Mitchell Institute for Airpower Studies

Presentation: Air Force UAVs—The Secret History
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Mitchell Study: Air Force UAVs—The Secret History

Grant: I am Rebecca Grant. I am the Director of the Mitchell Institute for Airpower Studies. I'm here this morning to do two things. One is to tell you a little bit about the institute, and the second, of course is to introduce Dr. Tom Ehrhard, which I'll do in a moment.

First of all, the Mitchell Institute was founded by AFA as a new think tank, a research arm for the Air Force Association. We hold Mitchell Hours, public papers like the one we've released this morning. It was named after William Mitchell to honor his achievements and to promote the advancement of airpower which of course he was very interested in. As you know, he was really the first JFACC, as we would call it today, the first to command a group of allied air forces in support of a ground offensive at St. Mihiel in September 1918. That's how he got his first star.

His subsequent career was quite colorful. He was, of course, court-martialed and left the Army in the 1920s. What we remember about Mitchell and why we honor him is his interest in the advancement of science and technology, research and experimentation on airpower, the advocacy of airpower, and of course his mentorship of people like Hap Arnold, [Carl A.] Tooey Spaatz, and the list goes on. That's the Mitchell Institute.

This morning I am absolutely delighted to have my long-time friend Dr. Tom Ehrhard. He has put together a simply magisterial and fascinating history of the early development of UAVs. I urge any of you who have not picked up a copy to go ahead and grab one from the back on your way out.

I'll tell you a little bit about Tom. I think he's well known to most all of you. He retired from the Air Force as a colonel in 2006. He also holds a PhD from the Johns Hopkins University. He has served in many different positions including some time in the CAOC over at the beginning of Operation Enduring Freedom, quite a bit of time on the Air Staff. He himself has mentored a lot of folks through his time at SAS and teaching and

his wider writings. He's here today to talk about a subject that's really, really near and dear to his heart. Of course his current position is as Special Assistant to the Air Force Chief of Staff, General Norton Schwartz.

I do want to make just one announcement about the ground rules. Tom will give his presentation. We'll open it up for questions after that. But Tom, being as he is, an Air Staff insider, tends to get a broad range of questions. I just wanted to let you know that today we'd really like your questions to focus on the work that he is presenting and on his broader academic research on UAVs. He's here speaking to us today, but obviously he is not able to entirely speak on behalf of the Air Force or anything like that. I just wanted to make those ground rules clear.

Without further ado, Tom, over to you. I'm so glad you're here.

Ehrhard: Thank you very much, Rebecca.

The Mitchell Institute does a wonderful service for the Air Force and the nation by continuing to keep aerospace power at the forefront of the discussion here in Washington, D.C. and of course with Bob Dudney and the Air Force Magazine to a much wider audience as well.

I want to say just a couple of things. This is going to be rather informal, I think, and hopefully educational and fun.

We're actually, we're one week out from a very important Mitchell day. These are things I keep in my outlook so I'm always up on what's going on. It was the 21st of July, 1921 when the Aus Friesland hit the bottom. Based on Billy Mitchell and his well-trained crews, I might add, and he was also operationally very astute. He's the one that figured out that he didn't have to hit the ship to sink it. He designed his weaponry and his targeting to utilize what he called the water hammer effect, which was to drop the weapon next to the ship so that the over-pressure would breach the hull. That, of course, is what eventually sunk the Aus Friesland in a sort of a display of what airpower could do, even in those relatively primitive times.

The same kind of aircraft and limitations and that that Billy Mitchell had to deal with in 1921 when he was trying to show how airpower could complement our coastal defense, is what you're doing when you come to the issue of UAVs. I'm going to use the term UAV because then I don't have to—The official Air Force term is RPA and all of that, but then when I use UAV everybody knows what I'm talking about. I don't have to caveat it in any way. That's still the most colloquially accepted term in the US and abroad, and so if you'll forgive me I'll depart from Air Force policy there for just this talk.

Basically what I'm going to do today is give you an overview of this fantastic piece of editing that Bob Dudney did, and I want to give him a lot of credit for doing this but there are some very interesting people here today too that I want to recognize that were

actually a material part of this thing coming together back when I did this research over now, over a decade ago for my PhD.

The first one is Elliott Cohen who could not be here today, but he was my professor at Johns Hopkins SAIS [School of Advanced International Studies]. I had a whole dissertation idea that I came in wanting to pursue, and he instead of that, one day I remember him bolting out of his office saying I know what you're going to do your dissertation on—UAVs. My heart just sank. [Laughter] It was like oh, that's a great way to alienate myself with my own service. And because I was captured at the time, still, by this sort of mythology that the Air Force, oh, that would be the most resistant to this, to unmanned aerial vehicles. And not being an aviator in my background—and I think that's actually critical to the analysis here, because a lot of this that may be, a lot of these principles that may be sort of innate to many of you who are aviators here, I had to really grind through it and learn it and really subject it to a lot of scrutiny. I think in some ways that gives it a lot of credibility that it might not otherwise have. I really had to run a lot of these things to ground and subject it to a lot of, and I would say maybe even obsessive research. So actually this is going to be a 50-some page piece, but it's part of a 750-page PhD dissertation that actually includes pretty much every major system, every major American and Israeli system that was built from the '50s on forward. So whether it's Navy, Marine Corps, Army, Israeli UAVs or whatever, I sort of wrote the research on that.

It's a wonderful thing to bring this all together and I want to thank Bob Dudney for really grinding through that and turning it into—he basically singled out the Air Force contributions and turned it into this beautiful document that I hope you all get a chance to take one or more copies back with you today.

