AA178\_Hypersonics\_transcript

**John "Slick" Baum:** [00:00:00] Welcome to the Aerospace Advantage Podcast. I'm your host, John "Slick" Baum 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 are 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 to you most.

This week, we are going to explore one of the Air Force's top technology areas, hypersonics. Now, technically speaking, this capability is easy to define. It all comes down to flying at over five times the speed of sound. But more pragmatically, what this means is harnessing speed to secure battlespace effects rapidly and in ways to empower new concepts of operations.

That's really [00:01:00] important given the severity of the threat environment and the scale of the operating theater, especially in the Pacific. It takes several hours to get anywhere at traditional speed. Think airliner transit times. Put that in the context of meeting dynamic military requirements, and fundamentally higher speed becomes an incredibly valuable commodity.

It significantly reduces the time involved to secure kill chain effects. Dramatically complicates an adversary's defensive calculus, and helps US forces seize the initiative. While hypersonic technology may ultimately extend across a variety of mission areas, current efforts are predominantly focusing on munitions.

Again, it's all about shortening that kill chain. For years, the US was the undisputed hypersonic field. Air Force and NASA experts spent years executing highly successful tests, most notably with the X 15 program. However, in the 1970s and 80s and 90s, other goals took priority, and the hypersonic community limped [00:02:00] along through a series of disjointed programs that were executed in fits and starts.

By the late 1990s, our adversaries increasingly recognized the advantage extreme speed would offer in the military context, and they pressed hard with their own hypersonic innovations. Whoever ultimately wins this race is up for grabs, which means what we do in both government and industry really counts because there is a lot at stake.

So that's what we're going to talk about today. We're going to hear from Dr. Michael Brown, who is the principal scientist at Air Force Research Labs High Speed Systems Division. We're also going to chat with GE Aerospace's Mark Rettig. He is head of their advanced programs in the Edison works division.

This conversation is going to provide you a great set of insights from both government and industry. And that is incredibly important because it'll take collaboration for the U S to secure its hypersonic edge. But before we kick that off, I want to turn to Doug Berkey and Heather Penny of our mission team.

They are going to help walk us through some background history [00:03:00] when it comes to hypersonics. And to prep for this, they went to the source. They no kidding visited the actual X 15 in the National Air and Space Museum and chatted with the curatorial staff about one of America's most impressive aerospace accomplishments.

Doug, Heather, awesome to have you here.

**Heather "Lucky" Penney:** Hey, Slick. Thank you. It's great to be here.

**Doug Birkey:** Hey, man. Always a pleasure.

Okay, guys, big question. What is it like to see the X 15 up close? That's one of the most legendary planes ever built.

**Heather "Lucky" Penney:** Slick, I have to tell you, I've been looking at this airplane hanging from the ceiling of the Smithsonian for decades.

And getting to see it up close was amazing. This is an icon. One of the gutsiest aircraft and aircraft programs, ever. But getting up close, you could see it was beat up. You can tell that it was used hard. This, I mean, you can really see the physical scars of a real flight test program. These guys were going in places, speeds, and altitudes that no one had ever been before.[00:04:00]

And the aircraft shows it.

**John "Slick" Baum:** Alright guys, how did you get the opportunity?

**Doug Birkey:** I've been really fortunate to know a lot of the team out at the Air and Space Museum for many years. I used to work in aircraft restoration out there as a volunteer. And I've continued that relationship up until today. And so when we saw this, airplane sitting on the floor of the restoration shop while they're redoing downtown's museum facility.

And we saw it, they were doing the TLC on it. Said we, "have got to get down there and check this thing out in person, that is a once in a multi decade experience." And, we really wanted to see it.

**John "Slick" Baum:** So walk us through some of the background to set the scene for the rest of the episode. Why did the government develop the X 15 and what did it achieve?

**Doug Birkey:** The biggest thing to really think about here is how fast aerospace technology was moving. I mean, think about this, the people that worked on that program and it was developed by North American Aviation at the time. Those people were on the North American payroll before World War II occurred. Those are fabric and wood aircraft [00:05:00] back then.

They worked on famous types like the P 51, the T 6, the V 25, and they just kept going. The learning curve was incredible. And after World War II, especially when we got the German data on a lot of the design and everything. It really went on a vertical ascent and jet power technology enters a fold and all that.

So it was an era of tremendous discovery because we were expanding the flight envelope. And that's really what that airplane came down to was that they kept doing these very rapid progressions. And that was just the next step to take that we want to go, hypersonic speed, super high altitude, you name it.

And that's just what was next. And so you think about, like I said, these guys began an era of wooden fabric biplanes, and so here they are working on literally a rocket powered space plane then their professional lifespan. It was very logical for them to think that they're going to have this you know, it was implemented operationally in, in a couple of years, it was just a very different era.

