DEPARTMENT OF DEFENSE BLOGGERS ROUNDTABLE WITH WERNER DAHM, PH.D., CHIEF SCIENTIST, U.S. AIR FORCE SUBJECT: KEY FINDINGS OF THE AIR FORCE "TECHNOLOGY HORIZONS" STUDY TIME: 11:03 A.M. EDT DATE: MONDAY, SEPTEMBER 13, 2010

(Note: Please refer to www.dod.mil for more information.)

PETTY OFFICER WILLIAM SELBY (Office of the Secretary of Defense, Public Affairs): I'd like to welcome you all to the Department of Defense's Bloggers Roundtable for Monday, September 13th, 2010. My name is Petty Officer William Selby, with the Office of the Secretary of Defense, Public Affairs, and I will be moderating our call today.

A note to the bloggers on the line: Please remember to clearly state your name and blog or organization in advance of your question.

Good morning. Who's joining us? Good morning. Who's joining us?

(Cross talk.)

PETTY OFFICER SELBY: With that, our guest is Dr. Werner J.A. Dahm, Chief Scientist, U.S. Air Force. Dr. Dahm will discuss key findings and summarize major elements contained in the recently completed Air Force Technology Horizons effort. With that, anybody who does not have their phone on mute, could you please do so now? And as we get to you, you can unmute and ask your question, and then please remute it after that.

Sir, Dr. Dahm, if you have any opening statement, you can go ahead with that now.

MR. DAHM: Sure. Thank you. And good morning, everyone.

The attendees here at the AFA conference just heard Secretary Donley state in his keynote address that the Air Force has completed -- (audio break) -- and implementation of Technology Horizons is among our major accomplishments this year in the Air Force. And last year, at this same conference, the attendees heard General Schwartz, the chief of staff, first publicly disclose that the Air Force had undertaken this

Technology Horizons effort to map out where it was going to be focusing its S&T efforts disproportionately in the coming decade and beyond.

Very briefly, Technology Horizons is the next in a roughly every- decade science and technology vision that is conducted at the headquarters Air Force level.

In my role as the Air Force chief scientist, my office led the development of this major four-volume document to map out those disproportionately valuable technologies that the Air Force is going to have to invest in over the next decade and beyond to meet the three elements of what Secretary Donley likes to call the trifecta of challenges that the Air Force faces -- namely, the strategic environment, the technological environment and the budget environment between now and about 2030 or so.

So the major findings that Technology Horizons -- and volume one of that four-volume series is publicly releasable -- the major findings include quite a number, but the three big ones are, first of all, that the Air Force is going to have to do far broader and deeper use of autonomous systems and processes to get manpower efficiencies, which we desperately need, as well as capability increases to meet some of the challenges we face.

The second one dealt with human performance augmentation -- again, to get many of the benefits that we noted above; that is to say, the augmentation of humans in part through greater use of autonomous systems and processes, but also much, much deeper human- machine coupling, as opposed to human-machine interfaces, as humans are recognized as becoming increasingly less well matched in terms of their natural capacities to the demands that technology has; and then finally even going so far as direct augmentation of humans using technologies in some cases developed from the world of prosthetics and elsewhere.

And then thirdly, technologies for greater freedom of operations in contested and denied environments, and those include quantum-interferometry approaches to provide us GPS-like capabilities for PNT, even in GPS-denied environments; a shift from cyber defense to cyber resilience using technologies for massive virtualization and (natural ?) hypervisors, and then finally, technologies for electromagnetic spectrum dominance in the increasingly crowded and contested EM (ph) environment that we work in.

So I think with that, rather than going into more detail on what's in Technology Horizons, I'd prefer to turn it over to you and try to address your questions.

PETTY OFFICER SELBY: Yes, sir, thank you. And we had a few more join us? Did anybody else join us? Q (Jean ?) Montgomery, Air Force.

PETTY OFFICER SELBY: Okay.

Q Thank you.

PETTY OFFICER SELBY: You're welcome.

Q Tim Oren (ph), Winds of Change.

PETTY OFFICER SELBY: Okay -- and you said it was Tim?

Q Yes.

PETTY OFFICER SELBY: Okay.

