The Aerospace Advantage Podcast – Ep. 202: Ensuring the Asymmetric Advantage: Jet Propulsion – Transcript (AI-Assisted)

Heather "Lucky" Penney: [00:00:00] Welcome to the Aerospace Advantage podcast brought to you by PenFed. I'm your host, Heather "Luckey" Penney. Here on the Aerospace Advantage, we speak with leaders in the DoD, industry, and other subject matter experts to explore the intersection of strategy, operational concepts, technology, and policy when it comes to air and space power.

So, if you like learning about aerospace power, you're in the right place. To our regular listeners, welcome back. And if it's your first time here, thank you so much for joining us. As a reminder, if you like what you're hearing today, do us a favor and follow our show. Please give us a "like" and leave a comment so that we can keep charting the trajectories that matter the most to you.

Ask any pilot about what makes or breaks an aircraft, and they'll say propulsion. I mean, after all, those of us who fly single engine jets, if you don't have an engine, guess what? You're riding a parachute down, right? A jet engine is literally the heart of an aircraft. It doesn't matter how good the airframe's design is, if it doesn't have the power and thrust to be able to exploit [00:01:00] that design, it's really a pig.

And, it doesn't matter, you know, again, how sweet the electronics are. If you don't have the electronic and the cooling capacity that the engine provides, it's really just nothing but kind of software and hardware. So, when it comes down to it, an aircraft's capability is fundamentally about propulsion.

America enjoys a fundamental advantage when it comes to military jet engine technology, and that didn't just happen. It's been earned generation after generation by developing the strategy, innovating the technology, and investing in the resources necessary to keep advancing the state of the art. That also means producing it in quantity because we need to see these aircraft, operational to understand how to improve that next generation.

So, that's what we're going to talk about today, America's Propulsion Advantage. How we achieved it, where does it stand today, and where do we need to go tomorrow? This is all about partnership, between government and industry, and that's why I'm pleased that we're able to have Dr. Michael Gregg, [00:02:00] Director of Aerospace Systems Directorate at the Air Force Research Laboratory, and Chris Flynn from Pratt Whitney to join us today.

So, Dr. Gregg, welcome.

Dr. Michael Gregg: Thank you. I appreciate the opportunity to chat with you today.

Heather "Lucky" Penney: And Chris, it's great to have you with us.

Chris Flynn: Great to be here, Heather and Larry and Dr. Gregg, great to have the opportunity to chat about propulsion. Can I just do a big shout out to a couple of the folks out here? First and foremost to our warfighters.

I'd also like to shout out the lawmakers that helped support the propulsion enterprise. I'd also like to recognize the propulsion enterprise and the professionals that make our advantage happen. And also I'd like to thank the Mitchell Institute for supporting this podcast.

Heather "Lucky" Penney: Well, we're delighted to have you here today and we completely endorse and support all of your shout outs because we're fundamentally here for the warfighter.

But, as you know, the tip of the spear is just the tip of the spear. We rely on, and we stand on the shoulders of [00:03:00] all the individuals who do everything from the design to the engineering to the production, and this includes everything from the research and development to those folks that are down there on the production floor to those maintainers that are taking care of the jet engines.

So, we are completely on board. And as you mentioned, we've got our Mitchell Institute Director of Research, Major General Larry Stutzriem. Stutz, it's always awesome to have you with us.

Larry Stutzriem: And it's always awesome to be back with you, Heather.

Heather "Lucky" Penney: Thank you. So let's kick this off with your operator's perspective.

Help us get our heads around, how important propulsion is to our combat crews. I mean, I spent my entire military career in the Viper, and I got to tell you, the F 100 and the F 110 were incredible. The power, the reliability, those were amazing engines. And it marked a major milestone that the Air Force and industry had fought to achieve over decades and generations of aircraft.

What was life like with the earlier technologies? Cause you flew the Viper, [00:04:00] but you also flew the Phantom.

Larry Stutzriem: I did.

Heather "Lucky" Penney: So talk to us about that.

Larry Stutzriem: Oh boy, Lucky. You're going to get me in trouble with some old Phantom drivers. It's not my ambition here to disrespect the old beast, the F4 Phantom. But, let me just say Lucky, everything I ever dreamed of while I was flying the F4, that I wanted and thrust and performance came true.

When I went to the F 16 and flew the F 100 and 110 engines, those turbo fans. That J 79 in the F 4, a turbojet, it was very dependable. You know, I think it came into service with the F 104 Starfighter in the mid fifties or so. So, by the time I flew it, it had lots of flight hours on it and it was dependable, but...

Heather "Lucky" Penney: It's a smoker, too, right?

Larry Stutzriem: Yes. But you add, what, 50 percent more power with the improved engines and, oh, wow, that was fantastic. And that [00:05:00] additional thrust made the F 16 quite a performer in the air combat arena. I just, a Vignette. I remember, out in the Pacific, I flew some training missions, air combat training missions against F 15s, which had the new engines. I'm flying my F 4.

And it was the first time I'd flown against the F 15 in training. And my gosh, these guys could climb high, fast, we could not keep up. They had a distinct energy advantage. And that was a big lesson for me early on in that, anytime I was going to be in air combat, I did not want to ever tangle with an adversary that had a power advantage over me.

So, you know, later in the F 16, that new generation of engines allowed me much more aggressive tactics and frankly, I'll say better survivability against an adversary.

Heather "Lucky" Penney: Well, I mean, if you [00:06:00] think about those older engines, I mean, we both flew the Tweet, the T38, right? The J69 and J85. And remember how, when you pushed up the throttle, you could literally count to 10 before you really felt that slow spool up of the engine.

