Major General Thomas Masiello
"Air Force Research Lab Game Changers"
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Maj Gen Masiello: Thank you and good morning. I'll tell you, it is a beautiful Washington DC morning and what makes it even better is I don't live or work here anymore. [Laughter]. I didn't mind living here actually, but I'm glad I don't have to work here.

Anyway, thank you for coming. I'm going to just spend hopefully about 30-35 minutes. I'd like to provide at least a few minutes for questions. But I usually start off with a joke, and I see General Heffelbower here and told me he was going to attend and he said hey, don't mess up. So that joke is kind of lame anyway so we're going to skip the joke and we'll go right into a real short video.

(Video shown)

I've seen that, literally I've seen that hundreds of times and I still get goose bumps. I don't know if it's the geek in me or not, but I absolutely love it.

In AFRL we have I guess what I would call three lines of operation. Or the three R's, we call it the three R's.

The first R is Revolutionary. So as a research laboratory, I mean the first thing I always get asked as the commander, well what's next? I mean we have GPS, we have stealth. Well that's our revolutionary line of operation. I'm going to talk about three of those today and that's hypersonic, directed energy and autonomy - basically technologies that will change the nature of warfare.

The second R which is by far the biggest part of our portfolio- Relevance. What do the MAJCOM commanders want? Well what are you doing for me? I'm necessarily in command now. We measure Revolutionary technologies in decades. Relevant is years.

Our final line or our final R is Responsive. That's getting technology out into the field in less than a year. I give the guys eight months, maybe up to 12, and that's where we have an

urgent operational need, if you will, from either a COCOM or a MAJCOM, something that we can turn quickly and get it out to the field fast.

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So as the commander, one of my most important duties is be able to articulate the value of Air Force S&T. As you know, the budgets are under extreme pressure and if you look at our budget, we've traditionally been funded at about two percent of Air Force TOA. If you look at Hap Arnold's quote there in the middle, I can't say it any better than Hap Arnold said it in terms of the value of research and development in terms of providing a world class Air Force.

I will tell you the senior leaders in the Air Force today value S&R just as Hap Arnold did.

You hear about these fully funded acquisition programs -- F-35, tanker and bomber -- but you don't necessarily hear about Air Force S&T. We're fully funded as well. We've got 100-percent of our requested funding through the FYDP, and two percent of the Air Force TOA, that's about $2 billion, $2.1 billion. That's a lot of money in anyone's checkbook.

We also execute another $2 billion or so of other people's money. I look at that as an affirmation of hey, we must be doing something right if we have outside organizations willing to invest in our R&D.

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So this is our mission. We're part of AFMC. They're down to five centers now. We are an integral part of those five centers and we couldn't do really what we do, especially with LCMC there, but if you look at the mission statement, and what I tell our folks, the most important word up there is leading. Our job is to help lead and shape the national tech base to provide S&T solutions to our Air Force. And it doesn't mean it necessarily has to come from AFRL.

Now we do internal research and of that $2 billion though, nearly 70-percent of that goes to industry or academia. So it's just not all about doing internal research, but by doing that internal research, yes, we have real breakthroughs that we get to the warfighter, but it's more important to understand the state of the art, to make the contacts, to know where that quality of research is being done, and go after that.

Now General Keyes and I, we've had some discussions that maybe we are about, maybe too much about what we're doing internally and maybe kind of competing with industry. But that's not what we ought to be doing and I'm looking forward to having that discussion. Maybe we can discuss that here, if you think we're more focused on getting our stuff out versus what is available not only nationally but more globally.

It's really important I think, especially our folks, to understand that that is truly our mission. What is the best S&T?

Then if you look at the final sentence there, the final three words underlined -- air, space and cyberspace. We are one of the only organizations outside of Headquarters Air Force, outside of the Pentagon, that have all three domains as part of our primary mission. It really makes us a unique organization.

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I'm not going to go through a Lab 101 because we really don't have enough time, but that gives you an idea of AFRL. We have nine technology directorates spread across the United States.

A couple of things I'd like to highlight. In Arlington, Virginia, that's our Office of Scientific Research. They don't do any internal research, per se; their job is to fund basic research, what we call 6-1. They have about $330 million and most of it is focused towards colleges and mostly universities within the United States, but we also have three international offices tied to AFOSR in London, Tokyo and Santiago, Chile. And their job is to seek out and try to leverage that great research that's being done globally, because more and more, I mean 20

years ago maybe the U.S. was the center of R&D research. That's no longer the case.

