within a budget ceiling to make full use of the space industrial base in a reasonable timeframe.

And I think that's why I would say, I mean the dates were set on the basis, this is the earliest we can do it on this budget profile.

Yes, sir.

You said the decision to go for solids instead of liquids for the boosters was the development costs as opposed to the operating costs.

And now, in this new architecture, the plan is to use the solid rocket booster.

It's something like it's proven to be the most reliable launcher ever developed or something along those lines.

It's true.

You've launched 228 of them with one failure.

I agree.

But, at the same time, if the idea then, if they went for solid they could sort of reduce development costs and sacrificing operating costs.

Is sticking with solids in the same configuration now kind of repeating the same possible mistake?

Well, I don't know.

First you seem to assume that going with solids in the first place was a mistake.

That a liquid strap-on solution would have been a better solution.

I'm not necessarily assuming that.

Many have argued that.

It's not really clear that the operating cost of a liquid booster would have been less.

One of the big concerns was you have a liquid booster, you've got a real rocket engine on it, and what happens when that lands in the ocean?

I mean there were real concerns about could you clean up and reuse a rocket engine once it's been exposed to salt water?

And we don't know the answer to that.

Maybe it's the time to segue, if we want to do this, to a quick look at the new architecture as it was presented yesterday, which is being driven heavily, the choices are being driven by budget ceilings again.

An interesting question, Mark, is whether you would be making the same choices now if you weren't constrained by budget, once again.

I didn't mean to assume that the liquid would be better than solid.

Just the observation of the basis the decision was made on.

What this is, or at a certain level what it isn't, is the briefing that is on the NASA website which is a 10-page briefing.

This is the 23-page briefing.

There is a clear set of top level requirements in this new vision.

And, if you're space types at all, you should know this.

An interesting attempt to develop rationale for exploration which, as you see, is mainly intangible.

Curiosity and leadership, they are very much the same things that started the shuttle program.

This is about the only mention of mars in the whole presentation, even though the President's vision says moon as

a way of getting to mars.

But here is why moon.

And you're developing technologies that you're going to use downstream.

And, in particular, this Saturn 5 class.

The Apollo 17 Saturn 5 launcher took 117 metric tons to low earth orbit.

This vehicle that's being planned is slightly larger than Saturn 5.

One of the few areas of technological innovation in this system is a new engine which uses liquid methane rather than liquid hydrogen as a fuel.

Why?

Maybe I'll ask the class, why would you be interested in liquid methane?

Yeah.

You could manufacture it on mars.

Yeah, precisely.

It's also a lot easier to store over the long-term, liquid hydrogen.

But the main reason is it is a potential resource that you could get in situ on mars and so you wouldn't have to carry it all the way out there.

And you could get oxygen on mars because there is clearly water.

Yeah.

This may be slightly off topic, but I wonder if you could comment on what you think the feasibility of [UNINTELLIGIBLE PHRASE].

Whether it's feasible or not, we're not going to do it.

Elements of Mars Direct are in the NASA planning for mars which does a fair amount of in situ resource utilization.

Maybe I should back up and say what is this?

Mike Griffin was sworn in as NASA administrator April the 14th.

He had been convinced for a number of months that NASA's planning for implanting the Bush vision was proceeding at much too slow a pace.

And distributing money much too widely, including to MIT graduate students.

Jeff will explain that if none of you were affected by it.

And so he ordered, on April the 29th, a so-called 60-day exploration architecture study to develop a specific architecture for getting humans onto the surface of the moon.

And that architecture was basically finished by the end of July.

And it's taken six weeks to get White House permission to release it.

And so it was formally released yesterday.

It was mainly because of two reasons, because the senior people in the White House were on vacation in August, as we all know.

And so the OMB staff could sit and snip at this and say, well, you can put all this stuff down, but where is the money to carry it out?

You have to show the business case that you can actually do this with the budget that is allocated.

And it takes a little prestidigitation, I think, to do that.

So, this is what NASA has now said is its architecture for the next step in fulfilling our destiny as explorers.

Safe accelerated.

Accelerated in the sense that when Griffin got there the schedule for the first crude flight of the CEV, crew exploration vehicle was 2014, and he wanted the shuttle hard date retired in 2010.

