UCAV Technology - Developments and Capability

by

Mr Scott Winship

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This seminar will discuss the fundamental case for Unmanned Air Combat Systems, and cover the importance of rigorous analysis in requirements development and trade-offs related to the design of an aircraft. In particular, Mr Winship will analyse the requirement to balance competing requirements for range, endurance, survivability and payload to enable development of an affordable system.

An Australian CONOPS [concept of operations] will be used to illustrate the type of capability that the ADF could reasonably expect with an unmanned system similar to the X-47B to be in place as early as during the next decade.

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Scott Winship: First of all, thank you very much for coming. It's nice to see so much interest and I'm glad to be in country. Australia's been absolutely wonderful to us in the week we've been here. We expect to follow up more as we go.

What brings us to this point is, number one—we've been thinking about UCAVs [umanned combat aerial vehicles] for a long time [while we've] been going through UCAS-D. We've talked mostly about X-47, only because that's what we're most familiar with and it's a good example of what a UCAV could be.

We were tasked by meetings through PACOM and PACFLT and the places we've been, talking about the next generation of Navy UCAS or Air Force UCAS. [We've also] talked to our allies about what they think—what are their needs; what are their problems? What can they address in the future? And with this kind of capability, you could talk to two allies on earth; you could talk to the Brits and you talk to the Aussies. And the guys at PACOM, the guys in Hawaii, wanted to know specifically: What do the Australians think? What does ADF think? And we're here to try and explore that and what are the unique missions and issue sets that are here in Australia as part of the joint force and allied force?

I'm going to take you through a little bit of what UCAV is, what UCAS is. I use the terms 'unmanned' and 'uninhabited vehicle' and 'system', all interchangeably, so if you have a question about that or I'm just rambling, stop me.

We're going to talk about what we've done recently for the Navy, in particular. When we started the program back in 2002-2003 with Dr Colonel Green, the Air Force was pretty confident in their ability to fly on and off of big, long runways. They can do that pretty easily with either a multi-piloted or automatic. The Navy had an extra step to go through. Our Navy had to fly them on and off a carrier and if the requirements held to be a flying wing, I can tell you that we were told many times that flying wings don't go on the deck of a carrier.

There was a program called A-12. You may or may not remember, or may have read the book, about what a disaster it was. A-12 was a big, heavy—a flying Dorito chip off the deck of a carrier. And because of the vision over the nose problem—12 degrees vision over the nose [is required] to land on a carrier. The high lift required, it had high lift devices, it's got leading edge devices; trailing edge devices; blown flaps and all kinds of variable geometry to try and make that happen—that made the airplane really heavy, really expensive and it died an anguishing death as a cancelled program.

When UCAS came up, we told the Navy, 'You know, it is that we're unmanned. We don't care about the vision over the nose anymore. And the angle of attack that we fly at is the best angle of attack for approach and enables a flying wing. It enables something that can penetrate deep into, into denied territory.'

That led to the Navy saying, 'Okay, you got to go prove the two things that we need; one is prove that a flying wing can go on and off a carrier, unmanned, and it can do precision approaches and can be as good as a pilot (and I'll give you some sea stories about that) and number two, can you air refuel it?' Air refuelling unlocks the power of unmanned [aircraft]. The only reason to go to unmanned is to be persistent at distance.

And we're going to go through a little bit of that set for you today. I hope it engenders a conversation or questions. It isn't necessarily obvious to the casual observer why UCAS is important. Kim and I have been thrown out of more than our share of meetings in the Pentagon. 'Why do we need this? What's different about this?' And we're going to try and show you a little bit of why it's different and what kind of thinking goes into this kind of a system.

First of all, I don't know if you can read that or not. The UCAS is not a small airplane. It's not a ScanEagle; it's not a Pred. It's 50 000/55 000 pound airplane, 62-foot wingspan; 38 feet long, has a single F100 aboard out of an F-16. We take the blower off and use only dry power, which is a big airplane. She has all the subsystems; wings are foldable to go aboard a carrier. It has an APU [auxiliary power unit]. It has essentially modified A6 landing gear; big landing gear, big thick landing gear. It has an APU for ancillary power. It has triplex controls for the computers.

It flies itself. It follows commands. It follows pre-planned routes or you can interrupt it. It is not remotely piloted—there's no stick and throttle. There's no ability to put a stick and throttle in and interrupt what it's doing. It follows a pre-planned route or it follows an interrupted route. You guys are probably familiar with how Preds work or how Global Hawk works or Triton works. [UCAS is] very similar but it also has precision navigation because it has to come to the deck of a carrier.

[It's] about the size of an F-18. There's an F-18 in juxtaposition. There's an F-35. One day we'll be able to align core to core on these and show you what real airplanes … how they compare. But it's okay.

Carrier demonstration was the first thing we did and we're going to show a quick demonstration of this; show a quick movie of this. And as we go through the movie, we're going to go through two pieces. One is carrier launch and I'll you that United States Navy will launch anything you want. They'll take your car and launch it, if you want to. They don't care. They don't care much about the certifications for launching. They do care about landing, and when you see the number of people around when it's landing, you'll know why.

Here it is at half speed and we'll probably show this a couple of times so you don't have to strain yourself. These brave souls up here in the left, standing close. She's a big airplane. It's at half speed and we'll show you another quick picture of it landing on centreline.

This is the camera gear, centreline of the airplane, centreline of the ship. Watch the paint. Watch it. There's about an inch of paint on each side of the wheels. That's how centreline she is. I will show it a couple of times just for clarity—it's better to have movies than charts.

When we first started this program, we got an awful lot of, 'Well, can't do that,' or, 'That's really hard,' or 'I don't know how you're going to wave it off'.