Some other people that are here that sort of contributed to this. One is, I have to thank General [Carrol H. "Howie"] Chandler for showing up today. He was not only is he the Vice Chief of Staff of the Air Force and right in the middle of budget deliberations, I must say, and so having him here today is really sort of a rare pleasure. But General Chandler was my boss back when I was trying to puke out this big huge piece of research. I had been sent back to the Air Staff before I was done, before I was completed with the dissertation defense, and I jumped into the Air Staff and started doing my sort of total obsession with work thing, and I was trying to get it done on the weekends and it was not working. Somehow General Chandler reached down through the ranks and saw me struggling down there, and a real testament to his leadership, but he basically found out that I had not finished yet and I was working on all these hot projects. He said to me, okay, you're done. That is it. Don't show up to work until you get this thing done. He basically gave me the space. It was basically a few weeks of where I could just concentrate fully on that, no getting it done, and I totally did my last edits and got it done and got it through to the defense and successfully ended my PhD. So actually my degree, my rank as colonel, and a lot of these things I really owe to General Chandler because he was able to look down—of all the things he had going on at the time, and really figure out what was the right thing to do for little old me sitting down there in the

ranks. So I really appreciate that, General Chandler.

Voice: He came today to see if that time really paid off. [Laughter]

Ehrhard: Let's hope.

Karl Mueller's here from RAND. Karl was my professor at SAAS, at the School of Advanced Airpower Studies, before I came back up here. He was my advisor, basically, for my thesis down there which I commend to all of you also about air campaign planning as sort of the theoretical framework for air campaign planning. And Karl was actually on my dissertation defense panel. So he's one of the guys that had to do the secret vote to see if I passed the test and to get into the union, get my union card as a PhD, so Karl is one of the few people in this room who have actually read the whole 750 page thing. It's actually 650 pages of body and there's a critical 100 pages of appendices that go back to the 4th century BC and the Chinese flying kites. So just so you know. I've sort of gone from the very beginning of aviation to the present. So thank you very much, Karl.

The last person I want to talk about is Chris Bowie. Chris is back there in the back row trying to be innocuous, but he's not going to get away with it. He's the guy who no-kidding—this is like self abuse—he has read my actual PhD dissertation three times. I don't know, I envision Chris at the beach or something with this big pile of paper going through it. But he is the one basically who—I did my dissertation, I was done and I was off to doing other things—and he's the one who really sort of catalyzed this whole effort and got with Dr. Grant and said we need to publish this. So I really want to thank Chris. You're the guy that made this happen and I hope all of you benefit from it.

Let's go through this. I just have a few, I want to just walk you a little bit through the travelogue of UAVs, so I want to give you an overview of what I'm going to talk about today. This is the overview. Let's just talk about UAVs, and really, let's talk about, we're going to concentrate on the Air Force contribution to UAVs over the past 60 years.

Now how can that be? You have the Predator, you sort of reluctantly picked up Predator, we're forced to take it or whatever. Sort of reluctantly employed it, and that's all people know. That's their historical sort of frame of reference for what the Air Force has done in UAVs. And what I want you to know is that I want to firmly establish in your mind that not only is that misleading, it actually is bad for policy in the future, that is to say the way forward with UAVs and where they can actually find their place in the Department of Defense. Here, I like that question of the Sperry flying bomb. I thought wind tunnel testing was unique in those days. Sometimes I think that characterizes the Air Staff projects that General Chandler gets to see in his office and throws out from time to time. But that was an early attempt at a cruise missile.

So one of the things I want to make the distinction in my research is, I made the distinction between cruise missiles, drones, and actual unmanned vehicles that were

going to be used, they were designed for return and re-use. This was not. That was a terminal system. And also that were supposed to be used for combat operations.

This is a big eye chart. It's to tell you this. All you need to do is worry about the red circle. These are the 22 major UAV programs that I studied. There were many many many more, but these were the major ones and I actually went through the pain of finding out how much they cost, and I rationalized it in FY01 dollars and all kinds of great stuff.

But when you look on here by service, when you break it down by service over that period of time from 1954 to basically the year 2000 the Air Force was responsible for some 66 percent of all of these systems. Compared to the other services. That does not sound like a service that is neglecting this innovative technology.

Let's start looking at some of these UAVs that were either developed by, designed for, or are part of the Air Force history, long history, in unmanned aerial vehicle development.

We knew as soon as we started U-2s over the Soviet Union, we knew they could see us. We knew it was only a matter of time. They kept coming up and trying to intercept us with fighters that could not get up to altitude, so they did all this zoom climb, and these U-2 pilots would fly over and they'd see these fighters zooming up and the missiles coming up at them and running out of juice and falling, right? But they knew it was only a matter of time before they could get up to hold those U-2s at risk.

So the US, and I must make this point right now, and that is for over 70 years this country has had as a primary strategic objective the penetration of denied airspace anywhere on the globe. Think about that. Seventy years. That's been a priority. I would suggest to you that that also should be a priority for us now and in the future.

But look at this. We said we're going to have trouble. We're going to have trouble in this denied environment because of the radar, so we had to come up with ways of doing it. Ways of solving the problem.

Actually, the ones that were sort of deemed superior were manned, supersonic versions. Because at the time the requirement as basically for still shots. We just wanted to see stationary targets. The requirement for loitering that we see so prominent today was not really an issue. And if you notice the design of this thing, they were designed to be as low observable as they could be in that era, not knowing what we know today about that. I thought that was a very interesting system.

I want to get on the Lightning Bug because one of the reasons that you'll see why the Air Force history in UAVs has been largely neglected is because most of the time when it appears that nothing is happening in this area, in fact the Air Force is like a duck. Looks placid on the surface, underneath paddling like crazy. So this is one of those systems. The Lightning Bug system was basically funded by the NRO, Program D it was called in

the NRO. It was run by the Air Force. And it was, one of the systems in here was called the Lightning Bug—the most ambitious US drone program in history. Really in many ways it's just now being eclipsed I would say, historically speaking, by sort of the Predator and Reaper series.

But here you had for a long period of time these drones operated, jet powered. It was a modified—if you see that on the left there, that's the Ryan Q2X which was basically the early version of what was designed to be a target drone.

We knew we were going to have trouble, the Army and the Air Force were going to have trouble trying to shoot down jets based on the Me-262 and that during World War II, so we needed to build target drones so we could try and figure out how to hold these targets at risk. Basically out of that target drone we adapted the Lightning Bug.