**Heather "Lucky" Penney:** Exactly. [00:06:00] And the advances that we made in flight performance was what translated directly into either an operational advantage or a national advantage. So, when you see what the X 15 program is, three primary objectives, speed, altitude, and heat. Speed because going hypersonic going super fast gives you the initiative and it also means that you can go faster than the threat systems.

So there's all sorts of operational advantages that speed gives you. Altitude again because you can fly above the earth's threat systems, but guess what both with both speed and altitude, you have to deal with heat. And so they had to literally invent specialized materials to address the thermal friction, the skin friction, and the heat from both speed and descending back from altitude.

**John "Slick" Baum:** So, was this a program that only lasted a few flights?

**Doug Birkey:** No, and that's really what sets it apart for what we see too often today. You know, normally you get a handful of test elements. And then they kill it [00:07:00] normally due to budget or lack of really just committed cause to it. They flew this thing nearly a decade for 199 flights.

They actually tried for 200th, but weather got in the way and then they ran out of a budget cycle. But think of that over a decade, the amount of discovery done in that was absolutely unreal. And these guys literally were pioneering new innovation every single time they went to the air and they were pushing the envelope and people died in this effort.

But they kept going because the imperative was that strong. And we need to get back to that considering the challenges we're facing.

**John "Slick" Baum:** All right. Given all that, what happened? Why did we see hypersonic discovery and innovation drop off?

**Heather "Lucky" Penney:** Slick, guess what? This is going to sound like a broken record for our entire audience.

Funding cuts, sort of a lack of a cohesive test approach across the broader portfolio, and the passage of time. I mean, as Doug said, this test program went on for nearly a decade. And so it [00:08:00] kind of got "old news" for people, even though it was still pushing the boundaries of known aerodynamics and thermodynamics and things like that.

Plus, with the context of the Vietnam War, there was strategic distraction. So that's really what caused the cancellation and the termination of the X 15 test program, even though they were still doing good work and making good discoveries. And guess what this does? It sets us decades behind, right?

Because those experienced teams, the people that had the know how, the technologies, and really the been there done that to be able to continue to advance the, uh, the knowledge. With those stops and starts, the teams, they disperse, they leave, they gray out, and now we're where we're at today. We're having to reinvent a lot of the knowledge that we had in the 1960s.

**John "Slick" Baum:** Okay. So things got restarted tough for the U. S., right?

**Doug Birkey:** Yeah. I mean, kind of picking up what Heather was saying, we really ebbed and flowed throughout the 70s, 80s, and 90s, where they'd do kind of a small effort, they'd spool [00:09:00] people up, and then funding could get cut. We'd lose focus. That team would get dissolved.

And it was this ebb and flow. It was very detrimental to maintaining a cohesive workforce. So, the first big success story was the X 51 and that happened in the mid 2000s. And that was successful in really delivering capabilities that were far more operationally minded. Just what they're reflecting and all that.

And they began dialing in more kind of munitions application and all that. But think about it, they only built four test articles. They had some successful flights with them, but only four. Compare that to 199. And so they got this thing, it was a great design, performed well, but we didn't do the discovery we would want, um, really over a concerted campaign, I would suggest.

But then, really what came to the fold to kind of ride to the rescue of hypersonics was the threat. It really became clear that China and other adversaries are pushing very hard in this area. And so, all of a sudden, we had to get in gear. And that's where we had to really create [00:10:00] a workforce and innovation base and all of that, almost from scratch, because so many folks had aged out.

It was so thin. And, of course, those people that were stalwarts and stuck with it and knew a ton, they've been the foundation of rebuilding this, but there's been a lot of rediscovery, there's a cost to it.

**Heather "Lucky" Penney:** You know, and Doug, I think what you point out is really important because we got into a position where we thought, "Hey, this is information warfare, right? We're in the information age and only digits and software matters anymore." We're now in a point where technology has proliferated. You don't have to be an American to be an awesome at software and awesome at avionics and awesome at integrating all these different capabilities. So what that does is it pushes us back into a competition where not only do you have to be really good at the information age stuff, but you also have to be really good and maintain the advantage in the physical industrial age stuff.

Is that's one another reason why this hypersonics really matters.

**Doug Birkey:** That's tremendous.

**John "Slick" Baum:** Okay. Before I let you go, I've got to ask you to have been around the X [00:11:00] 15 in ways almost no one has in decades. So what was it like to look in the cockpit and really study it? I mean, that's an icon, like really nothing else.

**Heather "Lucky" Penney:** Slick, I'll tell you it just being up close and being able to literally, this is going to sound weird, smell it.

