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A Settlement Strategy for NASA

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This is a transcript, with slides, of the Keynote Address of Jeff Greason, President of XCOR Aerospace, at the Awards Banquet at the 2011 ISDC in Huntsville, Alabama.

A video of this presentation is available at www.nss.org/docs/greason

This is going to be a space policy talk, not an XCOR talk, so my marketing guy is already bleeding from the ears just hearing me say that, but I try not to mix the two topics because they are really two different roles that I have. I don't do an awful lot of space policy talks but it just so happened that I did my first one in 2009 just before the Augustine Committee hit and I did my next one a year later at ISDC, and I guess it takes me about a year to work up a good head of steam to say something about space policy, so here I am at ISDC again. Unusually for me I am going to use a few slides, as few as humanly possible, but I am in a NASA town and if I don't have some slides nobody will be able to hear what I say.

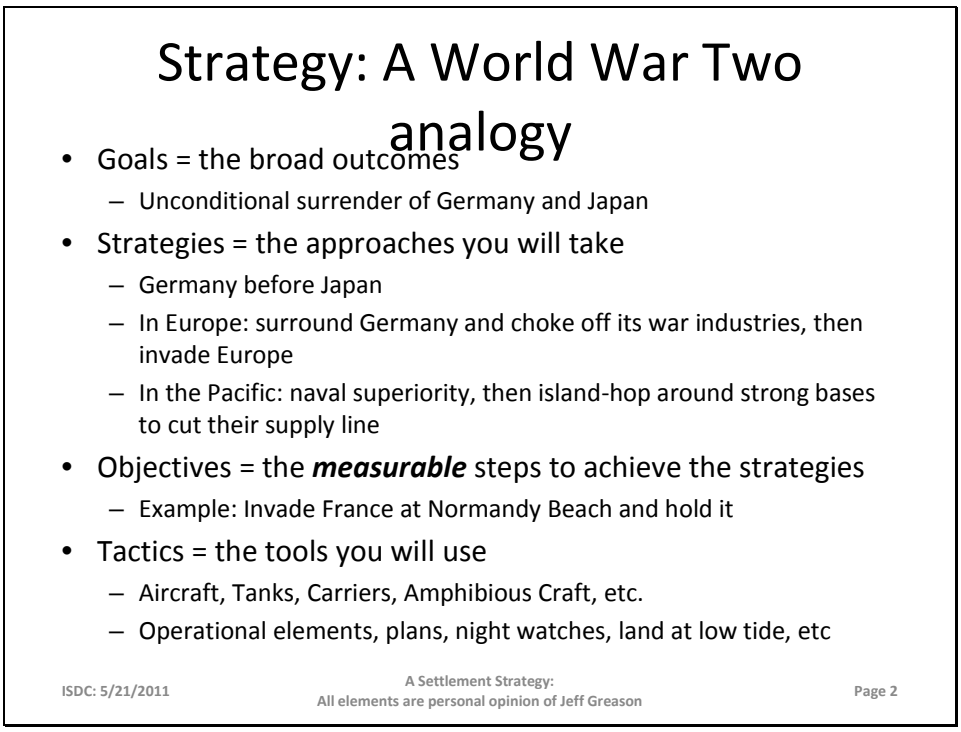
I want to talk about strategy for NASA, and in particular a strategy for NASA for settlement, because I think strategy is the void that we have right now. We have lots of people who want to talk about tactics – which rocket shall we fly, where shall we go, what order should it be in, which contractor should get the job. We have just started to realize over the last eight or ten years that we do indeed have a goal for the national space program, and I want to talk about that for a little bit. But between having a goal and having tactics, you have to have a strategy, *and we don't*. We don't even have the beginnings of a national agreement on what our strategy ought to be, and until we have one, we're going to continue to flail, which is more or less what's going on right now.

So for a long time after Augustine ended I was reluctant to go out and talk too much about what I thought the strategy ought to be, and when I would give talks about Augustine's findings I would confine myself to the very highest level goal elements of it. And the reason for that silence, although of course I had ideas on the subject, was because I didn't want to get in front of national policy makers – I'm just a guy looking in from the outside, and trying to figure out how to make sense out of national policy is a hard job, and we pay people, as taxpayers, who have this job full time. They work at NASA, and they are staffers for key Congress people, and they work in the White House, and it's their job to develop a national space policy. The minute they came up with one I did not want to get ten calls from reporters saying how come they didn't do what you though they ought to do. I went to a senior person at NASA recently, whom I have a great deal of respect for, and I told him that, and he told me he thought that was a mistake, and that the national conversation on what our space strategy ought to be wasn't happening, and it's high time we started having that conversation.

So having said all that, I have got to say there are multiple right answers to this problem. One of the problems we have in the space advocacy world is that there are a small number of people who have been very passionate about the details of space policy, and they're so passionate about it that if you are not in 100 percent agreement with them they think you are 100% wrong. I am not one of those people. There are multiple right answers. That has not prevented us, however, as a nation from pursuing one of the multiple wrong answers. So when I say things like "we should do this" that's an example, that's not a prescription. You don't have to do it exactly that way. But maybe we can shoot more over in that direction and less over in this direction.

What is a strategy? I am an amateur student of World War II history so I'm going to use that as an example [slide 2 below]. You start with a goal. What's the goal? Unconditional surrender of Germany and Japan – that was the goal. Now, that wasn't trivial, it wasn't obvious. It actually took a bit of time at the beginning of World War II to figure out that was the goal of national policy. Maybe we should have negotiated something. Maybe we should have made peace with one and gone to war with the other. But eventually the answer was no, that's our goal: unconditional surrender of Germany and Japan.

Strategies are the big picture approaches that you take to get to that goal. In World War II our strategy was first – Europe first – we were going to deal with the problem in Europe and we were going to do a holding action in the Pacific. In Europe, what are we going to do – we are going to surround Germany and cut off the supplies that were keeping its war machine going and build up strength until we could invade. What are we going to do in the Pacific? We are going to island-hop. We are going to establish naval superiority; we were not going to face the enemy where he was strong because most of our forces were over in Europe. We were going to take islands where he was weak, cut off his strong points, deny him supplies and starve him out, and then move on to the next island – what became to be called the island-hopping strategy. That's an example of what a strategy is.



Objectives are measurable steps: what are you going to do that you can tell whether you did it or not. We are going to invade France at Normandy beach and we are going to hold it. That's an objective. Tactics are things like: do we need tanks, do we need airplanes, are we going to do daytime bombing, are we going to do nighttime bombing. The details that people fight about in space policy, like which factory in which state is going to build that bomber, doesn't even appear at the level of tactics – it's too small to worry about.