And he wanted to close that gap and thought that it might be possible to have the CEV as early as 2011.

It's turning out it is probably not going to happen.

Why is this just not Apollo over again sending people back to the moon?

Here are the arguments.

For all crew on the moon, you can go anywhere on the moon, not just in the equatorial regions.

You can begin the buildup for permanent human presence in a lunar base.

Do institute resources.

And it's more reliable and safer.

The argument is that, at least on ascent, you get almost a factor of ten improvement in the safety.

And how is that going to happen?

Well, there are specific charts on that later.

Oh, OK.

Although, the system is being designed from getting to the moon backwards.

It can also be used for the International Space Station, if we continue with the space station.

What are we going to do on the moon?

Learn to operate away from earth.

Do science.

Learn how to use local resources.

Develop one mission at a time.

A lunar base.

And develop techniques for the eventual human missions to mars.

So there is another mars mention.

Science group picked a bunch of places that were interesting.

I believe this was primarily a drill because going in NASA knew that its preferred site was the Shackleton crater at the south pole of the moon.

Why?

Because of the possibility of water ice which would be a very valuable resource for in situ utilization.

And each mission will go to the same place and begin to leave on the surface the elements of a long duration base.

How is this going to be done?

First you're going to have this heavy lifter, launch the earth departure stage and the Lunar Lander.

Then you're going to have the smaller rocket launch the crew exploration vehicle.

They are going to rendezvous in earth orbit.

Fire up the departure stage and head off to the moon.

Arrive in lunar orbit.

And then the lander will separate and come down to the moon.

This is the lunar orbit rendezvous method that was used for Apollo, plus an earth orbit rendezvous step.

Work on the moon.

Come back and rendezvous with the CEV.

Probably ablative heat shield for what is hoped to be a land landing in Western United States in Oregon, Nevada or California so you don't have to deploy the fleet.

The hope, but it's what the contractors will confirm, is that most of the CEV will be able to reused up to ten times by replacing just the heat shield.

Again, that's the hope.

That is not put in as a requirement, which is important.

It's a desire.

It's a desire, yeah, because they don't know they can do it.

The baseline design is for a crew to the moon.

The thing can actually carry six people, either six people to space station early on or six people to a mars transit spaceship downstream.

It can also be used, if you take the crew accommodations out, as either a pressurized cargo module going to space station and bringing stuff back from the space station.

Provides down mass capability which is missing after the shuttle goes away.

The Apollo capsule was 3.9 meters across.

This is 5.5 meters, 32 degree slope on the capsule.

So, it's a much larger capsule with hopefully better characteristics.

NASA is calling the bluff of the commercial industry.

It will issue shortly a request for a proposal with a half a billion dollars behind it that says you, you, the commercial sector, demonstrate the ability to have cargo or maybe even crew deliver to the space station and we'll buy those services.

We won't use CEV.

But, in case you cannot demonstrate it, the CEV will be able to be a space station transport and crew rescue vehicle.

I don't think anybody believes that, in the relevant timeframe, anybody in NASA believes in the relevant timeframe the private sector is going to develop crew transport to an acceptable level of reliability.

Maybe cargo.

The National Space Transportation Policy was issued last January that said that there should be full utilization of the evolved expendable launch vehicles, Delta 4 and Atlas 5.

And that caused a problem because NASA said well, for our purposes, we're going to build something else.

And part of the price of that is NASA agreement to use primarily Delta 4s and Atlas 5s for its robotic missions.

The problem with that is those things are expensive, a lot more expensive than the Delta 2s.

And where does that leave people like Elon Musk in space exploration in privately developed launch systems?

Griffin was party to a study commissioned last year by the Planetary Society that came out with the conclusion that a shuttle derived launch system was the best way to approach this.

This study examined that system, shuttle derived, and a number of possible alternatives and came up with this conclusion.

This is the so-called stick.

The first stage is the current solid rocket booster on the shuttle for segment solid rocket.

There's a new upper stage powered by some version one space shuttle main engine, liquid, hydrogen, oxygen fuel.

A capsule on top with a service module and an escape tower.

Now you can say why is it safer?

It's because the crew is above any debris.

And, if something bad happens in the first couple minutes with a solid, you've got an escape system to pull the crew away from it.

And so NASA's probabilistic risk assessments say that this is a much safer system.

