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DWG: Our guest today is Dr. Will Roper, Assistant Secretary for Acquisition, Technology and Logistics of the United States Air Force. No stranger to most of the people on the call.

Dr. Roper, thank you for joining us today at the Defense Writers Group. We're going to be recording this session and we'll put the transcript up in a day or two. Those who are on the call, however, will have a bit of a lead on those who are not.

Let me just start by asking a broad question. Here we are at what is close to the end of an administration that you've been serving in. Take stock for us. What do you think you've achieved in the last few years, what are the things that need to be done next in your area?

Dr. Roper: Big question. To be frank, I haven't achieved anything. I sit in this office every day but I've got a team of people that I think have really discovered their innovation roots. That was my goal coming in. It's why General Goldfein asked me to come over into this job. Introduced me to Secretary Wilson. I wanted to see if the kind of innovation that I did at the Strategic Capabilities Office could scale to something as big as the Air Force. I didn't know the answer to that. It was just as much a mystery to me. But I came in knowing that if we're going to compete against nations like China that have a lot of advantages of scale over us -- greater population, greater GDP, greater number of STEM graduates. The scale factors are in their favor. So the agility and innovation factor is going to have to be in ours.

And the litmus test for me was can the acquisition system appear competitive in response to that challenge? We're not there yet but I'm really impressed with how far the Air Force and now the Space Force have come. I put a lot of big challenges on their plate, David. I tried to see if we could overcome software acquisition. That was the most common question I had going

through confirmation. So many questions about failed software acquisitions. And this was before the Kessel Runs and the Kobayashi Marus and the Cloud ones and Kubernetes and now AI on a U-2. This was before all that, right? We still call it that. In less than three years, the Air Force and the Space Force have become true digital services but we haven't arrived at the digital goal line yet. In fact the finish line that people may see the U-2 AI flight as isn't a finish line at all. It's just a starting pistol. We have now earned our way into the digital race and have to compete against China. But I'm very proud of what the Air Force and Space Force have done in software. Very proud of the work that we've done in building bridges with commercial companies, AF Works, AF Ventures, the growing of partnerships of venture capitalists.

Who would have thought three years ago that we'd be talking about Air Force investments in companies being matched at an over four to one ratio by the big name venture capitalist firms of this nation. Us being viewed as a trusted partner in investment, bringing over $3 billion worth of VC funds in. That's amazing stuff in three years and we have to keep going on it because our partnerships aren't as broad as they need to be. China has a nationalized industrial base. There's no division in the industrial base that can bring capabilities to their military, and we're going to have to work hard to have the same seamlessness in ours while still keeping the advantages that markets give. So I'm very proud of that.

I'm also proud of seeing risk taking and prototyping come back. So I think we can still do better here. So we're on the verge of our first hypersonics program going into production and bringing that to bear for the nation. A lot of programs have moved to prototyping, bending metal, learning through doing which does expose them to the risk of failure. And yes, we have to fail if we're also going to have the big successes. And I've enjoyed bringing innovation it sustainment and doing 3D printing of parts and just trying to put innovation in a part of the Air Force that rarely gets the limelight. I'm very proud of the people that have brought in predictive maintenance for the very first time, so we're pulling parts before they break. That's not rocket science. That's the same thing you do changing the oil on your car. You change it before your car breaks down. We're now doing that across about 16 fleets of aircraft with a goal to get across the entire Air Force.

And I could keep going on but the point are not these things. They're indicative of how we need to be to compete against China. Innovation should be everywhere. There's not a single facet of the force that shouldn't be changing how it does business to make it better and to keep up with current technology.

In terms of the work that we have to continue doing, yeah, we just reached the starting line. The starting pistol has been fired. We've earned our way back into the race and now we have to keep up with commercial tech trends. We've got to be able to keep up militarily with China. And all the things we started -- software AI, hypersonics, any of that. We're going to have to continue to evolve. We're not even close to where the internet of things is made commercially.

What a horrible statement, that the military's internet of things, our advanced battle management system for the first time showed something that looked like the internet in September of 2020. The first time in the entire Department of Defense history we've done something that looked like the internet of things. Machine-machine data exchanges across a broad area of operations with AI driven courses of action and kill chains being completed in seconds, not minutes. The first time is in 2020. We can consider those innovation, but they tell us how far behind we are.

The steps that remain are catching up first with commercial industry and commercial technology; and then two, building those partnerships with commercial innovators, what we've been doing with small companies but now building into larger ones, working with companies like Google and others so that in the future we're not following commercial technology, we're helping drive it in a way that's beneficial. I think that really means getting our head around what the military market means in 21st century competition. We are a market and it has advantages to help companies commercialize. That's very different than the Cold War industrial model that invented most of the technology, operationalized it, and then much later on spun it out commercially after price points have changed. That cycle has to be shrunk much.

So we've accomplished getting into the race, David. Now the task I leave to those that coming after me is running the next leg of the race, and when is the race over? Well, the adversary gets a vote on that so we have to be able to run at speed but over

distance on this one.

DWG: Thank you.

John Tirpak, Air Force Magazine. You're next. Do you have a question?

DWG: Good morning. Thanks, Dr. Roper, for doing this.

I wanted to go back a little bit and close the loop on something we talked about a few months ago when you were talking about making the business case for the digital design concept for NGAD and other things. You said you had a team working on making the business case and whether it was going to be more efficient than doing things the old way. You thought that it would. I presume that those cost analyses have been done and you now know whether doing it digitally is more expensive or cheaper or about the same.

Can you talk about that a bit, and what the future holds for NGADs, the near term future?

Dr. Roper: Sure. I don't know if you're ever done reviewing something as complicated as a next generation aircraft and the family of systems that support it, but we have finished our initial round of analysis enough so to pull together a complete acquisition strategy on doing an E-series digital competition approach that has two or more competing aircraft being competed over time in smaller lots. The business case does close by our assessment. If you pull the picture frame back to the full cost of ownership to the taxpayer and that is something we don't currently do in Washington. We do track a lot of acquisition metrics like the average procurement unit cost. We care a lot about that. What does it cost us to drive a car off the lot? But every person that owns a car knows that the price it costs you to buy it is not the price it costs to own it. There are other things. There's the maintenance, there's insurance, and that factors in. And when we pull the picture frame and we look at acquisition as a whole, we discover the thing that you all know and so do I, but I don't think is known widely outside of Washington, that most of the money we put into systems is like the part of the iceberg that's below the surface of the water. It's not the part that's in the limelight. It's in the sun. That is the modernization and sustainment that takes up 70 percent of the funding we put in place. That's the place to

attack if you want to save funding.