It smells like an airplane. It smells like it's working. It's not this dead artifact. You can still see the desert. Dust in the, from the dry lake bed, uh, on the vehicle. Getting up close and being able to see the thrusters in the wing and the thrusters in the nose, which by the way, this is technology that translates directly into the space shuttle.

But what I love the most was the chance to lean over, don't touch the airplane, but lean over and see inside the cockpit and look at the seat and look at the instrument panel. I mean, this thing is dirty. It's gritty, it's very purposeful, and actually super basic. You know, we don't think about this, but it's all round dials, right?

It's interesting, there's a massive clock, [00:12:00] straight in eyeball, you know, eyeball distance from the pilot. There's no airspeed indicator. All you have is a Mach meter that goes up to Mach 8 and, uh, an AOA, so an angle of attack, indicator. So just how specialized the cockpit was.

It was also really chopped up as they added new instrumentation, new things that, so it was just to be able to see something that wasn't pristine, wasn't perfect, and had visible signs being used. That was awesome.

**Doug Birkey:** Now, and I'd just say, what you saw in that cockpit did not differ too much from what you'd see from a World War II fighter.

Obviously, a little bit more sophisticated on the instrumentation, but not a lot. And the airframe we saw was the first one. It was the lead fleet element and to think of what was pioneered there was Scott Crossfield's first flight all the way through. Everybody that was tied to that program flew that airframe.

And so, as far as aviation innovation is concerned, that is hallowed ground. And it is, uh, it is an incredible honor [00:13:00] to be with it and just thank the Air and Space team for A, taking care of it and B, allowing us that opportunity.

**Heather "Lucky" Penney:** I will say one thing that, uh, that the curators pointed out. And again, this gets back to this being an actual working airplane and evidence of the humanity like the actual men that took care of this aircraft.

Two switches right next to each other had been removed from the cockpit, the instrument panel, and they're behind the center stick, which by the way this X 15 has three controls with a center stick for normal flight, the stick on the right, for boosted control during hypersonic flight.

And then you've got the rocket thrusters on the left hand side. Behind the center stick were two little, plastic covers where the switches used to be and somebody drew eyeballs on them. Pretty funny.

**John "Slick" Baum:** Okay. Thank you so much. And up next, we are pleased to welcome Dr. Michael Brown, who is the principal scientist for Air Force Research Labs, High Speed Space Division.

If you want to know the heart and soul of Air Force hypersonics efforts, [00:14:00] all paths lead back to AFRL. So Dr. Brown, it is an honor to have you with us.

**Dr. Michael Brown:** Thank you. Much appreciate the opportunity to share what we do here in AFRL with your listeners. And if you don't mind, let me say a couple of things about AFRL just to help people keep organized thoughts.

So, the Air Force Research Lab, AFRL, supports both the Air Force and the Space Force and it's organized into technical directorates that has specific responsibilities. I sit in aerospace systems directorate. Which as a director when we think about the entire vehicle, regardless of its speed class, the entire vehicle, and within that directorate, I'm the principal scientist in the high speed systems division.

So, we focus on vehicles that are moving in the hypersonic flight regime, and we use the textbook definition of hypersonics, meaning Mark 5 and above. Specifically in our division, we work on propulsion, structures, [00:15:00] and aerodynamics associated with the vehicle. When we need help with materials or manufacturing solutions.

We reach out to the materials and manufacturing directorate. When we need help with sensors, we reach out to the sensor directorate and with weapons payloads, we reach out to the weapons to the munitions directorate. So it's, very much a team effort. We're sort of the heart and soul of what we're doing in AFRL and hypersonics now, but it's very much a team effort across AFRL.

**John "Slick" Baum:** Well, sir, that is absolutely incredible. And, you know, I've had the privilege of visiting members of your team out there, and it is amazing what you guys are accomplishing. And AFR in general deserves so much credit when we think about air and space power accomplishments throughout history. It really begins there at your lab.

So hats off to you and your team. Heather and Doug helped set up our conversation earlier in the podcast by explaining the milestones we've passed on in the hypersonic journey throughout history. And as you just explained, you're charting the future. Uh big [00:16:00] picture, can you explain the charge the Air Force and DoD leadership plus the science and technology community in general have issued to you?

What do they expect from you in the broader AFRL team when looking at hypersonics, you know, where do you fit in the ecosystem of innovation?

**Dr. Michael Brown:** Sure. In very general terms, we do what is often called, "a blend of tech push and tech pull." So with regards to tech pull, you know, the "big" Air Force, the MAGCOM, so to speak, have reached back in the lab and say, "Hey, do you have a technology solution for the set of requirements that we have?"

