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"Technology Horizons:"
Building Future Air Force Capabilities

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Dr. Dahm: Thank you for the introduction, and thanks to you all for turning out to hear a little bit about what the science and technology future of the Air Force is, at least from the perspective of this effort called Technology Horizons.

Here at the Air Force Association we hear a lot or we have heard a lot today about the current state of the Air Force and our attention will turn here to a view of the future and in particular of some of the capabilities that are technologically achievable over the next 20 years, and that could lead to the capabilities on which the Air Force is going to derive parts of its vision in the 2030 timeframe that this study was asked to look at.

As Joel mentioned in the introduction, Secretary Donley this morning mentioned Technology Horizons as one of the efforts that has been completed by the Air Force during the past year and those of you who were here a year ago will have heard when General Schwartz first mentioned publicly that we were doing this assessment this ten year, as it turns out as you'll see, a 15 year assessment of Air Force science and technology.

The whole idea here is to try to identify those technology areas that are disproportionately valuable for the Air Force to pursue over the next 10 years so that in 20 years we can have technology derived capabilities from those.

My role as the Air Force Chief Scientist, the whole design of that office is to provide the Air Force with independent objective advice on where the opportunities are in technology, where the risks are, and where the technology that could be developed with appropriate focus can feed into an A-link capabilities for the Air Force in the future. So Technology Horizons is right up that alley.

If we're going to talk about the future, I always think it's good first to look at the past. I use this chart very

often when I brief in various public forums to remind people of the role that science and technology plays in developing the capabilities that the Air Force counts on to accomplish its missions.

So if you start at the top left with the advent of powered flight, and you move towards the lower right, through the development of gas turbine engines, of space systems, of LO systems, and as we reach the bottom right we're into technologies that we're working on today, on hypersonics, on cyber systems, and unmanned aerial vehicles, remote piloted aircraft. And the point of that tour is just that almost everything the Air Force does in one form or another involves a technology that enabled capabilities.

Obviously the airmen that operate those systems are critical but we have to have a continuing [inaudible] science and technology advances to be able to enable that continuing set of capabilities that gives the Air Force its technology superiority over its adversaries and potential adversaries. And it's because of that critical dependence on S&T that the Air Force is unique among all the services in having a headquarters level, in our case an Air Staff level position of a Chief Scientist to provide that added input to the Air Force corporate decision-making process as we look at where we invest our limited resources to have the biggest return.

That chart was the past, and the real question that Technology Horizons addresses, and really the question that's more important for the Air Force is where those next capabilities will be, what S&T they will come from and what the resulting capabilities might look like that are going to enable the Air Force to maintain its technology superiority.

Those of you, and I know all of you here with your interest in the Air Force, are aware of the enormous challenges that we face. Those challenges, in my view, come in three different categories. The first is the strategic challenges which are changing very very quickly. If you look at the threat systems that are there, if you look at the strategic landscape that we're likely to face between now and say 2030, there are fundamental changes that are happening there and that the Air

Force needs to be ready to maintain its edge in that environment.

Secondly, there's a technology environment that also presents a certain type of challenge in the sense that there are going to be far more players in the science and technology world over the next two decades. There already are more than we've ever seen in the past. And many of those have the ability to translate science and technology advances into militarily significant capabilities. So the number of peers and near peers that we're going to be facing as a result of that is going to be very different.

Finally, all of you are aware of the likely budget environment that we're going to be facing over the next two decades. This is coming from the federal government's constraints and so these are likely not to be one or two years, but more likely to be a decade or more where we're going to have to be much more judicious about where we make our science and technology investments.

It could be argued, and I think it's correct to argue, that over the past decade or maybe a bit more we've had the luxury of being able to take a very high hedge approach in many of our investments including science and technology, but the likely forecast for the future is that we're not going to be able to take nearly as heavily hedged an approach. We will still take a balanced portfolio, Technology Horizons is not the be all and end all of what the Air Force should do, but we will have to focus more than we have in the past, and Technology Horizons is there to try to help enable that.

The way the Air Force has gone about doing that historically, in fact ever since the Air Force has been a separate service, in fact even starting just a bit before that in 1945 when General Hap Arnold asked Theodor von Carmen to come from academia into the Pentagon and to provide a vision for what the disproportionately valuable S&T was that the Air Force should focus on. That was a year-long process. It led to the development of Toward New Horizons that today is still taught in the Academy, and indeed much of the Air Force as we know today I

think originates from or could be traded to S&T investments that were started as a result of that vision.