The space race – we'll go through the same thing [slide 3 below]. Why do we have a space race? What are we trying to do? We are going to demonstrate to the world that the American system of government is superior to the Russian system of government. We are going to show them that our space capabilities are better than their space capabilities. To quote from *The Right Stuff* movie, "Our Germans are better than their Germans."

Strategy – what's the strategy in the space race? We have to pick some objective that we think, even though the Russians might be ahead of us today, that we can beat them to clearly – something so far out that we can beat them there in spite of their having a lead, and we're going to make that what the space race is about.

What's the objective? Put a man on the Moon before 1970 and return him safely to the Earth. We'll know if we did it; it's measureable.

Tactics – we're going to use lunar orbit rendezvous, a Saturn V program to build the ship to get us there, and we're going to need something in between that became the Gemini program that would teach us how to do all the things we need to do to make Apollo work.

It may seem, and certainly has seemed to me from time to time, like in current national space policy and really in all of national space policy since the end of the space race and since the end of the cold war, that we have not had a goal, let alone a strategy, tactics, and objectives. It became clear to me on the Augustine Committee that we do have a goal, and that there is a consensus among policy makers that we have that goal. But everybody is kind of afraid to say it, because they are not sure we can do it. So committee after committee after committee kind of edges up to the thing: they kind of belly up to the bar and peek over a little bit and say "it's kinda like we should be doing [whispers] – settlement."

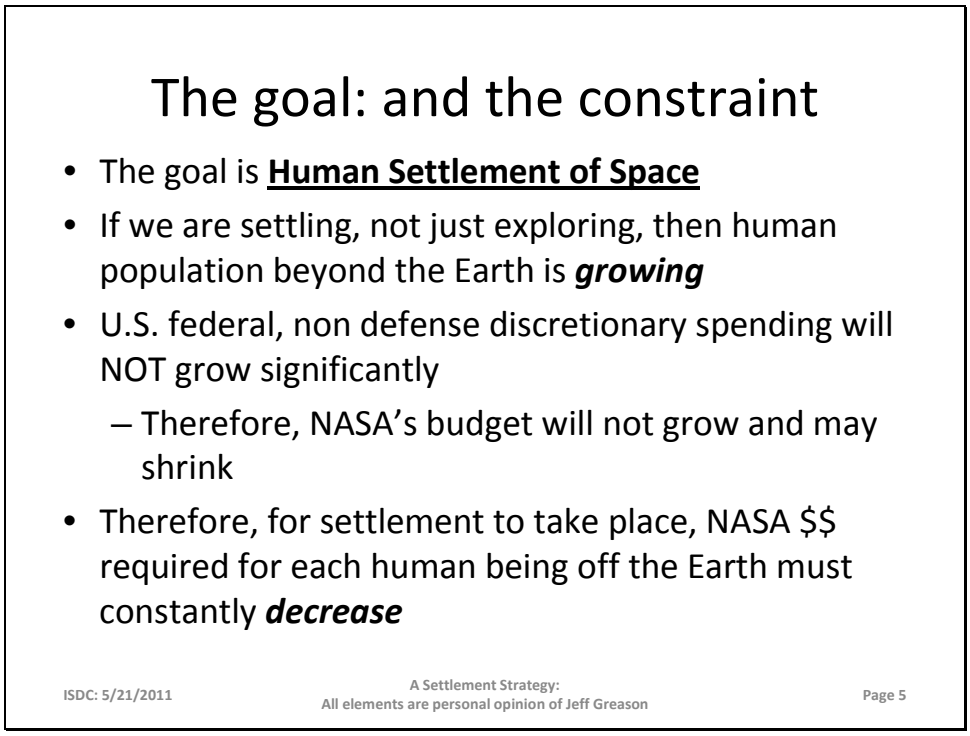
The only reason I put up this slide is [slide 4 below], and I don't want to read every quote, but I want to provide some documentary evidence to back up my assertion that in committee after committee for some time now the national objective of the United States has been identified in things like national space policy documents, findings of presidential commissions, statements by presidential national science advisors, statements by presidents, statements by NASA administrators – they all use different words, and none of them are quite willing to use the "S" word, but they all come right up to it, and if you know the code, they are all saying the same thing. When Marburger says in the Bush administration that the Vision for Space Exploration is about putting the solar system within the economic sphere of humanity, and President Obama gets up a few years later and says that our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time in ways that are *indefinite*, we're talking about settlement. It is actually the national policy of the United States that we should settle space.

I'm going to put one last quote in because it is commonly misattributed to me, I don't know why, but the reporters right after the hearing where this was said all said that it came from Greason. I wish I had said it; I wish I'd had the guts to say it. But it was actually Chris Chyba, one of my co-members on the committee, who says "Humanity should become a space faring civilization…. If that is not the point of human space flight, what the hell are we doing?"

Now here's the bad news, which is why nobody quite wants to talk about it. Ok, so, fine, the goal is human settlement of space. But what would you have done in World War II if your honest assessment had been we can't win? Would you still have set the national policy objective as unconditional surrender of Germany and Japan? There's an uncomfortable feeling out there that it [settlement] is the only worthwhile goal of a national human space flight activity, but we don't think we can do it. So maybe we shouldn't talk about it too much. I think that's a mistake. I think we can do it. I think we should do it. I think we better do it.

Now, what does it mean to take settlement seriously as a national goal? Well, first let's face an uncomfortable truth: the national NASA budget is not going up. The fight is going to be how fast does it go down. A year ago I was so sufficiently timid, even though I saw the writing on the wall, to say it's going to be a struggle to keep it level. Now I'm going to go farther than that. We are not going to succeed in that struggle. The NASA budget is going to decline. I don't think that's a good thing, I don't think that's a desirable thing. I may not think earthquakes in California are a good thing, but we get them anyway. Because the U.S. federal non-defense discretionary funding is going to go down, and the entire fight in Washington is going to be, probably for the next generation, how fast does it come down, how smoothly does it come down, and do we get elements of it down so that we still have time to deal with the problems, or do we wait until it's a catastrophe – that's the sum total of the policy debate that there is room for right