And a trivia for folks out there. That's why when you come around the base to final turn, when you fall off the perch, you pull out the speed brakes so that you have enough drag to justify adding power and keeping the engine spooled up in case you had to go around. Cause, those older engines, if you didn't have that higher power setting and you had to go around, guess what?

You're going to have to wait about 10 seconds for that power to show up and you're going to smack the ground.

Larry Stutzriem: And it might be too late. Exactly. Right.

Heather "Lucky" Penney: Yeah. So, as a pilot, what were the things that you were looking for from an engine? Like what made a dreamy engine for you?

Larry Stutzriem: Oh, I thought about this a lot and, you know, from my fighter pilot perspective, if I was to design a new fighter. My first design question would be what's the threat I'm facing? And of course, you know, why? [00:07:00] Because I want advantages over that threat. And the very next design question I'd ask is what's the leading edge engine design that I can grasp for this new design, because that informs everything else I want out of my fighter.

So, in terms of performance, I want lots of thrust when I need it. And like you said, I want it when my throttle says I want it, I don't want to wait for it. But I also want, you know, good gas mileage, when I'm just cruising along. So, I don't have to carry a, you know, big load of heavy gas. So, your comment about the spooling up of the engine is very interesting because there's some other dynamics.

In fact, we were talking earlier, Lucky, about our adversaries back in the Cold War, you know, we could kind of count on Russian fighters to have a lot of engine issues and [00:08:00] delicacies in a, say, a dogfight of some sort, having any kind of stagnation, but they did. And so, you know, all of that, lots of thrust is there for me.

That's all the fighter pilot wants. That's what I want. But I'll say that the, war fighting commanders, they want a little more, they want reliability, they want ease of repair and maintainability. And those engines need to come out sortie after sortie. We need that when we're, you know, in a war or in operations to gain and maintain superiority.

Now, now. You had me harking back to the F 4 days and that was Lucky, a third generation system. And the systems we had in that F 4, very simple radar, nothing like we have today. Simple threat warning, some radios, and...

Heather "Lucky" Penney: Lots of dials, but it's not fundamentally kind of the, the powerful avionics and sensor suites that we have [00:09:00] today.

Larry Stutzriem: Exactly. Very simplistic. When I, you know, when you sit in a simulator or cockpit F 35, oh my gosh, it's so space age. So, you fast forward to like, today, we have the Block 70 F 16s, we have the F 35, like I just said. And the avionics are the star components in those aircraft. So, what's happened is the demand for power has gone up to fuel all these new technologies.

And with that, you have debilitating heat that all this avionics, so you have to cool it, right? So, that all comes from the engine. And we know that, the more you sacrifice, there's only a certain amount you can take off the engine and start to really disrupt the performance of that engine to do the power and cooling.

And so new technology in the F 100, F 110 was really important in terms of its growth, [00:10:00] a pathway for growth and improving those engines across their lifespan to account for new avionics. And I think, I think about, and I used to go out in the flight line with the maintainers a lot. The J79 had these two little generators that came off.

You could not start or run an F 35 on the ground, with an F 4 power system. It just, it wouldn't even work. That's how, how much that power consumption has grown.

Heather "Lucky" Penney: Wow. That's amazing. So, the generators that you had in the F 4, the amount of electricity that they produced would not be sufficient to be able to just start an F 35.

Larry Stutzriem: Exactly. And, and keep it running safely if you got it started on the ground.

Heather "Lucky" Penney: Yeah. So, I really appreciate the fact that you brought up that SWaP-C, the ability to generate power, which we're taking air off the bleed air sections. We're taking air away from the combustion elements of the engine to be able to drive the generator and then also be able to cool and do all the other environmental control system [00:11:00] things.

Types of things, air conditioned pilot too. We don't want them to get too hot. That really, that's a big deal now. Those are physical attributes that we need to be able to plan for. Not just for what we envision today, but everything that we can't, haven't even imagined for the future.

Larry Stutzriem: Exactly.

Heather "Lucky" Penney: Yeah. And still be able to advance the capabilities of the aircraft from basic thrust to its specific fuel consumption to everything, maintenance man hour per flight hour, right? So, we're really asking a lot of future engine technology.

Larry Stutzriem: Yes.

Heather "Lucky" Penney: Dr. Gregg, you know, we just had this discussion about propulsion from an operator's perspective, but you represent a different part of that solution.

You're an innovator, one of the key leaders that are charged with stewarding the Air Force's jet engine propulsion development activities. So, can you help us understand how the Air Force works to maintain this propulsion advantage? Who are the main players, and what's AFRL's role in this equation?

Dr. Michael Gregg: Oh, thanks for the opportunity here.

This is a [00:12:00] fun discussion. I was listening to Stutz there and I was wondering if power and thermal management was going to come out. So it's like, yes!

Heather "Lucky" Penney: We do care about that.

Larry Stutzriem: Let me tell you, the cockpit in the F4 was very hot.

Dr. Michael Gregg: Much broader, propulsion from an AFRL perspective is much broader than just the engine.

And it's more than just a jet engine for fighter class. When I, when we think of propulsion from an innovation perspective, we're looking at new designs, new innovation for airlift, for supersonics, for hypersonics, for space propulsion, and beyond how you achieve combustion. We have to worry about the power and thermal management, and we're thinking multidisciplinary design about how you redistribute each of those parts and pieces that make up a whole propulsion system to include electrical management, thermal management, over what we have been able to do [00:13:00] historically, because our design tools have progressed so rapidly.

So that gives you a from an AFRL perspective, it's much broader than just engines, what we're looking at, but it's, it takes a team and overly use cliches. It really is a team sport. And if you think about what do we need to maintain a propulsion advantage? It takes the lab doing innovation and it takes the life cycle management center doing the acquisitions that's more focused on an end application.