So as we pull the picture frame and try to lower total cost of ownership, if we're willing to pay more for the average procurement unit cost, the sticker price that lets you drive the car off the lot, and we find that overall the total cost of ownership for the car, in our case the airplane, comes down and can be lowered below the level that traditional acquisition is at but with the benefit of having much newer much more modern planes. You're flying new airplanes, not modernizing old ones. That's a much better acquisition strategy to compete against nations like China.

I think going forward the real question is, is the Pentagon willing to pull the picture frame to its lightest extent? And if we are, digital acquisition looks fantastic for anything where you need to continue modernizing it. I can imagine doing weapons this way and things that have developed in other services, I'll leave to them, but I don't think it's peculiar to airplanes.

When I look at its analog in the commercial automotive industries, I see the exact same principle that we're trying to apply being applied already and successfully. I've developed some really good relationships with Formula One companies and they see what we're trying to do in digital century series or e-series as exactly what they do in Formula One racing. They got it from the first conversation. They do that across a racing season today. And they deal with 85 percent obsolescence of parts year to year. And they manage to digitally design and spiral and evolve cars around those obstacles and even optimize for individual racetracks.

A Formula One racecar on the ground is not that different than a fighter. It might be as close to a fighter on the ground as you can get, and certainly the competitive nature of racing and the fact that safety also depends on those designs, align it really well with the Air Force mission.

DWG: If I can follow up them, you've previously said the NGAD prototype has flown and you just said there would be a competition between two companies. Can you tell us, have both prototypes flown or is it that both companies are going to derive from a single design and compete on producing it?

Dr. Roper: I'm referring to the e-series approach where you

compete multiple designs over time. You don't make a single down-select and then move into a 30-year acquisition. You start the next competition immediately to compete six to eight years thereafter and buy the airplanes in smaller lots. That's the whole theory behind the e-series approach is smaller lots competed incrementally as opposed to a one and done, big winner/big loser acquisition. So that's my reference.

In terms of what we're doing now, I have nothing more to say on that other than we have flown a full-scale flight demonstrator which tells me that the digital engineering approach that we have seen done so successfully on T-7 is not unique to a trainer. It can be applied much more broadly.

DWG: Thank you.

Michael Gordon of the Wall Street Journal.

DWG: Thank you. I appreciate it.

I'd like to ask kind of a step back semi-philosophical sort of question appropriate for this transition period.

President-elect Biden to the extent that he's talked about defense, which obviously was not a big issue in the campaign, but he indicated that he wants to essentially improve conventional deterrence and reduce the role of nuclear weapons and doctrine and strategy. He's said as much with his sole purpose statement. This is all going to happen in an environment of large federal deficit and pressure on the DoD budget.

So my question is, if there were three things you think the new team coming in could do in your realm to strengthen deterrence, conventional deterrence, and build on what you've done so far, what are the three things you think they should not only carry forward but perhaps double down on?

Dr. Roper: That's a good question. I'll phrase my comment to say -- I'll say what I think needs to be continued and whether that advice is one that needs to be heeded that's ultimately up to those that succeed me to decide.

But I think that digital transformation is something that has to continue or we will find defense acquisition obsolete yet again. Just like we found ourselves with software still doing 1970-era

waterfall development in an agile software world, we could easily find ourselves there again doing analog design in the digital world, so we have to complete digital transformation across all facets of development through tests. I absolutely hope that would change the way we design systems so that we could be more open and interoperable in terms of standards that would allow us to bring more allies and partners in. I think that's a huge part of what gives the Air Force its deterrent value today, is just how interoperable we are with other Air Forces, how many of them buy their equipment from us, train with us.

We fight as a joint force but we don't architect as a joint force. We don't design as a joint or combined force. I think digital transformation now allows us to start thinking not just about U.S. systems but how they might convey to allies and partners in the future. I think that's hugely beneficial, the more interoperable that we are.

I think the last thing is something that has been sparked this week. I really do think that there has to be a strategic answer for artificial intelligence as one of the next big challenges for how we organize as a military and do all the things militaries do -- organize, equip and the rest. Because it's one of the first technologies that's common to the defense sphere versus the scale of force private investment that could really change the calculus of human experience and human decision-making advances.

I have been in many meetings in the Pentagon that have ended with a tough discussion over competing technologies between us and our adversaries that ended with when it's all said and done our operators have more experience and that experience will give them the advantage. And because of the rapidity of decision-making that AI can bring, maybe it's the first technology that undercuts that experience argument. We're woefully behind in the Defense Department. We finally got the first AI co-pilot on an airplane, in our case the first AI operator on a military system. We just entered that race and we need to be running it for years now, and we've just started it.

We just talked about getting AI into the fight, now we have to fight AI which means knowing how to break it. There's a whole measure of work that has to be done.

So I guess AI is really the bigger point I'm trying to make which is commercial technologies aren't going to stop and we have to

change the systems to keep up with them. That's more important, in my view for future deterrence than any individual system you're going to build because the longevity of it is shrinking. So it's really the speed and agility of your system itself that becomes the deterrent factor, that you will be able to keep up and keep fielding the world's most lethal Air Force, Navy, Army, Marine Corps. Not that you've got a snapshot of the world's most lethal service today. Right now we're behind in that but we've made strides. I would hope that we would continue changing the spear-building process as much as we're focused on the spears themselves.

DWG: Have you had any conversations with the Biden transition DoD folks? Are they receptive to these ideas?

Dr. Roper: I've spoken to the transition team. I think it wouldn't be fitting for me to talk about those discussions, advice that I'm giving them. But I have spoken with them.

DWG: Thank you.

DWG: Patrick Host of Janes. I see you're on, do you have a question?

DWG: I have a question about your ABMS and the dirt remark you made this week. I'm wondering what is preventing you from leaving one of these systems in the dirt after you test them like you said? Do you have to be approved by Congress to do this? Do you have to be approved in the NDAA? Do you have to have funding approved for this? What is actually preventing you from leaving one of these ABMS systems in the dirt to be used operationally by troops?

Dr. Roper: Great question. There are ABMS components operating today in the software world. A lot of the analytics and command and control capabilities are being used in the Eastern and Western air defense sectors today. But software doesn't really get dirt on it in the way hardware does and getting ABMS in the dirt is really bringing agile hardware to the equation which is what we will do with ABMS release one. I did a review with that team this morning and I think we'll have the acquisition strategy for that program done in January. But it's things that we've discussed before. It's data relays and I'm happy to discuss more on that if you have questions on it.