It also came also as an alternative to the U-2 replacement. So this is back when Harold Brown was the DDR&E. He's the one who made the decision actually that we would proceed with the SR-71 over a modified version of this drone right here, and the Convair Kingfisher, but this one was called Red Wagon, like the little red wagon. They were going to use a jet powered drone like this, and with a wet film system to go in and do recce at low and medium altitudes. The NRO kept this thing alive. It was almost killed when the SR-71 decision was made, but it hung in there. It just sort of hung around.

Then the Cuban Missile Crisis happened. Bingo. We need something else to be able to do denied area reconnaissance when Major Anderson was shot down over Cuba, if you might recall the U-2 that was shot down over Cuba. So we were going to send these drones in. Perhaps the only reason that drones were not used for reconnaissance over Cuba was that [General] Curtis LeMay did not want—he thought this was so important strategically—that he did not want to tip the hand that we had something like this to the Soviets even for the purposes of the Cuban Missile Crisis. So for some of us who are like old Cold Warriors, we remember those days of when those kind of decisions were made. But that's where this system came from.

So if you notice the timing kind of goes along, we kept them on alert for the Cuban Missile Crisis, and then things started to pop in Vietnam. And the number one thing that the leadership was concerned about in Vietnam was whether or not China would get in the war.

So the experience of Korea was foremost in our minds and we didn't want to be surprised like that again. As it turned out we used these drones for that kind of reconnaissance over Vietnam and China in the early '60s, ending up with over 3,500 combat sorties.

You can talk to old Vietnam vets and they'll remember, there was a hangar where you could not look, where these things were kept. And operations were done at night and this kind of thing because it was a super secret operation. In fact this was the system

that identified that Americans were at Son Tay prison and were withheld from doing recce over the Son Tay prison and could have told us that the Americans had left but the only reason they were withheld is they thought if we keep sending these drones over the top of that prison we'll spook them and they'll think we know they're there. It was a bad idea because if they'd have sent drones—one of the things that they used these drones for was when there was bad weather. They didn't care. They'd just send the drones in. It was just sort of low-level recce. They went in at low level. They were very good at doing that low-level recce. They used very good cameras. We could pick up a lot of intel that way. So even late in the war on some days 100 percent of the bomb damage assessment recce was done with Lightning Bug drones.

I just want to show you this. Here's the kind of system—we were having a conversation earlier today with Bob's daughter who's an aerospace engineer—we were talking about the importance here in this discussion of understanding aerospace technology. You have to understand how this whole thing works and why it fell out of favor later. This is one of the reasons.

You launched them with a C-130 under the wing, right? They were held up under the wing. They'd start the engine on the C-130 and drop it off and hoped that it worked. Sometimes they just, the engine shut off and they just kept going all the way into the ground. In this case they'd launch it with a specially prepared C-130, special crews for doing that mission. When they recovered them, they would come down under a giant parachute and they'd hook it. It was a system we developed for the Corona satellites, we now know, where those package would come down from outer space, a big parachute would come up and we'd hook it in mid-air and then a reel would bring it back in and they'd just basically fly it. Now that's an old CH-3, and again, some people, there are still people alive who did that mission but it was a specialized mission. Special units had to be put together to do it.

Think of what a unit like this cost to operate. This is not just a drone unit. It should be cheap, right? It's a whole system you have to have not only to do that, but every time that wet film came back you had to develop that film, and you had to analyze that film, and you had to get it back out to the people who—so you had a whole back structure of people, a whole support structure just like we do today. That impacts the cost and sort of the utility of these units. They're certainly not unmanned.

This comes from actually an old book on some of these drone flights. It shows the kind of missions that we'd do out of Okinawa with those things. I thought that was kind of interesting. That was a 1964 type mission.

So this is a very important series. And just to give you an idea of the way this was operated, here are all, again an eye chart just to make a point. These are all the different modifications of that one drone that were used for combat operations. Just an unbelievable number of different wing sizes. In those days they would say oh, we have a requirement for a low-level TV data link model. Teledyne Ryan was the contractor.

They'd whip one out in a month. Five of them or whatever, and they'd go fly them. That was it. It was flown by Strategic Air Command, operated by Strategic Air Command, and in some cases it actually expanded later to doing a whole variety of other missions.

Let me just take you through one that's classic drone operations and nobody ever heard about some of these fantastic things that these drones did. They'd fly a special UN package on one of these high altitude drones into Route Pack 6, for instance, in Vietnam, right over the top of SA-2 sites, because we'd pick up if there was some kind of change in the fusing, the signals that were coming up from the SA-2. All of a sudden lethality of this SA-2 system had gone up. They'd fly a drone over it with a [audio unclear] system. They had an EB-66 electronic warfare aircraft sitting back in a safe spot, right? And as it was about to die this drone sent back all the Army fusing data to that EB-66, stuffed it into their systems, brought it back onto the ground, plugged it into our ECM systems for the penetrating flights that were going in—just the next day. That's the kind of work that these drones did all throughout.

And by the way, I must just add a note. What we learned here was actually transmitted to the Israelis. They actually used a version of this drone in the '73 Yom Kippur War. They used actually two different modified target drones, but this was one of them, the Ryan 147 Lightning Bug.

One of the briefings I love to give is the UAVs of the '60s. I just love to give briefings about the UAVs of the '60s. Why? Because it really in many ways puts today to shame. It really does. We're flying a Mach 3-plus drone in operational sorties over China in the '60s. We don't have anything like that today. This is an unbelievable system right here. I just find it astonishing.

One day these crazy looking things showed up at the museum over at Dover [AFB, Del.]. I was over at Dover flying on a C-5 out to Europe. I said there it is. It was unbelievable. So you'll see these out from time to time. At the time, obviously, super secret operation.

Look at that. I see two vertical stabilizers there, then there's a third one in the middle that's supposed to leave the aircraft. The key to this jet is this is a ram jet on this—see the big nose, the air intake at the leading edge here of the drone. The SR-71 had to get up to Mach 2.5 just to start the engine. You had enough air coming through to get her going. So the SR-71 was just the starter. It was like a really expensive starter.