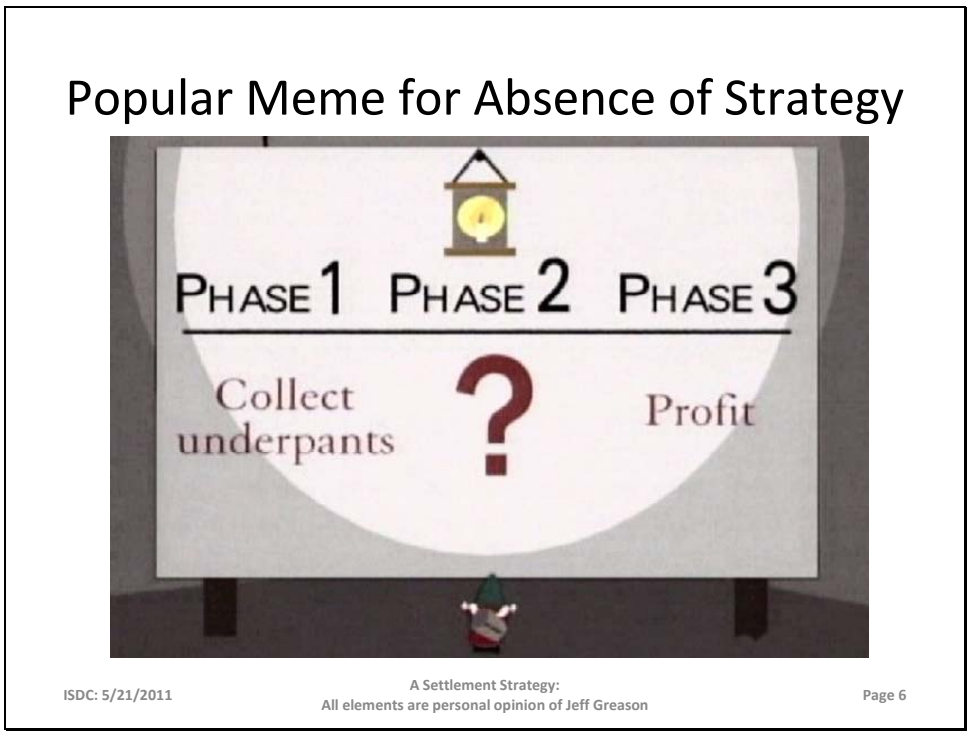
now. Now maybe in this administration or in that administration sometime in the next twenty years that will be reversed for a year or two – "on the fields of Pelennor you may triumph for a day but against the enemy now arisen in the East there is no victory." The budget's going down. Deal with it.



So, if we're having settlement of space, the population of human beings off the Earth would presumably be going up, otherwise it's kind of hard to call it settlement, right? So if the population is going up and the budget is going down, the central inescapable truth is that the amount of NASA dollars that has to get spent to support one human being off the surface of the planet has to go down, every year, year in, year out. Otherwise you can't have a growing population with a fixed NASA budget. And that would mean we can't win, we can't achieve our national goal. And that conclusion hasn't fully penetrated the people inside and outside of NASA who think about national policy. They're still fighting the last war. They still think that it's about fighting for the budget to go up.

Those of us in the commercial world who are struggling with figuring out a way to do things at a lower cost, and those of you in the government world who are trying to figure out how to achieve our national objectives on a fixed budget, should be each other's best friend, because you can't succeed in achieving national policy objectives without the success of the commercial industry, and your market – to the commercial industry, demand from any source is a market – that NASA demand can be a very important part of the market. You ought to be our best friend, we ought to think you are our best friend.

But it's that vacuum that there has been a lack of a national strategy for how we implement those goals, how we achieve them – on to that blank canvas everyone projects their worst fears (that's human nature). Everybody thinks that if I don't know what's coming tomorrow, and you want to change what I'm doing today, it's going to be bad. And I have to place the blame for that void with the executive branch. That's their job, that's the reason we pay them as taxpayers. It would be nice if Congress provided policy and leadership, but there is no sign of that, and I can't blame them for that because in some sense that's not their job, it's the executive branch's job.



Now those of you who watch television, there is a popular meme for how people react to the total absence of a strategy. This slide [slide 6 above] is from a South Park episode called The Underpants Gnomes. Phase 1: Collect underpants. Phase 2: ?. Phase 3: Profit. This doesn't work.

This is the Exploration Paradigm, as I call it, or the Apollo paradigm [slide 7 below]. It worked great for the Cold War because we had different objectives. Today our goal is settlement. Phase 1: We are going to put boots on – pick your target. We're going to return to the Moon. We're going to go balls-out and put people on Mars. We're going to send human beings to a Near Earth Object. And then – ? – and then there's going to be settlement.

There are some other people out there, one of them used to be a NASA Administrator, some of them are very active out there in the space advocacy community – they have what I call the Base Paradigm [slide 8 below]. We're not just going to put human beings, boots, on another planet, we're going to build a base, like ISS. We're going to build a base in low Earth orbit – and that didn't work. We're going to build a base on the Moon, and then – ? – and then there will be settlement. It doesn't work.

The Exploration Paradigm

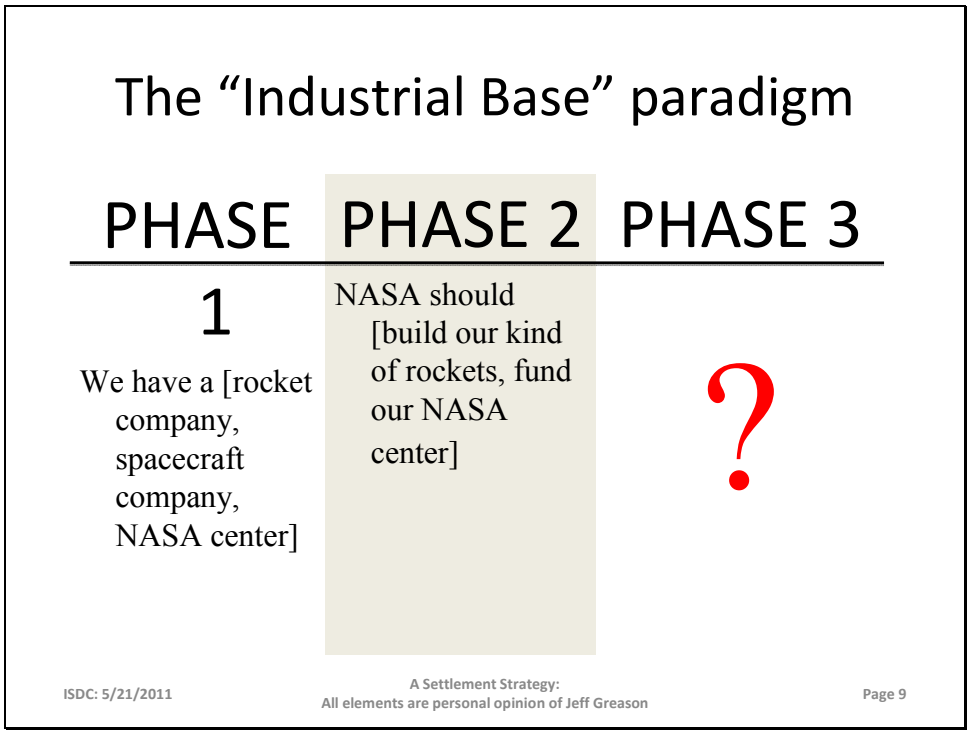
PHASE 1	PHASE 2	PHASE 3
Fast as possible, put boots on [Moon, Mars, NEO]: cost equal to budget	?	Settlement