Another thing I want to point out, you can see a little brown box there in Tennessee, Arnold Air Force Base, Tennessee. We have just stood up in the last week an operating location there to build our core competency in hypersonic. So, one of our game changers that I'm going to talk about today is hypersonics. We're trying to build a competency within the Air Force that has this technology, which is real, which is more than just PowerPoint deep, as it's transitioned now into or hopefully soon will be into a program of record. We need experts in the test community, in the acquisition community that understand that so they can shepherd this technology as it leaves the lab and goes out into the field.

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What kind of context are we dealing with here? What helped shape what we do? Well, I listed just a few things up here, and they're not new to anybody. The limited budgets are the new normal. We have to figure out how to leverage the precious dollars we have.

I already talked about the R&D competition we are facing and it's important to leverage good work being done wherever it is. Cyberspace, we are on our heels and you all know that. We are being attacked every day. In a military operation you want to take the initiative. Well, in cyberspace we are anything but on the initiative. Now we're working some medium and longer term things to include secure processors, secure architectures, those sorts of things, but near term we have some major issues.

The spectrum is another area that's becoming contested. One way is by the commercial sector. More and more spectrum is being sold off. Also, potential adversaries can go to Radio Shack and buy commercial off-the-shelf products and challenge us in an area where we used to have dominance.

Space. Another area where we once dominated. Maybe there was a handful of space-faring nations 20 years ago. Now there are over 100. And the commercial versus military totally dwarfs the

numbers in space in terms of satellites and as General Welsh says, space situational awareness, that's kind of the coin of the realm and we're putting a lot of resources, especially in GEO.

Then finally, we're shifting from Iraq, Afghanistan towards the Pacific and the anti-access aerial denial environment. It's more of a high threat environment and we've made changes in our portfolio to support that strategy.

Next please.

Really the game changers are part of that.

This is just the listing of our technology focus areas. I just put this up there just too kind of give you an idea. I'll tell you another challenge I have as the commander is articulating the depth and breadth of our portfolio. We had a review with Dr. LaPlante and Dr. Endsley, the Air Force Chief Scientist. It took two days, two straight days to really to be able to kind of get your arms around our portfolio.

We had an engagement with the Chief and the Secretary just about a month ago now. It was four hours. And I'll tell you the truth, we just barely scratched the surface. So, if you look at these tech focus areas and on the left-hand side it kind of gives you an idea of the level of funding and it adds up there at the bottom, I'm sure it's hard to see, about $2 billion. Again, this is just to help talk about and help articulate what we do.

We do not plan by tech focus areas. We do our planning and programming by Air Force core functions. So the MAJCOMs, they will be assigned the lead integrator for 12 of those core functions. ACC has five -- air superiority, global precision attack, personnel recovery, ISR, and command and control. So we have teams with the acquisition community, the S&T community, and then the MAJCOMs. They work through the gaps in requirements. We propose S&T solutions. The acquisition community works kind of the developmental planning. And we actually have technology roadmaps as part of what's called the core function support plan signed off by, again, well really the

MAJCOMs own it and they submit it but there's a technology annex to that.

Next please.

So let's talk about the game changers, the focus of this briefing.

We have three of them up there.

Hypersonics. What really put hypersonics on the map was our X-51 and I have some video of that. That flew in May of last year, and it was truly an aviation milestone. The vehicle flew for over 200 seconds. Had scramjet power. The previous record was 7 seconds. Again, now by proving that again, it's real. It's just not PowerPoint deep, it's really added a lot of momentum to the program.

The second one is directed energy. Under directed energy there are two areas. Lasers and high powered microwave. So we've had lasers around for a long time and we had the Airborne Laser Lab back in the '80s. But those were chemical lasers. The advantage of chemical lasers, they produce a heck of a lot of power. The disadvantage is, you've got to carry a flying Hazmat around with you and you need a 747-size aircraft to do it.

The real breakthrough over the last couple of years is in solid state and electric lasers. Now you can actually package it to eventually fit on a fighter size aircraft. We have roadmaps and I'll show you kind of how we're getting to that.

