Center for Strategic and International Studies

TRANSCRIPT

Online Event

Complex Air Defense: Countering the Hypersonic Missile Threat

DATE

Monday, February 7, 2022 at 10:00 a.m. ET

FEATURING

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Transcript By
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Seth G. Jones: Welcome, everyone. My name is Seth Jones. I'm senior vice president and director of the International Security Program here at the Center for Strategic and International Studies.

I'm happy today to introduce our Missile Defense Projects' new report on countering hypersonic weapons. Hypersonic weapons of various kinds have been in the news for some time in defense media and wider, and we've heard many reports about Russia and China building and testing hypersonic weapons and how the U.S. has been lagging behind.

The Secretary of Defense and Deputy Secretary of Defense just last week had a meeting with a number of CEOs to talk about the importance of hypersonic strike and defense, and the state of the industrial base to support hypersonic strike and defense capabilities.

The U.S. has begun to develop its own hypersonic weapons with numerous programs spread across services, but less frequently discussed is the broader subject of hypersonic defense and that's what we're going to be talking about today. How do we defend against these high-speed maneuvering threats? How is hypersonic defense different and similar to other kinds of air and missile defenses? Is it even possible?

To answer these questions, we're pleased to have a panel of experts here. Our conversation today will be moderated by Mr. Steve Trimble, Defense Editor at Aviation Week magazine, who writes a significant amount about hypersonic missiles.

We have a great group of individuals. We have – Ms. Kelley Sayler is an analyst for Advanced Technology and Global Security at the Congressional Research Service. Dr. Gillian Bussey is Director of the Joint Hypersonic Transition Office – JHTO – at the Pentagon's Office of the Under Secretary of Defense for Research and Engineering. Mr. Stan Stafira is the Chief Architect at the Missile Defense Agency. Dr. Mark Lewis is the Executive Director of NDIA's Emerging Technologies Institute. And Dr. Tom Karako is a Senior Fellow in ISP and my colleague, and the Director of our Missile Defense Project. And Tom will summarize the report he co-authored with Masao Dahlgren, which is titled "Complex Air Defense," which is a way to frame the hypersonic defense problem.

I also want to say that CSIS is grateful for the co-sponsors of this report, Raytheon Technologies and Lockheed Martin. I'm looking forward to hearing our panelists talk through this problem set, and with that, I'll hand it over to you, Steve. Thanks!

Steve Trimble: Thank you, and welcome to the presentation. So hypersonic defense came into existence in the Defense Department's budget in fiscal year 2018. It's

four and a half years later, and I think we've now gotten a pretty good understanding of what the initial architecture for DOD's hypersonic defense capability will be.

On the interceptor side, it starts with the glide phase interceptor program. The options there include the SM-3 or a derivative of that, and the THAAD, also a derivative of that, as well as probably others. There's the Sea-Based Terminal program with the SM-6 adapted for this role, and DARPA is involved with the Glide Breaker program, which they describe, generally, as a critical enabling technology for hypersonic defense.

Now, if you dive deep into the budget documents it's actually identified as an advanced form of a direct – or Divert and Attitude Control System. The Missile Defense Agency has also commissioned Raytheon to set up a high-powered microwave test bed where they are being – where they're developing a capability to project microwaves at extreme range – extreme power and very long range, as they describe it.

On the sensor side, there's a lot of activity with the Space Development Agency working on a constellation in low Earth orbit called the tracking layer with a medium field of view sensor – infrared – that would queue what the Missile Defense Agency is working on with a hypersonic ballistic tracking space sensor with a medium field of view sensor for actual target-quality tracking of hypersonic objects.

More recently, in the summer the Space Force said they had started working on a similar capability, not in low Earth orbit but in medium Earth orbit, with Millennium Space Systems signed up, which is a Boeing company, to work on that capability. And then, you know, obviously, the Overhead Persistent Infrared program is in development, which could provide at least a queuing capability at that level – at high Earth orbit.

So why are we doing this and what capabilities are necessary? Are these the only ones that we need? Do we need others? Is this sufficient? Is it redundant? These are some of the questions that we can answer today, thanks, you know, to the 70-page, very detailed report that Tom Karako and his staff has published today that I encourage you to read, and also thanks to this very distinguished panel of experts, where we can discuss those details even further.

Please, as you're listening to this opening – to all these opening remarks, start thinking about your questions, which we can present to the panel a bit later.

So with that, Tom, you can start.

Tom Karako: All right. Well, thank you, Steve, and thanks to all the panelists for being here today.

Again, I'm Tom Karako. Happy to summarize the report co-authored with my CSIS colleague, Masao Dahlgren, but the entire Missile Defense Project team absolutely contributed to this project.

So the last National Defense Strategy identified long-term strategic competition with our near peers as the central challenge of our time, and advanced missile threats present a – represent a key problem for power projection in a military dimension of that strategic competition.

Now, in one way or another, access to strategic theaters requires us to counter these missile threats. Passive defense and attack operations are a big part of that. But for the things we can't move or hide, we will need active defense.

Now, about a century ago, some military planners had it as an article of faith that the bombers would always get through. Then it was the ICBMs that would always get through. But air defenses and then ballistic missile defenses have at least limited and constrained those perceptions.

But now it's the so-called hypersonic missile that in its more breathless depictions, we are told, will always get through. Open some leading newspapers of record today and you'll find hypersonic missiles dramatically described as unstoppable. But are they really?

I guess the contention of this report is that hypersonic defense is a difficult but, ultimately, tractable problem. Relative to the legacy Ballistic Missile Defense System, these new threats will require considerable change, to be sure, to include different defense designs, new sensing in our interceptor capabilities, different concepts, and doctrinal organizational changes as well as modified policy expectations for the defended asset list, much of which is already underway.

So what is this threat exactly that we're talking about here? Well, in some respects, it's all footnotes to Wernher von Braun. Air Force historian Richard Hallion points out that the word hypersonic is an American invention, a rough translation from the German for high supersonic, and you see here an image from a captured Nazi document depicting a boost glide weapon from the 1940s.

So today's hypersonic gliders may be a kind of poster child for the emergence of a new missile age, but in another sense that we're activating today the potential for aerospace flight that was foreseen from the very early days of the missile age.

Now, the high supersonic, or hypersonic flight regime, beginning around Mach 5 corresponds to a set of aerodynamic and thermal phenomena that a vehicle undergoes in that regime. This report emphasizes at some length that hypersonic is an attribute, not a particular thing, for several reasons.

For one thing, the relationship to the speed of sound underscores that this is an atmospheric phenomenon, and a focus on the characteristics or the attributes of hypersonic flight is also to emphasize that the hypersonic threat spectrum is not confined to boost glide vehicles, to scramjet type cruise missiles, or MaRVs. There may yet be other possible delivery systems and types – FOBS, space planes, and hypersonic trucks among them – that partake of high-speed maneuvering characteristics and sustained hypersonic flight.

In other words, the threat is only going to get more diverse and so we need to focus on the characteristics, not just one or two types of things. The penchant to call everything a hypersonic makes things a little bit more convoluted and, in some ways, underestimates the scope of the challenge.

Nevertheless, the attributes of hypersonic missiles represent a broader trend in advanced missilery away from purely ballistic trajectories and toward lower, more maneuverable, and more – and less predictable flight. It's not just about the speed. The more circuitous routes may, in fact, take longer than a simple ballistic flight.

But how we approach hypersonic missile defense and the characteristics of hypersonic missile threats will shape the broader missile defense enterprise. Conversely, giving up on hypersonic defense could, ultimately, result in capitulation for the active missile defense mission.

Finally, focusing on the characteristics of atmospheric hypersonic flight points to how we might reformulate the active defense mission. As with other air defense threats, it's going to require a more limited defended asset list. But also, as it turns out, every feature that makes hypersonic missiles attractive also comes with a cost. They bring a different set of vulnerabilities for a defender to exploit, and the vocabulary of air defense is different than that of BMD. It may be possible to impose costs upon and shape the character of the threat.

Now, as Seth said in the opening, the offense side of the house is getting a lot more attention. This is a relative breakdown in terms of the publicly available budget numbers of offense versus defense. Again, there's a lot that we can't see here. But this is in relative terms the kind of tradeoff.