And I don't know how many of you are familiar with naval aviation, but there's a nine-point matrix at the out aft centre of the, of the ship where you're high and hot, which means you're, you're high on centreline and you're going too fast. There's low and slow. You're low and you're not going to make it up over the fantail.

And the United States Navy doesn't have any waivers. It is essentially a Navy aircraft. It's to Navy standards. So they said, 'Okay, you're going to have to demonstrate that you can do a high hot engagement; you can do a low slow engagement; you can do it from the left; you can do it from right; you can come back; you can do an in-air; you've got to demonstrate that you can do all these things.

And as I thought through that, with my little pointed head, the only way to do that is I have to program [it to fly] in the wrong position [because the UCAV] knows what the right position is. I have to program in at six miles, at the tip-over, I have to program in that … okay I know you know where centre is but I want you off to the right and I want you high and I want you too fast on speed.

So when we briefed our Navy on that—and Tim and I have those same scars right down the side of our back—[we asked] 'Why are we doing that? What's the point? If it knows where centre is, if it knows what it's doing, let's do that first and let's see how many times we're off.' Well, we did over 10 000 landings in a simulator and we did in the order of 70 or so arrestments with the centreline and she never missed by a square about nine by four inches on a strike. We had to program in an offset because it was wearing out a hole in the deck.

Tim: I'm going to run in one more time [on the video], but the reason for the half speed is so you can see how stable it is on the approach. Any of you that fly Hornets or whatever, know, it's kind of hard to fly an electric jet, how to keep everything moving or not moving much. This is iterating at about 100 hertz whereas we fly airplanes at about three hertz. So it's a much faster response.

The reason for the centreline … the nose camera was because that's the most critical part of the carrier landing for any airplane. And captains worry more about landing on centreline than everything else because they've got guys on either side and they've got airplanes that are expensive so we have to be able to track-down [the centreline]. The landing – I don't want to call it elementary or rudimentary, but next to the track-down the centreline, that was secondary. And so I'll run it one more.

Scott: Okay, and the reason we bring it up is not necessarily to teach you all about naval aviation or how cool this is or anything like that. It's more to think about what the machine is good at, versus what people are good at. The machine is really good at this. It is flying airplanes. It is meeting precision points. It is doing a very set piece of zeros and ones. And Tim mentioned how stable it is. You notice the airplane's not flopping around, not trying to keep up. That's because it is operating at such a rate that [when the UCAV enters] the burble that comes over the deck, off the island, it actually starts to make small corrections instead of making big corrections to keep up. So it makes very small corrections all the way down and to us, it looks stable. To the airplane, it's like watching an hour hand run.

Question: It looks like it was a pretty nice day when you were doing those trials. Have you done any work with higher sea states or greater wind conditions?

Scott: Good, good question. The test environment here was the calmest of days. I think even I could put an airplane aboard, which would be saying something. We did over 10 000 runs—it's probably over 100 000 now—at up to sea state five. And other than hook skip, which is a random event, it just doesn't miss. It can keep up with deck heave; it can keep up with winds. It goes at the computer rates. It doesn't have a problem keeping up with that. And when we get the chance to test it in those conditions, which we will eventually, I have a lot of confidence that we can hit those numbers.

And that brings up a good point—the airplane also doesn't care that it was a nice day. It could have been the middle of the night; it could have been raining; it could have been a storm. It didn't have a bad night the night before. It doesn't care how many times it does it. If it has enough gas aboard, it's going to just keep doing what she's told.

So one of the things we bring up with naval aviators in particular is, that it could be the middle of the night. When we did another quick sea story four on unmanned, when we were getting ready for first flight, the Navy and the FAA and everybody's involved in certifying for first flight, getting ready for first flight. And there's a rule—it's kind of a rule of thumb, but it's a rule—that says: if you're going to go to high speed taxi, you have to have a flight clearance. Because about 20 years ago, we had an F-16 that went ripping along the runway and it had what's called flight zero. It wasn't first flight. It was high-speed taxi. But the airplane all of a sudden was airborne and the pilot yanked it into the air because that was the safest spot for it, if you're running out of runway. Well, he had flight zero before that. So since then, if you're going to high-speed taxi, you're going to flying speed, we want you to be able to have flight clearance in case it goes flying.

I was completely unsuccessful in convincing anyone that it doesn't know how to fly. It doesn't know that the best way to keep going is to go yank into the air and the safest spot is in the air. It has no idea. It knows where its next waypoint is. Even though it's got flying speed, it's not going to just lift into the air. It will just keep itself down because it's trying to meet points.

We couldn't convince everybody. We had trouble getting clearance for the airspace around Palmdale [Airport], PAX [Naval Air Station Patuxent River], Edwards [Air Force Base]. You guys are probably familiar with all those places. And we had problems just getting enough time to go do that. And so we said, 'Well let's do it in the middle of the night. We can go fly in the middle of the night. The airplane doesn't care.' 'Oh no, no. Oh no. No, we can't do that.' 'Well we've got to have a chase.' 'Why? Why do we have to have a chase?' You know you're following dogma of how we've always done traditional things. And the reason I bring it up here is 'cause we're all collectively going to have to think through all those pieces and parts.

Scott: The other move that we bought or the other thing that unlocks the power of unmanned is air refuelling and I'll give you another set of data to think about.

You're going to see the X-47 get gas on her own. It's an Omega tanker sitting there doing lazy eights around PAX airfield.

The airplane is solving for the tanker. So, it knows where the tanker is; the tanker's giving it a position. And the tanker doesn't have to know … I mean in a test environment, we had a tanker crew that knew what was going on. But the tanker crew is essentially doing lazy eights in a pattern and when she [the UCAV] launches from PAX, it solves for how it will rendezvous with the tanker, how it will chase the tanker down. It gets into position and starts just following around by GPS. Searching in infrared and visual bands, it acquires the tanker.