And then we respond, uh, we'll respond in kind with what we can do. Reporting back up through the chain. Those tend to be activities with relatively near term timelines, you know, think less than a decade. But we also do tech push. Uh, you know, we look out a decade or more and go, [00:17:00] "what is the art of the possible?"

"What can we do that doesn't break physics and provides additional war fighting capability to our men and women in uniform?"

**John "Slick" Baum:** Well, sir, that's absolutely incredible. And, you know, when you talk about the pull and the push, how does strategy development really happen? I mean, you obviously have your team and you've got your own set of AFRL leaders to talk to folks in the Pentagon and others, but it's very complex.

Something like hypersonics, it's got so many different potential applications. So what's the process for focusing your efforts on a specific line of effort and then dialing that in?

**Dr. Michael Brown:** Yeah. We have to think about the problem from a number of different perspectives. But an organized way to do that and let's talk about hypersonic missiles, just to help focus the conversation here. You think about concept vehicles. You think [00:18:00] about, you know, I want this particular capability. Can I package that in a way that doesn't break physics, completes the mission and is compatible with the current vehicle fleet?

You know, I can't come up with a missile that is so large and so heavy that it can't be carried by one of our bombers. That does not, that, you know, that doesn't help anybody. So we do what we're called, what are called trade studies. We think about concepts in terms of cruise speed, cruise altitude, cruise range, payload size, potential target sets and things like that.

And then we run our various engineering tools on that to make sure that we can package all those attributes into a weight and volume that is consistent with being an airdrop system. In parallel with [00:19:00] that we do what are called military utility studies. So, taking for example the baseball card representation of a particular vehicle, its various attributes.

We then ask ourselves through a very rigorous simulation process, "what is the survivability of that vehicle concept in a military theater when, you know, the opposition is trying to knock you out of the air or slow you down or confuse you to the point that you wander off away from the target.

Those two things are going on in tandem with each other to make sure that we then get to a what I might call a government reference vehicle. That we can then look at the detail level. So now we have, now we've got our completely fleshed out baseball card. We're happy with the performance on paper of the vehicle.

Now let's think about what technologies and sub [00:20:00] technologies will make that realizable. Are any of those technologies and sub technologies currently available on the shelf? Are they, you know, current state of the art? Or do they ask us to go beyond the state of the art? And then that's where the research really begins, you know.

We need a propulsion system that's got some attributes that predecessors don't have or we need a more optimized aerodynamic shape, those kinds of things. And that's where the lab then really goes hard to work using all of our capability, all of our know how, and all of our facilities.

Some of that work we do in house. And some of that work we do in concert with other government organizations and some of what we do together with industry.

**John "Slick" Baum:** Yes, sir. It is absolutely incredible, especially that really collaborative approach. Whether you talk about, industry partners or resources you have here at the lab, I mean, you know, you talk about adding two and two and getting five.

[00:21:00] So recognizing we need to keep this unclassified, uh, what are your main lines of effort right now?

**Dr. Michael Brown:** Sure. First, a little bit of relatively recent history. The X 51, which flew a little over a decade ago, was a, a vehicle to design to demonstrate that you could get a scramjet powered, vehicle to accelerate. I mean, interestingly you can find textbooks from decades ago that will show with a superficially simple line of logic that a scramjet cannot accelerate.

They're kind of funny to look at now, but what the X51 showed is we truly can accelerate a missile using scramjet propulsion. Okay, and that was a joint activity with DARPA, FRO and DARPA plus industry. We then work to weaponize that vehicle, so to [00:22:00] speak, and that was what the HAWC program did with a couple of industrial performers.

We looked at how to move away from just an engine demonstration activity to something closer to a full on missile and further develop the technology. And a little over a year ago, we then passed that off to the Air Force Life Cycle and Management System to actually weaponize that vehicle through the HACM program.

I think your listeners are probably seen mentions of those programs in the popular press. All right. In parallel with that, we are looking at, okay, what if we can from a conceptual point of view, design a vehicle that's a little bit bigger than the X51 was, and can carry a larger payload or different kind of payloads.

So, [00:23:00] we worked with industrial partners over the last few years on what I might call an analogy, a hypersonic pickup truck. You know, a pickup truck has got a bed with a very fixed size and fixed load capacity. But you can put all kinds of different things in that, in the back of the pickup, in the bed of the pickup, and the vehicle is still safe. Drives and handles as you desire it to be.

So, you know, maybe you're from a military point of view, maybe your payload is one really big bomb, or maybe it's 2 or 3 smaller bombs, of the same equivalent weight as the large one. So we spent a lot of time working on that. It required an engine, which had capability about 2 to 3 times greater than that was on the X 51.