You see here in this depiction, above all, the challenge for sensors. This is a notional mockup of a 360 radar on Guam and the degree to which a low-flying hypersonic glider might under fly what the curvature of the Earth limits in terms of sensors. This, of course, also poses a big challenge for the command and control, and this is what makes space sensors the single most important program element for the hypersonic defense architecture. And this depiction here, of course, shows that they can't hide from elevated sensors.

Of course, the sensor challenge for hypersonic threats is different than that of ballistics, as this notional depiction illustrates. Looking down upon clutter, there is a(n) IR signature that can be brought up, but it's a different challenge. And that's why we have to go get a different kind of sensor architecture.

But it also translates to the interceptor side of the house, and today's interceptors may not be sufficiently agile and have a sufficient divert to cover the full possible place where maneuvering vehicles of one kind or another may be, and that's why you see movement on a glide phase interceptor that has greater divert capability – it flies out further. Whether that is hit to kill or whether that is blast frag and its effector remains to be determined. But these just depict that kind of option for the current program.

But, again, the suggestion here is that, perhaps, we can understand something or appreciate something by framing it in terms of complex air defense. Hypersonic weapons are fast but they don't quite turn on a dime, and if high-speed maneuverability is a key feature and attribute it's also a potential weakness.

The heat and drag imposes limits on their ability to maneuver and they expend energy in doing so, and this suggests that there may be things that can be done to either encourage maneuver, and even in the absence of a space sensor layer, forward-based sensors – forward-based radars even at the surface can do a lot of good.

You know, if you want a new idea read an old book, as they say. This is a depiction of a balloon apron that was used outside London in both World War I and World War II, the idea being if we could – aerostats attached to steel nets that would force a German aircraft higher. Could it be circumvented? Absolutely. Did it have an effect on German mission planning? According to the Germans, it did.

It could be circumvented but it imposed a cost. Think of this as a part of a layered defense to affect enemy mission planning and channel the threat.

Because that maneuverability is possible on these threats, perhaps, there's things that we can do in our defense design to affect their seeming unstoppability.

But because this is an air defense challenge, there's also other failure modes that, perhaps, are worthy of exploring. So, again, the space sensor layer, the glide phase interceptor – those are the single most important things to continue now.

But because of the regime which it is, because of the stressing thermal and aerodynamic aspects of that, there may be other things, whether it be blast frag, particulates, or high-powered microwaves that are ways to compensate for the error budget, for the uncertainty of where it may end up.

And so this is a depiction of something like that, the area wide effects, as it were, be it on the directed energy side or something else. Because this is a different threat, this is also a way to think differently about layered defense and so, perhaps, different kinds of effectors imposing upon the design cadence and the – increasing the tolerances within adversary design – that they don't know which kind of effect they need to contend with.

This is also not something that the United States can do alone. This is something we must do with numerous allies and partners. Australia is depicted here. That's Woomera Test Range next to a comparable picture of New Jersey. It's a very large test range. And, of course, the U.S. industrial base. The production of various offensive and defensive systems are currently limited by certain wind tunnel and other TPS bottlenecks. There's also been a boom and bust cycle in the workforce. All these kinds of things are well known.

I just want to leave you with this right here, that as indicated before, the hypersonic missile threat is not a thing. It's an attribute or set of attributes that is increasingly coming to characterize the broader spectrum of advanced missilery. In this respect, how we approach the hypersonic missile threat is going to define and, I think, shape and properly should shape the emergence of the MDS out of the BMDS.

This is not going to be any one particular silver bullet that fixes this problem. It's going to be a number of different things that are going to be necessary to deal with it. And I also want to reiterate those policy expectations, that we don't compete in strategic competition with unlimited resources.

We're going to have to be very selective in terms of what we, truly, defend. That goes for hypersonic missiles. That also goes for cruise missiles and the like. But, again, because there is this increasing diversity of threats arriving in and through the atmosphere, framing the problem as complex air defense, I suspect, will be increasingly useful.

So, again, thank you, Steve, for moderating, and I'm going to turn it back to you and for discussion among the panelists. Thanks.

Mr. Trimble: All right. Well, I think each of our panelists has some opening remarks to begin with, and is the order which – I see. Sorry. Kelley starts. Thank you.

Kelley Sayler: OK. Well, thanks, Steve. It's a pleasure to be here today and to see people in real life.

Today, I'm just going to give us a quick overview of some of the issues related to the complex air threat before my co-panelists dive into some of the details, and I just wanted to, briefly, start with the threat picture because, again, this is talking about complex air threats.

As Seth alluded to, in addition to ballistic missiles, China and Russia are believed to have fielded operational hypersonic glide vehicles in around the 2019 to 2020 time frame. Both countries have stated that the reason that they are developing hypersonic weapons is because of U.S. missile defense, because they are concerned that their nuclear deterrent has been compromised by the development of missile defense, just leaving aside the fact that both countries likely could already penetrate U.S. missile defenses if they were to launch a salvo of missiles that would overwhelm our interceptors.

But all things being equal, hypersonic weapons are more challenging to defend against than traditional missiles and that's due to a combination of speed, maneuverability, and altitude of flight.

So hypersonic weapons and ballistic missiles do both travel at hypersonic speeds, but ballistic missiles are traveling along this predictable parabolic trajectory whereas hypersonic weapons are able to maneuver throughout their course of flight. It can make it challenging to determine what their intended target is.

Hypersonic weapons also fly at a lower altitude than ballistic missiles and, as Tom was sort of showing us in his opening remarks, that means that they can under fly the line of sight detection capabilities of ground-based radars. It's also challenging to detect them using our existing space-based sensor architecture.

I think former Under Secretary of Defense for Research and Engineering Mike Griffin has said previously that hypersonic weapons are 10 to 20 times dimmer than most weapons that we would generally track with existing architecture. And so it's really, again, that combination of speed, maneuverability, and flight altitude that is increasing the challenges of defending against them.

The United States is, of course, defending against them. Per the 2017 NDAA, MDA is the executive agent for missile defense and they have been, since that time, exploring a number of options for missile defense. They have examined white papers on everything from hypervelocity projectiles, directed-energy weapons, kinetic interceptors, electronic attack systems.

They've looked at some of the longer-term options before more recently turning to the glide phase interceptor program, which they believe is intended to give us some level of hypersonic intercept capability by around the mid to late 2020s. And as Steve mentioned, DARPA is, of course, also working on Glide Breaker, which is the technology development program that could, potentially, give some capability for long-range intercept.

In addition to the kinetic interceptors, the FY '22 NDAA did grant MDA the authority to begin budgeting for some of the directed-energy weapons testing. So they are able to look at high-powered microwaves.

DOD is also looking at using laser weapons to, potentially, intercept ballistic and hypersonic weapons. That is, certainly, a longer-term solution. Their DOD direct energy roadmap states that that's probably something that we might not have until around the 2030 timeline at the very earliest – potentially, much later than that.

Now, in terms of dollars for these programs, the budget for hypersonic defense is comparatively modest. This is exactly what Tom was mentioning earlier. So MDA's request in FY 2022 was $248 million. DARPA requested an additional $7 million for Glide Breaker. But if we look at DOD's request for offensive weapons, that's around $3.8 billion.

So in terms of the hypersonic space writ large, certainly, the bulk of the funding is going towards that offensive side of the house.

There are also some enablers worth mentioning. It's the tracking satellites that are – that SDA is developing. Those are intended to queue the MDA's Hypersonic and Ballistic Tracking Space Sensor, and that's to provide more precise target quality data so that you could actually

develop a fire solution that would allow you to intercept that weapon. I'm sure that Stan has some stuff to share on that later.

And then I'll wrap up with a couple of considerations for policymakers here, because there is a diversity of opinion with regard to the cost, the technological maturity, and, really, even the necessity of hypersonic missile defense, and a lot of that is hinging on where people believe that – or what people believe the strategic implications of hypersonic missiles are.

So, for example, there are some analysts that believes that the strategic implications of hypersonic weapons are minimal, that China and Russia and other countries, potentially, already have the ability to penetrate U.S. missile defenses, that they have been deterred from doing so and, therefore, the – there is not a(n) urgent need to develop missile defenses. Those analysts also, generally, argue that hypersonic defenses are unaffordable, that the technology development costs are too high when we compare those with other defense priorities.