So we'd get it up to speed, they'd light the engine, and now, think about it, you're at Mach 2.5 plus. Now you've got to separate. Right? What happened actually with Tag Board or Senior Bowl, was that in one of the test flights, this was all from the fertile mind of Kelly Johnson at Lockheed, and he was personally involved in this program. It was obviously a very very critical issue because it was designed to go and do reconnaissance of the Chinese nuclear facilities deep inside of China. What happened is during a test of this aircraft it had a problem separating. When it came off the SR-71 it rolled and took out one of the vertical stabilizers. Now remember, this is all happening

at a very high rate of speed. It takes out the vertical stabilizer, goes into a spin, and actually the crew ejects. So it was actually a drone operator. Unfortunately they ejected into the Pacific Ocean and the drone operator panicked in his pressure suit when he was in the water and he panicked and popped his helmet off and the water rushed in and he drowned.

Kelly Johnson was just so horrified by this that he canceled the program himself. Remember, this is the contractor saying okay, we're done. This is over. We're not going to do this. It's a crazy program. And he gave all the money back to the government. He just signed a check and said here's your money back, I'm not doing this anymore. Basically at a very very high level they went back to Kelly Johnson and said no, you need to tell us how to make this work, but we have to have this program. It's critical that we have it.

So what he did, if you look down at the bottom, down here, here's how they eventually did the operational flights. They launched it from the under-wing of a B-52 with a rocket booster. So this rocket booster attached to the drone, would accelerate it up so the ram jet could ignite, and off it would go. No kidding, this was the CONOPS for this. Remember, four operational missions and that's the record of it. Oh for four. They never got any of this film back. I can tell you about each of the four missions. But think about this, they penetrate, launch the drone from someplace in the Pacific, it would fly the mission, come back out, and was recovered in the vicinity of Hawaii. It would pitch up, the airframe would pitch up. It would eject its avionics and its wet film package, come under chute, and the airframe would detonate and explode and destroy itself. That was the mission of this drone. No kidding. This was a Cold War system if there ever was one, and obviously, again, operated by SAC.

Now we get to the Compass Arrow. Again, super double dog secret system, being developed just to go into these denied areas. This is one of the first aircraft that actually incorporated stealthy elements to this. Any of you who understand stealthy design can see them right away, but this actually had designed into it not sort of as a tack on, but stealthy aspects.

As a matter of fact those engines that were specially designed for high-altitude operations—60,000, 70,000-plus—are still used today on prototype aircraft. I can name you some of the prototypes that have been flown as late as, less than 10 years ago, that use these engines that were developed back in the '60s.

Look, $63 million per aircraft for Compass Arrow. So we have a big problem today. Those are '01 dollars, so that would be even more in FY10 dollars. We have a problem today with certain systems like your Global Hawks or whatever, and we think how can global Hawk cost as much as it eventually cost? Well because, if you're going to do this kind of a mission you have to have a reliable system. And it is not cheap. It just isn't cheap to be able to fly reliably and do these sensitive missions.

One of these came down, by the way. There was a big scandal, it came down some place in New Mexico right in a town. And of course it was super secret and everything and they had to cordon off the town and do the men in black thing and take a picture of them so they would forget everything they saw. [Laughter]. But it's a fascinating drone.

Actually the Israelis found out about it, so this is flying around the '70, '71 timeframe. The Israelis found out about it and asked President Nixon if they could get this bird. They wanted it because things were revving up in the Middle East at that time, if you remember, prior to the '73 War.

Nixon's response was to not respond to the Israelis, and these were put in the aircraft guillotine. So they took the engines out and they chopped these up. I guess there was no chance of bringing them back at that point.

I just want to mention a couple of other ones because they're very interesting. These are developmental aircraft. But really, these are your predecessors to what we now know as the Predator and the Reaper in many ways, and look when we're flying these. We're flying these in the early '70s. There was a huge interest in RPVs as they were called then, in the early '70s.

And one of the points I want to make here analytically, and this isn't just a travelogue of UAVs when you read the monograph itself, but there's a lot of analysis in there that I think sheds a lot of light on the way you think about UAV development. One of them is that UAVs have been, throughout history, a cyclical phenomenon, not progressive.

So we think of them as oh, nothing was done before, now we're doing a lot more, now UAVs are really exploding and sort of progressive, right? So it's going to be nothing but more UAVs off into the sunset, right? That's not the way history has gone, and it's not the way it will go. It's always cyclical. It goes up, there's a big interest in them, and for whatever reason, and I could go at great length into some of the institutional and other technological reasons why they go through a down period, but during this time there was a lot of interest in UAVs. We flew both of these, they were obviously sort of adaptations in the one case of a Schweitzer sail plane. And look at, this flew over 24 hours, the Martin Marietta version flew—This is at set flight, over a day, just droning along up there, and why did they come unglued? Was it because the Air Force hated them? As a matter of fact the Air Force was trying like crazy to get these things into the European theater, and basically they could not get European nations to clear them for flight in civilian airspace. Is that not a problem that we have still today? This is still an issue with us today, getting UAVs really much more incorporated into the way we do not just civilian controlled airspace, but it's a huge issue in even the airspace in wartime.

So we have all kinds of drones flying all over. Ask any AC-130 guy. What was he looking for? He wasn't looking for AAA. Wasn't looking for SAMs. They're looking for Predators. It would be the ultimate—What was that? There's a bzzzzz, and the thing is going by. It was a Predator.

We have a French colonel in our office in the Strategic Studies Group—great to have—we have a French colonel and a British group captain. It's fantastic to have them as a member of, a full member of the Air Staff.

But one of his buddies came up there and had flown recce flights over Afghanistan. He talked about three times where he had to do—He pulled 9Gs evading a Predator one time on a recce flight.

Anyway, this is a case where commercial airspace got in the way.

Look at this. Here's kind of your predecessor to Global Hawk. Teledyne Ryan, the predecessor to what we now know as Northrop Grumman, Ryan, they bought up Ryan, same company, these are the same guys who built the Lightning Bug drone. Remember the big one. Those guys have been doing the UAV business forever and ever and ever and have phenomenal sort of corporate historical knowledge of that. And Boeing has always been in the game. Boeing's been in the game a long, long time but nobody knows it, right? Because a lot of these systems were done in the black.