All right. Robert, you were first on the line, so you go ahead with your question.

Q Robert Haddick from Small Wars Journal. Doctor, as you know, many other state and perhaps even non-state adversaries are rapidly acquiring the scientific engineering skills that you described in the Horizons report. How would you assess the risk that the United States military may face some kind of technological surprise in the decade or two ahead at the hands of potential state or non-state adversaries in the technological dimensions that are described in the report?

MR. DAHM: Yeah, thanks, Robert. You're absolutely right. And if you -- it appears that you've read the public-release volume, so you know that one of the underpinnings of this whole effort was a much greater awareness that many others in the world are gaining access to both scientific capabilities, to the engineering capabilities and industrial abilities to translate science and technology into militarily significant systems. And we know that's happening, and Technology Horizons paid special attention to that.

There is, I would say, greater risk as a result of that. The number of peers and near-peers who we could potentially face over the next 20 years and beyond is certainly going to grow. The world, as we say, is flattening from a science and technology and engineering-derived-capabilities perspective.

I think our job and the way to address that is to stay aware of that and, through efforts like Technology Horizons, in effect stay ahead of the curve to have a better, a clearer, a sharper understanding of where those disproportionately valuable technologies are, both on the opportunity side for the U.S. Air Force and the broader joint force, as well as on the -- on the threat side, you know, those technologies that would be disproportionately valuable, in turn, to our potential adversaries.

I think if we do that, we certainly are not going to be able to stop the world from flattening. That is a one-way train that is going to continue, and we recognize that, and it is irreversible. And it's the Air Force's challenge to maintain its technological superiority in that environment. That challenge is greater than it has been in past decades because of those fundamental shifts that we've just referred to.

I think we can avoid technology surprise or at least we can minimize the risk of it through efforts, like Technology Horizons, that allow the Air Force to step back from its day-to-day narrower -- (audio break) -- look at technology landscape and really look from the 65,000-foot view over, say, a decade-long period and assess where the great opportunities and risks are, and then prepare itself to address those risks.

Q (Inaudible.)

MR. DAHM: So I think -- I think you're absolutely right, but the -- it is (efforts ?) like Technology Horizons that will let us address those things.

Q Okay. Thank you, Doctor.

PETTY OFFICER SELBY: And on to Rachel. You are next on the line.

Before we jump to that, did somebody else join us?

Q Hello. This is Shirley Collier.

PETTY OFFICER SELBY: Roger that.

And Rachel, you can go ahead with your question.

Q Thank you. This is Rachel Eisenhower, Signal Magazine. I'm wondering: Of all the findings and all the things that you think will be on the horizon, what's the most pressing technology or science issue that you think is going to be tackled, maybe in the coming years here? What's first on the list of all the findings that you're going to go ahead and dive into?

MR. DAHM: Yeah, Rachel, that's a great question because part of the charge from Secretary Donley and General Schwartz to us in conducting this effort was that we should not simply provide a laundry list of all the things that could be potentially valuable to the Air Force, but rather to provide a prioritized ranking, so that the Air Force could make intelligent decisions about what efforts are most critical to pursue and which we would pursue if the resources are available.

So Technology Horizons does that. It is a prioritized list. And it calls very clearly -- if you have a chance to look at volume one, the public release volume, it calls very clearly for this much, much greater and deeper use of autonomous systems and processes, so not just more and better remotely piloted aircraft, but a broad use of autonomy and autonomous decision-making throughout a much broader range of systems and even decision-making processes in operations like our air operations centers and so forth.

The technology to do much greater autonomy in significant part already exists. It'll have to be advanced much further, but it significantly already exists. It's the verification and validation piece

of that that Technology Horizons calls out as the single greatest Achilles' heel, if you will. We will need to be able to demonstrate certifiable verification and validation that these autonomous systems will in fact operate the way we need them to operate: under an incredibly wide range of conditions. And that's an enormously difficult technical challenge as these systems take on high degrees of adaptability and high degrees of autonomy. Our adversaries may be very willing to gain the advantages of using similarly autonomous systems without the need to burden themselves with verification and validation.