On the other side there, there are analysts that argue the exact opposite, and Tom and Masao's report does a great job of sort of spelling out that perspective. And those analysts will argue that there are actually significant strategic implications for the development of hypersonic weapons, that hypersonic defenses will actually increase deterrence because that gives you a credible capability to deny an adversary's attack, and, therefore, missile defense is vital to defending the U.S. homeland, to protecting forward-based troops, and that it's really an essential part of preserving American national security.

This report also lays out an argument for how we might develop an architecture that would leverage existing systems such that we could provide missile defense in a cost affordable manner.

So there are, really, at least two different perspectives, probably combinations in between, that are going to come to the attention of policymakers and that they're going to need to weigh as they're considering sort of future investments and defense capabilities.

So I'll stop there. Thanks.

Mr. Trimble: All right. Who's next on the panel? Go for it.

Gillian Bussey: All right. Thank you for having me here today. It's really great to be doing this from an actual place instead of my office at home on Zoom. (Laughter.) So appreciate that.

I'm going to echo a couple of Kelley's comments in terms of why hypersonic defense is hard so that we can kind of understand some of the opportunities, some of the technology challenges, and then, finally, some of the synergies between offense and defense.

So hypersonics, they allow an adversary to penetrate an opponent's air and missile defense systems by combining the best attributes of ballistic and cruise missiles. I think Kelley touched on a few of those.

You know, ballistic missiles travel very fast whereas cruise missiles, they're maneuverable, they're unpredictable because they fly in the atmosphere. So that gets at two of the three primary challenges associated with hypersonics – maneuverability and speed. The third – altitude – I would say is, really, happenstance just based on the physics of flying at high speeds in the atmosphere.

The requirements for achieving lift and minimizing drag and heating force hypersonic systems to operate in what is typically called the near space regime, which is between 20 (kilometers) and 60 kilometers, where hypersonics usually flies 20 (kilometers) to a hundred (kilometers) is near space.

By the way, the Chinese appear to be approaching hypersonics as a domain, like land and sea, that they can exploit and see the significance of this altitude regime by often using the terms near space and hypersonics interchangeably. So I agree with Tom. It's not a thing. It's an attribute, and some might argue that it's also a domain.

By the way, you can take a look at some of their military writings and some of the papers that they've published, particularly at – 2017 at the ARWA conference in China. There's a number of papers by an institute called the Beijing Institute for Near Space Vehicles on hypersonic glide vehicles. By the way, near space can also be very, very slow, but it's a domain that they want to dominate the same as land and sea.

What altitude gets you and why it's important is it gets you lift over drag, which gets you maneuverability. Altitude gets you control authority, and then it also gets you heating. So it results in different technologies in terms of what you need for ballistic missile defense, so, typically, divert attitude control systems for ballistic missile defense but then for cruise missile defense you're using aerodynamic forces, control surfaces. So hypersonics, you know, forces you, really, in that sweet spot of where traditional air and missile defenses lie. So you need to, you know, have a mix of technologies or, you know, a new approach to missile defense.

As someone who has spent most of their time in the hypersonics weapons world, we don't envy the Missile Defense Agency with the task that they have. (Laughter.) But my office – the JHTO – is here to help as much as we can in supporting the relevant S&T.

One thing I will note, that there's two things that, I think, make this task easier. With the exception of aircraft, they all come down and they tend to come down in the same way. So terminal defense for hypersonics can look a lot like that for supersonic.

But that's not sufficient because we're expecting to see a large number of missiles coming at us. So we need a layered defense system because we have too many threats to deal with to depend on a terminal defense.

But there's also advantages to dealing with a hypersonic threat earlier in trajectories. In the terminal space, yeah, it can maneuver and it should be in order to avoid those terminal defenses. But in the mid-course phase, maneuvers come at a cost to range. They come at a cost to survivability in terms of the heating that's incurred on the vehicle, and they're typically less stressful during the glide because of those heating and structural constraints, because of the lower dense atmosphere and thermal stresses imposed, or sometimes because of the limitations of maintaining adequate airflow to a cruise missile engine.

So hypersonics definitely shifts towards near competition – near peer competition as being offensive dominant, which, of course, has a whole host of implications for stability and the likelihood for conflict. I'm not going to get into that, but I think Kelley alluded to that a little bit. Essentially, this means it's a lot easier to attack than it is to defend against such an attack. So despite the obvious threat, as a department we've chosen to focus on offense first because a good offense is the best defense and offense is a lot easier.

So going into some of the key technologies and technical challenges and then opportunities, so at the JHTO we've been focusing on a couple of technologies to support missile defense applications, so infrared window technologies and RF antenna technologies.

So you need to be able to develop materials that allow the right spectral energy to pass through while protecting the seeker from stressing thermal environments. Aero optics – you need to understand sources of optical distortion for IR sensors such as ablation or erosion on windows and what the hypersonic airflow looks like over that window.

Having enough divert capability for containment through either on-demand propulsion or a high lift over drag interceptor. You need high-

temperature materials in manufacturing. For directed energy, we need to understand what the kill mechanisms are and the effect that they have on materials and vehicle response and control.

Other areas of importance that I know that MDA is looking at, over-the-horizon radars we talked about earlier – how hypersonics fly below the radar horizon. Proliferating LEO with IR sensors is very important, low-latency communications to support beyond line-of-sight engagement, fusing and blast fragmentation warheads, solid DACS for naval launch systems, systems that require a combination of aero and DACS control for higher altitudes for glide phase intercept.

Optimize battle management and decision-making – that's a particularly challenging area. Predicted intercept points – can we predict where the target is? Can we predict maneuvers? Anything that we can do to reduce the three-to-one G requirement for interceptors and close the kill chain.

That's a very hard aspect of hypersonic defense, having enough maneuverability to get that three-to-one overmatch, which presents opportunities, perhaps, for AI and machine learning. And then, finally, on jet interactions for systems that have DACS – you know, those jets can impinge on the vehicle. They can interact with each other. You need to understand what effect that has on your interceptor.

So what are the opportunities for offense in some of these investments that we can make in missile defense? Well, what has the maneuverability, altitude reach, and speed to hit a hypersonic missile? A hypersonic missile.

So concepts for defense that can be used to advance – so there are concepts that can be used to advance offensive designs. The seekers and guidance are different. The booster may be different, but the fundamental aero vehicle can be the same. We've seen a number of proposals using what could be an offensive strike weapon used as an interceptor, and vice versa.

Targets – MDA is really at the forefront of thinking about what future hypersonic weapon concepts and designs will be because they need to get ahead of the threat and design targets that interceptors under development today are facing back – you know, in 2030 what do those expected threats look like? Long-range kill chains, so a proliferating LEO for IR detection and comms for missile defense. The offensive strike community needs long-range kill chains as well and so we can leverage that infrastructure, we can leverage that architecture.

Materials and manufacturing – we have a lot of the same challenges there. So my office has been investing in materials and manufacturing relevant to both offensive strike and defense. In fact, some of our key offensive strike investments are funded through MDA because MDA has a need for them.

Signature management reduction – as we understand the signatures of threat hypersonic vehicles, that informs our own designs as well and what we can do to reduce those signatures. And then, finally, work on characterizing lethality to directed energy. That is something that we're working together on because we need to understand what that looks like in case our adversaries are developing those threats as well.

So with that, I'll turn it over to my next panel member.

Mr. Trimble: Stan, please.

Stan Stafira: Sure. Thanks. Thanks for inviting me today. I was happy to be out here this morning. The weather is great here. I was out in Colorado Springs last week and had some big meetings out there and got snowed out one of those days. So it's great not to have snow here today, and so I'm happy to talk about what we're doing here at the Missile Defense Agency as far as hypersonic defense.

As Kelley mentioned, Congress designated Missile Defense Agency as the executive agent for countering hypersonic threats in the FY '17 NDAA, and we've been working with other DOD organizations to develop the technologies and the capabilities to do that.

MDA really uses – categorizes hypersonic threats in three ways. We look at hypersonic maneuvering reentry vehicles, hypersonic glide vehicles, and hypersonic cruise missiles. So when we're talking about hypersonic threats we look at all those together as we're developing our architectures.