Since then, about once every ten years the Air Force has undertaken a major headquarters level articulation of where the disproportionately valuable opportunities are that the Air Force should invest in. A total of six prior S&T visions. If you look at the timeline you'll see they're only roughly every decade. It turns out it's been about 15 years since we did the previous one. That was New World Vistas that was done when Sheila Widnall was the Secretary of the Air Force and General Fogleman was the Chief of Staff. So that even if it hadn't been 15 years, I would contend that a vision effort like this at the headquarters level is essential given the environment that we find ourselves in. Things are simply fundamentally different than they were certainly a decade ago and certainly more than they were five years ago.

So with that in mind, against that backdrop, the Secretary of the Air Force and the Chief of Staff had the Chief Scientist's office lead the development of this next decadal Air Force S&T vision. This was a year-long effort. It was begun, planning began back in February, over a year ago. The study actually kicked off in June of 2009. As you'll see as we go through this, I'll keep it short on process, although understanding some of the process that led to the product I think is important for you to understand what's being recommended.

But you'll see there was a very broad set of inputs that led to the development of this vision.

It's very important to understand that if you ask a bunch of technologists what their vision of the future is, you might get an answer that is substantially different than what you'll find if you go and get the publicly released Volume I of Technology Horizons. That's critical, because this is not simply an opportunity-driven study. The question before us was not just what could be done with S&T if we were unconstrained. Because as you no doubt get already, and it's certainly a point I tried to emphasize a moment ago, we are not in an unconstrained environment.

So the question was more out of everything that could be achieved with S&T, what parts of that, what subset of that maxed well into the strategic environment, technology environment, and budget environment that we are likely to be working in during that time.

So this was indeed a clean sheet of paper study. We were not constrained. The results here were not dictated in any way. But they were informed by those three elements that constrain the Air Force today and will likely continue to do so for at least the next decade.

We were asked to describe to the Air Force what the capability environment could look like in the 2030 timeframe. So the key challenge, the number one challenge, was to understand what capabilities could the Air Force have in 2030 in the air, space and cyber domains. And General Schwartz in particular was very clear in his articulation that he was also looking for those cross-domain insights that don’t neatly fit into one of the three Air Force domains.

But it’s very important to understand that the Air Force is not the National Science Foundation. It doesn’t support science for the sake of science. It does science to support future Air Force capabilities.

So as I was pointing out earlier, we are interested in S&T investments that the Air Force could begin today, perhaps continue today, and sustain that will then enable capabilities that fit into that environment that I was articulating for 2030.

So we were trying to understand what future Air Force capabilities would look like in 2030. And because it takes us in general about a decade to go from TRL-6 level technologies to fieldable capabilities, understanding the capabilities face in 2030 means we have to understand where the technologies we brought to in 2020. So what S&T investments can we start today to be able to get to that point?

So that problem of understanding the 2030 time environment is really, that 20 year environment is really two ten year

steps. A ten years S&T advancement, and then a ten year translation of those TRL-6 level technologies into fieldable capabilities.

Another key point is that the S&T that the Air Force is going to use to develop its future capabilities, much of the world will have access to the same science and technology, and they in turn will be using that in potentially very different ways under very different warfighting constructs than we do. So we have to also envision not only what we will do with those technologies but what others, including our potential adversaries, might do with those technologies. Then we have to understand what the counter-capabilities are that we would need to be able to offset those. And indeed, as we envision the capabilities that the Air Force could have in 2030, we have to make sure that those capabilities in turn are not readily countered by our potential adversaries. So it is in that sense a constrained, or as I like to say, an informed vision.

Then once we understand the 2030 environment, then we have to backtrack and say from 2030 where does technology have to be in 2020, and then what S&T investments will we begin today?

Ultimately this is not about telling the Air Force what capabilities it should buy. Indeed, as we get into the capabilities in a second, you will see there is no way that the Air Force can afford to buy all the capabilities that we're describing here. Instead we're trying to understand what S&T investments would enable a broad set of capabilities that play well in that 2030 environment.

So this chart I think is, there's no expectation that you will read all of that and I don't think you should, but the key point is that it makes a point that this was a product of the Chief Scientist office, but it was informed from a very very broad set of inputs that reached across the Air Force and indeed outside the Air Force and dealt with the other services, with OSD, with representation from the FFRDCs, from industry, and even from academia.