The "Base" paradigm

PHASE 1	PHASE 2	PHASE 3
Build a taxpayer supported [Moon, Mars, LEO] base	?	Settlement

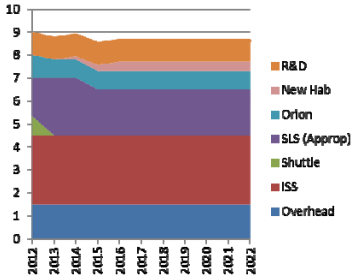
All of these strategies involve a system that has a very high cost per human being living on the other planetary body, and there is no strategy for how it's ever going to come down. So all that you are ever going to get if you ever successfully executed one of those, which I have grave doubts about, but if we managed we would be sorry, because now what we would have is ISS on the Moon or ISS on Mars or ISS on a NEO or we would have visited six more NEOs and planted six more flags. And then what the heck are we going to do? We still have no strategy, we still have no plan, our national objectives are not met.

So in the absence of this, all organizations, large and small, public and private, have prime directive one: preserve the organization. It's not a unique feature of NASA, it's true for all large organizations. So if you don't give them any kind of clear direction, what they do is they structure themselves to keep doing tomorrow more or less what they are doing today. So that leads to what I will very charitably call the Industrial Base Paradigm [slide 9 below] Phase 1: We have a (fill in the blank), we have a rocket company, we have a spaceship company, we have a NASA center in our district – so, NASA should (fill in the blank), build our kind of rocket, buy our kind of spaceship, keep work for our NASA center. And then we'll be around to figure out what we should do tomorrow. And that is essentially current national policy, by default. These don't work.

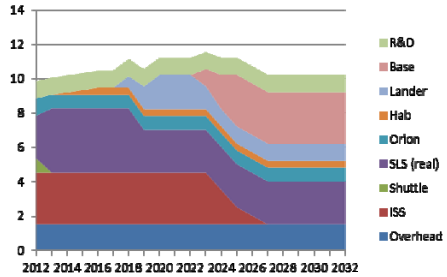


None of these work

- They don't achieve the goal of settlement
- They require budget to GROW for each new step taken
  - In practice, we just stop, and start over each time



2011 NASA budget extrapolated
(qualitative $$ for illustration only)



2011 NASA budget + SLS costs, ISS cancel 2023
(qualitative $$ estimates for illustration only)

I took all of an hour and made up numbers to make these ever-popular NASA sand charts [slide 10 above]. Don't go parsing where I got these numbers from. In the best tradition of the NASA administration under the previous administrator, I just made them up. But they are qualitatively indicative of the problem. If we go down the strategy we are going today, which is the graph on the left, all of NASA's budget becomes consumed by ISS and by keeping the operating cost of some kind of Senate launch system alive. Those two alone eat the entire NASA human spaceflight budget. You can now have a booster and a capsule but nothing to do when you get wherever, nor can you have a lander to land on a planetary surface if you should manage to get there. It's barely conceivable that if we go down this strategy we might eventually manage to visit some low-gravity targets that aren't too far away like near Earth objects. I am underwhelmed.

If you envision adding money it doesn't take a ridiculous amount of added money – it depends on how creative you want to get with the acquisition strategy – a couple of billion a year, three with the number in Augustine but I think with creative thinking it might be two, then you can consider doing something more aggressive and more ambitious. But it only pushes the problem off. Even if the extra three billion a year appears, and now you can afford to do a lander, then as soon as you want to start to build some kind of facility on the lunar surface – you are right back where you started, the budget crashes, you can't afford to build the new thing without cancelling the old thing and now we are in gap three, where we are sitting here thinking we are going to have to cancel ISS and not replace it so we can afford to build ISS on the Moon, and then that will take longer than you think and the public will lose interest, and besides we are not going to get the extra three billion a year anyway so there is no point. It just isn't going to work.

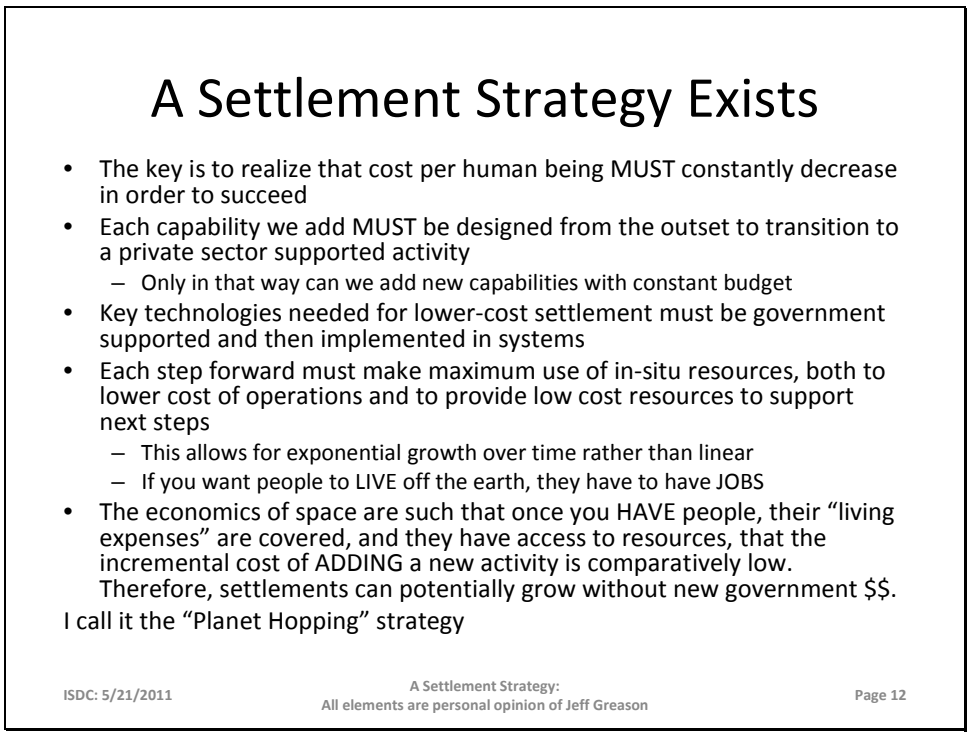
In the absence of strategy…

- The "industrial base" paradigm prevails because only current stakeholders care enough to fight
  - *"For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order"*– Machiavelli
- Most of Congress either doesn't care or supports NASA's budget because "space is good"
  - The details of policy directions are outside their focus
  - Responsible committees dominated by current stakeholders
- It is the job of the Executive branch to develop and articulate the strategies to achieve national goals
  - So far, neither NASA administrator nor President has done so
  - This absence opens door for "industrial base" actions
  - You can't beat something with nothing