So that's our single biggest finding, the fact that we, as the U.S. Air Force, and the rest of our international partners need to get a handle on fundamentally new ways of doing verification and validation of highly adaptable autonomous systems. Otherwise we're going to see very capable systems coming at us and we will have held ourselves back from being able to field comparably capable systems to match or exceed those.

PETTY OFFICER SELBY: Thank you very much, sir.

And John, you are next on the line.

Q Sorry. I had to take my mute off.

Thank you, sir. Good morning. To -- (audio break) -- expand a little bit on this notion of autonomous systems, will this be autonomous to the exclusion of unmanned but manned controlled system in the future? Will that be going away? And will there be any future for manned systems, particularly manned aircraft, in the future, or are we coming to the end of that era completely?

MR. DAHM: Yeah, John, it's a good question. So let me say, first of all, that we're in a transition phase right now. And if you step back even beyond the specific topic of autonomous systems and processes and look at what's happening over the next 20 years, certainly by the 2030 time horizon that Technology Horizons was asked to look on, we're going to cross through a period in history where humans were more capable than machines, to where, by 2030, for a wide, wide range of applications, the natural human capacities are going to become badly mismatched to the data volumes, the processing capabilities and the decision speeds that are either enabled by technologies or required by technologies.

So this is really a unique time in history. You know, everyone likes to say that their time in history is special, but you could argue that this really is a genuinely unique moment in history where, by 2030, we're going to see humans interact with machines in fundamentally different ways. And autonomous systems is one of the great areas where that's going to be seen.

So we're in that transition now. It's not going to happen at the flip of a switch from one day to the next. But we are already beginning down a path where the discussions for framing many of our future Air Force systems are beginning to talk about optionally manned systems: in the near term or the mid-term, still accommodating a pilot,

and then that system perhaps being operated with a pilot either in a supervisory mode or actually in a direct-control mode, but with a pilot in the cockpit or in the system itself, whether it's (after ?) or else -- or something else; but also, being able to allow those systems to operate optionally unmanned. And depending on the mission, we will operate them one way or another.

Over time, you're going to see that shift continue to where the manned roles are likely to become less frequently used, and the unmanned more frequently used. We refer to that in the technology world as flexible autonomy, where the user -- or the Air Force, writ large -- can dial up the level of autonomy that it is willing to turn over -- and it can do it on a minute-by-minute basis, if you will -- to an aircraft or any other kind of system.

I think it's also fair to say that in the air and space domains, and broadly, we're not talking about autonomous strike. That's something that we have policies, for well-founded reasons, that we will not go down that path in the timeline that we're talking about here. And frankly, we lose almost nothing by having the human on the loop to make the strike decision. The real benefits of autonomy are not in that very last moment where the strike decision is made, but in the -- in the whole chain of events and the coordination that leads up to that.

So if you understand autonomy in that more nuanced way, that it's not going to be a -- you know, suddenly we're shifting a hundred percent unmanned systems. It's going to be a stepwise approach where, over time, we will be becoming increasingly unmanned. I will leave it at that.

Q Thank you.

PETTY OFFICER SELBY: And on to Sandra.

MR. DAHM: We have three people in the room here. So once we cycle through everyone there, if it's within the rules of engagement, we'll -- we'd -- we'll ask the three people here to ask questions as well. And we'll repeat those for the benefit of those on the phone.

PETTY OFFICER SELBY: Roger that. Thank you.

Q Thank you, Dr. Dahm. Sandra Erwin, with National Defense Magazine.

In reference to one of the challenges, which is the budget, how are you prioritizing the Technology Horizons wish list, so to speak, so that potentially, you know, budgets -- when budgets become a problem what's going to be a higher priority versus a lower priority?

And as a sort of a secondary part of that, I didn't see any mention of energy in your -- in the Technology Horizons. Is that something that is being factored in as far as maybe technologies for reducing fuel dependency and so forth?

MR. DAHM: Sure, let me -- let me address both those questions, Sandra.

Q Okay.

MR. DAHM: First of all, regarding the budget challenges, we are always budget challenged. It's a -- it's a matter of degree.