Beyond those representations on the working group, and we had members there from NASIC as well, from the MAJCOMs, from the

research community, and so forth, but beyond those representative of the working group, we spent the better part of a year going out into the broader Air Force including out in theater to look at operational environments and talk to our international partners as well at great length, and pull together a very large set of inputs.

Now the product that we'll see in Technology Horizons is not simply a distillation of those man inputs because that I think is not by itself all that useful. I think there are other ways the Air Force can tap into that.

Really, the job of the Chief Scientist is to stay at that 65,000 foot level informed down all the way to ground level, but then step back up to 65,000 feet and try to understand where the really valuable insights are. That's what Technology Horizons attempts to focus on.

If you'll go on the web you'll be able to find the public release version rather easily. If you can't find it, send me an email and I'll send you a copy, but it is something that I hope all of you in your roles will take a look at and see ways that you can contribute to helping the Air Force achieve some of those capabilities.

I mentioned the planning started the end of February, beginning of March '09. This was conducted in five phases. The draft final report, our total of 3.5 volumes, as I like to say. Volume I is the main vision. That's most of the meat that will be of interest to you. That was written to be publicly releasable, and indeed is.

There's a Volume II that is restricted access and provides a snapshot of things that AFRL, the Air Force Research Laboratory, is working on today. And an appendix to that, an 800 plus page appendix that's nothing but a set of frankly mind-bending road maps of every program that we have going on in AFRL today. Then there's also a SAT Level Volume 3 that's nothing more than supporting information for the [inaudible] in Volume I. Volume I is the one that I think is the really valuable one for you.

We are in the fifth phase of that right now. We have been since on May 15th when the final version, that initial draft, was taken through all the MAJCOMs, all the product centers. We got a broad set of inputs. Didn't dilute our message at all, but made sure that all of those advertent equities that were being stepped on that we didn't need to step on were addressed so that we had a final message that would not fail to get the embrace that it needs because of not paying attention to other organization's equities.

So that final product was delivered on the 15th of May. About a month later we had the public release version cleared. And since then, indeed since the first draft was delivered, we've been in the implementation phase where we have been working together with the broader Afghanistan, with HAF, with the Air Force Research Laboratory, the product centers, the MAJCOMs and so forth, to make sure that the key elements of that vision are in fact implemented and we're getting, I'm very happy to say, a very broad embrace of that whole process.

A lot of people imagined that this vision before it was released would be a list of the Chief Scientist's favorite technologies. I'll tell you frankly, if it had been that it would have been dead on arrival, and indeed I claim should have been dead on arrival because that is not what the Air Force needs. This isn't a document that isn't read once and then put either on a shelf or maybe on a lower place here on the floor, but is a document that's supposed to guide Air Force S&T investments over a period of a decade. IN order to do that it has to be much more than a simple asserted list of this important and valuable technology areas.

In fact Technology Horizons consists of the eight elements that are shown here and in total those eight elements comprise the S&T vision.

It starts with an articulation of a strategic context that the Air Force is going to be facing in that 2030 environment, and that's there because S&T, as I mentioned earlier, exists to support Air Force operations within that strategic environment.

The second element is a set of enduring realities. Even if the Air Force were to want to turn on a time and suddenly move into very different capability areas, there are a number of constraints or as we refer to them in this report, enduring realities that prevent the Air Force from doing that. These are, in effect, the boundary [inaudible] that constrain the Air Force. Articulating those as part of that vision is important so that we can understand how S&T investments measure up against that.

Then we begin to get into the new elements. We define 12 overarching themes which we'll look at in another chart or two, that collectively articulate some of the attributes that future Air Force capabilities are going to have in that environment. Then we begin to drill down the list like things. The report identifies a set of 30 potential capability areas that emerge from this process that fit well into that strategic environment, technology environment, budget environment, fits with the enduring realities, with the overarching themes, and so forth.

For every one of those 30 central capability areas which we'll look at, at least most of them, in a second, we identified the key technology areas that are needed to enable that potential capability area.

Out of that we identified a further set. It's not the bottom line, but it is a further component of the vision. We articulate a set of branch [inaudible] problems that the Air Force research community should take on to not only advance technologies but to integrate them into a set of demos for some real structured capabilities.