So, as I said, in the absence of strategy what we get is "preserve the industrial base" because Congress has people sitting on the relevant committees and they are on those committees because they have NASA centers or large NASA contractors in their districts. Otherwise, why would they be on the committee? Nobody gets on the committee because they think space is great. Which committee you get on in Congress is a question of how you can best serve your constituents. That's just the way the system works. I bear them no ill will for this.

What that means is most of Congress either couldn't care less about space, but a surprising number of them do, but they care about space in a sort of "space is neat" way. Space is neat, NASA is neat, it does good things, we should support it. So that means that when policy debates like the one we are engaging in now come along, what happens is people like you go into Congress people's office and say "Do this good thing." And then you leave, and they turn to their staffer and they say "What was all that about?" And their staffer says "I don't know but we'll find out" and the way they find out is they go down to the staffer of the people who work on the subcommittee that worries about space issues. And they tell them what's good for their current constituents because that's their job, so in the absence of a strategy again that's why we have to fall reflexively back to the status quo. And that's why we will until there is a strategy articulated.

So, I'm going to set one out, and I'm not saying this is *the* way to do it. I'm saying this is *a* way to do it. Think of it purely as an existence proof, that it is possible for us to have one going forward. So again the key to putting one together is to realize what has to be the central feature: the cost per human being living off the planet has to go down. It has to go down not just once but on a fairly continuous basis. It doesn't mean the cost total has to come down, I mean the cost *to the taxpayer* per human being has to come down. It doesn't matter how much private sector money they suck up because that comes out of a different pot.



In order to pull that off, each new line item of things we develop, and there are a lot of things that have to be developed, has to be designed so it gets off of NASA's budget. So NASA comes in, they develop something or they pay for something to be developed, and then, the important part, they have to *get out*. And the history of NASA shows designing a government system by and for government purposes to be operated by government people, and then we'll hope we can find somebody who wants to pick it up as a private capability isn't going to work either. If it's going to transition to private sector operation on a for-profit basis and find other customers, it has to be designed from the beginning to do those things, which means NASA has to change the way that it develops systems – it has to become one of many customers for each critical step of the system.

And it's not just LEO and it's not just commercial crew. After commercial crew comes along we're going to need reusable Earth departure stages, we're going to need reusable planetary landers, we're going to need habitats in space, we're going to need habitats on planetary surfaces, we're going to need a lot of stuff. Every single one of those pieces has to be designed in such a way that it shares its cost and its customer base with the private sector from the beginning, so that when NASA has established human presence on some body it can move on to the next one but it leaves behind it all the suite of capabilities that is necessary to maintain human beings on that planetary surface, with a cost structure and an operations cost – that's the critical piece, the annual operations cost – so low that it is credible that other private customers for these things will exist.

It also has to develop key technologies. I've spoken about that in other meetings and it's detailed in the Augustine report. There are technologies we need that we don't have sufficiently mature yet. The private sector is unlikely to pay for them. That's a critical role of government. It's not

like NASA doesn't have things to do. The people who claim that if we shift to an exploration regime and a settlement regime in which NASA's role changes, the people who take that and claim that means NASA's role ends, are lying. They may be lying because they don't know any better, but in many cases I'm convinced that's not true.

Each step forward also has to make a maximum use of in-situ resources. You don't colonize or settle a place and then ship everything from the home country. Never worked before, no special reason to expect it's going to work this time. What's crystallized my thinking about this over the last two years about this is while we don't Know (with a capital N) everything we'd like to know, we can now make a pretty reasonable guess that we can get propellant at a bunch of critical places that are interesting. We can get it on the Moon, and we know that about as well as we are going to without more people walking about on the surface, we can get it on Mars, and it looks increasingly likely that we can get it on Phobos or Deimos.

This begins to suggest what the strategy ought to be, and I call it Planet Hopping, by direct analogy to the island hopping strategy in the Pacific during World War II. What we got to do is take the planetary destinations in sequence. In each one of them the purpose of the initial human outpost is not to be there and look cool, it is not to unfurl flags and take pretty pictures, and it is not for the holy grail of science, although we will get all of those things. *It's to make gas*. You are miners. You dig stuff up, and more likely you repair and operate the robots that dig stuff up, and turn it into propellants you can sell back to NASA to fill up the gas stations that they need so they can move on to the next more interesting place. Again, I'm not saying that this is *the* way to do it. I'm saying this is *a* way to do it.

If you do that, a lot of really interesting things fall out. One of the interesting things that falls out is that if propellant is treated as a commodity right from the beginning, then you treat it that way in Earth orbit. Instantly something very interesting happens: if you do exploration missions on sort of Apollo scale, or Apollo plus a little bit, you develop a market for 250 metric tons a year of propellant in low Earth orbit, which would roughly triple the current American demand for launch. That would have salutary effects on the price of launch immediately, simply because of increasing the volume of production of existing expendable launch vehicles that are currently operating way under capacity. And it would have even more profound effects on the cost of launch in the longer term, because right now the factor that's holding back companies like mine from developing a fully orbital, fully reusable launch vehicle is not technical. It's because it's very difficult to close the business case that says you should do it, because the demand for launch is small and uncertain. If NASA starts buying 250 tons a year of propellant in orbit every year, the market becomes large and predictable. The bankers love large and predictable.

It also has the advantage that each new destination we reach and put a permanent presence on lowers the cost by a further multiplier to get to the next destination. So if we cut the cost of launch by a factor of two or three, which is quite credible, by having propellant in storage for transfer in Earth orbit, then when the Moon comes along and starts exporting propellant up someplace like L1, all of a sudden the cost of going to a NEO or to Mars has dropped by another factor of about three. And if you start putting propellant on Phobos, and you make your first Mars expedition go to Phobos or Deimos instead of going to the Martian surface, you can cut the cost of going to Mars surface by a factor of another about three. This is starting to really add up.