A U-2 replacement. I like to call U-2 the UAV killer because ever since basically 1956 when we first start flying U-2s, we've been looking for unmanned variants and the U-2 just keeps on going. It just keeps flying and they killed these. The Compass Copes never flew. They wanted to fly these—the same as the Compass Dwells—to do SIGINT along the inter-German border. Basically design did them in.

The payload was being developed concurrently with the air vehicle. So all the contract guys in here are nodding and smiling now. They know how this story went, right? [Laughter]. The payload eventually exceeds the weight of the aircraft. And of course the cost for the payload goes like this, and every other thing, and everybody just kind of backs slowly away from the UAV and things kind of go away.

It's very interesting though, U-2 replacements.

Same story here. This I love the fantastic, really inventive name for this—the Medium Range UAV because it was designed to fly at medium range. [Laughter]. At least the other ones were called [audio unclear] and things like that. This is the Medium Range UAV. But this is a fascinating system because now you're starting to get into where everything's got to be joint. And all the problems that go along with joint acquisition programs, we're doing this with the Navy. And guess what? You have to put all the special Navy stuff on it that are required to do on shipboard operation which weights it all down. And now it's kind of a short to medium range UAV, if you know what I'm saying. Right? Now it starts to not be able to do its job exactly right. And this was going to be, we were getting out of the RF-4 business and we were going to go into, if you remember, some of you, RF-16s or F-16Rs or something. We were going to use for Tac recce. This was quite an inventive idea. They were going to actually be able to launch

these from an F-16 and launch them from the ground from the same unit. So it was kind of an interesting sort of composite unit idea where they'd have manned aircraft with these systems working together to get tactical recce.

The thing that did this in was the TARPS pod. Actually if you were here, General Israel who later is in this story because he's the head of DARO. [Maj.] General [Kenneth R.] Israel will never admit this, but he was the guy that did in the TARPS pod. He was like the program coordinator for the TARPS. But basically what they were trying to do was funny. TARPS was trying to take in all the recce and store it. So this is the '80s and you had to store this on a hard drive. This was like really pushing the limit of hard drive technology in an aircraft going like this. And as of takeoff he was in that rocket right there, and the cost was astronomical to make that happen.

We really pushed forward the whole technology of hard drives, let me tell you. That was all done at program expense. But the TARPS pod just went crazy over budget and this program ended up being canceled I think by General [Merrill A.] McPeak.

Some of these more interesting ones. I hope I can bring this to a close quick, but I love this picture of the Dark Star. I call this the flying clam. This was not, the designers did not follow the looks good/flies good philosophy of aircraft design. This is just a crazy looking—And by the way, if you look in the lower left, it flies that way, not that way, just so we're clear no which way it actually flies. [Laughter]. You can't really tell.

But what a system here. This is where we've gone now into sort of second generation LO technology. The interesting thing about the RQ-3 Dark Star is that something happened in 1986 called Goldwater-Nichols. So right when that MR-UAV and several other UAV programs were going on, basically Congress, all the post-Vietnam War acquisition debacles were going on and they wanted to get more control of some of these programs, and UAVs came under the spotlight. What they did was they stood up an office called DARO, Defense Airborne Reconnaissance Office. What it did right, what DARO was right about is that airborne reconnaissance has always been sort of a red-headed step child in the military, in all the services. All the services sort of neglect the mission of reconnaissance relative to its importance.

Unfortunately in the '80s and the '90s, all of this reconnaissance became more important. So at the same time as it's becoming more important to do it and you have more of a requirement to do loitering, staring type reconnaissance, the same constituencies remain and so basically it was the Clinton administration decided they were going to break this logjam by putting together an advocate for the DARO, and I think you'll find the analysis of what happened to the DARO very very interesting in the monograph, and I commend it to you.

But the short story is, they became sort of a UAV advocate of their own, but the problem was the services were only peripherally involved and mainly sort of suspicious of everything DARO did. Congress was even suspicious of everything DARO did. As Ken

Israel said when he took the job. Remember, I think General McPeak took him from the TARPS program to DARO. He said we all knew we were on the Titanic. I thought that was a great quote. [Laughter]. We all knew we were on the Titanic, but this is a joint system. So actually the services paid like a tax to DARO. DARO actually had money. This is what we all imagine, right, as being really great. Some super conscience that isn't parochial is going to do the right thing in acquisition, right?

Well, it's not what happened with UAVs. What happened is a lot of these systems were developed sort of willy-nilly without any kind of service input or buy-in or constituency and they ended up kind of going the way of the buffalo throughout this process. I can name you so many really awful systems that were built during the DARO years that really ended up being nothing. But some that came out that made it out the other end, we'll talk about that in a minute, are Predator and Global Hawk.

There was a tiered system. Tier 1 was the GNAT-750, went to the CIA. The GNAT-750 was actually sort of invented out of a DARPA program in the '80s by a guy named Abraham Karem who's just a wonderful, he's an eccentric. He's a very eccentric—But he's really the guy who sort of designed what we kind of now know as the Predator, but it was called Amber. Out of Amber came the GNAT-750. That went to the CIA. They already existed. Actually what happened was I think Turkey had actually bought some GNAT-750s and then reneged on the contract for whatever reason. And the CIA picked up those birds from that program.

Tier 2 would be Predator.

Tier 3, excuse me, Tier 2-plus. Remember Predator, non-stealthy, regular sort of conventional looking aircraft; and Tier 2-plus was going to be Global Hawk. They call this Tier 3-minus. What's the obvious question? We obviously went stealthy, right? What's Tier 3? This is Tier 3-minus. What's Tier 4? Once again you get back to the Air Force story. The Air Force story is everybody was saying during the DARO years, well the Air Force is not involved at all. Well, au contraire, this system right here ends up going through sort of the DARO process and then DARO was disbanded about 1998, and the Air Force canceled this program after one particularly bad crash. The colloquial term for this in the black community is Dark Star because that's—[Laughter]—when it—

And for any of you who know the Grateful Dead, you should look up the lyrics to the Dark Star song, that actually talks about Dark Star crashing. So I don't know if that's all karma or what, but that was quite a unique system.