We then have the principal findings. Finally, and very importantly, a specific implantation plan that is now underway for ensuring that the elements of this S&T vision actually inform that Air Force corporate process that ultimately makes the decisions about what S&T we invest in. As I said, I'm very pleased to see that this is getting enormous traction not just in the Air Force research laboratory community, but much more broadly than that.

I mentioned the 12 overarching themes and I've listed them here. The way they're described, they are listed on the left hand side as a set of attributes that Technology Horizons believes they should have decreased emphasis in the future toward the attributes on the right where emphasis is increased. Understand, this is a matter of degrees and judgment. On any given system we're not talking about pegging the meter from the left to the right. We're talking about ensuring that the attributes, the collective 12 attributes on the right are properly reflected for the type of system that is under consideration.

Frankly, individually, if you read any one of those lines, to a technologist you would say that's kind of obvious. Look at some of the platforms to capabilities, fixed to agile, control to autonomy. Individually those are not surprising at all. Collectively they begin to paint the very highest level, if you will, picture of what future Air Force capabilities should look like.

Most of them are pretty well understood. There are a handful of them on there that are not. And I'll look at just two of them. Number five, integrated to fractionated. You generally think of it as being good when something is well integrated, and this doesn't speak against that. But it does say that up to this point in our Air Force history technology has in effect forced us to integrate most of the functions that it takes to fly an aircraft or a space craft or whatever it might be onto a given platform. That platform becomes large and heavy with attendant second and third order effects. It becomes very expensive. We may not be as willing to use it in every situation as we might want to. So those are all attributes that flow from having a heavily integrated approach to system architecture.

What technology is beginning to allow us to do is to take the core elements of that system and disaggregate them onto separate platforms and allow those platforms to operate in a spatially disbursed but coherent manner. So they still act as a system, but they are spatially disaggregated. They are now individually small. In fact you can envision a set of common platforms, canoes if you will, airborne canoes, that have common

propulsion, common airframe and what not, and have something like 500 to 2000 pounds of payload specific mass that allow you to customize each of these common elements into one of the fractionated elements of that together to comprise the system. By using relatively short range RM links or possibly even laser links at the ranges we're talking about, that's possible even in bad weather. And by intelligently fractionating the system so that the communication requirements between elements of this fractionated system are in fact quite low. Then it's possible to maintain link integrity and have this thing still operate as a system.

The advantage of that fractionation is that you can now compose a system for the mission that you need. So if it's a simple EOIR imaging mission, you may only fly that canoe by itself. If it's a hunter/killer mission, you may fly that together with a strike system. If you're going against a major adversary IAD system, then you may fly all the elements in a strike package. And indeed, you may add levels of redundancy to the individual elements in that architecture. If you work through the math behind that, it's actually a beautiful example of where the number, the cost burn on an adversary for denying U.S. strike capability when not one thing is coming at you or not three copies of one thing is coming at you, but say a system that's fractionated across five times say three copies, about 15 things are coming at you, you start taking out elements of that and your numbers have shrunk, go up tremendously to be able to eliminate even that capability.

So very useful insight for future air [inaudible] architecture in this case.

Finally number 11, I'll just mention a shift from cyber defense as we know it today, increasingly to cyber resilience. I'll have more to talk about that in just a second.

Number 12, the systems that we fly today for 50 years or more, not surprising to technologists, but a shift towards open architecture systems where we can far more easily gain the technology refresh cycle that you gain from your cell phone when you throw it away every two or three years and get a new one,

you wouldn't use a 50 year old cell phone. We want to not be doing that 20 or 30 years from now with our Air Force systems.

So beyond those 12 themes, the idea then was to envision what the potential capability areas are and we have a process we're going through that I'm not going to get into great detail on that. It was important that we are not recommending individual technologies. Professor XYZ at University ABC has this way of doing whatever the heck. That is much too fine a level of detail. We've aggregated those into technology areas. Maybe micro fabrication, for example, on non-silicone substrates. Then we look at what is the state of technology today, where could it be pushed with ten years of focused investment, and then what kind of potential capabilities that would enable certain system functions, could be produced from that.

That's all the process.

Now what I want to do is go through some of the highlights of the results that are contained in Technology Horizons.