The reason it takes a little more work to leave behind hardware as opposed to software, if you want to put it on an aircraft and view it one time that's one certification process. That's one testing process. That's a waiver that says it's okay to fly this aircraft under these restrictions. We do that all the time with testing. But if you want to leave it behind and actually go use it operationally, you need to do the full testing and certification process. When you're only doing experiments that never gets jump started.

So what we're doing now with the Rapid Capabilities Office coming on-board as the PEO, is we're jumpstarting that process so that when we complete the first prototyping experience of release one, we've put in all of the operational underpinnings so that we can safely leave that in the field. That's way one getting in the dirt.

The other way you get in the dirt is with industry. You need to prepare for production. Building one or two of something is nice, we get ready to build things in quantity. In the case of the data relays we're proposing for the KC-46, we're interested in having them across all of our KC-46s. So we've got to get the production lines on it as well. And ABMS has just now turned the corner where we're ready to do that.

You have to deliver an architecture. You're supposed to deliver something that looks like the internet. Every capability released for ABMS will look like a mini-internet applied to a component of our force. A mini-internet is many things. So there's not one thing you can do a focus on and deliver and say hey, there's ABMS. You have to deliver things concurrently and we just hit the point where we have enough of those concurrent things for me to give Chief Brown a mini-internet that we can baseline and train to and I think once we get release one fielded, I think ABMS will feel like a normal program at that point.

Kind of like people say they're going to go buy their next phone but they really mean they're going to buy their next phone and it's connection to the cloud and the data plan and all that. They actually are thinking about the architecture even though the focus of their purchase is the phone. We had to do a lot of work to put in the cloud in analytics so that we can now focus on the hardware that connects to it. In our case the first phones in ABMS are going to be the tankers that are standing outside of the

area denial bubble being data tankers, relaying critical information in and out of that contested environment to tactical fighter like the F-22 and F-35 that may not be able to communicate to their big cloud but can communicate through a data relay that is the tanker acting effectively like a cell phone tower in the sky so that they can communicate via proxy to that big cloud-enabled analytics and data that are so powerful connected to our personal devices and we expect will be equally powerful connected to our warfighting systems too.

DWG: Thanks. Are there any F-1 teams that you're really inspired by when it comes to this digital engineering?

Dr. Roper: I can say we're in discussions currently with McLaren and have been very impressed with them. I don't know where the relationship is going, but both sides have been excited to share where we are with digital engineering and I've learned a lot in talking to tech companies.

DWG: Why McLaren?

Dr. Roper: When we were getting into digital engineering, and I got T-7 was the first thing, was a shot across my bow and I was like wow, this is a game-changing technology. This is the unicorn we've been waiting for in this procurement. I immediately started doing market research on commercial companies who are good at this, and McLaren popped up in that research as a leader in bringing digital techniques into the racing circuit. We had a contractual relationship with a company that was affiliated with them and that's how we started talking about the potential of a partnership and future.

I doubt they're the only, and I don't claim to be a Formula One racing expert. Far from it. But as I went through how they approach their digital environment to the racetrack, it's exactly what we're proposing for e-series. They win in the digital environment. That's where the race is won or lost. The actual making of the car and the winning on the track really just brings in the idiosyncrasies of the race day itself.

That's very inspiring as an acquisition exec who wants to believe that we can win the fight in the design space and that ultimately the fight itself is just the idiosyncrasies of combat, but that we have given that decided advantage through the digital design approach itself. Formula One does that today. The real world

checker flags are won with digital design.

DWG: Thanks.

DWG: Sandra Irwin, Space News.

DWG: Hi, Dr. Roper. Thank you for doing this.

I wanted to ask you about the Space Force. They're now a year old and they always tell us that they're trying to do things differently, that they have to go fast, they have to acquire things faster. Obviously one year is not enough to change the acquisition system, but what do you think they need to do in year two? At some point Congress is going to get impatient and say what are you doing to get faster? Thanks.

Dr. Roper: Great question, Sandra. Happy Birthday to Space Force.

You know this as well as I do. You can't go back and radically change programs that are already under contract, so you can only do the best you can with them using the old approaches and then try to do new things in the new programs. So that is where Space Force will be. But fortunately there are a lot of new programs that are being created and in space defining things.

The things that we will have to crack in space acquisition is one, bringing digital acquisition, digital engineering into satellites. It hasn't been done yet. To our knowledge it hasn't been done commercially. But I already have the first satellite program that is in the [lead] of Space Force right now. Not publicly releasable today but I will see if by noon today if I can get that released to the group. The team that's doing that. I think it can be done. I've done a thorough deep dive on the program and I see the same tasks to simplifying acquisition, simplifying touch labor, increasing interoperability through digitizing interfaces that I have seen in aircraft. I'm really excited about that.

The next thing that's going to be important is bringing containerization of software in. I think we're a little further ahead on that right now in Air Force, but I did a review with Kobayashi Marus this week and they are hot on the tails of programs that are out to [pouring] containers and we need to have that first real-time software push to satellites in orbit and I

would hope that can be achieved near term. I would hope in 2021. Ultimately what I want Space Force to be able to do is the same thing that we did on the U-2 and I gave Kobayashi Marus that task this week. Having an AI co-pilot for space operations. The reason I think that's really important is that space is going to be unlike any other domain in that physics is going to make it far more predictive. Fuel is very precious in space so if you're using it to change your predictability, to make Keppler your friend as opposed to your opponent, then that's fuel you don't get back. Also technology of retail satellites in orbit which I think we should.

So with that factor, with being more deterministic and with space operations being at higher speeds and further away than any other domain, a prediction that I have as the service acquisition executive for Space Force is that we're going to have to operationalize and keep updating autonomy and artificial intelligence faster in space than perhaps any other domain because there's not that human factor that changes the predictability. It's not like in an airplane where the pilot can change course and you can't predict what they're going to do easily.

I think that's going to really challenge space acquisition. If space acquisition becomes digitally dominant then I think that sets the stage for their next effort an then if digital acquisition, digital engineering brings in hardware agility, then that could create the same benefits we've seen from aircraft. And the main thing I'd be looking for for satellites is that picture frame analogy I discussed with NGAD. You pull the picture frame for satellites. Oh, there's not 70 percent sustainment because the satellites don't come back from orbit. So there's not this big part of the iceberg below the surface. So the thing you'd really be trying to simplify is integration so that you can have payloads being mated with satellites later, so that you could have more interoperability options. Then also dropping touch labor, dropping the direct cost of the satellite itself.

So mostly digital stuff. I think that's the next phase.