You want to comment on that?

Well, the probabilistic risk assessment, I think it's fairly obvious, if your escape system has a 90% probability of working then you have cut down, whatever the reliability of the main rocket, you've just increased your survival probability by a factor of ten if the rocket blows up.

Now, if you listen to some of the stories that Professor Cohen has alluded to, and we'll probably talk more about that, there were some serious questions in Apollo about how well the ejection rocket would work throughout the flight regime.

And he said everybody always breathed a sigh of relief when the ejection rocket was jettison in the course of the launch.

But, nevertheless, we've never used it in the US Space Program.

But there was one example of a Russian Soyuz which they did have a pad abort and the crew was pulled off the pad by the ejection rocket.

At a very high G load, like 15 Gs or so, but they survived and went on to fly again.

You want to comment on the comparison of that to your level of confidence on return to launch site aborts on the shuttle?

Which was never done, thank heavens.

We'll actually talk about some of the abort schemes for the shuttle in more detail.

And I think I'll leave it for that.

But there's no question, the only way to survive in the shuttle is for the shuttle itself to survive.

We now have the capability either of returning the shuttle to the launch pad and landing or going across the ocean.

But if you cannot quite get back for a landing, we do now have the capability.

I showed you the pictures of the escape.

You can actually bail out of the shuttle now, but it has to be under controlled flight.

And there's definitely no system of just extracting you out of the shuttle.

I mean the whole logic is this is claimed to be an order of magnitude safer for the crew on ascent.

Well, I think the other point is that the solid booster by itself is more reliable.

Right now, for the shuttle to have a safe launch, you have to have both solid rocket boosters work, plus all of the three main engines.

So you've got a lot more failure points.

This is a simpler system so only one solid booster.

And then the second stage is your liquid rocket.

So, there are a lot fewer things to go wrong.

Plus the whole aerodynamics is much simpler because it's a simple stack formation.

I think, just from an aerospace design point of view, it is a simpler and safer system.

Apparently, there were some concerns because this was so tall of bending and that sort of thing.

Well, that's something they'll have to deal with.

But we've launched tall skinny rockets before.

And I suspect they'll be able to figure out how to do that.

The heavy lift is built around something derived from the space shuttle external tank with five versions of a throw-away version of the space shuttle main engine, plus two five segment solid rockets.

So, it's adding one more segment to the existing booster.

The upper stage will be powered by one or two derivatives of the J2 engine used for the upper stages of the Saturn 5.

So, this is a pretty retro system.

But it was a good engine.

And the other thing to mention, some people had suggested using five segment solids for the crew launch vehicle.

One of the other things, when you talk about reliability, as John said, we've had now 228 launches of the solid rocket boosters.

And one of the great things about the recovery is not just the economic impact of being able to recover and reuse the solid booster, but you get to examine how it performed.

And that makes a huge difference in terms of flying safely.

Because, if you look back at the history of the Challenger accident, we knew for many years that we had a problem with blow by around the O ring seal.

Unfortunately, for various reasons, management chose to ignore that and fly anyway.

But if you can recover your rocket after you use it and actually see how it performed and look and see if there are any critical failures which are suggesting that there are problems, that also improves your reliability.

So, we have a lot of experience with four-segment solid rocket boosters.

And, by choosing not to use this new and improved five segment booster for the human launches, we're basically saying we're going to go with what we have experience with and what we understand.

Well, besides that, we don't have it now.

It will be developed, but when we develop it and use it for this, some day, after we get a lot of experience with it, we may decide to -- Well, it says can be certified for [OVERLAPPING VOICES].

Now, this is the heavy lift thing.

Right, but you're going to want to fly it many times before we decide to [OVERLAPPING VOICES].

And the intent is not to human rate this from the start.

Without the upper stage, you can get 100 tons, 106 tons to low earth orbit just with the first stage and 55 metric tons to, well, you can read, I think.

That's a new development, obviously.

This is Marsha Ivins who presented this yesterday, one of Jeff's former colleagues.

This really isn't what it's going to look like, the Lunar Lander.

What's interesting is, in addition to carrying the crew down, the idea is that you can carry a fairly significant cargo load down to the lunar surface and leave it there.

And that enables the fairly early buildup of a lunar base capability.