Possible objectives & tactics

- Start with propellant storage & transfer in LEO
  - Eliminates need for large "NASA unique" rocket
  - 35-70 mT rockets can be provided by ULA, SpaceX
  - NASA human exploration missions offer ~250mT/year propellant market
    - Adding that to DoD & private demand would roughly triple size of launch market
    - At once, without further government action, business case for new launchers & new launch technology closes
  - Provides all the "Air mail act" stimulus needed for cheaper launch in a way that U.S. government can sustain as long as exploration continues
- Once proven, add a cislunar depot (L1, for example)
  - Cislunar depot allows REUSABLE landers, refueled on Lunar surface and at L1, as well as staging point for deep space missions

Lunar Poles: Our first mining town

- Lunar poles appear to have economically exploitable propellant deposits
  - Return to the Moon, not to explore, but to USE it
  - Teleoperated mining is state of the art on Earth today and can be used effectively on the Moon
  - Purpose of humans is to keep the machines running
  - Export the propellant to L1 or to LEO
- Once there are people living on Luna, with habitat, mining machines, and a job to do that pays for them to be there….
  - It becomes a short step to exporting metals, fabricated parts, raw regolith for radiation shielding, and so on….
  - Not guaranteed but credible that private investment will expand that base indefinitely
  - Tantalizing data suggests poles have enough C, H, N to support a sizable human population

I won't bore you with the technical details, but it turns out that if you refuel your vehicles on the Moon and at L1, and you refuel your vehicles on the Martian surface and on Phobos, you don't need any expendable bits any more. Everything can be reused. That has further salutary effects on the cost of launch. It's actually easier, crazily enough, to figure out how to design a reusable ship that goes from Mars to Phobos to Mars than it is to design a reusable ship that goes from Earth to Earth orbit and back, because it's single stage, you don't have to stage anything, you don't have to invent new technology, and this dreaded Mars entry and descent and landing problem that we keep hearing about turns out to be solved if you are able to have enough propellant that you can do propulsive braking from terminal velocity in the Martian atmosphere, which you can do if you picked up your gas on orbit and didn't have to bring it all the way from Earth.

Along the way we're going to have a couple of pieces, like Gemini, that we are going to have to demonstrate just because we have got to learn how to do them. It is not all just going to be destination to destination. In particular, there are a couple of nasty problems that we haven't solved yet. Clearly number one on those is cosmic radiation. We don't know enough about galactic cosmic ray hazards, and it's not just on the trip there, it also applies to the design of planetary surface habitats and things like that. We have so much uncertainty about it we are not even sure it's a problem. We just think it's a problem, but we think it could be a really serious problem. And it's very, very difficult to study on Earth. So we're going to need to put some kind of laboratory facility somewhere outside of Earth's magnetosphere. L1 suggests itself. We've got a gas station that has to go there. Whatever company we are going to buy lots of habitat volume from (I'm sure you can all think of at least one), we can park a module there, and astronauts can visit it when there are on the way to and from the lunar habitat and they can stop and drop off one set of lab rats and pick up the next one, and we can learn all the things we need to learn about galactic cosmic ray exposure before we have to send astronauts on a three-year voyage or a two-year voyage.

We are also going to need – we are not going to go to Phobos, I think, and I know that my colleague Mr. Zubrin may well disagree, but I do not think that we are going to do missions that that are less than a light minute from Earth over and over and over again, and then the next thing we do is going to be a two-year mission. I just don't think it's going to happen that way. I think we are going to do some missions that are intermediate length. Visiting Phobos is very much like visiting a near Earth object. It is just further away. So, you have got all the same ships, you have got all the same capabilities, except it is energetically easier, you can do it earlier, and it's where no man has gone before, so I think we should probably knock that off. So, I'm all in favor of a manned expedition to a near-Earth object, as a *tactic*, as part of a larger strategy in service of a larger goal, not as an end in itself, not as a stunt.

The purpose of Gemini astronauts living for fourteen days in a phone booth was not to replicate in space what we do with clowns in VWs. The purpose was – it was a capability we had to prove that we knew how to make human beings stay alive in a spacecraft that long because that was how long it takes to go to the Moon and back. The purpose of going to a NEO is to figure out how to go to Mars and back. If we do it with planning, with forethought, as part of a strategy it makes perfect sense. As a stand-alone stunt, as a poor-man's Apollo showing that we can go plant flags and footprints, someday still as long as there is no gravity there, what's the point?

L1 and NEO's: the next Gemini

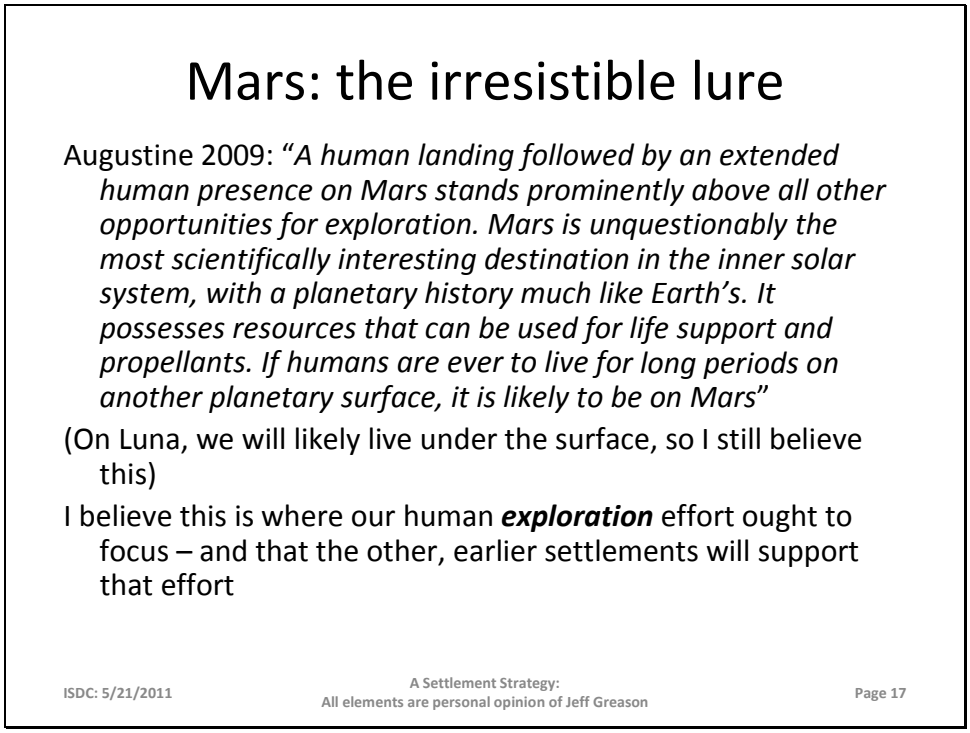
- Two classes of missions are needed to gather data we must have to develop Mars flights
  - We need a long-duration facility outside the magnetosphere where test animals can be kept to gather cosmic ray data. The cislunar depot is the logical place for this
  - The same capabilities needed to go to Phobos/Deimos can be tested with flights to a NEO – earlier and easier
- Many have written about how NEO's might be developed as resource deposits; the challenges are substantial – but these expeditions will provide the technical foundation needed.