By the way, designed to fill a JROC requirement that was laid down in 1990 for denied area loitering ISR that still exists to this day.

So we all know Predator. My main point about this is Predator really comes into its own when DARO goes away and the Air Force gets back in the game. The real hero here is back in 1995 General [Ronald R.] Fogleman comes in and he says where are all these

UAV programs? Bring them to me and tell me what's going on. He looks at this and he says it's got wings, it flies off of airfields, it's ours. He said other things about what would happen if the Army got the program but I won't share those with you here. His theory would be that we wouldn't be flying them right now. But this is probably why we're flying them right now, because General Fogleman—People say well, it was reluctantly forced on the Air Force. Wrong. Read my monograph. I'll tell you exactly how it was. It was going to the Army 100 percent. General Fogleman threw down and he said I'm going to open up units without even having—Nobody said I'm getting this yet and I'm opening up a unit. He laid down, he threw down, and he said I'm going to put my best pilots in there. They were sent to this program early on. He said if this program fails it's not going to be because of my pilots. He totally threw down and said I'm going to grab this thing with all the gusto I can. He's the guy who really brought it about.

But guess what? It took a series of Chiefs and Chiefs of ACC like General [John P.] Jumper, General [Michael E.] Ryan. All these individuals really took this drone thing on, this UAV thing on, and they made it their own. General Jumper is the one who put a laser designator on this because we couldn't see—You'd look down and see there's a target. We see the target, we know it's there, and the fast jet guys are flying all over and they can't see a damn thing. He said we're going to put a laser designator on it.

And that's only one short step to—Why don't I shoot it with it? Even when I put the laser designator the fast guys can't see it. Why am I messing around? Why not just go direct, take out the middleman and we'll go right to it? And instrumental in getting—I just happened to be personally involved in the whole process of getting—It's a long story about Hellfire-Predator and how it eventually gets tested. Why it gets tested against the objections of some in the US government. And then it is not designed to kill terrorists, just so you know. Not designed. That was not the purpose. That was not how we got Hellfire-Predator. We got Hellfire-Predator because the Air Force took a program, dedicated itself to the maturity of that program, and thought about how to innovate with it. That's how you get innovation. The service has it. They figure out what they need to do with it. They innovate, they turn it into something it never was designed to be, and it does that job, I would say, since I was involved, I can talk about it now but at the time it was a big deal, I was involved in the very first lethal operations with this, in September and October of 2001. So I was a lucky guy in a sense, or you could call me unlucky, but I was actually here for 9/11 and was lucky enough to actually deploy out right away soon thereafter and was a strategy chief there. But I was involved in Hellfire-Predator operations.

So when I see these things with a Hellfire underneath, I get a soft spot in my heart. I love these people out here. The unmanned Predators. There's just people all over these UAV operations, and great people, fantastic people, great great airmen. They're the reason that these things fly. They're the reason why they fly as well as they do.

By the way, here's a myth. I'm the keeper of all UAV myths. UAVs crash a lot. Here's the deal. Anybody who understands aviation design knows they crash exactly what they

were designed to crash. If they have actuators that last so many revolutions, guess what? They normally last about that long. They have engines that are only designed to fly a certain amount of—Every one of our aircraft has a design failure rate. By the way, all the aircraft you fly on to get anywhere in this country or overseas, also has a design failure rate. Some of you would be shocked to know the difference in the design failure rate between a commuter aircraft, a local commuter and like a 777, a big wide body, big jet. There are several orders of magnitude difference between those aircraft. The same with these. They're all designed to do something. These are designed to be cheap. They're going to fail at a certain rate and guess what? They have. They fail just about right on the money even in combat operations about what they're designed to do.

So if you design them well, they'll fly well.

I love that Reaper over there. Those are all the lethal operations they've done marked on the side.

So we have Global Hawk. I'm going to go through this. This is funny. This is a photo of, an overhead RQ-4 photo of the presidential palace in Haiti during the Haiti problem that we had recently. What I love about this photo, it looks kind of bad. What's great about all these aircraft is we've come so far in our imaging technology now that this actual photo is magnificent. It's magnificent beyond belief. The detail is fantastic. I just can't show it to you here.

Let's just go over some of the conclusions.

These are major programs. Billions and billions and billions of dollars have been going into these programs, and the Air Force has been materially involved in them since the '50s. And there really have been very few down times. Even in the monograph when I say there's sort of a UAV hiatus, I promise you there's something I couldn't write that's in there. I promise you. There's always something going on under the water. But UAVs aren't just intrinsically good. You have to have a reason to have them. Why do I need to take the pilot out of the aircraft? Why? What does it get me? What do I get out of it? We have to constantly answer that question.

For a micro UAV it's an easy answer, right? Can't fit in there. For the bigger ones that the Air Force operates, a much more dicey deal. And what I talk about throughout this study is when you're competing with other systems, it isn't just a matter of wow, gee whiz, the alluring nature of UAVs. They have to be able to compete with manned alternatives, with cruise missiles with satellites, and you'll see that throughout the study, that in many cases programs came to an end for very very pragmatic reasons.

I talked about the cyclical nature. It's not progressive. If you believe that, then we should be at least cautionary about whether this whole UAV thing is finally taken hold and it's going off and it's going to continue out into the sunset as a progressively improved system.

With that, I just want to conclude at this point again, and thank you Rebecca for making this all possible. Now I want to open it up for questions.

Grant: Thanks. That was a great presentation.

Any questions for Tom?

Question: The Air Force has a flight plan to 2047 for UAVs. Based on what you're saying, that it's cyclical and it's not progressive, that cycling is kind of based on the assumption that it is progressive.

Ehrhard: I would say that it's based on the assumption that in order to realize what UAVs can do and be, you have to be a good advocate. One of the strong messages in this study is that it doesn't—these systems are not created and maintained and built and go through all the minefield of acquisition just on their intrinsic good. It's done by human beings and constituencies who really, really are invested and want to see that system get to the end.

So if I said to you, if I named a system like F-35 you could all name me the human beings, the constituencies inside a particular service that would be the natural advocates. And guess what? If you look around you'd find those natural advocates actually doing that advocacy and making sure that system stays alive as much as it can be when it finally gets to the field.