Once it acquires that vision, and that tanker can be an F-18 drag and a drogue; it can be an A-330 drag and a drogue, well it can't be a Boeing airplane 'cause they don't have any of those. That airplane has now taken each of those dots, in infrared and visual, it's solving each of those dots for a velocity vector. And it's chasing those velocity vectors around. When it [determines] the left wing tip and the right wing tip are turning, it turns its velocity vector. It stays with [the tanker]. So when it gets in position, it's going to follow that tanker wherever she goes.

We did that purposely so that the tanker has freedom of movement. The tanker doesn't have to maintain a straight line. It doesn't have to do anything unique for this particular vehicle. It also is that the tanker isn't doing anything special. We didn't do anything specific to the drogue either. The drogue is just a standard drogue.

Tim: Watch the horizon now.

Scott: If you can see in the back there, the horizon tilts. The tanker pulls all the Gs it can, both of them. And we follow that around; it's not hard to follow. We'll run that a couple of times.

But it is that we've visually solved for the equation and the airplane will have enough control power to keep up with a drogue, and it does because the rates are so high. We solved the drogue problem 'cause that was the harder problem. Flying in formation behind an Air Force boom-style of receptacle is actually a subset of this problem, 'cause I can just change the position where she flies to put a boom in. The drogue does not have any modifications and the airplane has just a standard probe and a set of cameras embedded in the wing. That's the only change.

Tim: As some of you may know, when you approach the drogue, the airplane's bow wave pushes it out to the right or up and to the right and the pilot has to compensate. You aim for the probe to get where it's going to be. But we had to ultimately put a couple of biases in to enable that but [it] took one or two and we were in.

Scott: We didn't have any way to model how much the bow wave [affects] the drogue. As you approach, it tends to move away from you. Some of you have probably done that with a Hornet. We had no way to model how far that would be so we built in a set of gains—essentially a gain table, that have offsets, left, right, up, down, so you could do it in increments of six inches or a foot and try and figure out where she should be. We missed a couple of times. Once we dialled it all in, [the UCAS] plugged every time. It doesn't have a problem, whether it's in a turn or it's on the back or it's downwind.

Now the next set of tests are station keeping and how do you do the control? The demonstrator is built for refuelling [because that] is so fundamental to UCAS. When you think about how long can a UCAS stay up? Fuel is obviously the first problem you have to go solve. And refuelling is so fundamental to the concept of distance and persistence and, and allows unmanned [aircraft to do the missions].

We solved it two ways. The airplane has a probe drogue. We have one from a company called Cobham in the UK that has a retractable drogue for a stealthy aircraft. But we also have a flip-over receptacle, like an F-117 has or an F-22. F-22 has a door. But we wanted to be endogenous; it can take fuel any way. And that just keeps unlocking the power of these things at distance.

So overall, we've proven the concept. You're seeing a concept [that] is coming to the fore here. This thing is now, to some TRL—technology radiance level—above flight. It is done. But why is it needed? And that's the part where we want help in thinking through.

First of all, why would it be tailless, stealthy and refuellable? Obviously tailless has something to do with its stealth, with where it wants to go, where it wants to go fly. What kind of threats it wants to be in. What kind of threat bands it wants to be in. As Colonel Green said, 'There are reasons why Preds are where they are; there's reasons for what they do. They are a unique machine. It does what it's programmed to go do. There's a unique reason for Global Hawks. There's a unique reason for Triton. There's a unique reason for a 15-hour helicopter. But when you start talking about tailless, refuellable [UCAVs], you're in really tough territory.'

[There's a] massive increase in mission and combat endurance. We typically run about 50 hours. If it's refuelled, it can stay in the air about 50 hours. And you say, 'Why 50? Why not 100? Why not 1000?' We limited it because of existing inspection criteria. You have to actually look inside of a wing at an actuator at a certain number of hours of flight. And we didn't want to get beyond reason here and start inventing new technologies that don't need to be inspect for thousands of hours. So being in the air more than about 50 hours, just seemed to be getting to the ridiculous.

So, 50 hours is what we limited it to but she's got an organic range of about eight hours, then goes and gets gas and chainsaws, and I'll show you an example of that here in a minute. But a massive increase in combat endurance. So at distance, 50 hours. I'll show in a minute on a, on a vignette we run what that means at 2000 nautical miles.

Enhanced survivability in persistent operations. Because we don't have a cockpit and we don't have a pilot aboard, [it has] enhanced survivability in persistent operations. So she's persistent and we've enhanced survivability. That's a very flat looking airplane. It looks like a blade, boomerang here. Actually, that was one of the names that came up for the airplane early on and I think if we had a roundel with a kangaroo in it, we probably would have done that.

No aircrew capture or casualty risk. Obviously when you're going somewhere, you've got to set that up, got to set the CSAR [combat search and rescue] up. That can take weeks, as you probably know. I see a lot of Air Force uniforms who know how long it takes to get CSAR. These things [UCAVs] are instantly usable. You can send it right today and go.

Potential cost effectiveness advantages. Now that's something we're exploring and we're starting to understand. Cost effectiveness is not about the airplane being cheaper. I can tell you that that airplane costs about the same—I won't say as the F-35—but it costs about the same as a Hornet, about the same as any fast jet, say an F-16. The savings from not having an ejection seat and not having an OBIGS/OBOGS [on-board oxygen generating sytem] system for pilot support is a nit compared to the overall cost of it.

The cost advantages are not in the unit cost. The cost advantages are that I don't have to train pilots in it; I don't have to fly it to train it; I don't have to keep currency on it. Those things tend to drive how much you fly an airplane and how fast you wear out an airplane. There was a study on it from a company called Center for New American Security, and we'll make that available to you, if you want to, or it's online and you can get it online. My guys can provide any of that for you. But it is essentially a study of if you replaced all the EFs [Super Hornets] in the United States Navy with an unmanned version, how much would that save? How many less airplanes could you buy? I think the airplane buy comes down by about half.