The single greatest finding is that the Air Force can get enormous increases in capability, in manpower efficiencies, and in cost reductions through much much greater and much much broader and deeper use of autonomous systems. Systems and processes. So we're not talking just about more and better RPAs, although that certainly is part of this. But in fact the Air Force has many different kinds of systems and beyond that many different processes, many of which are very manpower intensive, parts of which, in some cases many parts of which, can be adequately, more than adequately. Can be automated or autonomized, I should say, because there's a big difference between those two, in the 2020 to 2030 timeframe to allow us to have not only a reduction in the manpower, in many cases manpower that has to be deployed. For example, if you look at certain elements of what goes on in a CAOC, parts of those functions can be autonomized. Autonomy here we're referring to autonomous reasoning and control. And not only would we gain manpower cost reductions through that, but if done correctly you can also get capability increases at the same time. We're going to be increasingly operating in environments where we're flooded

with more and more information, where the time scales on which we have to operate are going to get faster and faster. And frankly, humans will pretty soon no longer be the best way to do certain pieces of that.

So much greater use of autonomous systems and processes. Very very important.

The processing, exploitation and dissemination of ISR data is another case where not all, but certain functions can be autonomously performed. Certainly the cueing level, and we get great advantage that way.

A really important point here is that parts of the technology to enable this much broader and deeper use of autonomy already exists today. What we don’t have today is the ability to do verification and validation of highly adaptable, highly autonomous systems. These are near end state systems. The classical approach to a verification and validation where we present a system in all of its possible states with all of its possible combinations of inputs and try to ensure that the system will work the way it has to, we already cannot do that today. AS we go to even higher levels of autonomy and numbers of inputs that the system uses to make its decisions, the classical approach is not going to work. We’re going to have to have fundamentally new ways of certifying, reestablishing trust and autonomy.

A very important point is that already today all of you know, around the world, autonomous systems, primarily still remotely piloted aircraft, are being developed already today. Our potential adversaries also recognize the value that these highly adaptable autonomous systems can bring them. And they may very well be willing to field these kinds of systems and gain the advantages that they gave from that without burdening themselves with this V&V challenge.

I think the Air Force has probably the single greatest beneficiary of these more highly adaptable autonomous systems, has to take on the lead role in developing the fundamental scientific and engineering principles to be able to conduct V&V, to avoid that exhibitry.

The second greatest finding, and we touched on it a moment ago, is that today humans are still more capable than machines for most tasks, but by the 2030 time horizon of this effort for a much much larger set of tasks the natural human capacities are going to be far outstripped by the increasing data volumes, the processing capabilities and the decision speeds that are either offered by technologies or are demanded in order to take advantage of technologies. So we're going to have to move into much much greater augmentation of human performance than we do today. We already do low levels of this today in various ways, but what Technology Horizons is advocating is a much much greater use of human performance augmentation.

There are three specific ways that we're recommending to do that. The first couples with the previous chart. Greater use of autonomous systems as a way of leveraging natural human capacities to make up for those parts we're not particularly good at or we're not wired by nature to be good at.

The second one is to move away from human/machine interfaces to genuine human/machine coupling where the connection between you and the machine is no longer through a keyboard, to a screen or whatever, but where the machine will be able to tap into your own intuitive responses. And while that sounds far out perhaps to many of you, hopefully most of you are aware of the progress that's already been made on these EEG skull caps, being able to localize responses, still at a fairly coarse level today, but the science already exists to show that with sufficient focus we will in ten years be able to tap into many of your intuitive responses.

So if I'm looking at full motion video going past me, maybe at five or ten times natural frame rates, I may get an intuitive response that says aha, I saw something there. It may not rise up to the level where I will articulate that into wait, go back, I just saw something, but we'll be able to tap into that.

So connecting or coupling the human with the machine to be able to tap into the human intuition, which is a tremendously higher level of processing than what your conscious performance is something that's going to be important.

Many of you I think have seen, two years ago [OMNA] demonstrated an operator wearing an EEG skull cap being able to control a robot, telling the robot to stop, go, go left, go right. Trivially simple, laughably simple capability two years ago. But with appropriate focus, imagine what we could do with that sort of thing in 10 or 20 years from now.

Finally, direct augmentation, using what's happening in the world of prosthetics and implant technologies to be able to achieve that direct coupling.

Thirdly, looking at technologies for much greater freedom of operations in contested or denied environments, and there are here also three key areas that we've recommended focusing on. One is increased cyber resilience, moving away from static architectures. Think of a network today. Our networks are essentially standing architectures. Adversaries gain access to them despite our efforts to defend those networks. Once they're inside, they can watch how we operate. They have all day, all month, all year long to watch how we operate. Plan where to conduct attacks to have whatever effects they want to achieve, and even implant the tools to be able to allow those attacks.