And like Tom talked about in advanced integrated air missile defense, we consider countering hypersonic threats as part of an integrated air and missile defense architecture. MDA has a number of ongoing activities to increase our knowledge and reduce technology risk in countering hypersonic threats.

We're working with academia and industry as well as conducting analysis and executing tests, as Gillian talked about, on both the offensive side and using offensive technology to help us as we do our defensive work.

We believe countering hypersonic defense – hypersonic threats is feasible. We've looked at it. You know, as Steve mentioned, as Tom's talked about, these threats – hypersonic threats are fast. But we've engaged fast threats before. Ballistic threats are just another class of hypersonic threats.

And as Gillian talked about, and Kelley, it's speed and maneuver. We look at speed and maneuver. That's the key there, and maybe these are things that we can use to our advantage when we're looking at defensive architectures.

Our recommended architecture for countering threats includes elevated infrared sensors, integrated command and control in battle management and communications, and layered defenses with effectors in both the glide and terminal phases of flight. When we look at this, we look at it from a detect, control, and engage framework.

You know, I need to detect the threat first. I need to use all the sensors' capabilities I have to detect that threat because I need – since it's maneuvering, I need to know where he's at. I need to be able to pass that data to the right guys to be able to engage it, and then I need to have effectors out there to be able to do that, be they kinetic or non-kinetic effectors.

As we look at the different capabilities that we're talking about, as I mentioned, we're using – we're looking at elevated infrared sensors to do the necessary detection to provide that continuing tracking. MDA is developing a prototype system to be launched in '23 – as Steve mentioned, the hypersonic ballistic space-tracking sensor.

That capability will provide us fire-control quality data, the data that we're looking at to get down to the effectors so that we can get the effector up so that it's in the basket so that it can engage those threats when it gets near them.

We also agree that – and we have also looked at as our analysis has shown that engaging in these layers is important. We need to be able to engage that throughout its phases of flight. We want to challenge the hypersonic threats in the glide phase. The glide phase of flight, as Gillian mentioned, there's a cost to be imposed there. The threats are trying to conserve energy.

We believe that using kinetic and non-kinetic capabilities in the glide phase we can affect the hypersonic threat, and then should that threat not be gotten in the glide phase, we do have terminal capabilities. The Sea-

Based Terminal program provides an initial terminal defense to counter hypersonic threats.

Certainly, additional improvements are scheduled as you go in there, and as you engage in the glide phase it makes the terminal defense that much easier to be able to engage those threats.

And so, really, that's an overview, from my perspective, of what we're doing at MDA as far as developing an architecture to handle those threats and will be happy to talk about that on the panel.

Mr. Trimble: Thank you.

And Mark?

Mark Lewis: So, thanks, Steve.

So the disadvantage/advantage of being the last speaker is a lot of my points have already been covered. But that's a good thing. So I want to – I, actually, want to start out – I want to start off by congratulating CSIS on this report.

So this morning as I was walking to my office, I bumped into NDIA's President and CEO, General Hawk Carlisle, who, I think, many in the audience will know. Hawk was, you know, Air Force four-star general. He commanded in the Pacific and he commanded the Air Combat Command. Certainly, knows as well or better than any other person on the planet the potential threat that we are facing as a nation as these capabilities are being developed. And I mentioned I was going to be on this panel. He said, well, what did you think of the report? And I kind of said, you know, it's so good I wish I had written it. So, Tom, again, congratulations to the team.

I think there are a couple of takeaways. I want to start out with the first sentence in this report because I think it's really important because the first sentence – and I'm going to read it. Defending against hypersonic missiles is strategically necessary, yes, technologically possible, yes, fiscally affordable, but it will not be easy. And I think that captures why this is such an important report and such an important effort.

Hypersonics is, in fact, hard to defend against. That's why we're interested in hypersonics. That's why our peer competitors are interested in hypersonics. It's, ultimately, about survivability and also getting inside an opponent's OODA loop – observe, orient, decide, and act. That's what it does.

As I like to point out, a vehicle that's traveling at hypersonic speeds is traveling at least a mile per second. So every second it takes for you to identify, every second it takes for you to track, every second it takes for you to decide, that's a mile that that thing has traveled. One minute at 60 miles, two minutes, 120 miles, at least, at a minimum. Possibly more.

So that's why these are such challenging threats. That's also why we, as a nation, need to be pursuing hypersonics. I sometimes have been asked the question, is the United States simply pursuing this technology because peer competitors are pursuing it. No. I argue we would have been pursuing this anyway.

We should have been pursuing this anyway, just as we pursued stealth. This is – arguably, the American way of war is build on technological superiority. So this is a capability that we would want regardless of what peer competitors are doing.

However, the peer competitors are imposing a timeline. As was mentioned, they've already gone, in some cases, to deployment. The Chinese were very happy to show us some of their capabilities as they did a military parade in 2019. Vladimir Putin himself has bragged about some of the Russian capabilities.

So we know there's a timeline. There is a race, and whether or not we choose to participate in that race we've got competitors who are already marching to the finish line. So that's part of the imperative.

I'll also point out, you know, often I'm asked the question, so why do we want hypersonics, and I like to turn that question around, which is, why wouldn't we want this capability.

I can offer some explanations why we wouldn't want a hypersonic capability. If it's too expensive, so cost is important. If it reduces – if the price of speed and maneuverability is a reduction of other attributes – for example, range – then that factors in the tradeoffs.

But I'm, actually, convinced and I think our competitors have also figured out that they can have the attributes of hypersonics, they can have the benefits, without a significant, significant financial impact. They will not be – contrary to common belief, I don't think they'll be that much more expensive, especially when the cost of effects are considered.

So I'm going to come back to this report and why I think it's so important. In 2016, a couple of us on this panel were involved in a report of the National Academies and the Air Force Studies Board that looked at defending against hypersonic systems, and it was a report that – gosh, I've

been on so many reports of so many panels and been involved with so many of those sorts of activities. That one really seemed to resonate more than almost any other one that I've been involved in.

I checked yesterday and it had – as of yesterday, it had almost 5,400 downloads, which is remarkable for a National Academies report. Usually, it's a couple hundred, maybe a thousand. By the way, a lot of those downloads were in our peer competitors' locations. So the National Academies actually gives you a map that shows you where it's being downloaded.

But I think back to that effort. So we began that effort – we, actually, started that effort in 2013 and then we started it in 2015, and there were – at the time, there were a few notable events. So then we visited one of the defense laboratories. This would have been late 2015.

So we visited a defense laboratory and we met with their internal committee that was addressing defense against hypersonics. And at first we were really impressed that this laboratory actually had a committee that was considering this, until the committee admitted that they had only been formulated a week before we arrived and they were formulated in response to the fact that we'd asked them questions about how are you defending against. So they weren't even really thinking about it.

Similar experience at the time we had a – this is, again, the 2015 time frame – we had a briefing with the Missile Defense Agency, and much to MDA's credit their leadership came and spoke to us and said, this is a part of the mission we think we should own, but at the time did not own it.

And so now I fast forward to where we are today. First, the Missile Defense Agency owns the mission and is pursuing it aggressively, although we can argue whether it's sufficient resources. But this is a mission that they're taking very seriously.

Two, working in close conjunction with the Space Development Agency to handle what, I think, is the important first part of defense, which is seeing and tracking the target. If you don't see it, how do you stop it? So that's absolutely critical. And, again, I think we see the work of HBTSS as being that first important step. So, clearly, a lot has changed.

I want to come back to some of the other great aspects of this report. So one of the things that I truly resonated with is – and Tom mentioned it in his opening comments as well – hypersonics isn't just one thing.

You know, I'll often be in discussions where people say, oh, well, we'll defend against the hypersonic, or, they're going to launch the hypersonic.

It's not a hypersonic. Hypersonic is an adjective and it applies to a wide range of weapons and systems, which this report correctly points out.

It also points out that there are some weapons that we should be more concerned about than others. From my own perspective, it's, really, the tactical systems that I worry about the most. It's the things that can, you know, hold our air bases at risk, things that can hold our aircraft carriers and our surface ships at risk. Those are the ones that, I think, are the real impactful systems because those are the ones that allow a potential adversary to use a tactical system but have strategic implications.