Tim: Yeah, it's a whole new airplane though; a new manned airplane or a new unmanned airplane.

Scott: What should you buy … it's a thought piece on what should you buy next? And it just engenders some thinking about how much fewer airplanes you can buy.

To give a persistent coverage and perspective, we used the West Coast of the United States. We got criticised one time for that. 'Wait, we're not going to attack the United States from Hawaii.' That's not the point. We have our share of knuckleheads in the US. This is to get your head around the perspective of how many airplanes for how much coverage from familiar places. I'll give you some Australian familiarity also, just to get perspective. But here's Hawaii. Here's 2000 miles to the West Coast and I live down in San Diego. Tanker safe line is 250 miles off the coast, so the tanker safe line is backed off to where the tankers are operating with impunity. We can move that in our analysis to between 500 and 700. We can move it to anything you want. It just changes the calculus a little bit, but we'll show you what this means.

The airplane is essential an X-47. Ninety percent FMC [full mission capability] rate, turnaround time's eight hours. So when it actually does have to return, you turn it around in eight hours. In-flight refuelling is 30 minutes at the tanker and refuelling at tanker safe lines required.

Tim: We looked at 100 airplanes. Maybe not a logical number, but that was for the study.

Scott: The luxury of the 24/7 surveillance and attack coverage of 100 aircraft fleet. A hundred aircraft fleet is not what we suggest. It's just a number you can get your head around. It's a number of airplanes that could be bought in an air force.

Fifteen minutes time sensitive attack. You guys are probably familiar with that but what you're doing is setting up a network of these things that have a 15 minute–response rate. The problem we're trying to solve is one of the hardest problems for an advanced air force: emergent targets, when a target presents itself for 20 minutes and then goes away. You have to be there when it presents itself. So mobile relocatable targets are a problem and one of the ways to solve that, if you don't have overheads and you didn't pre-calculate everything, there's lots of other ways to solve it. But one of the ways to solve that problem is to have a persistent force over an area that you're trying to control. You're trying to put force over a selected area of interest. So we gave it a 15 minute time sensitive attack rate.

So what we're doing here is we're flying from Hawaii, refuelling as necessary and then we set up a network. It's pre-programmed mission planning, because these airplanes aren't just sitting there doing circles around their 15 minute target. They're actually ingressing and moving around and then another one will come by in 15 minutes then another one will come by. It networks that in so that it has enough airplanes to do it. So what falls out is coverage. So 15 minute coverage, over something that we're familiar with.

For perspective, with 100 airplanes, from Hawaii, you're covering a third of the United States for a 15 minute response rate. That combat power, at distance, is what we're after. That's what the power of unmanned [aircraft] is. So you're refuelling them as necessary. They're heading home as necessary to get re-armed or getting inspected. Make sense? Those numbers are staggering. I'd love to see that same analysis for any manned fighter. Number one, [it] can't go from Hawaii, in and back, unless you're in that seat for eight or ten hours. If the tanker safe line goes to 750 nautical miles, most fighters today can't get from [the tanker to the target area] over that distance. So the Pacific becomes what we're most interested in because of the distances in the Pacific. As General Deptula said, 'The tyranny of distance in the Pacific.' The distances are so vast, it makes a difference.

We're here mostly to talk about what are the requirements for a system like this? Range, endurance, survivability and payload. Those four balance at an affordable position. You have to find the [optimal] balance of those. In the United States, we've seen our Navy push for, 'Okay, we want a 14-hour airplane'. If you're prioritising endurance, that means payload goes way down, survivability goes out the window and range … although range is up organically, if it doesn't meet the requirement of refuellable, you're not taking advantage of the full Monty.

In range, it's real simple. What range is enough? Is it 2000 miles; is it 5000 miles; is it …? How far does it have to fly organically? How many tankers do you need? How many tankers do you have? So range becomes how much organic range and we found a sweet spot at about 1500 nautical miles for the airplane; 1200 to 1500. But then how far do you have to operate? That can be in the thousands, say 2000 miles. And that has to be done with a tanker. And how many tankers do you need?

Range—a notional example. You've got to balance speed in this because range is speed, in some cases. In this particular example, they fly with the Hornets and I don't mean that they fly with the Hornets because the Hornets are not out at those ranges. But you want it to be an airplane that's not slow. It's not a Zeppelin. It's not taking its forever to get there.

Tim: And the 3000 is out and back.

Scott: Yeah, it's 1500 out, 1500 back. Max sortie endurance is 50 hours.

Tim: This is organic range. Now we looked at your south-western islands [Indian Ocean Territories] because it was much less controversial than looking in other directions.

Scott: Because we're weak.

Tim: Our resident expert gave us a heads-up on that because I had it going the other way and I got, 'Yeah, not so much on that'. So we're going to take six ships out of Pearce and we're going to put a tanker out there and assume a tanker all the time. Whether it's realistic or not, please just bear with me, but we're going to try and generate the maximum amount of coverage with six airplanes over those islands out there.

So you put your tanker and the airplanes are going to hit a tanker coming out. They go out and with the six airplanes and the 90 per cent FMC rate, the turnaround time and so on and so forth with six, you could keep a 24/7 coverage of those islands. They only get two hours apiece out there but you're cycling them back and forth. Now you've got to keep a tanker out and that's a given in every conflict, it seems. But it gives you an idea of what 15000 nautical miles out and back and endurance of eight to ten hours and then having the fuel for a 50-hour enduring flight will give you, as far as coverage. Small number.

Scott: That's similar to the example of the Hawaii/West Coast thing that we went through, six airplanes from Pearce gives you two hours 24/7 at these kinds of distances.