More recently, our gaze has shifted away from missile technology, not entirely, to some [00:24:00] extent, to think about the possibility of a reusable hypersonic aircraft. So, you know, think back in history, there was a period of time when we flew the XP 70, which is a supersonic bomber. Able to operate at speeds of Mach 3 and a little bit above. Well, what if we look at a bomber that's capable of flying truly hypersonic speeds, Mach 5 and above.

And so the folks in the building here and in our sister buildings. And some of our industrial partners are looking at that possibility. What does that take to make the technology leap from an expendable, a single use vehicle to one that can take off and land? So that's where our heads are right now.

Largely.

**John "Slick" Baum:** Again sir, a totally impressive. And you know, in that journey, I remember when the X 51 program was in play, and talking to folks like Dr. Mark Lewis and [00:25:00] Dick Hallion and others, it was just so impressive. But to see, the latter parts of this journey, where you've taken it again, hats off to you guys.

Now, when you explain, to people the sense of urgency, why is it so important for the U. S. to regain its hypersonic lead position, and what are your main arguments when you're trying to help them understand that?

**Dr. Michael Brown:** Let's see. First, let's make sure we don't get ourselves into mental, uh, into mental rabbit holes.

Um, we sort of grew accustomed during the Cold War to thinking about, "okay how many intercontinental ballistic missiles does the USSR have? How many do we have? That number needs to be larger than theirs." And that is a somewhat superficial way to, to look at military, power balance. And what we really want is we want our men and women in uniform to be ready for any potential conflict.

Anywhere in the world, we want them to have the best [00:26:00] training, the best leadership and the best technology available for the fight. Hypersonic technology is a technology that can assist them in the overall mission. So, let's make an analogy with a chess game with a chessboard. Even for your listeners who don't play chess, I'm sure they're aware of the fact that the chess pieces have individual attributes.

 Um, you know, they can move in various prescribed ways, and individual pieces have their prescribed movements are different from the pieces adjacent to them. You have pawns, and you have knights and bishops and rooks, and a king and a queen, and they have different mobility attributes.

And in winning a game of chess, you use all your pieces working together. You would never go into a chess game against an opponent and go, "you know, I'm going to try to win this just using my pawns and [00:27:00] bishops." Once your opponent's figured out what you're doing, he will counter that very quickly and you'll lose that game pretty quick.

So we want hypersonic chess pieces, so to speak, on our chessboard that then enables the Air Force and the joint force to think about, okay, under these situations, we're using the hypersonic chess piece.

**John "Slick" Baum:** So that is a great explanation. So how does what you do at AFRL compared to what happens at other service labs and DARPA?

Is there a broad collaboration or are you more focused on the nuanced areas tied to service? Uh, and specific domain interests.

**Dr. Michael Brown:** See, there is both individual nuanced work and collaboration. So let's look at some general examples. The Navy, uses surface launched weapons from ships and submarines.

The Army [00:28:00] also uses surface launched systems, from ground. Both have the ability to move their assets around, as needed. There is commonality in their hypersonic research, and that they're looking, they're both looking at what we call glide bodies. So these are vehicles that are boosted to the appropriate speed and altitude with a rocket motor or rocket motors.

Depending on the stack and then the glide body is released and moves at hypersonic speeds toward its intended target. The Air Force is largely focused, not entirely, but largely focused in terms of research on air breathing vehicles that can be dropped off the wing or out of a bay. So the three services have different vehicle attributes that are required that meet their particular.

Missions in a joint service environment. And so we do [00:29:00] separate work because that makes sense. Now, on the sub technology slide side, this is where there is, there's collaboration and coordination. Um, each vehicle needs, for example, a guidance and navigate navigation control system. So, the services engage in joint workshops, where the subject matter experts, you know, in the hands on engineers.

Are engaged with conversations to make each other aware of how they're working technology and sub technology and look for opportunities to collaborate that, you know, that makes sense, that do good by the taxpayer so to speak. And with, uh, you know, within DoD, within the Test Ready Management Resource Center.

I'm sorry if I got the name wrong, the T. R. M. C. You know, they are funding projects that enable all three services to test their various [00:30:00] hypersonic vehicles. So, providing test platforms, so that the services don't have to do that individually again, you know, the taxpayer wins when we work collaboratively like that.

On larger scale collaboration, the AFRL and DARPA have worked together on a number of projects, together to mature hypersonic technology. Beginning with X51 and moving to HAWK, and MOHAWK, and now they're conversations going on about, you know, whether or not we need to work together on a reusable vehicle, or waiting to see if, you know, Either big Air Force or the DoD tells us, "you know, please do march out in this and march out quickly." For years, the division I'm part of has worked collaboratively with folks at NASA. Primarily NASA Langley, but also NASA Ames and NASA Glenn. NASA, the aeronautics side of NASA [00:31:00] very much has an interest in vehicles that move quickly at hypersonic speeds.