Imagine a hypersonic missile swarm that can sink an aircraft carrier. That's, really, quite a capability, and that leads to us asking the question, are we willing to risk an aircraft carrier, say, in a potential scenario?

It also would allow a peer competitor to control the narrative, plant doubt in the minds of some of our allies – would the United States risk an aircraft carrier, for example? Risk an airbase because of being held at risk by a hypersonic attack?

So if I do a priority order in what I want to defend against, tactical, really, comes out first, and I think that's important that we pay attention to that. At the end of the summer, there was a fair amount of reporting on an alleged Chinese launch of a Fractional Orbital Bombardment System and immediately I heard people saying, oh, my gosh, we need to figure out ways to defend against it.

I wonder if that is a little bit of a watch my right hand while my left hand does something important, right, and the left hand, I think, in this case are the tactical systems. And so, Tom, to the extent that you highlight that in this report, I think, absolutely critical.

Let me wrap up with resonating, again, with some of the comments were made. You know, Gillian's comment about the best defense may, in fact, be a strong offense, and we can't lose sight of that, that these two sides of the coin are, indeed, very, very much coupled. If nothing else, we need to learn how to defend against these systems by developing our own offensive systems that will give us the knowledge that we need to defend against them.

But also it is possible that, at the end of the day, the only defense we have is taking out a hypersonic launch system or launch capability with our own hypersonic weapon system. So we cannot lose sight of that.

And then, finally, I'll emphasize that one of the most startling elements of what our peer competitors are doing is that they're, clearly, investing for

the long haul. We see that in their investments in their workforce, in their universities, in their test capabilities, and that's important for us as well.

And so the work that, for example, the Joint Hypersonic Transition Office is doing and investing in workforce, the work that the Test Resource Management Center is doing and investing on new test capabilities, we need to be in this for the long haul as well. This can't be a few years' effort – we deploy a couple of systems and then we move on – because this is the future of warfare and we need to be in this race.

So, Steve, let me stop there.

Mr. Trimble: All right. Well, first of all, thank you – the panel – and Tom. You know, I've been writing about hypersonic defense for a few years but this is, you know, the most in-depth discussion I've seen, certainly, available in the public domain. So I appreciate that.

Now, in regards to the report – and I should say please keep the questions coming in. I've seen them, and we're going to get to those in just a few minutes. But I do have a couple questions I really have to throw at you guys.

One of the really interesting arguments, I thought, in the report is that – because it sort of widens the aperture with hypersonic defense with all these other capabilities and these very sophisticated and sometimes even creative type systems.

You mentioned one with the Fractional Orbital Bombardment System sort of coming back – you know, what used to be the Russian capability, now the Chinese demonstration. You know, there's other things you keep saying – you know, the combination of drone and UAV and the sort of ambiguity of that, even with, like, the Chinese WZ-8 and so forth.

And then there's new propulsion concepts like rotating detonating – rotating detonation engines, solid fuel ramjets. I mean, there's just a plethora of things, and that the argument in the report is that this should – that as this architecture develops for this new thing of hypersonic defense that this should drive a rethink of how we approach the missile defense architecture, in general, including for ballistics.

So, Stan, you know, what do you think about that, that argument in the report, and how is that manifesting itself, if at all, in the MDA strategy?

Mr. Stafira: Well, thanks for the question. When we looked at – I'll say that over the last year, we've been looking at defending a lot of different assets. Guam, per se, has been in the news. The Missile Defense Agency has been at the

forefront of looking at that with the department, and as we've looked at that, along with hypersonics, what I think we've come to discover is our adversaries are looking for that asymmetric advantage. They're looking at different capabilities and how they can use them.

I think what we've come out with is that we need to look at all of those. We can't ignore one or the other because our adversaries will use that capability as a way to create a hole so that they can have a – they can get their capabilities through or their will through.

And so as we've been looking at the architecture, we know that we need to make sure that the architecture is flexible. We need to make sure that as we look at it we're looking at both ballistic, hypersonic, cruise missile defense, how do we integrate those architectures together. We're working with the department as we go forward to make sure that we're looking at that whole spectrum and how do we do that.

I won't say that – you know, you're not going to have a silver bullet and say this one thing is going to solve all those problems. I think it's a number of different capabilities. But you need to leverage the sensors that you have, the command-and-control system that you have, and then the effectors that you have out there and be able to command that across the battle space to make sure that you can handle those threats, and I think that's what we're looking at as we look into the future, these kinds of threats.

Mr. Trimble: Anybody else want to contribute there? Tom?

Oh, sure. Gillian? Yeah.

Dr. Bussey: Yeah. So I really like how Tom, in the report, kind of laid out the different types of hypersonic weapons and kind of, you know, what really is a hypersonic weapon and what's, you know, a maneuvering reentry vehicle or an aero ballistic.

When I was involved in the intelligence community we got ourselves wrapped around the axle so many times trying to bin things, and there are reasons why things needed to be binned but mostly it was because, you know, we were concerned that if MDA, for example, was developing an architecture or an interceptor based on, you know, one type of threat rather than the spectrum of threats or characterizing a threat – OK, this is a hypersonic weapon and, you know, the category is too broad – that they would not be able to adequately address the threat.

So we were always, you know, making sure to understand the nuances and the differences, and, you know, we're seeing, particularly from China,

that, I guess, they see it as a domain. So, yes, you have glide vehicles. You have cruise missiles. But you have things that, you know, can mix both. If you go back to the 1990s, at one of the Russian air shows they showed a glide vehicle with a scramjet underneath.

And so these concepts aren't new. You can look at their papers. They have gliding scramjet vehicles. They have glide vehicles with scramjets. They have glide vehicles with liquid rocket, solid rocket, propulsion. There's a whole host of propulsion systems that they're working on. You know, you go to that 2017 conference and there's so many papers on many different propulsion systems.

So I think, you know, when we look at defending against these threats, we need to understand, really, the nuances and why these are different from a classification and identification tracking standpoint as well as an intercept standpoint, and design our architecture and our interceptors, I guess, to be agnostic to the type of system that it is.

And I will say, kind of going back a couple of years, I thought it was important to have clarity in terms of, you know, what is really a hypersonic weapon and what's not because you go back seven years or so, you know, the DF-26 was a big thing and we were just starting to think about hypersonics and just starting to think about the defense challenge, and everybody would glom on to the shiny object that was the DF-26 and try and, you know, characterize that and the threats against it while ignoring that the glide vehicles and the cruise missiles had very different challenges and were going to require a different solution.

Dr. Karako: So I'll just say, briefly, first of all, returning the compliment. Your 2016 report that, Mark, I think, you were the executive director of and, Gillian, you were part of, one thing I really liked about it is that the title said high-speed maneuverable threats, right. So often in this space, I feel like I'm standing athwart jargon, yelling "stop." (Laughter.)

You know, we need – when we need to talk about specific delivery systems, we're talking about specific things, say what you mean, right, as opposed to calling it this, that, or the other thing.

And so what you've just described there, and, Gillian, you just highlighted the mixing of a scramjet thing with a glider, I mean, and this is why we spend a good bit of time in the report, you know, talking about the mixing and matching, because if we don't get it right conceptually in terms of framing the problem now, right, that's going to retard us in terms of developing the solution by understanding the problem.

So it is, fundamentally, a spectrum. And I like the word "agnostic" in terms of thinking about that. There's going to be lots of things, the full diversity of this missile renaissance that – you know, Gillian, when you're talking about the high atmosphere domain, for instance, I mean, I think about the inter-service rivalries in the 1950s about whether the Air Force gets to own the aerospace domain.

Well, guess what? Now we have the Space Force versus the Air Force. So those fights may yet, you know – (laughs) – be hashed out. And so figuring out this spectrum and appreciating the enormous diversity yet to come, I think, is one reason why it's important to focus on that.

Mr. Trimble: Mark, did you want to –

Dr. Lewis: Yeah. So, Tom, absolutely spot on, and I've actually often wondered if our competitors use our bureaucratic stovepipes against us. You know, put a scramjet on a glider and then, well, is it a cruise missile or is it a glide vehicle? And I suspect they are and we need to get past that.