Tim: Twenty-two sixty [nautical miles].

Scott: Twenty-two sixty, that's a long, long ways away. That's our Pacific and Indian Oceans. They're just long distances.

Tim: Now that's a Triton mission. We're not trying to subsume that in any way, shape or form or send another signal because we are wholeheartedly in on the Triton/Global Hawk world. But to give you an idea of what this [aircraft] could do in other directions, when you have to have stealth and weapons, it may give you that sense.

Scott: Endurance. A brief talk about the air refuelling. You saw the video. Refuelling allows you to not make every nook and cranny in the airplane a fuel tank. You can carry weapons. You can carry SIGINT [signal intelligence equipment] or ELINT [electronic intelligence equipment]; you can carry ISR [intelligence, surveillance, reconnaissance], strike; you can 'missionise' the airplane to be what it needs to be for whatever the mission is. You make it ubiquitous. You make it so it can do multi-utility. There's few airplanes as good as the Hornet but multiple things to go on in the wings and to do different kinds of missions.

But we found that eight to ten hours of unrefuelled [flight] is about right. That's about what can fit in a reasonably sized airplane and about 50 hours refuelled. When we went before the Collier [selection committee for the Robert J. Collier Trophy awarded by the US National Aeronautic Association] two years ago, we tried for a win again. This time I knew that wasn't going to work but we tried. I don't think you'll ever see another airplane designed without air refuelling.

The reason why Global Hawks/Triton has such long slender wings and a little tiny engine, you know, fuel sipping, little business jet engine, is because it's trying to take advantage of its persistence by having a big tank of gas and using it very slowly. If you wanted to put

4000 pounds of weapons aboard a Global Hawk, you could do it. All the gas would come out. So you want to find that balance with refuelling.

So we tried to talk to the Collier Committee that the design criteria for airplanes from hereon out just changed forever because every airplane—every unmanned airplane—will want to refuel. It will want to be able to take gas and take advantage of that design space. Design space for unmanned airplanes just opened up and that's the demonstration that did it. Make sense?

Tim: We have an artificiality that's imposed on us as far as design space. It's the width of the aircraft carrier flight deck. So we've got to stay within that and that's where you get eight to ten hours and that's where you get 1500 nautical miles back and forth, because that's about as big an airplane as you can make and still keep it inside the landing lines on the ship.

Scott: And while that's true, if you start to design unmanned airplanes as big as a B-2, which is a big airplane—I think my first apartment was smaller than the B-2 weapons bay—you start to get unaffordable. It's dollars per pound. So airplanes have a constraint, not just the size, like Tim talks about, of a United States Navy carrier, but also as they start to get bigger, they start to get more and more expensive.

We're going to run through a vignette with … what was the name of the paper, Ken, that you sent me from … was it from ASPI?

Ken: After the F-35.

Scott: Yes, after the F-35. I read through that back in the States. Read through it again and they said, 'Well what's a six-gen fighter look like? What's next? What's the next thing?' And I'm going to run through a brief comparison of what could be next and why. You're taking a mythical flying wing, looks kind of like an X-47 with a cranked wing, just because I like the look of it and it's near and dear to me. I have a bunch of tax I've got to give away.

And an airplane that is a stealthy, wing by tail. Wing by tail so it has the manoeuvrability that we require and also it's a reasonable airplane. It's an F/A-XX. It's a NGAD—next gen air dominance.

And just for assumptions, cruise speed is the same. The flying wing can carry a lot more fuel. Because of the design of a flying wing, it can actually carry a lot of fuel and there's a lot of internal volume for efficient volume. It can carry a lot of fuel. It's 1500 nautical miles and 600 nautical miles. Actually, divide those by two for range.

Max sortie [length] we set at 50 hours. We set at ten because it's a manned fighter. Serviceability rate the same. Turnaround time, same. In-flight refuelling, same. Fuel reserve, same. So a brief comparison of a manned and an unmanned fighter. Now you say, 'Well you gave your UCAS 3000 nautical miles; you gave your manned fighter less than half that.' We'll show you why that doesn't play; it doesn't really matter.

I hope you guys can see this because I can't. Maybe I'm the only one that can't see it.

The scenario is a manned fighter and some UCAV. And the measure of endurance is the clock—it's time on station in enemy territory. It's just a way to measure what's going on. So the airplanes fly to the tanker safe line. Tanker safe line at this particular time is at 500 nautical miles. Again, we can move that around in our analysis. The calculus changes but it's pretty much the same. Takes half an hour to get gas.

Goes feet dry—they're all exactly the same. Everybody's all the same right now. Once the manned fighter is .3 hours [into the flight], because of the amount of fuel on board, she has to go get gas. So the UCAS has got more fuel so it's still running around doing its thing in those little 15 minute circles I showed you.

[The manned fighter] gets gas. But at this point, after it refuels, if you look at the clock closely, she's sitting on a total time of 5.7 hours. That's 5.7 hours in the cockpit on a steel ejection seat. It gets gas and has to start heading for home because this trip is 2.2 hours, remember, coming out. So it has to come home before the pilot reaches his ten-hour endurance limit. It's the pilot [that is] reaching ten hour endurance. So the manned system makes a single ingress in defended airspace; forced off station by fuel exhaustion but then gets back to the tanker. Even if it got more gas, it couldn't go back in because the man in the cockpit is reaching his endurance limit.

Meanwhile, the UCAS reaches its fuel endurance, gets gas and goes back in.

Look at the clocks. So after it's all over, six ingresses into defended airspace, eight hour end of endurance turnaround time, 18 hours off station, 53 hours in the air. We couldn't quite get it exactly at 50 but about 53 hours total, six refuellings, 18 hours in country. And I think you see the math here, that even if you put big wing tanks and tonnes of things on this, if you had magic engines that didn't use much fuel, that's not the limiter. It's the man in the cockpit. At these kind of ranges, they're a problem; they're the issue, the limiter.