Uh, to enable them to get near space access and do the kinds of research they need to do in the upper reaches of the atmosphere. And so there have been both collaborative, formal, collaborative projects and programs and informal ones. Um, you know, some of our closest colleagues at the engineering level are counterparts within NASA. We share an awful lot of information with each other where that makes sense. And we've done some joint projects. You may have heard of the High Fire Flight project, which is now concluded, but it ran for roughly a decade. It was a joint activity between the US and Australia.

And on the U. S. side, you have the AFRL and NASA participation. I work with NASA colleagues on High Fire Flight 2, [00:32:00] which was a sounding rocket based demonstration of a scramjet engine going through mode transition. So a lot of good, useful information. For both civilian applications and military applications come out of those efforts.

So the, you know, the one sentence summary, to your general question, there are formal avenues of collaboration. There are informal avenues of collaboration, and then there's an awful lot of individual work where we share with each other what we've learned and how we're moving forward.

**John "Slick" Baum:** Sir, thank you for that.

I've got to ask what yardstick would you suggest our audience use when they track hypersonic developments in the news and also when they're formulating their ideas and expectations? Uh, you know, where do you think we should be in five or 10 years? And what are the key factors that we should look, at investments to make it happen?

**Dr. Michael Brown:** Again, I'm gonna, I'm gonna caution us in thinking too simplistically [00:33:00] about single yardsticks of progress. And let me explain this by pointing out the following. If God forbid we were to get into a military conflict with China, it would almost certainly be in the Pacific Ocean, close to their border and a long way away from our borders.

And so they would be playing a home game, so to speak, and we would be playing an away game. And so our military systems don't have to be one for one because that may not make military sense. And so when you read reports about the Chinese fielding hypersonic weapons, don't get too upset about the fact that we don't have exactly the same thing fielded, because maybe we need something slightly different in order to actually be useful in the theater.

I believe the [00:34:00] technology is important going forward. The ability to use the combination of speed and range clearly has military utility. It is easier to make progress when funding levels are persistent and don't go through big peaks and valleys. You know, nothing we worked on can be solved in a single fiscal year of funding.

Almost everything we work on takes, takes multiple years and success is, um, success is predicated on a consistent funding line to be able to do that. Steady funding also helps us do a better job of workforce development and training, and it helps us do a better job of developing and maintaining and encouraging industrial manufacturing base, so to speak.

You know [00:35:00] programs like MI HAWK you're making, you know, just up a half a dozen or so vehicles. Well, when we got to feel something, we need larger numbers than a half a dozen. So we've got to have that manufacturing base that enables us to do that. And, you know, and optimized in economic ways and study funding certainly helps in areas like that as well.

**John "Slick" Baum:** Well, sir, I really appreciate it. And Dr. Brown, thank you so much for spending so much time with us today.

**Dr. Michael Brown:** Sure. Very glad to do this. And hopefully we were helpful to your listening audience.

**John "Slick" Baum:** Absolutely, sir. You bet. Up next. I'd like to welcome Mark Rettig from GE Aerospace, where he is head of their advanced programs in the Edison works division.

The GE team is one of several industry teams focused on helping advance America's hypersonic capabilities. And this is really crucial because it's going to take a lot of work by both government leaders, like Dr. Brown and Mark to net the goals that we need to meet and the threat isn't slowing down.

So we need [00:36:00] to speed up. So Mark, thanks so much for making the time to join us today.

**Mark Rettig:** Yeah, John, it's my pleasure. Uh, very much for having me.

**John "Slick" Baum:** Well I tell you, I just want to jump right into it because we've got a lot of great stuff to talk about. And, you know, you and your team have announced a really important accomplishment this past December regarding, uh, GE's work in hypersonics.

So can you let the audience know, what did you guys do and what'd you achieve?

**Mark Rettig:** Yeah. So, you know, we've been in the gas turbine space for quite a while. We recently acquired a hypersonics company Inoveering and with Inoveering, we've developed the dual mode ramjet. And we've started to look at how we apply our other technologies to improve the capability.

And in December of last year, we had a successful subscale demonstration, leveraging a lot of the work we've been doing in rotating detonation to improve the operability and performance of the dual mode ramjet and that was a significant milestone for us in our overall [00:37:00] strategy execution in this space.

**John "Slick" Baum:** Well, congratulations on all of that. And, you know, for the non technology experts here, do you mind to break that down a little bit? You know, what does it actually mean and how do you do it?