DWG: Do you think the Space Development Agency is helping advance acquisition the way they're doing things with faster contracting? They're using all the same authorities that anyone else has, but they seem to be moving pretty fast. Do you think

that's a good model?

Dr. Roper: I think time will have to tell. Right now I'm just wanting to have space as a whole be able to make this digital transformation pivot and having multiple groups attempting to do the same thing, we'll be able to do lessons learned across the enterprise. But starting is where it's easy. Get your contracts out, start your design reviews. When it's time to start bending metal and integrating, that's where the real world comes in. What I'm really looking to see is a space program that starts changing the game at that inflection point. When integration starts getting easier, when touch labor starts going down. In a magical world, and we can change the tolerances, the stacks of our clean rooms so that we can design satellites in garages as opposed to in places that are like medical clinics, then we'll be changing the game in satellite acquisition. We haven't done that yet.

I think a lot of people think that commercial satellite building uses the same digital engineering that we've seen in T-7 and the automotive industry. It uses exceptionally good lean manufacturing is what I've seen. Far better than we are in the defense industry. But because they're moving towards rapid production or mass production in the case of the mini companies, there's not the need to go to full digital twins and full digital [threats] but I think there will be a need for us because I see the benefit of that across programs that are similar. Look across our SATCOM programs, lots of similarities.

So I think that is what will drive us to go a step beyond where the commercial satellite industry is currently. And the cool thing is if we do that, maybe that technology will help spin off into the commercial satellite industry just like I hope digital engineering that we're doing in military aviation will eventually spin off into the U.S. aviation industry as a whole.

DWG: Patrick Tucker of Defense One.

DWG: Thanks. Back in April GAO had some criticisms of the ABMS program as it was designed. It said the program lacked firm requirements to inform technological software engineering, said it lacked a plan to maintain mature technologies for the need to track development, ensure technologies, et cetera. Said it lacked the cost estimate to inform budget requests, and it said that it lacked an affordability analysis to ensure sufficient

funding is available.

Back in April the Air Force said that it agreed with all the recommendations so since we're at the end of the year, the end of the Trump administration, what have you done to implement those recommendations? Or do you not agree with them anymore?

Dr. Roper: I absolutely agree with them, but I do have to pull the picture frame broader. I guess we're in a picture frame mode today, at least I am. They're right in that ABMS did not resemble a program with a baseline, a documented test program with five years' worth of requirements. They're absolutely right. And were they right that we need to aspire to get to that level of documentation? Absolutely. But we couldn't have done it then. Nor could anyone. They mentioned we lacked formal requirements, we lacked a baseline, we lacked documented test plans. We did lack those things, but we also lacked an internet in the military. We had people coming to work everyday with much more connectivity in their pockets than they ever saw in their military system. That's the big thing we lacked. So you actually have to answer that question to then go back to why we took the approach we did.

We lacked the internet in the military because we don't have the same basic digital infrastructure that commercial industry has. We didn't have cloud. We didn't have connectivity in transport layers. We didn't have data as a service, to feed data to analytics and microservices. We just didn't have it.

So you could go create a program, you could build any one component of that internet but you wouldn't have been able to field it and say hey look, there's an internet of military things.

So ABMS had to begin non-traditionally with the groundwork of building up all of that tech stack that makes the internet possible. There were 38 different projects that were created over the course of that first year that did pretty well. Did pretty well. And what happened in that GAO report to September of this year is we finally had sufficient maturity for the first time to demonstrate a true internet of military things. The military's internet was birthed in September of this year. The first time I've seen it, where I had five combatant commander all sharing the same cloud-based situational awareness by data moving machine to machine across over 40 platforms geographically

separated. AI creating decision tools and analytics and even kill chains in seconds that were interfacing with people and ultimately using that to put our money where our mouth is and she found a cruise missile target.

So the military's internet was birthed on that September [on ramp]. At that point, now that we have that foundational infrastructure in place, now we're ready to do what the GAO wants which is to start making ABMS a program. We built the road, it's like building a foundation. We can now build the firring on top that the Pentagon [lacked]. So release one that we're working on now will be the first documented program within ABMS that will have an acquisition strategy, just like any other program in the department. Rigorous documented metrics, test baseline, funding baseline, cost estimates, have a delivery date, IOCs, quantities and that's why the Rapid Capabilities Office has been named as the PEO. They will be responsible for delivering release one that will have the data gateways that are acting as a cell phone tower connecting big cloud based analytics to forward edge fighters and doing it very similarly to the way the internet works. The RCO will be responsible for fielding that. But if I had tapped them a year ago and said RCO, go field this. I've got this thing, it's called release one for ABMS, go field it. There was nothing to field. The basic building blocks were being developed.

So what I think we will accomplish by January is documenting that acquisition strategy so that we can show the GAO and others here is the first release of ABMS as well as the process to create the second release and the third which are all of those developing product lines that are being demonstrated as they mature up the technology readiness level step function. Every time we demonstrate them they go up a little higher on the rung and as they reach a level between four and dix, they're ready to go into the capability release. We'll be able to show this as a program like any other.

I'm glad we're able to get to this because I'm not sure we could have survived another year of criticism. I think it would have been very fair criticism. But I couldn't have given the department or anyone else release one a year ago because it just simply wasn't mature enough to document anything.

So I'm grateful that I've had the flexibility and the time and I'm really grateful that I think given latitude by Congress and

the department to go do this while I've been in the position because I know that we can build this, I knew I had a team that could do it. But I knew it would be so unconventional that we would bear a lot of criticism. The cool thing, and I'll end with this, is most of the criticism we got very early on was that I don't think you can build something like the internet for the military because the Pentagon has failed to historically at digital programs. I don't hear that criticism anymore. The criticism now is tell me your plan, tell me your baseline. That's an improvement. We've moved to a better criticism. And I expect in the future that criticisms will change again, that we're late or we're not doing enough or we're not doing the right things, and that is a healthy discussion to have or capability that will be arguably the most important for our military which is the system that enables machine to machine data exchanges across the joint force. That may arguably be the most important thing we take to war.

DWG: Have you had to fund the ABMS experimentation at the expense of any other Air Force resourced priorities?

Dr. Roper: No. ABMS is I think other than nuclear modernization the highest ABMS priority. So no, it hasn't pushed other things to the side. I've actually seen kind of a contrary effect. IT's actually accelerating a lot of research because these ABMS on-ramps are providing opportunities for things like the Skyborg attritable aircraft. They provide them an opportunity to go show their stuff. They just flew a Valkyrie with an F-22 and F-35 this week. So I see it actually pulling more of our research and development into the experimental world which is great because it's hard for us to get warfighters enthusiastic about science and technology when it's stuck in the laboratory. But you get it out into a flight test and their imagination starts churning.