So when you're thinking, 'What's next?' When we're collectively thinking about what's next, this is the problem—this range endurance is the problem. You've got to think through what kind of UCAS you could buy. What kind of UCAS is next? And that's the kind of thinking we're trying to engender. That does not mean that every single mission ever is unmanned from now on. That's not what this is about and it's a silly spurious argument. It is that these things work very well together as a team. It's a family of systems. They can do some things better. They can do some things not as good. But if the problem is distance and you want persistence at distance, you're going to have to go unmanned. That's just what the math shows.

Male Speaker: Of course a better comparison could well be getting a B-2, not a sixth-generation thing.

Scott: It's a similar situation, you're exactly right. We actually could have [done the same thing with] a B-2. B-2s do missions that are 40 hours. I mean you pour them out of the cockpit at 40 hours, but they can do it. Their limit is more in combat. How many hours can they spend in combat under threat, constantly getting painted with threats? And if you allow the bigger size for the manned, you can allow the bigger size for the unmanned and the math still stacks up the same way. You still spend a lot more time in enemy territory but you've still got to bring a crew home on the B-2. But we've done that math too.

Male Speaker: You're leveraging a new-generation system off old-generation technology, tankers, for example. You make a point that they [UCAVs] weren't going to cost any more [than manned aircraft]. Tankers cost a fortune. Why wouldn't you have a flying wing acting as the tanker, which you could refuel from? Is there a reason? Tanking's a hygiene factor.

You don't need people on the tankers. That's just how things are now. Using analogies, using old, old generation legacy systems. I mean right now the US is in a competition for a new tanker. Why would it be manned?

Scott: That's why I'm here. It's good thinking. The tanking mission, at range, is perfect for unmanned.

Male Speaker: Absolutely.

Scott: If you're using what we had [in the trial], that's one thing. I think in the US they've done a lot of thinking about carrier based air refuelling system, CBARS, MQ-XX, MQ-25, or whatever they want to say it is next. They're actually starting to think about that. If a tanking mission is a really dumb mission—you just sit up there and do lazy eights, and everybody joins in when they can—it does tend to be a good mission for unmanned [aircraft]. You're exactly right. We just used what we had [on our trials].

Male Speaker: Now the reason I'm putting that forward is, air forces and navies or professional aviators at the high end, are going through this step-change function right now between what was and what will be. There's a lot of programs coming forward that should be systemised. So I guess my question is: In the States, is Northrop Grumman part of the new system of systems, not the old one, noting that a well-adapted new system will also leverage off old systems? But are we designing truly the next generation system, not platform by platform by platform?

Tim: You're exactly right. You may have read in the paper that Northrop Grumman won the B-21 program. Keeps us alive for a long time. When the bomber started off as being kind of a *Battlestar Galactica.* It can be everything to everybody and it was alone and unafraid in deep space, doing its thing. That became completely unaffordable. So we're seeing the light of moving these systems to multiple platforms, but making them utility so they can be different players on different days and making that a cheaper overall solution. So you're exactly right; it is that you don't want this thing to be everything all-in-one airborne platform. You do want multiple sets for a family of systems. And that's become a thing to say. It's like, 'I'm doing innovation', you know? It's a thing to say.

But the family of systems concept of breaking these things up but making them all open mission systems architecture and netting them all together, making sure you're interoperable with allies, all that is being put into thinking for everything coming up next, and that includes this.

Tim: Back to your operational tanker, our optimum design for what we would like to propose to the Navy can give more gas than any tanker we've ever had aboard ship. It's just a high cost to put this thing up and is the relative cost [worth it?] Why not just buy more Hornets as opposed to buy this single mission aircraft? And once you starting building an airplane, you have to make the decisions. If it's going to be a stealthy airplane, you make that decision in the design stage, not afterward. You don't just apply paint to make it stealthy. There's a lot to that and it goes in further.

Why don't you give them a quick dump on your trip to Whiteman when you talked to the B-2 guys?

Scott: OK, I sent a UCAS guy to Whiteman Air Force Base to the B-2 wing. It's always interesting. You have to take your lumps. The general in charge and the wing commander and the guys that were there all were kind of, 'Why are you here?' We wanted to talk to them about a concept. B-2 flies at night, very stealthy, does its thing, then comes home.

One of the concepts we gave them is: What if you had two of these things [UCAVs]? One four miles off the bow and one at four miles trail and they were armed with air-to-air weapons? [It's an] unmanned AMRAAM barge and it's flying with a B-2. You now have put in the B-2 an air-to-air capability that doesn't have to be indigenous in the airframe. And once we started that conversation, I actually got a coffee out of them, got to sit down. It was one of those things that they think, 'Oh well that's a pretty good idea. Why don't we do that?'

Well you can do that. You can give control of these things to a B-2 pilot, to a guy in the cockpit. And you also can make it a spoof. If it's unmanned and things start to get hairy on you, you can command one of these things to pop up a bunch of repeaters and sensors and make itself known. It now becomes the biggest target in the sky and you can get away from it. They [UCAVs] will give themselves up, if required. They won't complain. I would bitch about [them] not brining my airplane back but nobody [else would].

Scott: You guys probably know as much about stealth and all aspects stealth as any of us do. It depends on the threat. Where do you want to go and how long do you want to stay? And there are stealth characteristics of an F-35 that are very specific for a very specific mission. If you're going to stay in an area and loiter and move around, you got to be stealthy from all aspects and you've got to be broadband stealthy. So even the low frequency search radars are going to have to ignore you; you're not going to get painted all the time.