**Mark Rettig:** Yeah. So, you know, in a hypersonic vehicle, and we're really looking here at reusable vehicles. Where you would leverage a gas turbine, which is very much in our area of expertise for a vehicle to take off from the ground, and then you would, as you got up to a transition speed, you transition from the gas turbine to a dual mode ramjet, which is effectively ramjet and a scramjet combined.

That can operate below and above Mach 5. So once you get up to an adequate speed, you would transition to the dual mode ramjet, get to a hypersonic speed, go and execute your mission. Come back, and then transition back to the gas turbine. So it's this transition back and forth. And really what [00:38:00] our focus here is on integrating the gas turbine and the dual mode ramjet and infusing technology into both of those pieces to optimize our ability to transition effectively so that the vehicle can perform its mission as effectively as possible.

**John "Slick" Baum:** Okay, so for those that may have seen, Top Gun 2, is that, one of the scenes in there. Is that kind of what you're describing, um, that we could see be reality soon?

**Mark Rettig:** Yeah when, when Maverick switches from gas turbine to ramjet or scramjet, I can't remember how he articulates it, but that's exactly the transition we're talking about.

We want to optimize the handoff from the gas turbine to the dual mode ramjet and then back to the gas turbine to best enable the vehicle to be as efficient and effective as possible.

**John "Slick" Baum:** Well, it's absolutely incredible, and I would love to fly it. So, so you could sign me up for that, [00:39:00] Mark, but I really want to ask you are there particular mission applications where this would be most useful?

**Mark Rettig:** Yeah. And I think, you know, that there really it's about speed and capability that speed gives you. Capability to go and respond to finding threats you're looking for manner that, you know, before the threat can move, and then to go and address that threat in a timely manner.

It's really that, that tyranny of speed and responsiveness that this enables and the ability to transition back and forth from hypersonic to subsonic potentially. Hit a tanker and then go back out and do the mission repeatedly where you're looking at surveillance capability and strike capability is the objective here with the reusable hypersonic aircraft or, you know, a hypersonic missile where you have a threat and you need to address that threat in a timely manner.

[00:40:00] From a great distance.

**John "Slick" Baum:** Yeah. And, you know, and as you describe it, I mean, having that flexibility, right. To be at, 300 knots with the tanker and then going, you know, beyond Mach five, that's absolutely incredible. But we know that these things aren't cheap and that's been some of the criticism people often have for hypersonics is, you know, the tie to cost and some solutions on the table just frankly are not cheap at all.

And, you know, and budgets are finite and missions against the peer threat are going to. Demand capacity as well. So how does that shape your thinking on this sort of technology?

**Mark Rettig:** Yeah. And I really look at it, you know, from an affordability perspective. We obviously want to manage our costs and we want the solutions to be affordable.

And that's always, I think, in the forefront of our mind. The capability is going to cost a certain amount, and if the services, if the US deems that capability to be necessary to execute a mission, we want to provide that capability as affordably as possible. Absolutely hypersonics is not [00:41:00] an inexpensive capability, but potentially a necessary capability.

So I think you really just want to... our intent is to make it as affordable as possible while also making it as effective as possible.

**John "Slick" Baum:** Yeah, you know, I have a little bit of a business case for you. Just knowing what you all do and you're great at building jet engines and as an F 16 pilot, trust me, I'm a huge fan.

Uh, and I have a lot of time flying a GE engine than the F 16. Um, but you know, why hypersonics, for GE aerospace and what's the driver to look into this new area.

**Speaker 2:** Well, you know, a couple of things. I mean, we're clearly preeminent as a gas turbine company, and a lot of the capabilities, a lot of the technologies, the material systems, things like that, that are inherent in a gas turbine lend themselves very well to a dual mode ramjet and integrated inlet exhaust. All of those pieces that a hypersonic [00:42:00] propulsion system are comprised of, I think what we see here is with the evolving scenarios around the globe, a pull for hypersonic capability that we haven't seen before that makes it more attractive. And we also now, particularly with the acquisition of Inoveering see that we can provide an integrated comprehensive propulsion solution that maybe we are uniquely capable of putting together all of those pieces to provide it an integrated capability.

**John "Slick" Baum:** Yeah, you know, I'm sure that you guys have a lot of strengths that you can leverage, you know, from your existing product line to help pursue this new effort. You do a lot with advanced materials and you clearly under understand propulsion. What else are you able to bring to the table?

**Mark Rettig:** You know, and I would clearly agree, you know, advanced materials and our materials capability are fundamental here. Our integration capabilities, our abilities to [00:43:00] integrate propulsion systems with our airframe customers, our ability to integrate the pieces of a propulsion system between inlet engine and exhaust system, I think, is a unique capability.