Now imagine a system that makes use of the massive virtualization technologies that are happening in the [cloud] computing world, together with very agile hypervisors that allow that network, for example, to change its internal topology perhaps 100 times a second. So that if an adversary gains access they have almost no time to be able to exploit the advantage they had from getting that access in the first place. In effect negating much of the value of gaining access in the first place.

The second one is for precision navigation and timing in GPS denied environments. You all know that our potential adversaries are well aware of our dependence on GPS and you also know how easy it is to jam GPS. So ways of augmenting or supplanting GPS in those denied areas are going to be critical.

There the biggest payoff, and there are a number of them that are called out in the report, but the biggest one are these

cold atom or [inaudible] condensate technologies that make use of quantum interpherometry. In effect making use of the fact that atoms and molecules when trapped in a very narrow range of quantum states emit a nearly pure wave, and you can do interpherometry with those waves much the same way we do optical interpherometry in ring laser gyros and other approaches. But because the wave lengths are so absurdly small for these quantum matter waves, the level of precision, and more importantly the drift that you can maintain, how low you can maintain that drift, could allow you to operate for days, possibly weeks in GPS-denied environments and still not have less than GPS certainty in position, timing.

Finally, electromagnetic spectrum warfare technologies. Everything from dynamic spectrum access, spectral mutability and all of the things that we need to support a much much broader set of electronic warfare capabilities that we have today.

Very quickly here, two others. Processing enabled [inaudible] sensors. Some of our sensors today could be enabled with [inaudible] processing on say the back plate of a sensor. Things like change detection are relatively easy to implement today. With focused investment that looks not just to advance the sensor technology itself, but to allow the sensor to do pre-processing if you will, certainly at the cueing level, so we don’t have to consume these enormous amounts of bandwidth transmitting raw data on the ground just to look for cues. We can’t do it for everything, but for a substantial number of functions we will be able to do that kind of on-board intelligent sensor processing in the next decade or beyond.

I talked about the fractionated composable architectures, that’s absolutely critical. I think it’s a way of getting cost savings by having this common architecture that allows you to conduct operations across the spectrum of threats, from the irregular warfare environments all the way through to major conflict operations. Not necessarily by themselves. There’s an element of the way we operate as a system.

The report goes on and goes through a substantial number of other potential capability areas. It’s a total of 30. They address everything from manpower, energy and sustainment costs

all the way through to new capabilities. I think in the interest of time I'm just going to click through a couple of these charts before I wrap up, and I'll be happy to try to take any questions when we're at the end. I want to leave some time for that.

We talked about the need to reduce fuel costs. Many times our ISR platforms will, they're obtaining lift aerodynamically and in so doing consuming fuel and driving up maintenance hours on things like engines and what not. Airship technologies, while certainly not the solution for every case, for some applications that provides a way of having systems that can remain aloft months or even years at a time and in some cases those can be large enough to be outfitted with very impressive sensors and could meet a number of emerginal requirements that we may have in the future.

High altitude, long endurance aircraft, I think you've followed what's been going on in that world with solar powered regenerative fuel cell technologies and so forth, battery storage technology in some cases, that allows some very impressive time aloft. Even though those systems are very early, they could be out sometime down the road.

Further with airships, partially buoyant cargo airlifters, for example, we think could have a potentially valuable role for certain kinds of systems.

Hybrid wing body aircraft where we use aerodynamic improvements to get substantial increases in fuel efficiency without touching the propulsion system necessarily. We had X-48B fly for the last two years and demonstrate at about a 28 foot scale that this kind of performance is for real. The Pershing S technologies for stitched composite fabrication with broad reinforcement has moved a long way. And we could build pressure vessels that allow these kinds of non-circular fuselages to be built.

Many of you are aware that we had the first flight of X-51A earlier this year. Largely successful. And really has shown that the technology in [inaudible] propulsion has advanced enormously since X-43 which was hydrogen fueled. X-51A was JP

fueled and it had a cooled combustion. That is to say the fuel [inaudible] combuster. That is one of the really key steps that had to be moved forward.