There has never been a time, certainly that I've been aware of in the Air Force, where we do not have to take budget considerations into account as we make our technology development choices. I think the landscape that's in front of us is one where those pressures are simply going to become more acute than they have been in the past. And it's for that reason that I certainly wouldn't characterize Technology Horizons as a wish list. It's much more grounded than that.

So we had to take, as I mentioned, the three elements -- the strategic, technological and budget challenges -- into account. And as we looked at a very, very wide set of possible technologies and technology-derived capabilities, those that did not play well in the strategic environment, regardless of whether they were technologically achievable and technologically defendable, or whether they fit into the likely budget environment, they would not make it onto the recommended list of technologies.

So a technology had to meet all three of those criteria, and everything in Technology Horizons does that.

Q Mm-hmm.

MR. DAHM: It is true that we're going to be facing greater budget challenges. I think certainly this is not a one- or two-year thing. This is likely to continue for a decade or more, if you look at what's happening at the federal level and indeed at the global level. So I think Technology Horizons helps position us for technologies that are achievable within likely budget environments.

The second part of your question dealt with your interpretation that there is little reference to energy. And I would point you to a number of places where in fact energy plays very strongly in Technology Horizons.

As I said in part of the report, and perhaps I mentioned it in my opening comment, there are three specific operating cost centers that we are looking for technology to help us address. Those are manpower costs -- which I referred to earlier. The augmentation of human performance and the greater use of autonomy will help us address those. Energy costs -- which have -- they rose very quickly. We've had a about a year, a year and a half pause now, but we know that they're going to go up again very sharply in the time horizon of this report. And then the third of those are sustainment challenges. If you look at energy, rather than calling out a set of technologies under the heading of energy per se, you will see in there reference to advanced engine technologies, gas turbine engine technologies, for example, that allow us to achieve

much, much higher aircraft engine efficiency, fuel efficiency. You'll see reference to things like hybrid wing body aircraft, that have much improved aerodynamic efficiencies and, in so doing, allow us to reduce our energy costs, our aircraft operating energy costs. You will see reference to a variety of airship technologies for ISR and other applications, cargo airlift and so forth, all of which contribute to much, much larger reductions in our aircraft energy costs.

And even more broadly beyond that, there have been a number of studies done in the Air Force recently that look at basing energy, for example, and how technologies can contribute to that. Our scientific advisory board just completed a very valuable study where it did an assessment of alternative energy sources for Air Force bases. I think that's one of the really valuable things that our independent scientific advisory board for the Air Force brings.

So I think you'll see that energy plays a very big role in the Air Force's thinking, explicitly and implicitly in Technology Horizons and in a number of these broader technology assessment efforts.

Q Thank you very much.

PETTY OFFICER SELBY: And Tamir.

Q Hello. This is Tamir Eshel from Defense Update. I have two questions, one about past reports, how accurate past reports, past Horizon reports were, tested by the coming years.

And another question. Is there a place or what role do you see for commercial and civil entrepreneurs to contribute to these studies or research in the future, and if you see a role for open systems or international cooperation with companies and academic community in these studies.

Thank you.

MR. DAHM: Sure. So let me address your second question first, regarding the role of this much much broader set of partners that indeed, the Air Force does rely on to achieve its technological objectives and the capabilities that flow from that.

The Air Force is absolutely aware that it cannot develop either the underlying technologies or the systems that will make use of those technologies by itself. We have always relied on our interactions with the other services, with the broader DOD, science-technology and research-and-development activities. And even well beyond that, the industrial base is absolutely critical. The role of various entrepreneurial companies -- we of course have very vigorous small-business innovative research and STTR -- you know, SBIR and STTR programs designed precisely to allow the small-business and entrepreneurial community to help us address some of these technology challenges. And those kinds of things are absolutely critical.

And it goes far beyond that. We have strong interactions with the international community. I'll point out to you, you may not be aware that we have had for a number of years a European office of aerospace research and development, located in London; we've had an Asian office of aerospace research and development located in Tokyo; and just this past fall, I helped open a brand new southern office of aerospace research and development in Santiago, Chile. So all three of those are part of our network for reaching into especially the academic community internationally, around the world, because we know the best ideas do not necessarily originate in the U.S. And we actively look for ways that we can partner -- support the S&T activities of these other countries and partner with them to tap into their academic and broader communities.