We've come to find that as we progress down our hypersonic journey that we have a significant testing capability inherent between our Inoveering acquisition, between our aerospace research company in Niskayuna, New York, and between our Evendale test facilities. We are able to do a lot of testing. I don't think that we fully appreciated the capability that we had.

And then just from a technology development perspective, I think we are continuing to innovate. And invest in technologies and bring those to bear to make the systems, not just so our engines operate more efficiently, more effectively, um, but also we were finding we bring a lot of capability in the hypersonic world, [00:44:00] specifically with dual mode ramjets and the integration of those into the system.

**John "Slick" Baum:** Yeah, Mark, the testing piece is really interesting that you bring to the table there. Um, and I'm sure that is a huge help. But I've got to think about other conditions, that are out there. They're, you know, kind of barriers to entry, if you will. So, you know, what conditions do you and other industry actors need from the government to help foster and drive this sort of innovation? I mean, you know, funding and predictable requirements are important on one hand. And we also know Continuing Resolutions are bad. So so what else would be helpful for you to get over the hump here?

**Speaker 2:** Yeah, and I'll just echo what you said.

I mean, funding for propulsion and specifically, you know, we've seen a lot of funding out there, but hypersonic propulsion dual mode round jet, propulsion system development funding is going to be critical as a pull for us. We're investing a lot right now, and we will continue to invest as long as we see an opportunity.

You know, [00:45:00] down the pipe. So just a foot stomp that. Um, but the other piece here, I think that's critical and that we're coming to appreciate as you scale these systems up to relevant vehicle sizes, testing capability, and I'm talking beyond what we can provide. But national testing capability, I think, is going to become fundamental to demonstrating and qualifying these systems.

And I think that's a place where the U. S. really needs to focus and invest and would significantly be a critical enabler for what we're doing in this space.

**John "Slick" Baum:** Yeah. A lot to unpack in that answer, and I really appreciate it. And it just, it's making my mind really spin and think about, you know, the capabilities and especially with testing and things of those... along that line, I think of what you guys bring to the fight is really interesting. But of course, there's got to be, the support behind you to really execute it and execute it well. And so I know you have a lot on your plate Mark. So what challenges keep you up at night as you work this effort?

I [00:46:00] mean, it's, uh, I'm sure our listeners understand this is ultra high varsity when it comes to complexity.

**Mark Rettig:** We're on the cutting edge of technology and we're pushing the envelope in this space at these speeds and temperatures of material capability.

But I would say, you know, we have enormous confidence in our team and our business here at G. E. I don't stay up at night worrying about the capability of us to execute what we're doing or to come up with great technologies. The challenge, I think, in this kind of a world is just the evolving threats.

The evolving geopolitics and how that shapes the things, the solutions that the DoD pursues and funds. And as the, as that whole ecosystem evolves, does this continue to be a needed capability down the road? And I think everything our crystal ball says right now is this is going to be a fundamental capability for the foreseeable future.

[00:47:00] But, you know, if anything, if I wake up in the middle of the night thinking about anything, it's "how is that threat world going to evolve and how are we going to adapt to it? What do we need to do next to stay ahead of it?"

**John "Slick" Baum:** Yeah, I totally agree. And I know that you guys are on top of it. Well, Mark, now I've got to ask what's next for you and your team as you continue to develop this technology.

Are there specific things that we should be tracking?

**Mark Rettig:** Yeah, so we're going to continue developing technologies and infuse them and incorporate them into our designs as we continue to innovate and come up with new ways to improve the capabilities of the systems. But right now, our focus is really on scale, and we've run our subscale dual mode ramjets, both at our interfering facility and at our research facility in Niskayuna.

You know, our next step is to scale those up. To product relevant sizes, and we are just on the verge of running our product relevant dual mode [00:48:00] ramjet down in Evendale in our larger test facility. So that's an exciting next step. And we're looking to be able to provide some feedback about that in the fairly near future.

Um, we will continue looking to scale. As we develop and get closer to a product, but, that's our primary focus right now.

**John "Slick" Baum:** Well, Mark, I have to tell you, this has just been absolutely awesome. And thanks so much for sharing your thoughts on the program. And I mean, to take it back on how we kicked off this episode with the X 15, that sort of accomplishment doesn't happen unless we push hard with new innovation and you and your team are absolutely a key part of that ecosystem.

So thanks again.

**Mark Rettig:** Yeah, John, it was a pleasure talking to you and thanks for having me.

**John "Slick" Baum:** 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 our listeners for your continued support and for tuning into today's show. If you like what you've heard today, don't forget to hit that like button and follow or subscribe to the [00:49:00] Aerospace Advantage.

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Thanks again for joining us and we'll see you next time. Stay safe and check six.