You know, to the points that were previously made, and I think an excellent point in this report, it needs to be a layered defense. You quoted Dick Hallion in your opening comments, and Dick Hallion has actually likened this threat, philosophically, to the kamikaze threat and the way we defeated the kamikaze threat was, indeed, with a layered defense. And I think this the same thing applies here. We need multiple. It can't be a single solution. It has to be adaptable.

Mr. Trimble: That's the perfect segue for the question I was going to ask next, which is the sort of level of effort that we're talking about here as we talk about broadening this capability from, I mean, in a way, a silver bullet solution that is GBI – ground-based interceptor – THAAD, or SM-3 for a very specific threat set to this, you know, very – more flexible architecture with new sensors in this – in space, multiple different constellations, it seems, multiple different interceptors on the ground, high-power microwaves. You know, you see that OV-1 slide with a couple of GPIs, you know, degrading the threat as it comes in. You know, then high-power microwaves shooting it with electrons and then, finally, you know, an SM-6 or something getting in in the terminal phase.

So, I mean, you know, we've spent all this time and all this money to create what we have today in comparison to something like that to an SM-3 or a THAAD type system, what kind of level of effort is going to be required to bring this about.

Sorry, Stan, if I can pick on you again to start with that one, yeah. (Laughter.)

Mr. Stafira: Well, certainly, as we said, it's not – it's not going to be easy. It's going to be a challenge. You know, as I said, detect-control-engage is where we're looking at as far as the architecture. So you do need to see it. We do need to have a capability to see these threats as they maneuver and glide, to be able to do that. So you're going to need to have those capabilities there as well. We have command-and-control capabilities. We believe we can leverage command-and-control capabilities that we have to be able to get data to where it needs to go.

And then, as we were talking about, this is kind of a different regime. It's kind of the regime in the seam, if you ask me. We know how to engage things and we have capabilities to engage things in the thick atmosphere. We have capabilities that engage things in space. But this near space is that in between layer that, you know, it's not easy to transition between the two. So how do you develop your capabilities, either kinetic interceptors or not kinetic interceptors to do that?

You know, I think the level of effort right now is kind of on par with what we need to be doing. We need to keep advancing, and then as we have done in the Missile Defense Agency, we spiral the capabilities. We develop a capability and we increase that capability as we go out and make it better to be able to handle those threats.

Mr. Trimble: Anybody else want to –

Dr. Lewis: I just want to chime in. I want to remind that, you know, the Missile Defense Agency is also a science agency and they're actually doing some phenomenal work. I know Shari Feth and her folks in the S&T office are doing incredible work on developing sensor technology and things that will enable the capabilities that Stan just alluded to.

So you have to actually look beyond the programmatic investments to look across the broad range of activities across the whole department to really get a full sense of what's being invested.

Mr. Trimble: All right. Well, I just have a couple more questions. You know, so we've talked a lot about hypersonic glide vehicles. There's a lot of things going on with hypersonic cruise missiles.

You know, Russia has got at least three or maybe even four different programs that I'm aware of, you know, not including even BrahMos – what they're doing with India with BrahMos-II. France has a new scramjet-powered cruise missile for their nuclear deterrent. You see these things popping up everywhere. South Korea just announced theirs a couple of months ago.

So what is being done about that? How much of this hypersonic glide vehicle architecture can apply to that? How much is going to be new just specifically to deal with that particular threat?

Mr. Stafira: Well, so from our perspective, as I mentioned before, that we look at hypersonic threats. We look at all of them. We look at the maneuvering ballistic, the glide vehicle and cruise missile there as we develop the architecture – one architecture that can be able to handle all those. You know, when you say cruise missile a lot of people think of – when you say cruise missile, people immediately go to subsonic cruise missiles, cruise missiles are flying low in the atmosphere, hard to detect. These hypersonic cruise missiles just don't do that. They can't fly in that thick atmosphere because of the heating because they're going so fast. So they have to fly higher.

So by doing that – and they'll still be heated as are the other systems – again, we should be – we want to be able to detect them with our sensor capability, be that overhead sensors, over-the-horizon sensors, whatever sensors that we can get on them – terrestrial sensors if they're in the area.

We want to be able to find them and send the data across the network using whatever com layer that we need to get the data to the right effector, be able to do that, and then use the right effector against that, be that high-power microwaves in a mid defense, a glide phase interceptor or terminal interceptors, depending on where the threat is going.

So, I think, when we look at the architecture and what we're trying to do with the architecture we're trying to make sure it's flexible enough to be able to handle all those different kind of capabilities and be able to plug in those different effectors to be able to handle the different regimes that they're going to need to operate in.

Mr. Trimble: Well, and, Gillian, I know JHTO has funded offensive scramjet-powered capabilities with SCIFIRE, with HyFly2. You know, do any of those technologies – you know, can you harvest them to apply to the defensive system?

Dr. Bussey: I think so. Maybe not for a first-generation system, but I could imagine, you know, eventually a scramjet-powered interceptor. So the very, very original HyFly was designed as an anti-air – well, anti-missile defense interceptor. Yeah, a missile defense interceptor. So but, you know, they, you know, changed it and it eventually became a strike weapon.

I can also imagine that you could have a hypersonic vehicle that's carrying submunitions. Those submunitions, they don't have to hit things on the ground. They can hit things in the air. And then I guess, also, just to get back – and then I think there's some other – you know, just understanding the basic aero, maybe some of the materials, maybe some of the manufacturing, maybe some of the guidance algorithms or some of the seeker development, you know, if you're – particularly if you're doing an IR seeker and some of the window and antenna materials. But kind of getting back to the idea of, you know, hypersonic cruise missile versus hypersonic glide vehicle.

For reasons I don't really understand, for some reason ballistic missile threats always seem to get more attention than cruise missile threats. And I had a manager who once kind of said advanced conventional weapons are weapons of actual destruction. You know, they are actually used, and, yet, for some reason, we always seem to pay way more attention to the glide vehicles.

And so I always got a little frustrated years ago when I'd sort of see MDA talk about just the glide vehicles and never really acknowledge the cruise missiles, which are a very real threat, and there are some differences about them.

But I am happy to see that MDA is capturing those differences and is looking at technologies that can be applied to both because the danger is that you look at a hypersonic glide vehicle and you say, well, that's higher, that's faster, so if we got that covered we got the cruise missiles covered, and that's not true because the cruise missiles they fly, you know, in the deeper atmosphere. So if you had an interceptor that, you know, came over the top then it's going to have a harder time getting down. Or if you have a sensor system that's looking – that has a floor that's designed for the glide vehicles you might miss the cruise missiles because they are dimmer and they are, you know, lower in the atmosphere.

So there's some nuances and there's some differences that need to be accounted for. But from what I've seen from MDA they are accounting for them.

Mr. Trimble: Well, Kelley, I should ask you about congressional views. There's been, certainly, some reporting by me and others about where the funding is for hypersonic defense and, you know – but, you know, what's the feeling in Congress about where the funding levels are right now and where they're going?

Ms. Sayler: Yeah. I think if we look at legislation that Congress has passed, in addition to establishing MDA as the executive agent in the FY '17 NDAA, that NDAA

also directed MDA to establish the program of record for hypersonic defense and that account has been plussed up by Congress every single year since FY 2019.

Last year, I think, they plussed it up $70 million. This year, they plussed it up $62 million. Both the authorizers and appropriators support a $62 million plus-up, which was MDA's unfunded priority list request for Glide Breaker.

So I think if we predict the future based on past trajectory, I think there's likely to be continued congressional support for hypersonic defense.

Mr. Trimble: All right. Well, let me get to some of the questions from the audience. To start out with, this one comes from Tony Capaccio at Bloomberg, and he addresses it to Director Bussey but I'm very interested in some other comments here, especially yours, Dr. Lewis.

This is both the DOT&E in its annual report and the Pentagon IG in a report last week have raised serious questions about DOD's ability to adequately operationally test hypersonic weapons and defenses against adversary weapons. What's the Transition Office's overall response to both? (Laughter.)

Dr. Bussey: So I don't have a response. (Laughter.) I don't think I've even seen that report yet. But, you know, I do understand that flight testing hypersonic systems and, you know, flight testing defenses against hypersonic systems is, certainly, more challenging and, you know, I do understand that, certainly, from the research development acquisition standpoint that we have capacity and throughput issues and, you know, we have capability issues when it comes to our next-generation systems. So I guess, perhaps, I'm not surprised that they have that assessment but I can't really comment.