One of the unique features of a UCAS like this is it doesn't care how long … when it's moving its spikes around – spikes to read a rate of return at whatever frequency – it doesn't care how long it flies that day at a sideslip. It doesn't care how long and how much manoeuvring it does or weird manoeuvres it does. It doesn't get dizzy flying weird profiles to make itself stealthy against pop-up targets. So those kind of things become another tool in a toolbox to defeat some really nasty threats.

I'll also say that we've been having our own set of conversations with the United States Navy about clip-on stealth or spray-on stealth or do something later. 'You don't need stealth anymore. We've got all these great jammers.' All those are tools in a toolbox. All of that has to be brought to the fore to take on some of these really rough problems we're trying to deal with. But it isn't retro-fittable. You can't go clip it on later. 'Today I'm going to be stealthy' you know, press a button and it reconfigures into a transformer and does something different.

It is somewhat tailorable once fielded. Tailorable means I can adjust things. If I want to be a tanker one day … if I was going to build a UCAS for the Navy or for the Air Force, I'd want to be able to build it to have hard points and put tanks aboard one day. It's not stealthy, but I want to put tanks aboard. I want to ferry external weapons from Hawaii to Australia. You know, if you want to, you want to be able to configure what kind of condition she's in. It makes it more utility. Okay?

And just an additional word about that. There used to be very different frequencies to work in threats. Search radars are different from fire control radars. Little things called pocket computers have made that all kind of irrelevant. They all work together now. You can have radars that are search and detect. They see you, they bucket what they can calculate. If that looks like an airplane flying, then I can tell where it's going to be in the next ten minutes, taking into account that it could move around. But it's a limited bucket. It's a limited piece of sky to look through. And I can net in closer and closer, more lethal radars and more lethal weapons, to bring the fight to you. And that's becoming the new norm for the kind of environment we have to work in.

Payload lessening is payload. As you think through what UCAS could be, what UCAS should be, we get a lot of bad gouge put into the system about, 'Well I want 4000 pounds of payload.' Sometimes they count what radar you're carrying, what radios you're carrying, what mission computers you're carrying as payload. We count payload as the amount of weapons you're bringing into the fight and what you're trying to defeat.

So the JSF, the F-35, has a great weapons bay. It is shaped and made such that it can take a utility amount of weapons. It can take lots and lots of different weapons from all over the world. That makes it very utility. It also can carry fuel. It can do those kinds of things. You would want to do the same thing for your UCAS. You're able to take everybody's weapon inside, plus you want to be able to change it into a fuel tanker if you need to. Or put golf bags in to go, 'Meet you at the field'.

Multi-functional electrical-hydraulics and fuel. There are some payloads that would look out weapons bays if you wanted to be able to power it. You want to be able to use SIGINT /ELINT payloads that could only fit inside of a weapons bay, looking through a window. If you had EOIR [electro-optical infra-red] sensors and you wanted to look through a window, you could do that through a weapons bay.

I'll bring up one other thing that I just thought was a unique thought when we were talking about the design of unmanned airplanes. If the bottom of the airplane is the thing that's getting painted all the time with radar, you want to make that the smoothest, cleanest surface on the airplane. It also is that the bottom of the airplane happens to be where gear doors go, weapons bays go, all the things that degrade your stealth.

So with an unmanned airplane, why wouldn't you fly it around when it's in country upside down? Or put it so it's most stealthy when it's flying upside down, all the time. When she comes home, she flips over and deploys her gear. When it launches weapons, you're going to open weapons bays anyway and blow your signature. It goes over, launches a weapon, goes back.

And those things, those kind of thoughts just rattle through my pointed head. That's just a unique way of thinking about the problem. It also is that when you ask a designer, 'Design me an unmanned fighter' usually the first thing they do is they take a JSF and they erase the cockpit and say, 'Look, unmanned'. That's not the kind of thought I'm thinking about. If you wanted to be in a dogfight, first of all, an unmanned AMRAAM barge coming at you would be a nasty thing to go up against, if you were a fighter pilot. But it also is that these things can pull 30 or 40 gs. They can go higher, they can go lower. They don't have to worry about the 9 g meatball they're trying to keep warm and happy at the front of the cockpit. That's not what it's all about.

So you try and engender that kind of thinking on what they could do next. And as you guys are future thinkers—I've met some really good future thinkers here. Met some good ones, met some bad ones. We tend to engender that kind of a reaction among some. We're not a status quo company. They just think through the status quo, just think through the latest and greatest fighter that looks like a F-35 or it looks like an F-18. What would a fighter look like?

Tim: Well inevitably, somebody's going to want to go to the merge and pitch and 'Okay colonel/commander, whatever, here's the penalty for that' And the weight just goes way up because of what you have to build into the structure. So we would have those iterations but that would be kind of a unique airplane that you pay a heck of a penalty for being able to pull 10, 15, 20 Gs on. It could be done but do we really need to do that?

Scott: Our analysis shows that if you put as many long range air-to-air weapons aboard as you can, the best thing to do with an unmanned airplane like this is to go into the merge, fire them of as soon as you get everybody, then boogie out of there, go get some more weapons and come back to the fight. We haven't found a place where you get into the merge and start fighting, jinking against an unmanned airplane. But it also is that we don't have the same limits anymore in design so we don't know, necessarily, if that's a good thing to do or a bad thing to do. I offer that for food for thought.

Tim: A quick sea story. Early on, I tabled this: 'Why don't we give the radar, the IR sensors and all the sensors a BVR [beyond visual range] capability, beyond visual range recognition capability, and launch the AMRAAMS on that?' [The response was] 'We're never going to do that.' Well, about two years later, the two-star that was leading naval aviation in the Pentagon, said, 'You know, we're thinking about an offensive and defensive air capability.' So it, it just takes people a while to work their way through it. But if we let a guy in an airplane launch on a BVR ID, why the hell not do it here because it is the same type of information? There will be somebody on the ground that will ultimately enable that though. We have to do that.