DWG: Theresa Hitchins, Breaking Defense.

DWG: Thank you for doing this, Dr. Roper.

My question's a little off the wall maybe but given that you've spent your entire time with the Air Force trying to digitize the service, to make it a software factor, since you've used those terms, how concerned are you about this solar wind [hack]? It seems to me when we're talking about JADC2 and bringing in C3 into JADC2 and everything's digitized from the design of your weapon all the way up to the production, that the vulnerabilities

introduced in the cybersecurity world must triple. So something like solar wind, doesn't that like raise the hair on the back of your neck a little?

Dr. Roper: That's a great question, Theresa. It's the first time I've been asked a question like that. Very insightful.

Yes. This creates a new kind of target for our adversaries. These digital factories that we are using to design things, they become crown jewels and they'll have to be protected as such. So as I look at programs like Cloud 1 and Platform 1 that are being used broadly across our development enterprise, that becomes a single thing to attack whose effects would ripple into other programs.

So we're pulling out all the stops and having red teams and cyber experts try to break our system to ensure that it is as tough as it can be. But the other thing that we have to bring into our software environment, into our digital infrastructure that the department is behind on are new technologies that allow you to deal with adversaries that have gotten into zero trust technologies and doing continuous monitoring.

We don't do that in the Defense Department. We certify things are impregnable and commercial industry assumes everything's pregnant and it has to deal with that after the fact.

There's a huge potential for doing both. I'd love to keep adversaries out, but I should have a plan if they get in.

I went to school in the UK and as you travel around Europe there are a lot of burnt castles in Europe and that tells me that just having a single perimeter that your adversary is never going to get through, if that's your plan there's a burnt castle in your future.

There are quite a few more keeps around Europe that are still standing because they of course want to have the outer perimeter be as good as possible, but they have a plan [inaudible] which are fallback positions and defense inside that perimeter. So zero trust technology presumes nothing is trusted and has security measures that allow you to deal with the potential for malware and other software effects getting inside your factor, and we built Cloud 1 and Platform 1 with zero trust as a foundational tool. But we have to keep up. That is a commercial

term. We have to keep up with this. And then also determine what do we need to add onto it or augment to make it suitable for defense? So there are no free lunches in defense procurement. If you create a game-changing approach to change the system that game-changing approach is likely the new thing your adversary targets. Welcome to the digital age.

DWG: Do you think you can scale what you're doing in Cloud 1 and Platform 1 across like the whole JADC2 network? Because it's not just the new things you're building, it's the old things too and they don't have zero trust in them. Your network's only as strong as the weakest link, right?

Dr. Roper: Very true. Fortunately some of our systems are so old, I don't know if anyone knows the coding languages to hack them anymore.

I'm very positive we can scale Cloud 1 and Platform 1. Cloud and Platform are very scalable commercially. We're following that commercial design model. And Space Force and ABMS are bringing in Data 1 that should be operational early next year, and that will bring data stream across our development environment as well. That will be awesome. Now you've got Cloud. What's Cloud? It's centralized computers that you can access from anywhere. What's Platform? It's a development environment that allows you to create software in the Cloud. What's Data 1? Data is a service. Making data available to the software you put in the Cloud. It's just building up the same kind of capabilities you get from Amazon Web Services. That technology is very scalable. My only fear on it is just simply not having the funding. IT never gets the same love that aircraft do.

The biggest LimFac we have right now is connectivity to it. The connection that we have at many of our bases is very poor. So if you've got the world's best Cloud and the world's worst data plan to connect to it, you're not going to be happy with your service and right now that's the thing holding us back.

Then your point, how do you deal with something being digital and something being analog. That is an area where we're simply boing to have to live in both worlds and be clear-eyed system by system. What is worth digitizing? Many of our systems won't be worth digitizing anything, especially if we're going to retire it. So I would argue we should at least digitize the data coming off of it so we can do predictive maintenance and things like

that. The data at least should be working for us even if the system isn't digital.

A completely new system should be fully digital, like Formula One racing.

And then things like B-52 re-engine or the A-10 re-wings. They're fully digital in components and fully analog elsewhere. Fully analog wing on the B-52, fully digital commercial engine power pod that will mate with them. And the A-10, fully digital wings and actually fairly digital rest of the airplane The A-10 program is pretty amazing in how much the government has done to recreate what we lost which were the authoritative source of truth from the original manufacturer. As we shifted from vendor to vendor we lost what was the true authoritative baseline of the program, and we have actually recreated that digitally. So A-10's more digital than you would think, but the wing had to be digitized for us to compete it, and not everything on A-10 is.

So that's a good case point. Some things will not be at all, some things will be fully, and then in the middle is where most of our programs will live. When they modernize something they will have to make the decision about what makes sense to take on that digital design [part]. What I'm confident every program should be doing is containerization of their software because it just makes everything easy. It makes deploying it easy, it makes checking it out, verifying it easy, and saves us all the regression testing. And there is no way we could have gotten AI onto the U-2 without containerization. None. That was a missing link for the department, being able to get AI out of our clouds and onto things flying through them. Without containerization, certifying the safety of that software would have been a nightmare, and with containerization, it becomes a sweet dream.

DWG: Jacqueline Feldscher of Politico. Do you have a question?

DWG: I do not have a question. Thank you so much for doing this.

Dr. Roper: You're very welcome.

DWG: John Harper, National Defense Magazine. Do you have a question?

DWG: Yes. Thanks for doing this, Dr. Roper.

I wanted to ask you about the new Sci Fire-Collaboration with Australia which I think is being run or managed by the Air Force CEO for Weapons. What do you envision in terms of the prototyping that's going to be upcoming? Do you have a timeline for when you expect full-scale prototype flight tests to happen? And once that happens, down the road do you anticipate that it will transition to some kind of program of record? Or co-production with Australia? What's your vision for that?

Dr. Roper: I'm glad you asked. I'm real excited about working with Australia on hypersonics, but also working with USD R&E, so it will be a great collaboration.

The team's working on the development timeline but the reason that we kicked of this initiative is that Scramjet is moving faster than I expected and I'm delighted to say that I did not predict well. I predicted it would take longer to get those hypersonic engines matured. And thanks to some stellar approaches to manufacturing, the acceleration period is compelling us to go ahead and start thinking through future programs of record.