Mr. Trimble: Any response at all, Stan?

Mr. Stafira: I haven't seen the report either. Certainly, from our perspective, we do a lot of testing and we've had a pretty robust testing program. As we – as part of the whole hypersonic effort we've canvassed the department, academia, country looking for capabilities who do testing, as well make sure we categorize those. And as we talk with our international partners, we look at them as well and discuss those aspects with them as well.

So, you know, certainly, you know, as we develop capabilities we, certainly, want to have a robust testing program and that's what we'll do.

Mr. Trimble: Mark?

Dr. Lewis: So, first, hi, Tony. (Laughs.) I'm going to argue that our test infrastructure is, frankly, right now inadequate. It's one of the things that's limiting our advances in air developments on the offensive side as well as the defensive side, and it's inadequate across the board.

So, for example, wind tunnels. I mean, at the same time the Chinese were building up their wind tunnel capability and they were freely bragging about it – you can go to YouTube and they've got videos of their wind tunnels – we were shutting down wind tunnels at about the same rate that they were building new wind tunnels, right.

We're trying to reverse that trend. TRMC is actively involved. But, still, we're in a situation now we've got programs climbing all over each other to get time in a wind tunnel. And why has that become bad?

Because imagine you get your slot in the wind tunnel. You've got, maybe, your one week of testing. Something goes awry. You lose a day of testing. You need more time. Sorry, you can't have that. There's another program coming in. Or you see something interesting in the data and you want to do some more tests. Sorry, it's booked up for the next four months. You're going to have to come back then and that delays –

Dr. Bussey: One month – try two years.

Dr. Lewis: Two years. Right. So that's on a wind tunnel. Now, ground is even worse. So we find ourselves competing with so many other programs – flight is even worse. We find ourselves competing with so many other flight programs when we try to do hypersonic testing. And it's the same situation. You get your slot to test. If you miss that slot for any reason – you're not ready on the day of the test – sorry, it's going to be months before you can test again.

I'll take it one step further. We don't right – we do not have right now a way to have repeated access into the hypersonic flight test regime. That's something that we need. We need reusable systems that allow us to enter the hypersonic flight test envelope, come back, let us look at things that we just tested, let us trade things out, swap them out, and fly them again. We had that in the 1960s with the X-15 rocket plane. We don't have that today and that's one of the things that's slowing us down.

Ms. Sayler: I'll just add that that tracks very much with the congressional perspective that I'm seeing coming out of recent NDAAs and SASC committee report on the FY '22. NDAA explicitly called out their concern about inadequate ground infrastructure. And so I think, you know, they've been trying to push for an acceleration of testing and there have been numerous

statements about how this is insufficient to at least meet the program goals as stated by NDAA, the services industry, et cetera.

Mr. Trimble: Well, and my colleague guy, Guy Norris, did some great coverage, you know, 10 years ago with X-51 and just the challenge it took using a B-52 as that platform and trying to get that launch speed correct with the – you know, the kind of analog controls, thrust controls, is – I mean, takes quite a bit of effort just to do that. So it's a very creaky infrastructure, as you said.

Dr. Lewis: It is, and, you know, the B-52 is a great example. The youngest B-52 in the fleet is actually older than I am, which is quite old, and, you know, they're practically singing incantations and burning incense just to get all eight engines started on the test vehicle just to get it off the ground. So we need to make that more robust.

Mr. Trimble: Huh. I'd like to see those – this on YouTube sometime.

Dr. Lewis: (Laughs.) It's metaphorical. No, they – yeah.

Mr. Trimble: Well, there's a really good question here about something we haven't talked a lot about today, C2BMC. You know, will it be critical for processing a volley of hypersonic threats? Will you leverage the existing C2BMC we have, I think, at Schriever with a hundred-missile defense brigade at least for the BMDS, or do you have to create a new command-and-control system?

Mr. Stafira: Well, the idea is to use C2BMC. C2BMC is a good command-and-control system that's out there. We have C2BMC deployed in a number of places across the world. It's not just for homeland defense. The regions have C2BMC as well. Both EUCOM, CENTCOM, and INDOPACOM have C2BMC. You know, there's suites that support each of the regional combatant commands.

Certainly, as we get into hypersonic threats we'll need to make sure – there'll be certain – some modifications necessary to C2BMC to be able to do that command and control. But we view that C2BMC is going to be critical to being able to do that command-and-control function that I talked about.

Dr. Karako: In some respects. I mean, this is the whole JADC2 conversation, right, because you want to have multi-service, multi-domains, coming in, going out, and it just so happens that that's one of the things that's been doing the joint and multi-domain thing before it was cool.

Mr. Trimble: Well, we've been talking a lot about the interceptors. I have a question about the sensors and the architecture that is optimal for that and just what your opinions are because a couple years ago, I mean, we were told it proliferated low Earth orbit. That's the way to go. You need 50 satellites to create the stereoscopic image and use that optical links transmitting the data back and forth.

But, you know, recently we've seen Space Force invest in medium Earth orbit, and the report calls that out as a possibility – a strong possibility or at least a good possibility. But what's the thinking now about what the right sensor architecture should be? As well, I should also mention that the report also proposes this airborne layer that is not necessarily dedicated to hypersonic defense but feeds into it.

Mr. Stafira: Well, so from our perspective, you know, from – as we develop the architecture, I want to use any sensors I can get. You know, we just don't see – we will never have enough sensors to do what we need to do so.

So we've been working closely with SDA and the Space Force as we've developed this architecture. We work with them on the report. We're going to work with them on what do we need to do next after HBTSS demonstrations and what – how that architecture is going to look like in the future.

We've looked at other sensors as well. We know that terrestrial sensors can provide us some data as we do that as well. You know, we've modified some of our sensors to be able to provide us hypersonic data. We know that the Aegis weapon system can do that as well – we've seen it in tests – to be able to provide us data and close the fire control loop as well. And so we're confident in the sensor architecture that we're looking at.

As I said, we need to look at it all. We need to figure out what's out there, be able to bring that in. C2BMC is a good capability because that's what it does. It brings in all those different sensors to be able to provide us that integrated fire control data that we can get down to those effectors.

Mr. Trimble: Another question has come in from Voice of America on North Korea, and I thought that might be an interesting way of looking at sort of the very specific application considering that, you know, there was a hypersonic glide vehicle test back in September that never actually reached hypersonic speed, or so we've been told.

There was a more recent test with what appeared to be something more like a maneuvering reentry vehicle with hypersonic speed, but, obviously, just in that terminal phase and maneuver.

So, you know, to the extent members of this panel can comment on it, what is our capability against something like that today, the MaRV threat, in particular, or some sort of nascent HGV threat from a rogue state, say, for example, North Korea on the Korean Peninsula?

Dr. Karako: I'm going to answer this by way of going back to, frankly, some of the things Gillian was talking about in terms of the aero ballistics and things like that. I mean, you just referenced, well, maybe it was – they call it a hypersonic thing but maybe it wasn't.

I mean, at some point, I think these guys are trolling us – (laughter) – you know, because our penchant for calling everything hypersonic and getting up and hot and bothered about it they think they can scare us. You know, folks have been testing maneuverable depressed trajectory, shaped trajectories, what have you, for a while now, including what, you know, is colloquially called the Kim-sander, kind of a Iskander-looking thing – the KN-23 or whatever they call it.

But so there are lots and lots of less predictable quasi ballistic things out there, and do they stress? Sure, because they, fundamentally, stress the lack of certainty about what your predicted impact point is going to be.

So, again, I see these things on a spectrum. I don't see it as a single thing. But this is why – and let me kind of tie this back, Steve, to your earlier question about kind of the scope of effort and all that sort of thing.

Stan said we don't have the luxury of just picking one thing or the other. We have to assume that they're going to attack us wherever and whatever constructive way suits them best. We have to contend with all that. We have to assume that the stressors, that the characteristics, are only going to continue to get worse. We want to get out there and glide phase in multiple layers and multiple simultaneous effects.