We don't mean to make light of it, but we love pushback. We've had a lot of pushback in the last ten years but when you get an audience that wants to get their heads around what's going on, inevitably, questions start coming up. When they see a payload bay that can carry lots of weapons or it can carry electronic warfare or SIGINT or ELINT or whatever and you've got range, you've got all this stuff going for it, so they'll start saying, 'Well could you? What about… ?'

So, out of self-defence, I built this chart and we started talking about anything you want to talk about. Let's talk about how we could do that. Unmanned kind of goes without saying, but if you want to support these guys up here, why not launch it off the ship or launch it from some place, anchor it overhead your special forces, give them the ability, with a PDA, to download the radar picture or the IR picture, whatever, control the sensors, and then give them the means to be able to deliver whatever weapon they want? Oh, the SEALs just went wild, but they didn't like 250 pound weapons, [they wanted] to small down your bombs. They said, 'Well how about five pound weapons?' I don't know much about weapons but that would have been a difficult matter there. But it's the type of thing that those guys were thinking about.

Scott: But we also told the SEALs we could offer you an aerial vending machine. They liked that.

Tim: Well, those are things that will happen because you can transfer these. They don't have to necessarily be under control of the ship or home base. Here's another one and I'm not an ASW guy. I'm not a P-3 guy. I'm an attack guy. And, 'What the hell do you know about ASW?' Well I know how to spell it but I also know that those submarine things come up periodically and they make a sweep. And they got to know where they are and if there's something in the air with the right equipment on it, you can pick up that sweep. You only need one. And if you have two in the air, like a Triton or P-8 or one of these, and you can triangulate it, you've got a good idea of where that individual or that particular unit is. That's what I mean by ASW. But I'm sure we could put things like sonar buoys in there too, if we want to.

Maritime interdiction. Here's one of the real winners. The bays are big enough and they've got electrics in them so you could do SIGINT and ELINT. All the stuff that you'd like to do, it's all at this point antenna dependent. Now we have to invent the, the antennas that will allow that type of work.

And last but not least, we got BMD [ballistic missile defence] boost-phase. BMD came up and we thought, 'Oh my gosh,' right? That's a stretch. However, about six or eight years ago, the Air Force actually executed it with an F-16 down at White Sands. They picked up one coming up and shot it with a Sidewinder. And it was at that point—I can't remember the agency, but it was some agency, four or five letters—the agency said, 'Why don't you guys look at that for this? Because you can endure, you can persist, you can survive, and if we give you the right weapon, maybe you are an answer to that.'

I'm not saying we're planning on that, but this is an outgrowth of sitting with audiences like you and people asking questions. I said well, 'Yeah, maybe we could do that,' or, 'Maybe we could program that in.' But I don't want to go away thinking, 'This is only a point-to-point airplane that delivers a weapon and comes home. There are different things that we could conceivably build into and write software for.

Tim: In answer to your question earlier about how do you interoperate, we don't ever want to get out of being able to operate with F-35s. If the F-35 needs support or the F-35 needs more weapons with them; if they need jammers; if they need BDA; if they need something, if we're part of that mix, it becomes a much more powerful force. If you bought an F-35 that did everything all itself—similar to the example on bomber—it might become a more expensive proposition than pushing some of these things off to other cheaper, smaller vehicles. I don't want to leave you with 'The only UCAS is one that's 60 feet wide and 30 feet long and 50 000 pounds'.

One of the things I like to bring up is you can change the dustcover to whatever it needs. Most of the expense, most of the smarts behind the UCAS, is in the software that does 'failure detection and accommodation'. So if you have a failure, what do you do about it? We tend to spend a lot of time teaching pilots yellow lights and red lights and what those mean, and how to diagnose what's wrong with their ship when things are going wrong. We have to actually program that in. The software has to be reconfigurable to accommodate any first fail or second fail, like or dislike. And that's something that's very normal for an F-35 design, very normal for an F-18 design. We are triplex on most of our channels, just so you constantly have a backup. But that makes the airplane much more reliable, much more doable.

The guts are what's important. If you wanted to host those guts, 'Colonel, we want into an X-47A,' You could put the smarts that are in a X-47B, into a little package like the flying Dorito chip of the X-47A. It does fit. Everything's on a thumb drive now. Make sense? Okay.

UCAS has enabled global regional responsiveness. That should be obvious to you after we've gone through some of this stuff. Long-range strike is what we do best. Combat power sustainability, continuing surveillance and coverage over an area. If you're trying to watch a hotspot, and you want the ability to do something about it, you want to have the ability to launch a weapon at it, you need something like this at range.

Battlespace penetration, depth, tanker survivability, stand-off threat. When the tankers start coming in too close because of the [short] range of fighters or the range of TACAIR [tactical aircraft], the tankers become a target. I mean, if you're a smart enemy, the first thing you're going to go after is the source of all the energy, and that's the tanker.

Manned aircraft survivability. There are CONOPS [concept of operations] that we will share with you over the coming year. We're going to make this a regular stop with our allies and what we're doing and what the future force planning is. But how does it work to do suppression of enemy air defences? How does this work as a jammer? How does it work with an F-35? How does it work with other assets? And as brought up earlier, it also can be a really good tanker if that's what is the most glaring hole in the force that we're building in ADF.

Risk tolerance and deterrence capability. It should go without saying. There is a usability to having an unmanned airplane. I mean, isn't that why I want to sentence all my UCAVs to death and take themselves out for destruction? But it also is that there is a usability, whether that's real or it's a deterrent capability. They are usable right away. You could send them over a really nasty area that you may hesitate to send sons and daughters into.

Thanks. I hope it makes sense. Okay, are there any questions or any thoughts?

End of Recording.

Note: Words in square brackets [ ] have been added to the transcript during the editing process for clarity.