It takes the sustainment centers who do the maintenance on our engines. It takes the test center to make sure that we ring all these things out before we get it into the warfighters hands. And certainly last, but definitely not least, it's industry partnerships. That is the relationship between the government and industry is absolutely vital.

And what we also expand to do, not only with, from a [00:14:00] military application, but we're also, have outreach into the FAA, the Department of Energy. This is really a broad national perspective that we try and take and bring all the elements together to understand who is doing what, who's working on what, what are the big problems, so that we maximize investments.

Heather "Lucky" Penney: So, Dr. Gregg, Sutz talked about moving from the F 4 to the F 16, and how that really represented a huge function change from a propulsion perspective. From an AFRL perspective, what are the indicators that you look for that suggest that a new propulsion solution is required, and how do you begin to identify the attributes that you need?

And what are the timelines required? I mean, I would assume that you don't just start a new engine when a new aircraft, program begins, right?

Dr. Michael Gregg: Unfortunately, historically, the timelines to develop new propulsion system is [00:15:00] a decade plus. And given the environment we're in, great power competition, we have to think differently about how we've, how we develop new capabilities, and it's a combination. We have to be thinking so far out in front that there is a technology push, as well as a technology pull that has more concrete warfighter, needs expressed to us.

So it's a mix, but you're absolutely right. If you start when the warfighter says, I need this, we will never be responsive enough. And so that's why we have to have this ecosystem between what the lab does and innovation, how they partner with industry to get that to a demonstration point. And then get it over into something like a production environment.

It really takes a long time. So, it's interesting though, the way the Air Force is going today with the Integrated Capabilities [00:16:00] Command and the Integrated Development Office. That we're trying to be very clear on what mission sets, what mission threads are, do we need for great power competition and how do we decompose that mission need into a technology or to a performance need?

So, that is going to help us, I think, tremendously from a lab perspective. Make sure that we're focused on the right thing while simultaneously doing a lot of innovation that nobody has even thought to ask for yet.

Heather "Lucky" Penney: I really like how you describe this being a push pull between how technologists and at AFRL, and in industry are imagining what the art of the possible is as they push the state of the art of engine technology, propulsion technology forward. As well as, listening to the warfighter and hearing what they need to be able to prevail within the battle space. Whether or not that's [00:17:00] thrust, responsiveness, speed, maintainability, that SWaP-C. What they're going to need to be able to address the threat, the range, the geography, as well as their organic capabilities.

So, in the 2000s, the Air Force launched a new wave of engine innovation. And one of the better known ones was the Adaptive Versatile Engine Technology Program, or ADVENT for short. And the family tree involves some twists and turns and a bunch of different acronyms, but it really kind of marks a key juncture in modern Air Force propulsion innovation.

So, Dr. Gregg, could you walk us through how that effort developed and evolved? I mean, as I understand it, ADVENT turned into AETD, which was then channeled into the first AETP. And now that after AETP got started, they then also split that off to a separate core development program for NGAP. So, can you help our listeners kind of understand, the story right now of engine development?

Dr. Michael Gregg: Sure. [00:18:00] Just a little history.

Heather "Lucky" Penney: Just a little.

Dr. Michael Gregg: Turbine engines were really optimized for either high performance, as in the case of a low bypass fighter engine or fuel efficiency.

Think of in terms of airlift. And what ADVENT did was to say, was to think about how do we combine these attributes so that we can have high performance when we need it, high efficiency when we need it.

So, ADVENT was developed as a program to look at the individual technologies and pull that together. And those individual pieces were put into AEDT to do a demonstration of all those things to show, yes, we can really do these multiple stream engines. And then after it was demonstrated and taken to a technology readiness level, then it was [00:19:00] transitioned to the acquisition community in the AETP program. Which worked with industry and got it to the point of a production model. AETD was a demonstrator. It's not something that you could take directly to an aircraft and put that in there. So, AETP was the production mode, mode of getting an engine into production.

So, it was, it's a equivalent form of crawl, walk, run. That's where we're at today. So one of the primary goals is, was at that time was to, Hey, we can see where we're going and we can see how we need to get there. And so we've done this series of demonstrations, but then it took longer than needed. Or I'll say it took a long time. And so now we find ourselves, that technology progressed faster than the engine did. And so there was a phase [00:20:00] mismatch between the pace of engine development and the pace of avionics, airframe structures, sensors, et cetera.

Heather "Lucky" Penney: So, that's interesting that there was kind of that phase mismatch, but really I think we're seeing a lot of energy right now within AFRL and within industry as we begin to think about those next generation advanced propulsion capabilities.

So, what's AFRL's role right now? How are you thinking about the requirements and sort of closing the gap between that capability and the state of the art, today?

Dr. Michael Gregg: This is actually a very exciting time for the propulsion business. So, I will be interested to see if Chris has the same view, but with the new tools that are available to us from a design perspective, we are now starting to think more parallel development instead of serial development.

So, if we have an idea that we're using a new radar [00:21:00] and we know that it's going to be an energy hog, then you start to think about, okay, I really need to amp up my work on power and thermal management. And then that tells you, what do I need to pull off the engine and the actual design of the aircraft comes last now.

And so what we think we can do is have better designs and do shorter turn times to make sure that we're focused just on the technologies that we want to achieve the mission performance. So, right now, we're working with various vendors like Pratt Whitney. We've tried a lot of digital engineering experiments and tools to say, how can we do this faster from a design point or from a contract execution perspective?

So, it's really exciting to see how we can pick up the pace and we can actually spend more time on innovation instead of grinding through [00:22:00] business as usual. So, we are trying hard to push that. Not only in the turbine engine business, but also it's something new called rotating detonation engines that could have a huge impact over the next decade. I think one of the things that we're pursuing that for is because, you don't have moving parts in a rotating detonation engine. And so you can think your combustion volume is much smaller.