I would not be surprised at all to see a hypersonic cruise missile program enter into our future Air Force set of programs. It makes a lot of sense with the trajectory we're on in terms of hypersonics. We're very close to putting Arrow, the Department's first hypersonic weapon into production. That will happen in fiscal year '22 to go on the B-52. That will give us a standoff prompt strike capability, so you'll have to fear standoff platforms that will not get close to you. I think that does create a nice dilemma for adversaries.

Scramjet technology in cruise missiles allows us to make hypersonic weapons that are cheaper and smaller. Small enough to be able to go onto our fighter inventory. And as we look to programs like F-15EX that can carry quite a lot of weapons externally, having something that can be a hypersonic strike platform closer in creates another conundrum for an adversary that an outside and closer to the inside strike to go with what we currently enjoy which is stealth penetration and having that truly inside threat.

So I like the fact of having a triple threat in the future and the fact that Scramjet is moving faster than we expected, and we

also have been delighted to be working with DARPA on this as well at our Air Force Research Laboratory and maturing this technology. We're excited to put our tech on the table, have Australia do theirs, and then work together to make this real for our militaries.

So I expect over the next few months as we share our technical data we'll have a better sense of how quickly we'll be able to get to fielding. But I'm not predicting long. We started Arrow when I came to the Air Force. And now we're ready to start talking production next year. I think we can go just as fast on Scramjet.

DWG: Tony Capaccio, are you on the line with us? No?

Then I'm going to go to Valerie Insinna, Defense News. Do you have a question?

DWG: I do. Thank you, Dr. Roper for doing this.

I wanted to ask about AI given the news from earlier this week. How do you push R2's capability forward at this point? What is it doing well right now? What is it doing not so well? And are there plans at this point to try out R2 on any other aircraft?

Dr. Roper: A great question. I love that I get to talk with you about what R2 is doing in the Air Force. I know you often say we're going way too far with Star Wars, but just forgive me this once for doing a Star Wars riff, it just seems like the perfect name for our first AI.

Let me unpack it. What does it do well? It does well what we trained it to do which is to operate the U-2's radar and to navigate. And when we presented it with scenarios where it's trying to find enemy missile launchers against a computerized, fairly smart system trying to thwart it, it did very well. Our pilot found working with it was beneficial. Still had control of the airplane but R2 was providing an important function and doing it faster than people can do it.

That was really just for us to get the first toe in the water for the department. It's been done. Algorithmic warfare is here. We have an AI pilot in the Air Force, and we actually designated it a pilot. If you look at the flight manifest, you['ve got a pilot [Voodoo] and then you've got R2. That's the flight

manifest. I think that's really important because that actually answers your question. What do we have to do now? Well now we've got AI pilots in the Air Force. The first AI operator in the military. We have to have a process to certify AI operators. We have a process to train and equip people today and determine that they are ready to go into operation, and now we need to do that for AI. That's the task that we're beginning now. In fact I'm meeting with the U-2 team today to talk through what it will take to get R2 ready to go into real world ops and to do valuable missions supporting the pilot. So that's the next step on the U-2.

Then beyond that on the U-2 it's really connecting R2 on the plane with the cloud-based analytics that are global via the ABMS program. We'll be working with Cloud 1 and Platform 1 to do that.

I really aspire to get to Tesla-like learning where when one airplane sees or discovers something, all of the other AI on the other airplanes learn at the same time. The same way that a Tesla car hits a pothole all of the other cars learn from that and they don't make the same mistake. It's a really powerful concept for future operations.

We are in discussions on putting R2 on other platforms. So I don't know which one will come through but I'll be shocked if the answer ends up being no. We're even considering having R2 participate in our DefCon 29 AI hacking challenge that we're discussing right now with the Defense Digital Service. We don't want to just raise the flag and say congratulations, the military has AI for the first time. We want to go into this clear-eyed and understand how to break AI. There's not a lot of commercial investment, commercial research on that. Not nearly as much as there is on making AI.

So we think this will be a cool challenge, do a DefCon to see all right, how do you beat R2? We're not going to be afraid of the fact that it will have vulnerabilities. It will have weaknesses just like any human does. And whatever we discover we'll try to fix. Then whatever we fix we'll try to break. And we'll try to break those fixes and fix those breaks and I guess that goes on forever in what we're calling algorithmic warfare.

The algorithms, the AI that we take into the fight, we're going to have to have an instinct for them and they will have

weaknesses that are very different than our humans and our traditional systems. So we'll have to have the same digital stealth and digital countermeasures to defeat them. We'll have to have the analogs of the traditional stealth and traditional countermeasures that we have today for radar, and our pilots will have to have a similar instinct for algorithms the way they do for radars and jammers today. So it's really important that we continue getting AI out into operational exercises so that pilots build an intuition for it. Because it's too fragile a capability when it's having a bad day, when an adversary's potentially messing with it, it's too fragile today for us to hand the reins completely to it. But it's too powerful when it's having a good day for us not to have it there in the first place.

So this begins a new epic of warfare and we've got to accelerate because the technology itself is moving so much faster than our procurement system.

I fear the future where we're fighting tomorrow's war with yesterday's AI, and if you wanted a prediction on what could very well happen, that's it, is that we get happy with AI and feel that we've accomplished something and we don't keep up with the [trend].

So it was a big day but I think it goes to the first comment I said. It was a big day but it was in no way crossing a goal line. It is hearing a starting pistol and this is what I fear a lot, Valerie. You and I have talked about AI a lot. I really fear it because it's just difficult to bound.

It could end up being that it's so easy to break that the offensive order of AI that's trying to out-fox its ability to derive rules from a complicated scene, it could be that is always so dominant that we don't really have to worry about it. We just have a lot of counter-AI capability and we muddy that water for both sides. But it could be that it balances pretty well, that the countermeasures and the counter-countermeasures balance well so that as you get into a cat and mouse game if you pick your plan well, you can always have a decided advantage. The good news is the Air Force is pretty good at cat and mouse games. We've done that with stealth and radars and jammers. We've done cat and mouse games with the electromagnetic spectrum and we've done it very well. Now it's time to do the same for algorithms.

DWG: Can I follow up really quickly on that? I know this is

probably an answer that's going to evolve as you guys learn more, as this technology gets pushed forward, but as you guys are thinking right now, what is like the optimal end game here? What's the optimal workload between what the human pilot will do in a U-2 versus what R2 will be capable of doing? Or is the kind of end goal here to maybe move the human pilot out of the U-2 altogether? Whatever your answer is, how far are we from getting there? Is it a couple of years? Are we talking decades? What sort of, I guess what I'm asking is where are we going and how far are we from getting there?

Dr. Roper: That's a great question.