And then in high power microwave, we demonstrated, this was in October of last year, not '13, but October 12, where we integrated a high powered microwave package onto an air-launched cruise missile, and flew it against a representative target set, and I'll show you some vide of the results. Highly, highly successful.

And then finally, autonomy. This has the potential to dwarf everything. And when you talk about autonomy, it's not taking the Airmen out of the weapon system, it's building an effective

manned or human/machine team. And I'll talk about that here too.

Next slide.

Let's go into hypersonics. Let's go ahead and start the video at the bottom. This is the X-51 being launched from a B-52 at 50,000 feet. It's got an ATACMs booster. It accelerates up to Mach 4.8, climbs to 60,000 feet, and you'll see a puff of smoke and when you see that puff of smoke, that is an indication that the ATACMs booster separated and the scramjet lit.

It's not the most exciting video in the world.

So the puff of smoke is where the ATACMs booster separated. Scramjet lit. Then it accelerated to Mach 5-plus. Again, it flew for 209 seconds until it ran out of fuel, and then we did some maneuvering before it crashed into the sea. This was a huge aviation milestone.

I will tell you, a good lesson learned from that program is 1) that hypersonics and scramjets are real. The other lesson is failure. So that was the fourth flight of a four-flight test program.

The first flight, the scramjet lit but didn't stay lit. It flew for under 10 seconds or so. But they consider, okay, one of the big technology risk areas is being able to light the scramjet at Mach 4.8. Have you ever tried to light a cigar on a golf course on a windy day? It's hard. Can you imagine going at 4.8, it's really hard, but they got it lit. So they said okay, we kind of understand the envelope now so they considered it a good success.

The second flight it did not light. We said okay, we've got to go back and do a lot more evaluation. On one hand it would be considered a complete failure. On the other hand it was much more important than even the first flight. They went back and redesigned the inlet.

On the third test, one of the fins broke off while it was accelerating, so it was kind of a no-test. I mean it wasn't really an opportunity to test the scramjet.

There was actually discussions on should we cancel the fourth one or not. But within an S&T environment you have to protect the opportunity to fail or else you're not going to make any real progress.

Now it's one thing if you're an acquisition program and you're going to IOT&E. No, you don't want to fail then. But you have to understand in early R&D and S&T there's going to be failures. Yet, they went ahead with the fourth one. Huge success. Again, really added momentum to the program.

What does hypersonic bring, especially in an A2AD environment? Well, it brings survivability and it brings the ability to hit time sensitive targets.

Next, please.

Here's kind of our, just a very high level road map of where we're going in AFRL. The first thing, we're going to concentrate on is weaponizing it. Turning it into a cruise missile. And we have two programs that we partner with DARPA. We're both throwing in $300 million each and at the bottom there it shows HAWC, that's Hypersonic Air-Breathing Weapons Concept, basically a scramjet. And then another program, Tactical Blue Squad where we're just going to accelerate it to hypersonic and then it glides in. We're working both of those programs again with DARPA and we're going to have demonstrations within the next five years on both of those.

Probably the highest risk area from a weapon aspect is a Seeker. So if you're going to hit time sensitive targets you have to have a Seeker in the end game to hit mobile targets. And integrating a Seeker in the front of that platform is going to be right now the biggest technical challenge.

As we move up into the 2030 time frame, we're going to scale up, and that MSCC stands for Medium Scale Critical Components. So hey, can we build kind of an ISR or maybe a strike platform?

But by 2030 it's not going to be a weapon system that we would consider a totally fielded system like we have today. It might be recoverable, not necessarily reusable. It might take days to turn it as opposed to a four hour combat quick turn. It may have limited service life. But we're doing is really not a huge amount of investment right now. But enough to mature the tech base to kind of understand what kind of capability we can have in the 2030 time frame. And then in 2040, if we make the right investments, that's where you'd have a fully reusable combat ready, persistent hypersonic vehicle.

Next please.

We're going to change our direction now and talk about directed energy.

Lasers are probably the one area that's been over promised and under delivered forever.

Let me go back to hypersonics for a second. You don't have to change the slide.

So last year at AFA we won the Aleson Award Trophy for the X-51, and when I went up to receive the award at the Wednesday night gala, General Moellner hands me the award. We're all proud and everything. And he says "Tom, I've always said hypersonics is the technology of the future and always will be. Guess what? It is truly, it's real now." I can't over-emphasize the significance of the X-51.