And so you can translate that into either higher performance or more range for a given SWaP size. So, things like that we have a number of initiatives going on with industry that we're looking at. We're also looking at lower end thrust classes for new vehicles. And we're experimenting quite a lot with how do we really get our power density up and how do we manage that?

So, hopefully I don't come across as too excited, but [00:23:00] this is just a great time to be in this business.

Heather "Lucky" Penney: I know, it sounds like it absolutely is. You know, with the rotating detonation engines, you know, Stutz, but I'm hearing a field trip in our future.

Larry Stutzriem: I think so. We'll come visit, doctor.

Heather "Lucky" Penney: But, you know, the agility that you're describing of your team to be able to exploit not only new materials, but also digital engineering, design excursions, partnering with industry, really is exciting. I have said for a long time that SWaP-C is a physical attribute of aircraft, and that fundamentally starts with the engine.

So, Chris, I'd like to bring you into the conversation. Could you help us understand what it's like to partner with AFRL on innovating lead edge propulsion technology? I mean, I'm assuming that the journey begins with responding to a request, drafting a proposal, and all that, creepy contracting stuff, but talk to me about what it's really like to get it done.

Chris Flynn: Actually, Heather, our journey with AFRL and really the [00:24:00] rest of the propulsion enterprise is what I would call continuous. And Dr. Greg described a little bit of that. We have all kinds of different opportunities to collaborate. And when you think about all of the different areas of propullsion that we're looking at for the great power competition.

It's a, you know, essential that we are continually talking, looking for the requirements that have been identified. So, these requirements come from a whole bunch of different places. They can come from the threat primarily. There might be a new requirement that comes out from another area. A weapons system contractor might come up with a better way of doing something.

We've got thousands of engineers at Pratt Whitney that are advancing state of the art technologies. And we also have our research center that works on these new way of doing business. And we're [00:25:00] continually working with Dr. Gregg and the rest of the enterprise to look for solutions to all of these new challenges.

So, from my perspective, that continuous collaboration across all of the different, requirements for propulsion really gives us the foundation to establish what a new requirement is. Then we move into the contracting phase in order to execute some of the demonstrations that might be needed.

Heather "Lucky" Penney: So Chris, when we think about industry and engines, many of us think about the production line.

But what we're talking about right now is way more in the R&D line of the work, right? The research and development and creating those new technologies. Can you walk us through what that's like for Pratt? Who's involved? What the facilities are? And are you working with scale models first and digital engineering and computer modeling?

I'm assuming that full scale articles like, you know, airplane size engines are a little bit [00:26:00] further down the line for you.

Chris Flynn: Yeah, that's a great question, Heather. There is no doubt about it that research and development is a world away from serial production. I, over my career, I've been fortunate enough to be on both sides of it, and I can tell you the R&D side of it is really cool.

There are tons of steps in the value stream, and the requirements, as we said, come from a variety of places. Always looking for new solutions for many of the things that Dr. Greg described. So, really start with a concept. With a digital model today, I would have said paper a while ago, but a digital model today, in a really controlled environment.

We have labs all over the country that really focus on advancing these new technologies way before they ever get into a full up engine. So, you might start with a component test. You might want to do [00:27:00] a new test on an aerodynamic improvement and you'll start down at the piece part level. Uh, then you might graduate from that piece part level into a system.

That would maybe take a, you know, a full up section of the engine and test it in a rig in a very controlled environment to try to simulate the future application into a full up jet engine. You graduate from the component, you might go to a system rig and then really full up test. So, it is a, it is a process that does take time.

As Dr. Gregg says, we've developed a great process for developing new technologies and new capabilities. It just takes too long. And so our focus today is really moving from how do I make this go faster? And the enterprise and Pratt and Whitney specifically is investing heavily in transforming [00:28:00] our industry to a model based enterprise.

Across really the entire value stream. We're not only transferring, you know, from a digital, into a digital environment, but we're really trying to change the way that we process things to. Again, we have a great process that develops the safest and most capable engines in the world, but they take a while.

So, we launched Gator Works a few years ago to change the way we approach that. To try to go faster to take a little bit more risk as we are developing the new capabilities, before it goes into an engine. So, that we can get that feedback faster and incorporated into future capabilities quicker.

Heather "Lucky" Penney: That's really interesting how you're adapting the processes and using model based simulation and using those excursions that digital engineering empowers you to be able to do.

I would assume [00:29:00] you're also leveraging a lot of the work that you're doing in the civil sector. Because you're doing a lot of innovation there, but as Dr. Gregg mentioned, it's a little bit different talking about the demands of a wide bodied aircraft or you know, some sort of mobility style aircraft and fighters or even something smaller like a CCA.

So how does this discovery, how do you cross pollinate across those different types of design streams?

Chris Flynn: Yeah, this is an area where I think the Department of Defense really gets a tremendous benefit from the commercial enterprise in propulsion. We invest hundreds of millions of dollars every year developing new capability.

In some cases, that new capability is very targeted at a commercial application. Sometimes it's very targeted at a military application. In a lot of cases, it could actually go across many applications, and it's quite agnostic. So, we have the ability to do that as we are developing new [00:30:00] capabilities, whether it's the commercial sector, our business sector, or our military sector. We've got some great examples of where the Department of Defense has benefited tremendously from doing this, where we've taken a derivative of one of our commercial engines. Today, the PW 4000, which powers the KC 46 Pegasus, commercial engine, essentially.

The C 17 is powered by an F 117 that is essentially a PW 2000 that powers 757s. These opportunities are tremendous. Really savings areas for the Department of Defense as we're able to incorporate these new engines into new requirements. Yeah, and there are tons of opportunities in that same area from in the CCA space. Where we have our business jet engines that, that really fit nicely, whether [00:31:00] it's commercial off the shelf or a modified off the shelf, in the future of CCA.