If those hypersonic propulsion and vehicle technologies continue to advance, that enables things like hypersonic ISR vehicles. Generally at the Mach 6 range where the thermal management considerations are entirely manageable. Especially some of these notional architectures that have been worked through in reasonable detail, show that you can have vertical takeoff or a lot of landing systems that can have very very rapid response and be able to get essentially anywhere on the globe without the predictable appearance.

Finally, this is somewhat further down the road and actually probably beyond the 2030 environment, but possible rocket-based combined cycle systems for two stage to orbit access to space. Ways that could potentially, if the technology progresses correctly, significantly drive down the cost of putting things in orbit.

Finally, directed energy is absolutely critical, especially at the tactical scale where you hear much less about it. For low collateral damage, strike, the kind of fights that we're in today, and for all other kinds of uses, even in major combat operations, the ability to do strike and self defense with airborne laser-based tactical scale direct energy systems is absolutely critical. We're making good progress there with our partners at DARPA in advancing the underlying bulk solid state laser technologies.

In the Air Force Research Lab, advancing the solid state fiber laser technologies that are likely to come behind that.

I mentioned the Air Force can't do all those 30 things. I haven't actually given you the whole list, but it's in the report, but we're not advocating in Technology Horizons those capability areas in and of themselves. We're advocating the technologies that enable those capabilities. What we've done is mapped those 30 potential capability areas, the PCAs, across the 12 service core functions. That's done to ensure that whether the Air Force ever develops PCA number nine or not, the

technologies that underlie number nine and underlie the rest of these, if they are cross-cutting enough across those 30, then we can ensure that we are in fact advancing technologies that will support our service core functions no matter what the Air Force ends up building.

So for every one of those 30 PCAs, here for example PCA-1, we've listed the underlying key technology areas that would need to be addressed or that together would allow that capability area to be advanced.

As I mentioned, we went beyond technologies and proposed a set of four grand challenge problems that would force us in effect not just to look at technologies, but from the word go, to be thinking about integrating technologies and developing them in a way that allows them to be integrated into some pretty challenging demonstration problems. Needless to say, the choice of those four challenge problems has been made to focus on things like cyber resilience, autonomy, GPS [inaudible] and so forth. The themes in Technology Horizons.

The main take-away points, I think I'm going to get off the stage or more precisely try to get to any questions you might have in just a second, but the main take-away points are that the Air Force really only has the luxury of doing one of these half-level, 65,000 foot views of science and technology and how it plays into the future environment, about once every decade. And it's been 15 years since we did one. I think the challenge that the Air Force faces put us in a position where this was the right time to do that. The leadership tasked us to undertake that effort, and that's not completed and is being implemented, and I would encourage all of you to get a copy of Volume 1, read it, send us any feedback you have. We're always open to inputs. But in addition to that, look for where you agree or disagree and where you can help contribute to the debate that is going to make sure that the Air Force has the best capabilities of anyone in the 2030 environment.

With that I think I'll stop and if there are any questions I'll be more than happy to try to take them.

Question: Congratulations on your approach. I'd like to extend your views on what you think of the adequacy of the human capital in the S&T infrastructure to realize your vision.

Dr. Dahm: That's absolutely critical. If you don't have the work force and you don't have the skill sets, et cetera, you're not going to get any of this. There are a lot of people that I think correctly say STEM, as we call it -- Science, Technology, Engineering and Mathematics -- is losing some of the role that it played in our society when we built the Air Force up into the great service that it is.

I think that's true, and the Air Force and broader in the nation we're taking steps to try to address that as best we can. I think it's critical. But I think we also talk about the stem activities that are happening, or the stem developments that are happening around the world. We're going to be partnering with a much broader set of people on the research scale, and maybe even in some developments to be able to enable pieces of what you see here.

So I absolutely agree, we have to have that. We have to cultivate it here within the U.S. We have to also look for where it makes sense to partner more broadly and tap into the work force we need. And the Air Force is doing that. We have offices in Europe and Asia and South America that try to tap into those.

Question: What about the infrastructure, like the wind tunnels and --

Dr. Dahm: That's the other half of it. It's simply a fact that the set of technologies, the set of facilities that you have to have to be able to do high end systems these days is so much broader than what it was in the past, that in 1947 we were able to focus on say capabilities at the Arnold Engineering Development Center. Very expensive, but very high value capabilities.

Today we have a much broader set that we have to focus on. So how we do that is going to require some very good judgments to be made.

I think you can’t make those decisions unless you know where you want to get to, and hopefully this report will help that debate.

Thank you.

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