I'll also tell you I'm a little miffed at the Collier Trophy Committee where we competed for that and we lost to the Navy U-Class. Okay, whatever. So you flew a UAV in 2013? Big deal. I mean we had -- [Laughter] -- a true milestone here. And I'll tell you, 20 years from now people will talk about this before they'll be talking about that U-Class. Anyway, whatever, I'm over it. Kind of. [Laughter].

So directed energy. Again, over promised, under delivered, and I'm telling you, I was very leery about some of the progress that our folks have been touting. I said, you've got to prove it to me. Because before we're going to go out and do this

again and get our legs cut off, we've got to make sure that it is real. We've had two independent teams come in, and the most recent one was IDA, part of what's called an ISET. It's a team that I kind of control as the commander. They came in and said not only is the technology matured so you can start talking about weaponizing it, you're moving too slow. So I just can't over-emphasize the progress we made in solid state lasers.

Initially we're looking at more self-defense, maybe blinding IRSTs and then eventually going to destroying soft targets. And eventually getting to, you know, a hard target kill with selectable effects. Think of the magazine depth that you can have.

Then high power microwave, the Champ. I've got some Champ video. Again, until we went out and flew it, and that's another lesson learned I think for the S&T community is demos. Demonstrations. They are expensive. Even our $2 billion budget, it sounds like a lot but when you start parsing out for demonstrations, it eats up a lot of coin, but you have to demonstrate it before people consider it, especially something revolutionary. It has to be demo'd before people believe it's real.

Next slide, please.

So we're going to look at lasers first. This is our road map. Right now in White Sands on North Oscura Peak we have what's called the HELAD Laser, High Energy Laser. It's up there in the upper right. It looks like this big monster, but actually the laser itself is packaged in a suitcase-sized area and it's getting up to 100 kilowatt class or so. And we're going to have it, it's ground-based, and we're going to use it to look at the ability to engage missiles and other type targets out there on White Sands. We're kind of reducing the risk as we go to the next step.

The next step is to put a laser in a pod and fly it on a fighter. Now we're looking at maybe just tens of kilowatts, not a huge amount of energy, but I'll show you something we did with less than five kilowatts. I have a movie here. But this is

very important for risk reduction of integrating a laser on a fighter.

So you have air flow issues, you have vibration issues, you've got to get the optical train. I'll tell you, DARPA has done the bulk of the investing in the solid state laser area. AFRL, our expertise is in the optics train and being able to steer and focus the beam. Looking forward to actually trying to get it integrated onto a pod and reduce the risk as a step towards eventually, and if you see it up there in the 2030-ish time frame, integrating a high energy laser onto a fighter size aircraft.

It's really all about size, weight and power, and thermal management.

So that's another big technical challenge, not only just developing the laser, but can your aircraft generate enough power and then dissipate the heat to support it.

Next please.

Let's look at this laser here. This is in 2009, this is less than five kilowatts. You can see what it did to a UAV. It's still a decent amount of energy and can actually accomplish military type missions.

Next slide.

This is a radome. This is at Arnold. It's in a wind tunnel at Mach 4. So we want to understand the effects of steering a beam on a surface to air missile radome and that's one of the toughest, that's the hardest part of a missile is the radome itself. You can see it blew it away.

Next please.

Let's talk about high powered microwave.

Go ahead and run the video, just so you can kind of get an idea of the concept. This is a little cartoon. Fire the high power microwave. And there's one major aspect of this cartoon that I

want to highlight it illustrates. It's the ability to steer that beam. So if you send something downtown, you're able to at least target a building, and if there's a hospital across the street, you're not going to shut down the hospital either. It doesn't just spew electrons all over the place. It is actually steerable and somewhat precise, at least by the building standards.

So I'm going to have some video of the Champ. We had two target sets. They were set up in Utah, the UTTR. We have kind of an office building there on the top in the middle, and then more of a hardened target with no windows and that was simulating a chem/bio type facility. We had DTRA fit it with representative electrical equipment and we just wanted to see okay, how well does it do.

Go ahead and run the top video. This is against just the office building. And you can see the computers, I know it's probably hard to see. You can see the computers were up and running and then when the Champ flew by, and I know you can't see the Champ, it just went by too quick, the computers went blank. Play it one more time, please.