Heather "Lucky" Penney: And I would guess that not only do you get a lot of advantages by leveraging what you've already done in that commercial engine space. The military gets a lot of advantages from the scale and the reliability, and just simply the thousands and thousands of hours and cycles that you've already developed in a track record that's proven.

Chris Flynn: Absolutely, right. That's where the scale of our propulsion enterprise really comes into play and the 100 years of experience that we have developing propulsion systems for both the military and the commercial sectors.

Larry Stutzriem: Dr. Gregg, so how does this innovation process evolve? Can you walk us through the major milestones?

Dr. Michael Gregg: The innovation process is never linear. It's not, if I apply this resource over this time, I'm going to get a flash bang and I've got greatness. It kind of goes in fits and starts. And so you have to be patient and you have to have [00:32:00] really great people working in the whole ecosystem.

It could be just a flash of brilliance by somebody. One of the researchers says, Hey, I want to try this... and it works. Or it could be someone had a great idea 30, 40 years ago, but the tech, either the technology hadn't progressed, the materials hadn't progressed, the ability to do the simulations hadn't progressed.

And now we can go back and revisit some of those things and we can see, yes, here's how we would do this, which was the case in rotating detonation engines. We, they had been around for a very long time, but we didn't have an understanding of the material needs and we couldn't model it to understand how to get it to go.

So, that's one way it's just, you know. Trying out some old things or having a flash of brilliance, but it takes caretaking. It takes gardening. And it's really a difficult thing to manage [00:33:00] the immediate needs. You know, what does the warfighter need in the next few years versus what do we think he will need, she will need 10 years, 15 years, 20 years from now. So, I think this is at this point where we're at today, we are thinking about a divergence over historical norms. As Stutz at the very beginning, it is always the best thing to have the most energy, to have the highest performance, and we don't ever want to give that up.

However, as we think about new operational concepts and we understand that we will be using more unmanned, uncrewed vehicles in the future, that's a different design space. And the need for exquisite reliability, performance, and safety, may not be the same in the future. So, we can start to think of a parallel path to exquisite [00:34:00] performance, to something less than, that enables us to get into the affordable mass space.

So, tying this back into innovation is we have to be futurists to some degree and say, okay, if I think this is the force concept of the future, what are the attributes of a platform or a mission system to get me there? And what do I want it to do and how would it look different? Now, I think the challenge for industry is if the trends follow our buys of exquisite aircraft, it will be going down while our number of uncrewed vehicles is going up.

So, how do we maintain that sense of innovation and how do we maintain a robust industrial base for both ends of that spectrum and how do we create the space for industry to experiment, to bring their own research in, and how do we enable that whole [00:35:00] ecosystem to make money for industry partners?

It's a really interesting time. So, back to innovation, I wish I knew that there was a recipe book that I could pull off the shelf and say, ah, that's what I need to do. But unfortunately it's a little jagged.

Larry Stutzriem: It's a well used word, but it's hard to really get to that. Uh, but, but you're at the leading edge of that and that's impressive.

I want to move to Chris for a second. And so Chris, there finally comes a point where technology scales. And it's time to demonstrate it. We've got to get the hardware out there in the war fighters hands. So, walk us through what that's like? I'm imagining it's nerve wracking, but it's highly rewarding.

Chris Flynn: And thanks for the question, Stutz. There is, there's no doubt about it. It is nerve wracking and rewarding, and it can all happen in the same day as a matter of fact. So, obviously we have engineers that have developed new capabilities. Let's just talk [00:36:00] about a new design that has come out. They have shepherded that design through a preliminary design through a detailed design.

We've gotten the approval to go take this new technology that might be at a technology readiness level of, let's say, you know, 5, and we're getting ready to go demonstrate it in a full up engine. When you go through that design process, then you've got to go out and build the hardware. You've got to source it, then you've got to go instrument it.

And there's always a push pull of how much instrumentation do you put in versus the reward that you get by getting the data off of it. That whole process is, you know, lengthy but again, rewarding. It's all about risk and reward when it comes to just how much data you're trying to get off of these, uh, these new engines.

So, here I'll give you a perfect example. You know, we just completed the adaptive engine transition program [00:37:00] where we were, doing very, doing, um, demonstrating new technologies that can be applicable to multiple combat applications. So, we've demonstrated those technologies. They matured to the point.

Now we are pulling those technologies into the F 1 35 engine core upgrade. And we're also pulling those into our next generation adaptive propulsion that Heather mentioned earlier. So, many of those technologies were successful. Some of them weren't, and we learned from them and we will go back and do an iteration on them to bring them to the next level.

So, it is nerve wracking. It's rewarding. I've had the opportunity to spend time on the test stand and conduct those tests. And it is a significant achievement when you get through a engine test with thousands of pieces of instrumentation. And have accomplished all of the major [00:38:00] objectives that you intended to when you set out on that, on that test plan.

Larry Stutzriem: Yeah, that's a lot. Let me pitch this back to Dr. Gregg. During this time that Chris just talked about, what are you looking for during this testing phase?

Dr. Michael Gregg: I'm looking for Chris to keep his sanity as he goes through that, it's always interesting getting into the test of getting something close to production, and it never is quite how you envision and how do you adapt to it?

So, that is, what Chris is describing is very interesting to the lifecycle management center and the propulsion director, because they're looking to test, to see the test data and does it meet the requirement? And is it consistent and getting back to that reliability and safety?

I'm not as interested in that. What I'm interested in the test phase is for, to validate, envision a future where [00:39:00] I don't have to build a full up, new engine and put it on a test rig and have a large contingent of folks to do very detailed testing and to find out that, Oh, I had a design flaw. I want to find those out very early in the process.