And then beyond that, we have critical partnerships with a number of nations that we work very closely with on research efforts to advance the technologies that we have a shared interest in. So that entire network is the way we look at S&T development in the Air Force. It's not something we do in-house. We cannot do it all alone. We have to, and want to, effectively work with that very broad set of partners.

Now, Tamir, your first question, I didn't understand what kind of system you were referring to. Could you -- could you repeat that? Q You had, I think, five past reports, and I wonder how accurate they were in the test of time.

MR. DAHM: (Inaudible) -- five -- we had five what?

Q Five future assessments like this. That's what I read in the introduction -- since 1949, I think.

MR. DAHM: You're right. So there have been five previous science and technology visions conducted at the headquarters Air Force level, these every-decade studies. Toward New Horizons was the first of those, led by Theodore von Karman for General Hap Arnold. It laid the foundation for the Air Force as we know it today.

If you look across that series of previous S&T studies -- or S&T visions -- you'll find that the impact varied quite widely. Beyond Toward New Horizons, which was absolutely central to the Air Force, a study that General Bernie Schriever ran for the Air Force in the mid-1960s, I believe 1964, was central to building the space element of the Air Force as we know it today. And 15 years ago, our scientific advisory board led the development of a vision that was called New World Vistas, and that also had a substantial impact.

I would say if you look across those, it has been absolutely critical that these visions not be just opportunity studies; that is to say, not focus only on what is technologically possible; but unless they held those technological possibilities up against the strategic environment, the budget environment, and what our potential adversaries were or could be doing with technologies -- unless all three of those elements were included, I think the impact of some of the prior studies was less.

So when you look across the prior studies, there's a wide range of impact. Several have been absolutely central to the way forward and the investment decisions of the Air Force. The feedback we've been getting since Technology Horizons was submitted to the secretary- in-chief back in mid-March and then broadly to the Air Force on the 15th of May, and then publicly released volume one about a month after that -- the traction that this has gotten is tremendous. And it's already being used to help develop our 12 decisions for our investments, and the groundwork has been laid and the elements of the implementation plan have been put in place to ensure that this vision is one that's going to inform our S&T decisions and our S&T focus areas for the next decade at least.

So with that, I'll turn it over. I think we're -- got at least a minute or so left, if there are any other questions on that end.

PETTY OFFICER SELBY: Well, actually, we had the -- we had the call scheduled for 45, so we could go another 15 minutes unless that's a problem on your end, sir.

MR. DAHM: No, it's not. We have carved out till 11:45, so we're happy to keep going.

PETTY OFFICER SELBY: Roger that. Can we go to Tanya Montgomery (sp)? Tanya (sp), you're still on the phone?

Q Yes, I'm on the phone, thanks.

PETTY OFFICER SELBY: Do you -- okay.

Q I just wanted to ask, getting these -- some of these projects going in the future, do you foresee any problems with -- I don't know, I guess our manpower capabilities? I mean, I'm seeing things about how the U.S. is behind -- scientifically behind other countries. Do we have the right people, the right minds to get these things going in the future?

MR. DAHM: Yeah, so what you're referring to is what we broadly refer to as the STEM challenge, the science --

Q Yes. Right.

MR. DAHM: -- technology, engineering and math challenge. I would not say that we are behind by any means. I think every nation has its own set of challenges in developing its science and engineering workforce. We have ours. There are always shifts under way in the attractiveness or the perceived attractiveness of various fields and, you know, what our young people -- you know, the areas that our young people are choosing to go into.

I think there -- you know, if you look more broadly, number one, we are -- we have active programs under way to address the STEM workforce and to help ensure that the Air Force will have access to the brightest minds that this country has to offer and to show them the exciting

careers that exist -- first of all, broadly, in science, technology, engineering and math, and then more specifically also in the Air Force.

The Air Force research labs hold enormous numbers of outreach activities. They hold open houses where people can come in and see the technologies that are being worked on. And I can tell you that, having had the chance in this job to see almost every technology that the Air Force works on and much of what's being done broadly in industry, there are tremendous opportunities for technologists within the Air Force S&T community.