You've got the screens, went by, they went blank.

Then on the bottom, again this is even less illustrative, but -- this is the chem/bio facility. The computer screen's up. It goes out. DTRA confirms that would have destroyed what other batch was in the process of being made.

Again, this capability is real. It fit on an operational weapon system.

Let's go to the next slide. So this technology is available today. Where we're going in AFRL, we're going to shrink it down. And we've already made significant progress on shrinking some of the critical components to be able to package it into maybe a JASM-ER size weapon. Then eventually integrate it into a reusable platform.

We had the Red Team look at this and they validated the results. Again, it's not on the cusp of being available, if we made the

decision today, the technology is mature enough where we can field it in a fairly low risk acquisition program.

Next slide, please.

Let's talk about autonomy. Autonomy, again, it's not about taking the Airman out of the weapon system. It's about making an effective team. This area is probably the most immature, and for sure harder for me to talk about it than the other two.

There are a lot of terms being thrown around. All kinds of different terms of what we want to do. But I think kind of what the essence of what our research is on, is we want the machines to make decisions. We want the machine and individual to be viewed as team mates. Then we concentrate on machines doing what machines do best and have them do those tasks to take off the burden on the individual, the human, and let them do what they do best. So that's kind of the essence of where our research is being focused. Why now? Why -- I already talked about hypersonics and directed energy where we've gotten to the point now that I feel comfortable standing in front of all of you and talking about it, that we're at the point where it can be fielded in operational systems in a relatively reasonable risk level.

Autonomy, I'll tell you some key technology areas that have just exploded. Number one; wearable sensors. So you talk about the Apple watch, that just came out and there's all kinds of shirts you can buy and other things you can wear and you don't even know, you can't even tell that they're sensors monitoring your bodily functions.

We are adapting that more to the battlefield use, but more importantly, as we try to integrate and go forward on this human/machine team, now this team, the machine can understand maybe the stress level of the operator, can understand if the person is distracted, what's his level of competency. We're doing research in sweat where there are markers in sweat that can indicate stress levels. So you can imagine now, when you fly with a crew mate (I flew F-111s). I knew when the [WIZO] I was flying with, when he as task-saturated. He definitely knew when I was, and distracted. So now hey, you can have a machine,

your digital team mate, can kind of have a better awareness of what's going on.

Another area that's really facilitated this is just the amount of commercial, non-defense commercial sector being poured into this. That area has exploded as well. So it really sets up a good combination for us to exploit.

Hypersonics is about speed. For sure lasers are about speed. It's the speed of light. Well, autonomy is about speed. Speed in decision-making. Speed in getting inside your enemy's OODALOOP. It's making decisions at the speed of machines, essentially.

Next slide please.

This is the road map. There are kind of two lines of operation initially. One is safety and the other one is efficiency. One product we're very proud of in AFRL is the ground collision avoidance system. It's actually being fielded on the F-16 next month. Can you imagine how many lives will be saved once we integrate that program into the F-16? And there are road maps for the F-35, F-22, and F-15. Again, that's about safety. But we learned a lot. That capability was probably available for the last ten years or so. We got a lot of push-back from the pilot community. Is it going to kill me? Is it going to interfere with my ability to do the mission? What kind of indications do I have? But we learned a lot. Really, just a simple application of what will eventually be autonomous operations. That is that trust, the trust of the individual working with their machine. They have to be able to trust that data, and they've got to give them indications to build that trust.

The next step on that is air collision avoidance. I have a simple video to kind of show where we are on that. That's both for manned and of course unmanned platforms. It's very important when operating in the national airspace to be able to kind of sense and avoid. I'll show you where we are. Very interesting.

Then the efficiency piece. PET. What's a natural place to focus our effort right now and that's on ISR? We're just collecting huge amounts of data. We're overwhelming the analysts. We don't have the manpower to provide the analytical capability given all the data we've collected. So it's a natural fit. I'll show you a few examples of where we're working on that.

We talk about unmanned systems, but you know, unmanned systems right now take a lot of men and women -- There might not be a man or woman in the cockpit, but there's a heck of a lot of people and force structure supporting that. So in autonomy we are going to be more effective, but as you know with the limited budgets and the pressure on manpower, it will allow us to efficiently and effectively operate with less.