So, what I'm looking for is data that can validate models. And I've built such a digital ecosystem with the program offices that I can burn down risk for them. I can do experiments and do. Collect data on the things that are most technically challenging, and then I can give them a design package that should speed up the whole, uh, innovation to delivery process.

That's a dream. We're seeing it play out a little bit. But it's an exciting time to try and make sure that's going to pan out the way we think.

Heather "Lucky" Penney: Well, because it's a process, right? I mean, I know there's a saying that, "all models are [00:40:00] wrong, some are just more useful than others." And I know you're trying to get yours as useful and as accurate as possible.

So, we love this innovation and ultimately though all of it is focused on airmen executing the missions. We need to transition all those innovation efforts and

R&D programs to programs of record that will equip operational aircraft at scale.

So, gentlemen, I'd really like your thoughts on that regarding, at what point do you begin to hand the work, over to the program office? When do you move from AFRL over to some kind of line of production?

Dr. Michael Gregg: So, I'll take that first. So, from an AFRL perspective, we look at doing the individual technologies. And it could be how do I have a more efficient, uh, blade system so that I can have more optimum cooling to influence my power and thermal management system. And if I can do that demonstration, I'm good.

That's the point at which we work with John Sneeden's directorate. [00:41:00] Propulsion Directorate to say, here's what we've got, how does that match up to the requirements that you have that's more formal coming from a warfighter pull? And if he says, yes, that's what we need, then we will, can easily do that transition.

And we're linked pretty good. A lot of folks have gone from AFRL to that directorate and back. And so it's a really good ecosystem. So, it depends on what it is we're demonstrating and the complexity of the demonstration. What we're trying to do in the future is not to do a, we don't do prototypes from a production context.

We are doing the demonstrations to get it to a, the technology, to a readiness level that can be moved to the next stage of acquisition.

Heather "Lucky" Penney: So, Chris, the F 135, which powers the F 35, is one of Pratt's newest operational engines and you're already looking at the next phase, for the F 35. Could you talk to us what it's like about [00:42:00] evolving for that. From a test article to producing engines at scale?

I mean, I'm assuming it's a pretty challenging process because what I've heard from you and Dr. Gregg so far, it really is kind of like bespoke small teams. A lot of engineering, a lot of modeling, and so forth. As well as testing both subscale and a little bit at scale and different components. How do you turn this into operational engines coming out of the end of the factory?

Chris Flynn: That's a great question, Heather. And very apropos for me, I had the honor of leading the F 135 program.

Heather "Lucky" Penney: Oh, super cool.

Chris Flynn: When we were transitioning from development to production and picture this. We've got three variants, multiple stakeholders. Very visible program. We're finishing the qualification and the requirements to demonstrate that the engines meet the spec. [00:43:00] At the same time we are ramping up the production capability.

So, challenges on the way as you develop the engine weight. Technical requirements. The integration, all that times three in the F35, but we complete the qualification and we're moving into production. Well, now you got to start all over again. Now you start the rigorous qualification for the multiple production processes for thousands of parts.

You don't just plop it into production. You go through a rigorous process to qualify, to first source the components to a source that is capable of delivering. You need to source, then you need to qualify. And we have very, very deliberate processes. To qualify sources so that they build exactly what we tested and qualified.

Clearly, single engine fighter focus [00:44:00] on quality, quality, quality, safety, safety, safety. And I would tell you over my career, while we've developed a tremendous process for delivering safe and reliable engines. Working with AFRL, working with the Life Cycle Management Center, and it shows up in the F 35 as one of the safest engines that we've got out there today.

So, you get through that transition process, and now you go 5, 10, 15 a month. It is really, it is challenging. It is very rewarding. The biggest reward is when you're delivering the engines and you're delivering the aircraft to the warfighter. That's what we're really focused on.

Larry Stutzriem: Well, Chris, let, let me, uh take you into the S kind of the next phase of this. And it's very close to my heart because having flown the early F [00:45:00] 100 engine. We're talking back in the eighties now, it's a long time ago, but, uh, it didn't come off the line as perfect. And there were a lot of, as it could be there in those early years, a lot of problems with the engine, of course, each laborious looked at, uh, laboriously looked at and fixed and so forth.

And I assume today, we have a much better process as you've described to have less of that, but still there are going to be lessons learned and there needs to be a feedback loop from operations as they begin to fly your engine, uh, in actual operations. So, how do those experiences, how do what we learn now as it's fielded, inform subsequent enhancements as the engine matures?

Chris Flynn: That's a great question, Stutz. The, in my, all of my years at Pratt, I've supported, most of our combat fighter programs, including the F 100. So, [00:46:00] I know exactly what you're talking about in the eighties when, we did put out the product. These were step change engines, uh, step changes in capability for the engines and there were growing pains.

And what I would tell you is that we have taken that process and matured it over the course of this generation of engines. To have a constant feedback loop on what is working and what is not working to identify the improvements that we need to put in there. So, if you think about the F 100, we went from the dash 100 to the dash 200.

You all talked about the sluggishness of earlier engines. We went to the 220 with the digital electronic engine control, and uh, that was a step changing capability.

Larry Stutzriem: Right, right.

Chris Flynn: Well, then we learned that we wanted more thrust, and so we brought the 229 into production. That engine is now celebrating 50 years of operation [00:47:00] around the world in 23, 23 air forces.

Pivot to the F 135. All of the lessons that we learned from improving the F 100 go into the F 135. We get out into the field, and I don't think I've ever seen an engine where when it gets to the field, it's used like it was designed and spec'd for. It changes all the time. So, we take that learning, we put that learning back into our process.