So who's the advocate for a UAV in the Marine Corps? For instance. They flew Pioneers in direct support of offensive operations in Desert Storm. 1991, right? In 2003, nothing. How did that happen? How did it go away, actually? Now they're leasing them.

I'm just saying service by service, I studied all of them, so what you see is constituencies are very important, and I think the UAV flight plan is part of a maturing Air Force constituency for unmanned aerial vehicles that I think was, in this case, was championed by [Lt.] General [David A.] Deptula who is the A2 and has really been aggressive about getting the word out not just about unmanned aerial vehicles, but about really making it better. About improving the system with all kinds of new technologies and concepts of operations. What the Air Force does with UAV operations today is quite, I think, impressive when you really figure out remote split ops and things like that.

Question: Can you shed some light on the Secretary of Defense's statement that the Air Force would not co-fund an air vehicle with the CIA unless it had a pilot in it?

Ehrhard: That was—Maybe Dr. Grant should talk about that since that's in her preface of this. I don't have much to say about that. We don't know what exactly he's talking about. All I'll say as an enticement is if you read the monograph you might have a very

strong hint what he was talking about, so read the monograph and you'll see a possible candidate for what he was saying.

Question: Can you comment on proliferation of UAVs [audio unclear]? Are other nations growing the capabilities as well?

Ehrhard: Yes, it's obviously occurring. But when you look around it's very very interesting. Because when you've done what I've done, which is sort of obsess, at least study these for the last 50, 60 years, you see all the difficulties in developing these systems. Really, the main question is why is it taking these other nations so long to get these systems into maturity? When you look at Israel, for instance, very very aggressive when it comes to UAV development, but for the most part they were interested in short range, line of sight systems only for a long period of time because that was their strategic horizon. Their NRO, if you will—our NRO had to see around the other side of the earth; we had to develop systems to do that—they had to see across their border. So they were specializing in very low tech, let's call them, UAVs for years and years and years.

Now as their strategic horizon has expanded, they've had to go over the horizon and it's been a very difficult process for them to get through to develop these much more sophisticated unmanned systems.

So it's been interesting to me that you just don't see sort of the pace of development that you'd like to see.

Now I think there are some interesting developments going on right now in Great Britain, with Taranis and things like this. There are some very interesting programs out there. But for the most part what you see in the United States is this sort of dizzying spectrum from very small hand launches to Mach 3 super drones that you just don't see in other countries. This wide variety, trying to apply UAVs to all manner of operations. So it's been really kind of interesting to see how the pace of—and I must say this—there's a huge technological factor that I didn't mention, and that's GPS.

Most people when you ask them, when did we really have a functioning global GPS system? They have no idea. They've lived with it most of their adult live or whatever. It's really 1995. It's only been 15 years. That was a huge boon to UAVs, because now you off-board, for the most part, all your navigation. It's fantastic for UAVs.

Other systems benefited too. They're really good for UAVs. So that's been one of the catalysts. So we've seen a lot of UAV development since the '90s because that's been a major motivator and I must say, paid political announcement, who brings you the Global Positioning System? Your US Air Force does. You're welcome. [Laughter].

Question: You're talking about how UAV development is cyclical. It seems like right now the cycle is sort of basic. What do you think the next cycle's going to be for the Air Force in the development of the—

Ehrhard: The next down cycle or the next up cycle?

Question: If you think it's a down or an up.

Ehrhard: I think the down cycle, the likely down cycle is when we, if we, when we start to withdraw from the operations in Afghanistan and Iraq, possibly. We'll just have to look at it. It's a factor you should all look at and you should all kind of watch that. You should watch each one of the services and how they react to it. My sense is that UAVs have, I am confident about the Air Force and the fact that these RPAs have really sort of gained a foothold and a constituency. We have units, we have wing commanders that just, this is what they do. We're developing a whole new system of developing operators and sensor operators and that. It really has a much firmer foothold, I would say, when you look at the Air Force in institutional terms which is sort of my metric for trying to understand weapon system innovation. How much of a firm foothold does it have in that service? And a lot of leadership decisions went into this. A lot of visionary leadership decisions went into developing these systems.

By the way, General [John D.] Ryan, the first General Ryan Chief of Staff, the General Ryan you all know, his father was a Chief of Staff back in the '60s, and he was a big proponent of the Lightning Bug system, for instance. He sent one of his special assistants like me out and toured all the units to make sure all of his commanders knew that this was an important system. So it always takes that leadership, and we seem to find those airmen consistently. Contrary to what you would think.

The point is, I'm not just saying this, I'm the guy who studied them, met them, talked to them, interviewed them, and checked out all their stories. So I find it fascinating that this has been going on for such a long time.

Question: A couple of years sago Lockheed Martin officials started talking about taking a different approach to design of UAVs. They were saying that the traditional paradigm was to take a manned aircraft and unman it, that type of thing. They were saying why not take like some cruise missiles, take missiles and then make them into UAVs and do the functions that UAVs have been doing.

Is that an idea that's starting to take hold? Is there some sort of cultural breakthrough that—

Ehrhard: That's actually an idea that's been around for a long time. I can tell you it's not a new idea. The problem is, the issue is, A, can they make it work? Can you actually show a sort of progression of engineering and technology and all that to make it work? Then B, what's your constituency? What's your mission? Who's asking for it? How do we sell—General Chandler is not an easy sell. Let me just promise you. And you've got to sell them. And he wants, he's got to be shown this stuff. He's been around aviation a little while. In other words the whole thing has got to come together. So it's much more than

just an idea.

The way I like to put it is, a demonstrating prototype, a flying prototype, is like the tip of the developmental iceberg. People do this all the time. Oh look how this UAV's flying. The Air Force invested untold millions and billions into the Predator program to mature it into what it is today. Untold. There was no tech data. I could go on and on about the developmental work that went on from '95 when General Fogleman sort of threw down and said we're going to take this system, all the way to what you see today. Unbelievable. Despite that, I like to tell these stories, but Predator is so amazing because it does such an unbelievable job. But it literally has a little metal toggle switch on the side that says on/off. [Laughter]. I'm not kidding you. And it is the on/off to the whole aircraft. It's this cheesy-looking kind of Radio Shack kind of toggle switch. Like checklist—make sure toggle switch is on. [Laughter].