Then as we go to the near term and talk about defensive systems. You'll have on board, on manned aircraft, a pilot associate or assistant to be able to give recommended courses of action based on the threat. It will be both in what weapons should be selected when, what targets should be hit and those sorts of things. Again, maybe it will make recommendations. UAVs, you can talk about actually making those decisions on board. But still, again, somewhere there's got to be an individual in the loop. Then bringing it up for command and control and for ISR. Again, automating those systems that machines do best to free up the individual. And then finally, kind of merging those into where you have maybe an unmanned wingman sort of thing. The possibilities are endless in this technology.

Next slide.

Let's look at just a few videos. This is the air collision avoidance system.

Go ahead and run the video.

(Video shown)

Okay, so you go big deal. There was a target out there. The aircraft sensed it, made the turn, and then corrected course. That's the whole idea. It's no big deal. It was done

seamlessly. Now there was a UAV surrogate, there was a pilot in the aircraft for safety, but the aircraft sensed it, made a turn, and then corrected back to course-- very very seamless.

Next slide. Next video.

I apologize for the South Park like animation on this thing. But you have an -- This just shows the level of maturity and it is immature like South Park. So you have an aircraft. It was given a task. And the task was to fly CAP. If it sensed a threat, depart the CAP and engage and then once the threat's clear, go back to the CAP.

Can you run it again, Darnell?

In the upper right you've got the aircraft flying CAP. And that was its role. That was the role that it was given and that was the priority until you sensed, it senses a threat, engages the threat, and then once it senses that the threat has been eliminated it goes back to its CAP.

Now we were partnered with the Navy on this. It's very immature, but it kind of just shows you our thought process and where we're going as we mature this technology.

Next please.

This is an ISR example.

(Video shown).

Next please.

That's it. I'm going to go ahead and end there because I want to provide a little bit of time for questions.

These are my priorities. I just put them up there. I'm not going to go through them. As AFRL, we're leading the S&T for the Air Force. The Chief and the Secretary just published the document, "A Call to the Future". We looked at that document, it's a 20 and 30 year look and helped shape our priorities of where we're going.

Next slide.

That's it. I've got a few minutes for questions.

Moderator: Thanks, sir. We've got several questions concerning institutional relationships. Your relationship with industry, what you expect from industry, your relationship with DARPA and other service-related R&D facilities and your relationship with international --

Maj Gen Masiello: That's great. Put that second slide up. Great question.

First of all, if you look at that last line, that last priority -- engagement in partnerships, it's unbelievably important. But let me talk about industry real quick.

I believe industry, and I tell my folks this-- they are our most important relationship. People go "well, what do you mean? Isn't the warfighter?" Well, yes, in one respect, but in another respect we transition our technology through industry. There might be small examples where it goes from the lab right into the warfighter's hands, but that's tiny.

We don't get our technology out of AFRL unless it goes through industry. So I think they are our most important relationship.

I also firmly believe that we need to do a better job, AFRL, in communicating our road maps, and vice versa in terms of where is industry going with their IRAD. And we can leverage each other's precious dollars. In IRAD, in industry that's very precious to get IRAD authority. So if we can work together, understand our road maps and interface with the warfighter too. If we can talk about okay, here's where we believe their gaps in requirements are, and get your perspective, we can be so much better off.

International, very very important. I have a strategic engagement plan for when we do our international engagement. Again, to leverage some of that great work being done overseas.

Then DARPA, by far they're our single biggest relationship since they fund us to do work for them. As you know, DARPA, they're just program managers. They fund us to several hundred billion dollars a year to do research for their projects.

Moderator: We had a couple of questions having to do with live virtual constructive. Can you kind of define it, where we're going, what the vector is?

Maj Gen Masiello: That's a great question too. LVC, we are embarking on, along with ACC, they're our transition partner on advanced technology demo in LVC. So it's over a three to four year period, the whole idea, and it's going to be at Nellis Yet, the idea of it is not Nellis centric. This can be implemented anywhere. This is all about taking advantage of the huge amount of strides we've made in computing and electromagnetics and everything, and really, the science behind simulation as well, to fully integrate an LVC capability for the first time.

Moderator: I had several questions. I thank you all for these. I will hand them to him so he can look at them and know what was on your mind. But sir, thanks very much for being here and sharing this information with us.

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