That's happening today, and you can see that in the F 135 engine core upgrade. Fielded it, realized that there was taking more bleed than than it was designed for. And we're in the process of doing that core upgrade, much like we did on the F 100 a generation ago. When we do that, that's where we reach back to Dr. Gregg and look for these technologies to help advance the state of the art as [00:48:00] we bring these new, upgrades into, into production.

Larry Stutzriem: Yeah, Chris, and I'll also say, you know, uh, the proof is in the confidence of the air crews and your company and your technicians have really earned that across the years. You mentioned, reaching back to AFRL. Dr.

Gregg, how does AFRL work with respect to improvements to existing operational engines? Is that done there or handled elsewhere in the Air Force?

Dr. Michael Gregg: I'll say historically we have done that work, but as budgets have shifted, we have moved away from more of the sustainment activities. Now, if there is a particular urgent need, then we will address that, with multiple directorates within AFRL. So unless it's something very urgent, we don't. We would probably be more doing [00:49:00] development work on some of the peripherals, for instance, some of the power controllers or there could be some fan development. So, it's relatively small, but as far as supporting the operational systems, that's really done more by the program offices in the sustainment center.

Heather "Lucky" Penney: That's really interesting. It's, you know, in some ways I think that the combination of the two from having the program office, but also still having that relationship live with AFRL, is really crucial to ensuring that we're solving real world problems that are happening for the warfighter today.

So, we've been talking about developing this engine technology for some of those demanding state of the art applications, but, uh, you know, Chris and Dr. Gregg, you've both talked about CCA and the, sort of the differences of the engines that we'll need at the other end of the spectrum. And so the Air Force is talking about lower cost, life limited aircraft.

I would assume that those that have to have some kind of implications for propulsion? Not just necessarily the size of the engine, the weight of the engine, the thrust of [00:50:00] the engine, but also, I mean, these are uninhabited and probably I would guess life limited in terms of how we intend to, how long we intend to keep them in the inventory in peacetime and certainly in wartime. So, how are your thoughts on this and how is this changing your approach to what you're designing? Dr. Gregg, let's start with you. And then Chris, let's hear what you think.

Dr. Michael Gregg: So with CCAs, we, we've really opened up the design space.

And as you just pointed out, one of the primary factors for CCAs is how do we achieve affordability? Which means I probably don't want to operate it as long as we have historically operated aircraft. I want to have a very thin maintenance plan to go with it. Um, maybe I don't need exquisite performance.

So, what does that mean? And we've been going back and forth with industry for about three years now about what would you do differently in this context? And we don't have a good answer for that just yet. [00:51:00] So, we continue to model to figure out what it is, but we know that additive manufacturing is, is a game changer.

So, as we move away from a manned system and the requirement for reliability in man rated safety and certification is reduced. Does that create some opportunity to go faster with a certification process? And we can use more of the additive manufacturing to do some of these smaller pieces or assemblies or even whole motors, depending on what thrust class there is.

So, we're looking at that. I think we're also looking at an innovation space where we would like to be able to design to mission. So if, if a CCA is more of a wingman concept, then you need a higher performance to match or be closer in match to [00:52:00] a Gen 5, Gen 6. But if you're thinking in terms of a, a next generation increment, two, three, four autonomous vehicle, then maybe long loiter time is of bigger interest. And so, how you would design an engine to meet that is probably different. So, I think a conversation we're having with industry is how do we allow you to have enough innovation space where we have these tailored propulsion systems and how do you, how do we get that into a production environment?

That seems to be a challenge right now, but it's an interesting thought experiment where we're working on.

Heather "Lucky" Penney: Yeah, I would think so. Here at Mitchell, we just finished up a CCA, uh, TTX, where we were looking at the logistical requirements for collaborative combat aircraft. And what you talked about regarding engine maintenance was one of the key pieces of that.

I would think at the same time, we'd need to be sensitive to the demand signal that we're sending to [00:53:00] industry, not asking them to develop 12 different types of engines because we've got 12 different types of, uh, of CCA. Chris, I'd like to hear your perspective from industry how you're thinking about CCA and how you're approaching this design problem?

Chris Flynn: Yeah, the CCA, space is a very, very interesting and fascinating space. Um, on one hand, we know how important it is for the Air Force to go fast, right? Iron on the ramp as soon as possible. So, you know, that is a focus on the, in the CCA arena. Now, we can accommodate that with engines that are commercial off the shelf today.

The challenge is, as Dr. Gregg described was that we have these engines that have millions of hours of operation that fly people all over the world. That have been qualified that we can [00:54:00] dip right into the production line and start delivering. But they're not as cost effective as everyone wants. So, we continue to, um, to try to find that balance is, how do you take a commercial off the shelf, modify it with minimal impact to airworthiness, and be able to provide it at the speed with which the warfighter needs the iron on the ramp.

So, today it's about speed to market. Tomorrow, maybe more capability. I think that gives us some trade space as Dr. Gregg described on, you know, trading off all of the reliability and life for something that is less expensive with capability that meets a future CCA requirement.

Larry Stutzriem: So, let me take us on a, on a little different topic here and that's, you know, what are [00:55:00] our adversaries doing.

I think you both, uh, observe, uh, what's happening in the world around you. And I'm curious what you're observing about engine innovation in countries like China and Russia. I assume they're trying to match us and surpass us if they could, right?

Dr. Michael Gregg: They are very much working hard to try and match us. China, in particular, is investing across the whole ecosystem for propulsion systems. We still have a distinct advantage, but we have a challenge of, the Chinese acquiring our intellectual property through theft, which is a problem. And that creates an opportunity for them to accelerate their learning curve. So, that's one thing we're concerned about. And so security will continue to be a challenge.

Um, right now we can still innovate. As far as we have [00:56:00] seen, the reliability is still not there with foreign, uh, engines. And so we still have that advantage and how do we, the question is, how do we invest enough to make sure that we have a robust industrial base to keep that advantage while meeting all the other needs? I mean, it's, it's very daunting task.