And, again, this ascent stage will use a liquid methane propulsion.

Any sense of scale on the habitat?

Well, this is enough for four people so it's not super big.

I've seen dimensions on it, but this is just a nominal design anyway.

This design, with all the tanks down here, is not very good for carrying cargo down.

They added the cargo capability and didn't change the picture.

Here is what NASA says are the commercial opportunities in this initiative.

It's interesting.

There were some other ones that have gone away from earlier briefings.

Here are the international opportunities.

And they are focused in the longer run on lunar surface systems.

And the reality is that without international contributions you cannot do a lunar base because, on the budget available, you cannot afford to build this stuff.

I am looking at this hard for the first time.

I saw a version of this in July, and there have been some significant changes.

The July version said opportunities for non-US astronauts going to the moon, and it's not here in this final briefing.

Committed long-term lunar effort is needed.

You can show mars up here, but this is really a plan for getting back to the moon.

And to reach for mars we must first reach for the moon.

A Griffin quote, Mike and I have talked about this, he believes that the spread of the human species into the solar system is inevitable, and the United States should lead so we carry the principles and values of Western philosophy and culture.

You can make a judgment whether you think that's a good rationale for doing this or not, but he means it.

Great nations do great and ambitious things.

We must continue to be great.

Cue the music now.

[LAUGHTER] This is interesting.

This was a presentation that was given yesterday.

And it is different than the presentation that was presented to industry yesterday.

And the biggest difference is the industry presentation had a budget.

[LAUGHTER] And the budget shows that within the next five years all of this fits within the plan budget curve and then stops in terms of the affordability downstream.

And it also shows no mars research and technology until fiscal 1917.

And a fairly big wedge for lunar outpost.

This is a US-only scenario.

Any relief from this is going to come from international contributions.

And one of the things that changed over the past week or so is now the phrase is go as you can pay.

In the trade between performance requirements, cost and schedule, what you're going to trade is schedule.

And NASA is very nervous of announcing this thing in the middle of the Katrina recovery saying we're going to spend $100 billion going back to the moon.

Actually, that was the first question that Griffin got at the press conference.

Right.

I talked with some media yesterday, and this is the same sort of thing.

It's interesting that the budget chart is not in the presentation I was given.

The budget said that you cannot do it?

The budget says that they can get started.

[LAUGHTER] What the budget is going to support and the hardware that we will be building, over the next few years it's just the crew exploration vehicle.

And the launch vehicle.

The upper stage in the launch vehicle.

Right, this.

We will retire the shuttle.

We will use that to support the space station, if we're doing the space station at that point.

And not until the shuttle is retired will then the money that is now used to support shuttle flights can start going into building this.

That's the way I understand it.

And that's the schedule which means you cannot get to the moon until near the end of the next decade.

2018 is the target date.

And that doesn't support any extra equipment once you get to the surface of the moon.

So, we don't have a long-term habitat, we don't have rovers, we don't have NC2 resources.

All the stuff that we'd like to do on the moon, that's over and above this.

I think that's fair to say, isn't it?

I think it's fair to say except that, as I say, in this budget curve it's in the budget.

But the only way to do the rest of it is to get that green part, the lunar base buildup to be paid for by somebody else.

So, we will see.

This is your future, I think.

If you're going into aerospace engineering, this is at least the NASA project for the next 15 years.

And maybe 20 years from now there will be a class here talking about the systems engineering of the Lunar Exploration Program.

So, you're kids can attend that class.

[LAUGHTER] Then it was typewritten memos.

Now it's PowerPoint.

For you engineering junkies, there is a thousand page report coming next month that has all the information of the trade studies and everything underpinning all this.

This is the output of a study.

The study report is coming.

OK, just briefly, from most of you I've gotten an indication of what you want to do for your projects.

I'll have a look at those.

If you haven't sent them to me, please make sure I get them by Thursday.

One or two of you have said you want to come and talk with me about it, that's fine.

Let's see, that's on the reports.

The last thing, just to remind you, is this really is the last of the kind of introductory policy, how did the shuttle program get started.

For the next six weeks or so we'll be going deep into the nitty-gritty of some of the systems.

Tom Moser will be here, and he will be talking about shuttle structures and the thermal protection system on Thursday.

See you then.