It will depend on the mission to answer the timeframe. For many missions we're ready today. Skyborg, the attritable airplane, that's going to be flown by R2 or another Sci-Fi named equivalent. In fact I wouldn't be surprised if the R2 make it into a Skyborg attritable in the near future.

Attritables are meant to go take risk and AI has no fear. And that mission we're ready to go do today. That is a very different mission than today's Air Force where everything that flies an airplane has life and limb to worry about so they certainly could do the above that. So we're ready to do that today. But the same thing I mentioned about counter-AI would convey. All of those AI pilots that are flying solo will be vulnerable to counter-AI techniques.

The kind of AI That ins at Chess and Go it knows the rules. It derives them quite quickly by playing itself if it's an unstructured learning with reinforcement, it learns a sense of the rules. And games like Chess or Go or even DARPA's star-fighting simulator which is a video game, has rules that are fairly well understood, but if you go to warfare in total and all of the capability the U.S. or a country like China could bring to bear, the rules, the fundamental principles will be difficult to derive. To gamify warfare at that level in an algorithmic sense will be exceptionally challenging which means there will be so many opportunities to exploit AI's need to extrapolate rules so that it can improve upon them.

So that AI in Skyborg will almost certainly hit AI countermeasures our adversary will throw at them and if they're properly designed then that system could fail. But hey, it's attritable so that's not as big of a deal.

For something like a next generation air dominance fighter which I am confident will have an AI-assisted co-pilot, maybe even R2 inside of it, the role will be very different. Now we're talking about a capital asset that we don't want to lose and that we may be giving more critical missions to. So in that case AI should have more of a support function and the human is there to help augment when AI is being thwarted, when it is being meddled with.

What I expect will happen in the pilot/co-pilot role, the Luke Skywalker, R2-D2 role, is that pilots will gain an instinct just like they have an instinct for stealth today, about when their AI co-pilot is performing well or could perform well, and will turn over more of the reins to it. And will have a similar instinct of when it won't be performing well and will pull the reins back to the human. Our job as designers, my job as the acquisition exec is to give them that knob so that they can tune in what AI is doing. And the really important thing that will not get the same spotlight as AI, is the containerized software approach below it. That is what allows us to localize what the AI does, creating something very similar to a breaker box for code, where the container either cuts the power on or off and nothing in between.

So for R2 flying the recent mission, R2 had complete control of the radar, and complete control of navigation. It had zero control of anything else. But if that U-2 had to fly through a very dense maze of radars, maybe the pilot would want to hand over actual control of the stick and rudder itself so that the AI could thread the needle. The key is giving the pilot, giving the operator that choice and containerization lets us do that. And if we design it that way, then it will be easy for the Air Force to operationalize because the risk doesn't become a safety risk. It becomes a mission risk. Our warfighters are trained to evaluate mission risk and take the appropriate course of action.

So the thing that will -- I wish I could underscore enough is software design, software design, software design is the key to operationalizing AI, and if you don't do it right you will make such a hard conundrum for the certifier that it's easier to say no, let's study it, let's think about it, and it doesn't make sense to study any thing in the era of AI. It's better to go ahead and let the AI start doing and learning because it's a living, breathing system very much like the human. Just silicon based.

DWG: Dr. Roper, we've gone over the hour you promised us. Do you have time for a couple more questions or must you move on to your next meeting?

Dr. Roper: I'm happy to take a few more.

DWG: Michael Bruno, asked to ask something. Michael from Aviation Week Network.

DWG: Hi, Dr. Roper. I want to ask you about I think yesterday I heard you talk a little bit about space primes, maybe, and trying to do something like Air Force Prime did with Joby during the sort of military certification in space, maybe around payload swapping or something like that. Can you talk a little bit more about that?

Dr. Roper: Absolutely. Agility Prime has been awesome. That's our flying cars program. It's already created a new market. We've got Joby certified to fly military missions and a year ago flying cars were the hypothetical Jetson's future that never happened. So that's what happens when the military gets involved and we bring something that's more than our money, which is our testing and certification process. The idea in 2021 is we do the next successor to Agility Prime, we do it in space. And the ideas we're kicking around right now with industry, we're open right now for input from them which is why we talked about it and been open that this is what we're going to do next are things like refueling in space and swapping payloads in space where our certification process within the Space Force could create a military cert which doesn't exist today, but hey, we're really good at dealing with the new and unforeseen challenges that warfare poses. So we can easily come up with a certification process. And if we granted that certification process for a company to refuel or resupply one of our satellites, very similar to what SpaceX does for the space station, then we feel that certification would help jumpstart a counterpart one in commercial regulations, commercial industry.

So we'll keep the door open for ideas over the next month or so and then we'll take the best one and get to work with the Space Prime. But the idea is to make a space mission or market happen faster because of a military first adopter, but not letting the military adopter become an anchor weight that slows down the market.

DWG: A really quick follow-up. Are you talking to legacy industry providers? Or are you talking to new space Silicon Valley providers?

Dr. Roper: Mostly new but we're open to companies of any type. The door's open to anyone. But we want to see new new. Right? The thing that's cool about flying cars is that if you read the research on them, you think flying cars, you think flying to work. But if you read the industrial analysis on it, it could really change our economy. That's what's really exciting about it. The military's accelerating a commercial market that's probably going to have a bigger economic impact on the nation than a national security impact. But shouldn't a military play that function for the nation that supports it? Shouldn't we be helping the nation compete economically where mission is something aligned with that? That's what's so exciting about Agility Prime. We want the same effect for Space Prime. We want the military funding and mission to accelerate a space market that doesn't currently exist and to bequeath that benefit to our nation and its industrial base.

So it hsould be fun. Agility Prime has been a ton of fun.

DWG: I'm going to take the prerogative of moderator to say I've got three people lined up who want to ask questions and I'd like to give them a chance to, but let's drop the follow-up questions please because we're otherwise really drawing too far on our guest's time. So first, Garrett Reim of Flight Global, and then Zack and then Sara.

DWG: Thanks for the time.

I had a question about the U-2 and its recently demonstrated ability to upload new capabilities while in flight. It sounds really neat, but I'm trying to understand the practical application of that. What sort of a situation where new capabilities are so urgently needed that they would be done, they would be uploaded in flight? And how soon could we see that? What would be the first operational example of that?

Dr. Roper: Great question. The uploading software during flight is actually a precursor for what we did with artificial intelligence and the two of those go together. As AI goes into operations, we may very well need to update it. Or if we find

that threats are not the ones that we forecasted, we'll need to upload new data and the software associated with turning that data into code on the jet, we'll need to do that before the jet lands or we'll abort mission, maybe even abort the aircraft.