Larry Stutzriem: Chris, I wonder what you think about that.

Chris Flynn: I would echo what Dr. Gregg. As mentioned, uh, we work closely with his team and the rest of the Air Force to understand, uh, the capabilities that our the great power competitors are developing. And we know that they have been investing heavily in propulsion capability.

As Heather said, at the start, the engine is the heart of the aircraft. And we have got to continue to focus on competing, keeping this competitive advantage that the United States of [00:57:00] America enjoys. So, um, how do we do that? We continue to focus on the basic research that gets us to the next level of capability.

We've got some really fantastic programs like the next generation adaptive propulsion program. The advanced engine development program are really good examples of continuing to advance our capability in these areas. Hats off to the Air Force and for our lawmakers for really understanding the importance of this capability.

Um, what I would say to close this out is continuing to focus on basic research and really starting to think about things like 7th generation propulsion is where I would like to see Dr. Gregg and the propulsion enterprise with AFRL go so we can continue to maintain this propulsion advantage for the next generation of propulsion systems.[00:58:00]

Heather "Lucky" Penney: Well, gentlemen, you make it look easy across the entire industry. And I know that every warfighter is incredibly grateful that they don't have to worry or think about their engine because our propulsion here in America has been an asymmetric advantage. As you mentioned, although China and Russia are peddling hard to try to catch up with us, they still don't have the reliability, the power and really the capability of their propulsion industry to be able to fulfill the potential of their other design attributes. Whether or not that's the airframe or their avionics and weapons systems.

And so thank you for everything you're doing there. This flip side of that is that because you make it look easy, people don't realize how hard engine innovation is and how much talent it takes and how much, how long the time horizons are. Because there's no magic on switch for manifesting a new generation of engine technology when you haven't continued to invest in that continuous improvement, innovation, research, and funding.

And that [00:59:00] requires stable funding. and stable requirements and problem sets that you drive to, as well as, from my perspective, we have to have the production, because the production side is the only opportunity you get to achieve those lessons learned that y'all and Stutz talked about previously. So, Stutz, I want to bring this back to where we began.

What does all of this mean to the warfighter perspective and why is engine innovation so important?

Larry Stutzriem: Well, my entire career, uh, flying fighters, and now the entire careers of fighter pilots who followed me. Like you, Lucky uh, you know, we had this clear advantage in propulsion. Both in performance, that's the tactical edge over the adversary and in things like power and cooling, and that's the technology edge.

That we can maintain over the adversary. But, you know, as we just discussed, the edge is closing. China and Russia, especially China, you know, they're racing to catch up and [01:00:00] surpass. So, I can't imagine as you called it an asymmetric advantage, which is a fantastic way to talk about, the nation's lead in this area of technology and production.

That is a military aircraft engines. I just can't imagine losing that. The impact would be incredible. So, I would say as from a fighter pilot perspective, you know, the next generation of engines is needed and the department needs to adequately budget. Congress needs to resource, not just the development of these, of, of these technologies on life support, but very deliberately.

I tell you, Lucky. Thinking of what could happen in engine technology. You and I could design a pretty fantastic fighter. Uh, you know, we've talked about the kind of things we would like. So, you know, performance, power, cooling, all those good [01:01:00] things. America's all volunteer airmen deserve this. They deserve to be able to have this capability to fly and fight and to come home safely.

And, uh, woe to any adversary that wants to challenge him.

Heather "Lucky" Penney: I completely agree. You know, I think in today's environment, in today's defense space, we hear a lot about, you know, it's not the Industrial Age of Warfare anymore, it's all Information Age of Warfare, which is true. Because, but we can't forget that industrial age still matters and the industry that creates these capabilities is truly the foundation that all that information stuff rests upon.

So gentlemen, thank you for a great conversation. We really enjoyed it here today. Thank you for making the time to join us.

Dr. Michael Gregg: Thank you Heather. This was, I had a great time talking about these things. I can really get excited about the future of our propulsion and our propulsion industry. And it's so much fun.

And AFRL has some deeply committed people working these hard [01:02:00] problems every day. And I'm, I'm very thankful for our great industrial partners as well. Thanks, Chris.

Chris Flynn: Thank you, Dr. Gregg. Thanks Heather and Stutz. That's just a couple of things to close with. The propulsion enterprise knows we have to go faster.

We're trying really hard to transform digitally and agilie. We know we got to continue to collaborate. We collaborate with Dr. Gregg and his team and the rest of the enterprise for the last 50 years, we're going to continue to do that. We really need a steady resources for big engines. We need resources for little engines, weapons engines.

You heard Dr. Gregg talk about all of the various areas that, um, we're getting pulled in and being able to support those, uh, are super important. And the final thing is, I will say is that the propulsion enterprise and the industrial base needs to continue to [01:03:00] build and deliver the best and brightest propulsion professionals on the planet, and with the support that we get from the Department of Defense, I'm sure that we can do that.

Thanks for your time.

Heather "Lucky" Penney: No, thank you, and thank you to your entire team, both at AFRL and at Pratt, for everything that y'all do for the men and women that wear the cloth of our country and go into bad guy land. Stutz, thanks again for joining us.

Larry Stutzriem: Yeah, it's always great to be here with you on Aerospace Advantage.

Heather "Lucky" Penney: With that, I'd like to extend a big thank you to our guests for joining in today's discussion. I'd also like to extend a big thank you to you, our listeners, for your continued support and for tuning into today's show. If you like what you heard today, don't forget to hit that like button and follow or subscribe to the Aerospace Advantage.

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MitchellAerospacePower. org. Thanks again for joining us, and have a great aerospace power kind of day.

See you next time.