Phobos: Beach-head for Mars

- Mars reference missions often ignore Phobos and Deimos
  - "NEO" like objects in Mars orbit
  - Hints that they are water-bearing bodies
- Chemical rockets, refueled on Mars AND at Phobos, can be single-stage reusable
- Phobos expedition much easier than Mars landing
  - By teleoperating exploration and propellant manufacture on Martian surface, paves the way for later landing
  - Could return samples from many points on Mars surface at a cost which is actually competitive with robotic methods
- As with the Lunar poles – a settlement can grow here; an outpost at first, but in time, perhaps more.

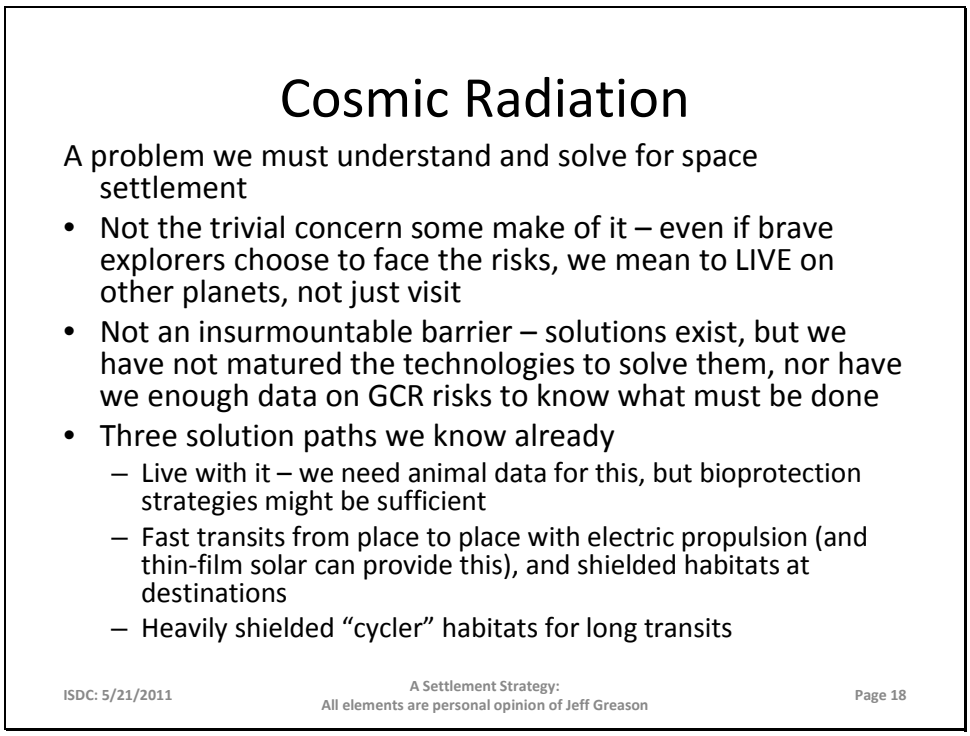
And our national policy makers have not articulated a point, they haven't explained a point, I'm not sure they know there is a point. So I can't blame the public for not getting the point. Nobody is telling them.

I am not any less enthusiastic about the long-term potential of Mars than anybody else. I yield to none in my enthusiasm for getting to Mars. I thought Augustine, which I will quote from (the Augustine Report): "A human landing followed by an extended human presence on Mars stands prominently above all other opportunities for exploration. Mars is unquestionably the most scientifically interesting destination in the inner solar system, with a planetary history much like Earth's. It possesses resources that can be used for life support and propellants. If humans are ever to live for long periods on another planetary surface, it is likely to be on Mars."



And the only caveat I would add to that today is I think that is probably still true because I think on Luna we are going to live under a planetary surface. Since this report was written, we've learned enough more about the Moon to know that the Moon probably can support a mighty civilization of its own, but the radiation environment there is going to be a real problem, so expect to be moles.

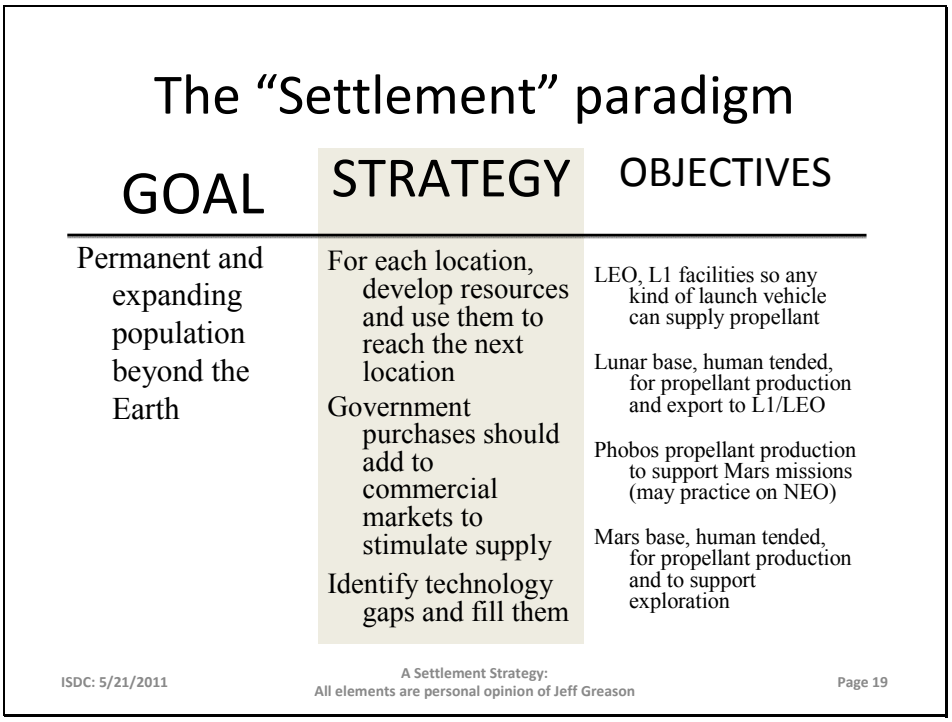
So I do believe that Mars should continue to be, as the President said in his address, our primary target for human exploration, I just don't think it's our first target for human settlement because the reason why we are going to do the earlier settlement is to establish the beachheads that are going to make getting to Mars in an economically rational way affordable.