But you are right that having the manpower workforce available to be able to address these things is critical. As I said in response to the earlier question about broader partnership interactions, we don't view that this workforce has to only be in-house. We rely on a vigorous industrial workforce that also needs to have the same STEM challenges being met, and increasingly we're reaching very broadly around the world to support many of the S&T activities that we have.

I think it's fair to say there are big shifts going on. I mentioned the flattening of the world previously that has, at some level, a risk component to it. But the other way to look at that side of the coin or to turn the coin over is to recognize that that also expands the potential workforce and the way we interact with that workforce.

So I think the short answer to your question is, the Air Force is well aware of the STEM challenge that it faces. We do not intend to allow those challenges to impede our ability to move forward in advancing the technologies we need. And so that requires creative ways of interacting with this broader set of technologists.

And we're looking to do that.

And I mentioned the EOARD, AOARD and SOARD. The European, Asian and Southern Offices of Research and Development -- Aerospace Research and Development are just one of many elements that we have put in place to do that.

PETTY OFFICER SELBY: Thank you very much, sir. And Tim Oren (sp). (Pause.) Tim, you still on the line with us? (Pause.)

Okay. We'll move on to Shirley Collier.

Q No questions at this time.

PETTY OFFICER SELBY: Okay. Well, with that, sir, yes, if you wanted to let the people in the room --

MR. DAHM: (Okay ?). We have Stephen Trimble here. Stephen, you have a question?

Q Yeah. Actually, I'm online as well, so hopefully you'll be able to hear me. I'm with Flightglobal and The DEW Line Blog. And I just wanted to ask about something that I -- some have perceived as a

disconnect between this focus on autonomous systems and the decision by the Air Force to in name and in fact operate remotely piloted vehicles in a remotely piloted way when other military organizations, including the U.S. Army and the Israeli military, operate very similar systems with almost complete autonomy in terms of the flight controls. And I mean, do you see that or do you sense that as a cultural barrier that has to be overcome in the Air Force, and going back to that issue of validation and trust and autonomous system?

MR. DAHM: So -- it's a good question, Stephen. The -- number one, I don't see the cultural element being either present and certainly not significant. I think there is a perception -- and it's a misperception in the broader public -- that the Air Force is somehow often painted as being resistant to remotely piloted aircraft. And historically that's simply factually incorrect. I mean, as far back as the 1960s the Air Force was involved in programs to develop remotely piloted vehicles. We were at the forefront of that whole evolution. And somehow that history has been forgotten. So I would encourage your readers to look at that.

There was a -- an excellent report on that released just recently by the Mitchell Institute that addresses exactly that topic. I don't see the culture barrier being there. I would say, though, that the way -- so firstly, you are right that internationally many, many countries are working on and developing very successful remotely piloted aircraft.

When we're talking about autonomous systems and processes in Technology Horizons, as I stated, we're talking about a much, much deeper and broader level of autonomy than what you see in even the most autonomous systems today. And I think the real challenge here is to work our way towards that vision of the future in an intelligent way. That is to say, if you were to embrace autonomy incorrectly -- that is to say, you were to peg the meter on putting as much autonomy as possible into systems today when the elements of the technological basis for doing that correctly are not yet mature enough -- then I think it introduced significant risk.

So the RPAs that you see being fielded by other countries today -- that's near term, and Technology Horizons is not focused on the near term. We're interested in systems that might be -- begin to be fieldable, say, 10 years from now. And our point in Technology Horizons is that by advancing the key autonomy technologies, in particular the verification and validation piece of that, we will be able to field systems that go far, far beyond anything you're seeing anyone fielding today, and we'll be able to gain the advantages of doing that.

So maybe the central point in answering your question is that the landscape that you've painted is one that exists today, and it's an accurate description, but it's very much a near-term picture. Technology Horizons is really looking more 10 years into the future and seeing what we could have if we focus on the right technologies.

Okay. We have another question on this end.

PETTY OFFICER SELBY: Yes, sir.