And yet the thing that is unbelievable, the things that it does. But it developed, it matured into a system that actually had, a lot of them crashed early, into an operational system through a lot of Air Force investment in time and energy.

Question: As you described kind of the '60s and '70s, we focused on penetrating contested airspace. And sort of adapting to that, and really that being the central operational problem.

As you look at today's or say the last 10 years of UAV development, it seems like it's gone a different way. It's been focused no persistence and uncontested airspace. That's an interesting sort of development. How do you think that accounts, maybe the question of the other gentleman here on where they're going. Does that—

Ehrhard: In that very nice way you're saying I didn't answer his question, so let me answer it this way. Ali's [sp?] one of my close colleagues on the Air Staff and he's fantastic and he keeps me honest. Thanks, Ali, that really is an important question.

All you have to do is look at the fundamentals of this. So let me ask you. Air defense systems. Improving, staying the same, decreasing? Which one? It's obvious, right? Dramatic improvements in both the capability, the protection of them, and the number of different types. Oh my goodness, the number of different types. And the proliferation of them. Tremendous.

So the requirement for persistent surveillance, that is the kind that we're doing today. It's sort of a full motion video kind of I need to stare, to watch it increasing, about the same, decreasing? Personally, I think it's all increasing. At the very high level, mobile systems and those kinds of things, and at the low level where you're targeting a person.

All of these are increasing in their strategic importance and their operational importance, through US military operations—not Air Force. US military operations.

Where are we going with, for instance, low observable technology? Well if we invest in it I know which way it can go. We should be going to the right, we should be improving on that, and I think you can pretty much count on your Air Force to be advocates for that.

Then you put that all together and you say what are the opportunities here for unmanned vehicles>? I think it's obvious. I think it's the question that answers itself. As soon as you understand those things. People are ignorant of that, though. They look at the operations we've been doing, no air defenses. I used to say, I'd quip to General [Tommy R.] Franks, every aircraft flying over Afghanistan is a stealthy aircraft. In 2001, there's no emitters. If there's no emitters, a B-52 is stealthy. Right? But where there are emitters, some aircraft are and some aircraft are not. And there's more to LO than just sort of radar, reflectivity and all of that, but I think there's a way forward with low observables with unmanned vehicles. I think maybe you've seen some of that. And I think there's actually a way forward, something people don't think about, but in my research how about quiet aircraft? They can be conventional, they can be non-stealthy in the RF way. But I need them to be silent. Guess what? We flew a silent manned aircraft over Vietnam. Lockheed Skunk Works built one that had specially designed subsonic props and all that to fly low over the jungle canopy and it was basically silent for reconnaissance.

So I think there's a lot to that. There's a lot of different dimensions that you could go with that. Again, you look at each one of the constituencies in the service and you should expect them to be working on something like that, and I think all of us should expect us to move forward in that. Because it's obvious, an obvious role for unmanned systems, both small, medium and large, that we go in that direction.

Question: What do you see as the biggest constraint to continued development of unmanned systems? Is it cultural, organizational structure? Or is it technical? We don't have—

Ehrhard: The answer is that—Because I have PhD behind my name I must answer it, it's very complicated and it takes a lot of study to understand it. [Laughter]. But the real answer is that depending on the system you're talking about, there are different sort of challenges because you're talking about different services, different service subgroups that would be the natural constituency for that. That's where I start. That's where the success and failure lies with the constituency. Is it a tertiary system to them or is it primary to their mission? Do they see it as primary to their mission? Who is it that really is the advocate for that system? I think that's where it starts. That's where the obstruction or the challenges usually come, and actually the opportunities exist as well.

I think we're in the information age, and I think the challenges of weapon system development with all of these, the rapid advance of information systems, incorporating them effectively into these systems, we have shown that this has been a big challenge for all of aerospace. And by the way, this is naval systems and everything.

In the '50s this country, the term weapons system came from the B-29 Super Fortress because for the first time it was so complex that you had to think about it as a system. So the term weapon system came from the late '40s and '50s. The United States became, had a competitive advantage n doing this complex systemic concurrent development.

But the information age has proven that to be challenging for us and everyone else too. Because now the systemic nature of all these systems, getting them all to work together with information systems is actually part of the problem that you see in some of the acquisition issues that you see today and it's very very challenging. So making all of this rapidly increasing—that includes data links, that includes very very complex algorithms.

Once you get by a million lines of code you're going to have an error every 10,000 lines of code if you do it the most careful code-writing way you can do it. That's one error in every 10,000, and I'm not going to do math in public. There are many systems that are way, way over a million lines of code. And most systems get into that.

So these are all sort of integration problems, and they're integration problems for the service and the contractors too.

And by the way, we were having a discussion, I'll just make a sort of a paid political announcement here. That is, this is just sort of a general problem that I see in my position in town. There seems to be a gap in knowledge between experts and practitioners when it comes to aerospace, and especially in information technology. Many of the things that I've described today, you have to understand lifties and draggies, and you have to understand data links and over the horizon and all those kinds of things. But today it's crazy, the level of knowledge you have to have to put all of this together. Most people can't even understand how LO works, low observables, they couldn't tell you, couldn't describe it to you.

So there's a gap, there's a growing gap. We like to say that we need to learn foreign languages, for instance. I'm an advocate for learning the foreign language of aerospace technology. I think there's a problem there. I don't think we're communicating very well with one another. The experts on the one hand and the practitioners and the decision-makers on the other. So there's a growing gap, even in a highly technological service like the Air Force, we still have problems communicating what it is that modern aerospace technology does and can do, all the way from design, conceptualization, to CONOPS and above.

So I would just leave that with you as a challenge, I guess, to everyone. That all of us have a job to do in being able to be more clear and concise and sort of persuasive about what it is that we can do with aerospace technology.

Grant: Tom, thank you for an absolutely outstanding presentation. Thank you.

Ehrhard: Thank you.

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