I do want to say a few more words about cosmic radiation. It is misrepresented, in my opinion, in many ways. It is not a trivial concern. There are those who would suggest that we are men in those days and we will just face the radiation bravely, and for exploration purposes that may be true, but for settlement it's not enough to get to the other planet get home, and make it all the way home before you die of cancer. You have to be able to have kids after you get there. That's not trivial. We aren't sure how to do it yet. So the people who basically say "damn the torpedoes, don't worry about it" are wrong. But it is also absolutely not a barrier to the human settlement of the inner solar system. We know we can solve this problem. We have multiple ways of solving the problem. We just don't know which one is the one that's best and most effective yet. And they require different mission architectures. You can't just plug them in, it's not the kind of technology that you bolt on – you design your whole mission around what your strategy is for dealing with cosmic radiation. So it's kind of silly to design the mission before you figure out how you are going to deal with cosmic radiation. Unfortunately that makes it sort of silly factorial to design and require and build the launcher before we figure out the mission architecture, before we figure out the destination, before we figure out the strategy, just after we have figured out the goal.

But just to list a couple of them, it may be that the risk is low enough that we can just live with it when you add certain bioprotective measures that researchers need to develop, and there are serious ideas for how to do that, but you have got to have a facility outside the magnetosphere to study it because we can't simulate those effects here on Earth. It might be that it's a sufficiently serious problem that we have to do something about it, and we can do something about it by making fast dashes from planet to planet with an electric propulsion system of one kind or another. And it's a myth that you have to have nuclear propulsion for that. I can show you in principle how to do it with thin film solar arrays. We can do fast dashes from place to place but

there is a lot of work to do to get there. Or it may be sufficiently serious that even fast dashes won't deal with it, but fortunately Buzz Aldrin solved that problem too, and you do that by putting cycler habs up and you shield the heck out of them and then you take the cruise line to Mars instead of taking your sprint. They are all different choices, they all have different architectures, they all work much better if you can pick up propellant and shielding mass in cislunar space more cheaply than lifting it from Earth, so we don't have to worry about changing our *strategy* depending on which of these solutions we need, but we are going to need to change our *tactics* depending on which one of these solutions we need, which is why we are not ready to do that [select tactics] yet.



So to be fair I did a South Park chart for my idea of what a strategy would look like that is not a joke [slide 19 above]. The goal is a permanent and expanding population beyond the Earth. The strategy is: For each location, develop the resources and use them to reach the next location. Government purchases should add to commercial markets to stimulate supply. And we have to identify the technology gaps and fill them. And then a possible set of objectives, and I won't even descend to the level of tactics, would be we build LEO and L1 facilities to do propellant storage so any kind of launch vehicle can deliver that propellant. We set up a lunar base, human tended, so that they can keep the teleoperated robots running for propellant production and export to L1 and then to LEO. We would replicate that same trick on Phobos. We'd set up an outpost on Phobos, and man I've got to tell you that would be the science mission of a generation if we had people in Mars orbit that could teleoperate rovers in real time on the surface of Mars and pull samples back from every one of those many locations and collect the samples and bring them home. Apollo would become a footnote before we even put the first boots on the surface of Mars.

But that's not all they do, they are not just there for science, they are not just there to explore, they are there to make gas. They set up the propellant production, and that may take a couple of missions – they have to study the geology of Phobos. And then we set the first footprints on the surface of Mars, after those teleoperated crews have already figured out how to set up the habitats, they have already set up and demonstrated propellant production. The Hilton Mars is waiting for you when you get down, and that makes that mission a heck of a lot cheaper. I won't bore you with the numbers, and anybody can quibble with the numbers, but I will say it's my belief that if we pursued this the right way, we actually could afford to do this, all the way out to the first landings on Mars, for the kind of budget NASA's getting now. It might even be able to go down a little bit. It would be better if it didn't. I'm not in favor of decreasing NASA's budget. I'd like to increase NASA's budget. But at this time our best shot of getting NASA to do something like this is to go to national policy makers and tell them, look, if you don't cut NASA's budget we can at least stop growing it and still get a great human space program. In the words of Norm Augustine, a space program worthy of a great nation. And I think we should get one.

So before I close let's just think for a moment about what the alternative is, not just to this strategy but to *having* a strategy. Well, the alternative is we will probably keep doing more or less what we are doing now, which is we are going to build a big rocket and then we're going to hope a space program shows up to fly on it. And in my opinion, that strategy – the strategy of default – is going to result in the end of the NASA human spaceflight program because what will happen then, in this time of national tight belts, sooner or later as the budgets get tighter and tighter, some Congressman who doesn't have a NASA center in their district is going to look with covetous eyes on that budget. And people are going to be asking: What have we gotten from NASA in the last ten years or fifteen years or twenty years that's really worth whatever the national priority du jour at that time is. And let's be frank, folks, if we haven't done better in the next ten years than we've done in the last ten years we're going to lose that fight, and NASA's human spaceflight activity will end. And that will be bad for NASA, that will be bad for the nation, and that would be very bad for the commercial spaceflight sector because you can't be a market for us if you don't exist.

And yet, the reason I chose Huntsville to make these remarks is that this hideous terrible threat to NASA is largely being done in your name if you live and work in Huntsville. It is to keep you able to do the things that you are used to doing that your future is being destroyed. So if you think that's a mistake I encourage you to let your elected representatives know, because I have the deepest respect for the people I have had the pleasure of working with in NASA. They are good people. Most of them share the dreams that we have. They are not at NASA because they couldn't have cared less if they build rockets or toasters. They are at NASA because they care about this stuff. The overwhelming majority of people that I have ever interacted with at NASA are great, good people. If we give them a new task *they will rise to it*. It is your elected representatives who seem to lack respect for you because they seem to think that you can only ever do the same thing you've done. I don't buy that. I think you're better than that. □