Q (Inaudible) -- atomic clock technology was mentioned in the -- (audio break). I was wondering if you could talk a little bit about why this technology is so critical and update on the development of that technology, and especially how that technology -- (inaudible).

MR. DAHM: Sure. So and you were -- were you on line so the people could hear?

Q (Off mike.)

MR. DAHM: Okay. Let me repeat the question. This is Titus Ledbetter -- and you're from Inside the Air Force.

So the question was that Technology Horizons refers -- in fact, as one of its highest priorities -- to the development of chip-scale atomic clock devices, and if we could give an update on where those technologies stand today and what kind of benefits they could bring. I would broaden that to not just chip-scale atomic clocks, but to advanced inertial measurement units, miniaturized units. For both -- and of course, the former is therefore timing information; the latter is therefore position information; both directed at augmenting or supplanting GPS in GPS-denied environments. We know our adversaries are going to try to deny us our GPS capability, because we are so dependent on it.

There are two classes of technologies in both the timing and the positioning information that are critical here. The first is based just on miniaturization, and that's the chip-scale clocks and IMUs fabricated using, in many cases, the same photolithography methods, the micro-electro-mechanical processing methods that are being used in a variety of other kinds of devices. Generally, those systems have drift rates, both in timing and in position, that are quite large by the standards of conventional clocks and inertial measurement units.

They -- the miniaturization allows us to build these kinds of systems into, essentially, any device and have a system that can operate for a relatively short time -- and for many missions, a short time is all you need -- but can operate for a relatively short time, with adequate uncertainties in position and timing.

The real big breakthroughs, I think, are going to come from these quantum interferometry approaches which can be used -- they're often referred to as cold-atom approaches, or Bose-Einstein condensate approaches, where we trap a collection of atoms or molecules in a very, very narrow range of quantum states. And we use the fact that at the quantum level matter -- in other words, atoms and molecules -- are waves. And we can do interferometry with those matter waves in the same way that we do with optical waves in ring laser gyros, for example. But the wavelength of these matter waves is many, many orders of magnitude smaller than optical wavelengths. And as a consequence, we get

incredibly high precision, low drift, in our position and navigation that we can achieve with those kinds of systems.

Now, those systems are at laboratory scale today, but they are advancing very, very quickly. And we have efforts under way to continue to advance the technologies, as well as early efforts to miniaturize those technologies and begin to get them down to the chip scale where they will, perhaps a decade or more from now, begin to be ready to insert into the systems that we field.

If we can successfully do that, then we will be able to have GPS- or better-than-GPS-like position and timing information, even in GPS- denied environments. And by doing that, we will, in effect, have negated our potential adversaries' value from their efforts to deny us GPS in the first place. So this is absolutely critical to everything the Air Force and DOD does. And it's for that reason that it -- that it's called out in Technology Horizons.

PETTY OFFICER SELBY: Thank you, sir. And I think we can probably stop right there. I think we're about to run out of time here.

So with that, I'd like to thank everybody for your questions and comments, and, sir, for your answers. And would -- do you have any closing statement, sir?

MR. DAHM: Sure. Just very briefly, I -- number one, you know, those of you who have questions about any of those things, you can get my e-mail address off the web very easily. You're welcome to send a question. We'd prefer to try to clarify any confusions, rather than have you write something that you may want to retract later on.

Technology Horizons is a -- is a big step forward for the Air Force. It's the first time in 15 years we've done one of these huge science-technology visions.

The reception it's gotten and the impact that it's already having in helping the Air Force move in productive directions for its science-technology investments is already happening and is very, very substantial.

Over the coming years, that document is going to continue to help guide our investment decisions. It's one of the key elements that we will be using in our corporate process to make investment decisions. And this was a big step forward for the Air Force, and it will continue to guide us for quite some time.

So with that, I think we'll sign off on this end.

PETTY OFFICER SELBY: Okay, sir. And once again, thank you very much. And thank you to everybody on the line.

Today's program will be available online at the Bloggers link on dodlive.mil, where you'll be able to access a story based on today's

call, along with source documents, such as the audio file and transcript -- print transcripts, sorry.

Again, thank you, everybody. And this concludes our call. Feel free to disconnect at this time.

END.