So AI and live software updates go hand in hand. And if you think about the commercial industry, software updates occur daily. That's not uncommon at all. And aside from AI, just the relevance of our code and the need to keep updating it, to keep it cyber secure motivates us to keep our code fluid so that code itself is not a sitting target.

If the same code sits on our airplane for years and years and years, that's a vulnerability. And a world of AI where AI is actually an attacker of our code, sitting there flight after flight could be a vulnerability, and maybe in the far future we can't even afford to have the same software land on a jet that took off.

So we're striving to push the envelope and I think AI will be the first thing that forces that to be operationalized. I think the other thing that could challenge it is if we went into a mission and the threat was different than what we expected and we had to make an immediate change to the code before that jet could come back and land.

DWG: Zack Biggs of the Center for Public Integrity.

DWG: Thanks. Dr. Roper I wanted to make take a cue from Michael and ask on the question of sort of implementation of AI and the broader risks associated with it. I wanted to ask, there's enormous competitive pressure between China and Russia and near peer competitors who are pushing aggressively in this technology. Do you think there's a risk that the U.S. is going to be pushed into implementing some of these technologies a little too early? Especially when it comes to questions of the lethal use of systems that may have AI in them? And how do you view those sort of competitive pressures in terms of any sort of break on the ethics of AI in weapons?

Dr. Roper: Very good questions. I think what I fear is that the ethics challenges that we will have to continue to bear and should continue to bear in the U.S. need to motivate us to work ahead of where our adversaries are. We're going to have to work harder than they do because we will not turn over decisions that

they will choose to do because of our ethics [inaudible]. That means we have to work harder at AI. That's why I fear that it's taken the military so long just to get AI safely onto an airplane to operate with a human. That's great. I mean it's a cool thing to say you've done for the first time in department history, but it's 2020. It's about to be 2021. And that's not even amazing, folks. That's simple technology in today's world, to put an AI co-pilot in a military system. We are so far behind what should be amazing for the military, and as we compete against nations like China and Russia, especially China that can match us militarily, economically, competing against yesterday's gold standard is losing. We've got to shoot for gold tomorrow.

I really just fear our lack to keep up. I don't fear us losing our ethical standards, our moral standards. I fear that our ability to forecast how fast we need to work to be able to maintain them as well as the capability needed to win will put us behind the power curve and that's why I'm passionate about trying to set the Air Force up to bring this capability into the operational Air Force that will start creating those challenges.

Aside from the moral or ethical dilemmas there will be personal warfighter dilemmas. Like how much should person A trust their AI co-pilot on given mission? They have that instinct for traditional systems today. How much should they trust their stealth? Think about that. We have people that take airplanes into harm's way knowing very well that if their stealth is not properly maintained that they're a sitting duck and yet we've got the world's greatest Air Force [support] who know how to keep that stealth profile up to snuff and we know how to go take an airplane into an environment that otherwise airplanes shouldn't be able to go into because radars are there to keep them out.

That same trust will need to be built up and that same knowledge that trusting AI doesn't mean trusting it as infallible. It means trusting it under conditions and risks that are understood. That will have to be built up. We have none of that today.

The fact that we decided to treat AI as a pilot, that was a local decision made at Beale Air Force Base by the 9th Reconnaissance Wing. A decision they had to make while DAI in some places, is it a system, is it a pilot? The fact they logged it in as a pilot, I think that will have broad, far-reaching consequences for the Air Force and I think they got the decision right. Because once you think of it as a pilot you don't immediately

upload infallibility. It's not a thing built on fundamental physics. It's built on convolutional neural nets that operate more like decision logic that we see in humans. And just like humans, we should expect the same strengths and weaknesses that we currently know how to manage. That's that next level of acumen that we've got to develop now, and if we don't get that right, that foundational framework right on how we train, how we trust, how we deploy, then don't worry about my side of it which is keeping up with the tech trend. We don't have the place for the tech trend to take home in the Air Force, and I fear that more than anything.

I fear all these technologies that continue to accelerate, and AI is accelerating AI. The fact that it's already moving so far is so overwhelming and such a challenge. It's kept me awake a lot of days. That's not a euphemism. I've really sat awake trying to figure out how to get the Air Force into this game. And the fact that AI is accelerating the development of AI means that staying out of the game too long may mean that you actually can't catch up at all anymore. And we're used to being able to hunker down and tighten up our belts and get it done when we have to, but you can't beat exponential curves.

I'm sorry, I went too long on that answer. But your question actually prompts the thing I fear the most and I appreciate that question.

DWG: Sara Sirota.

DWG: Hi. Thank you so much for taking this final question and staying over time.

I wanted to ask about the recent Valkyrie gatewayONE test. The press release that the Air Force published mentioned a connectivity issue with the communications payload and I was wondering if you could talk about what happened there as well as maybe describe how long the Valkyrie was in flight for with the F-22 and F-35 and maybe how close they were to one another.

Dr. Roper: That's why you get out and test, to have these on-ramps. The gatewayONE relay worked great. It pushed data back and forth between the F-22 and the F-35 and both on and off of the systems.

The one on the Valkyrie, we did learn something, and that's that

the board that we made it through, I was not happy with the rocket assisted takeoff, so we think we had a connector that came loose during it because the gateway itself was fine when the Valkyrie landed. So it's a thing we've learned from that we'll fix next time.

Fortunately we had a second gateway that was on the ground that was acting like a Valkyrie would in the air but doing the same thing wave form transposition, so talking MADL to the F-35, talking IFDL for the F-22 and pushing data back and forth.

They did a lot of firsts. It's the first time we pushed mensurated targets off of one of the systems to a remote platform. We pushed systems down to ground vehicles. Pushed off full motion video. So it was a great test. Valkyrie did great. I don't know offhand how close the vehicles got together. I'll ask my team to get that number distributed. But did well in flight.

Connectors are always a thing to worry about and the next time we get out and slide in the next on-ramp we'll probably check those soldering points more than one time.

DWG: Dr. Roper, thank you so much for staying overtime with us today and for your generosity with both your time and your ideas.

It just leaves me now to thank everyone, with them a Happy Christmas. I suspect we'll all be celebrating the New Year with even greater happiness than usual given what kind of a year we've had.

We don't have any sessions for the rest of December but there's some very exciting things that are at least penciled in for January, so stay tuned for that for the Defense Writers Group in January.

With that, thank you. And Dr. Roper, again, thank you so much for spending time with us, a lot of time.

Dr. Roper: Thanks, David. Thanks everyone. And again, I echo David's remarks. Have a wonderful holiday.

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