But we have to get – we have to assume that we need terminal effects as well because we're not going to be able to predict it even in glide as well. So, again, I see those particular things. I think we need to stay focused, keep our heads here. Those things aren't particularly new. Again, these things have been around for – since the dawn of missile age.

Mr. Trimble: So a question has come in. What is the single most important technological or industrial capability advance we need to make in 2022 to accelerate progress, and it says missile defense but hypersonic defense, in this case, capability?

Dr. Bussey: All right. Single most, I would say that everything we're doing in terms of the interceptors, the strike weapons, isn't going to make a difference

unless we have sufficient quantities. So having a dozen hypersonic missiles, regardless of whether they're really hypersonic or – isn't going to scare anyone.

So I think the biggest technological or industrial capability we can invest in would be to increase our production rates, particularly, of the thermal protection systems and additive – thermal protection systems for glide vehicles and additive manufacturing for cruise missile engines.

I think those are the long poles in the tent when it comes to production. Those are the things that take the longest. If we can reduce the production time and increase the capacity and, you know, double, triple, quadruple those production numbers, I think that's how we'll really make a difference, and those investments, I think, need to start now in order for them to be there when we're ready with a program of record or to start cranking out real numbers.

Mr. Trimble You know, can we expect any of those investments in the near future?

Dr. Bussey: I'm always optimistic. I don't know if those investments are what they need to be. But it's – I would expect it would be a pretty big number.

Mr. Trimble: OK.

Dr. Karako: May I make just the observation that the –

Mr. Trimble: Oh, sure.

Dr. Karako: – the PB-22 on that front was a good sign. I don't just mean the JHTO. But, you know, it wasn't like the trend line went down, right. This was a new administration, and I know you mentioned and Seth mentioned that meeting of the CEOs and the SecDef and DepSecDef last week.

But, I mean, that – those kind of things spell to me continuity of effort as opposed to discontinuity and a recurrence of the, you know, bounce back and forth thing that's been a problem in the past.

Dr. Lewis: So I was going to – if I can quote Richard Hallion for a third time. So Dick was the one who, I think, first pointed out this 15-year periodicity of hypersonics. And I know when I was in the Pentagon we were stepping up our hypersonic efforts. I was getting questions from industry, well, is it real this time? And I'd say, yes, this time it is real.

But to echo Tom's comment, I think the most important story coming out now is when the new administration came in they stayed the course. You know, the '22 budget was something that we had put in place when I was

in the building, and we were kind of waiting with bated breath to see if it held and, indeed, it did.

I'd like to see increased funding in a few areas. I think the JHTO should have its budget doubled. You can't say that. I can say that. You know, we need to continue pressing in a number of fronts. But, by and large, as a nation, it's pretty clear we're continuing to move forward in this area.

Mr. Trimble: I'm also curious on the allies and partners side where they can contribute to this type of effort. I mean, there's several different levels of that. There's industrial contribution. Australia is already on the offensive side of that. There's IP, that they can bring stuff that they are doing that we don't have. There's indigenous – you know, importing what we have or developing their own, and then just basing – allowing us to put our stuff where they are. You know, so to the extent what is – in that area what is necessary and what is being done?

Mr. Stafira: Well, from our perspective, I know that we engage with our allies. We've engaged with a number of them on different technology efforts. We're actually actively going out there and talking about things that they're interested in, things that we're interested in, to make sure we get mutual benefit out of that as we go and talk with our allies.

Certainly, we're looking for opportunities to be able to partner with them on different either technologies or capabilities. We know that we're going to operate in a coalition. We're always going to operate in a coalition environment. And so to be able to be better integrated with them as well and make sure that we're doing that integration efforts, agency is looking at that as well as when we talk to these guys and when we do testing with our allies.

Mr. Trimble: Can we expect to see a SCIFIRE, you know, like thing on the defensive side, or would that even be of interest?

Dr. Bussey: It's hard to say. What I'm really interested in in terms of – well, at least with Australia is they're the world experts in high-frequency radars and they have invested in a number of technologies there. They understand the phenomenologies.

I think there's a lot we can leverage there to have a diverse set of sensors to look at the threat and, I think, in general, what we can expect to see on the missile defense side is engagements like that, you know, use of their test range. It's a great place to test counters against hypersonics.

And just with our allies in general, in addition to basing there's always the concern that whatever we develop, whatever architecture we have, needs

to be interoperable and that our allies need to be able to use it as well, because, frankly, if we're going to go into the INDOPACOM region and there's a conflict, we're not going to be fighting by ourselves. We're going to have multiple allies there. They're going to be operating systems. They're going to be communicating across it, and so everybody needs to be able to use the same system.

So I'm not really seeing – I haven't seen the – a strong desire, you know, for a joint, you know, from scratch missile program. But there's, certainly, all these other opportunities.

Dr. Karako: I would just point out, I mean, this one of the reason(s) we really highlight the international cooperation thing. You see so much, I think, interest among Australia, Japan. Europeans tend to get their nose under the tent on the strike side. And then, you know, there's reports out there on the defense side as well. I would highlight the – about a month ago about Japan. I mean, they're kind of inching towards it, right, trying to figure that out, figure out what the right place is there.

But, I mean, I guess my prediction here is that, of course, they're going to get involved. They're going to want to get involved and probably not much longer for the simple, fairly basic, straightforward reason that, at end of the day, these are missiles, right, and as these things mature and proliferate, we're not going to call them, you know, fancy acronyms, hypersonics, or something like that. We're just going to call them missiles if they truly proliferate.

And so anybody who's interested in the act of defense mission is going to come around to having to be concerned with the active hypersonic defense mission if the trends continue the way they are.

Mr. Trimble: Well, one of the things I really enjoyed in the report was reading all the different things that you could do against a hypersonic glide vehicle, things I'd never even thought of. The dust defense was, I thought, really interesting. It reminded me of the old kamikaze approach where, you know, you just put up a wall of lead in the sky and let it fly into it.

You know, but I do have some questions about that. You know, how big is this, you know, cloud of particulates that you sort of explode in the air? Where does it go after it does its job against the hypersonic threat or if it does? Does it get sucked into turbine engines and how do you manage that? So, anyways, any thoughts about that and –

Dr. Karako: Look, what this is about is throwing up concepts that are designed, as I said earlier, to compensate for the uncertainty problem, designed to compensate for the error budget, as it were. And so it could be blast frag.

It could be particulates. It could be, like I said, like, different kinds of directed energy.

But the threat is getting harder. We're going to have to keep pushing in this direction. I think Mark may have some things to say about this. But these are aerodynamic objects, one of the reasons that hypersonic flight – sustained hypersonic flight that doesn't end catastrophically has been challenging as to managing that.

And so how can we monkey with the delicate flow problems that are happening at those high speeds? And I – interested to impose costs. This is an opportunity to impose costs on the bad guys with as many different problems as possible.

Mr. Trimble: Is there any – do you see dust defense fitting into the missile defense architecture at some point?

Dr. Karako: I don't know. I don't know. (Laughter.)

Mr. Stafira: Certainly, we're looking at a lot of different capabilities, kinetic and non-kinetic, and also near term and far term as we look at it. What can we get out there quickly to the warfighter as fast as we can – we're looking for capabilities like that.

We're also testing and evaluating capabilities that are more long term to be able to handle this threat as it evolves in the future. So, you know, could dust defense be there? I don't know. It's certainly an option, as is high-powered microwaves, directed energy, and kinetic kill vehicles. We're looking at all that stuff to see what makes the best sense as part of the architecture.

But we want to be able to make an architecture, again, flexible enough that I can take any of that stuff and be able to plug it in the architecture to be able to handle the threat in layers because, again, it comes down the layers – how do I layer that defense so that I can weed out the threat so that I make the end game easier to handle like we did in World War II with the kamikazes, which, I think, is a great example.

Mr. Trimble: Well, another example like that in the report is the modular warhead concept that, you know, could have submunitions, could have a kill vehicle, could have a sensor, could have an HPM payload. You know, I guess – you know, how far out is that kind of capability and is it – from a government perspective, you know, in your experience is it desirable?

Dr. Bussey So I would say we are interested in asymmetric defenses so, you know, things that impose the costs on the adversary rather than, you know,

result in a significant cost to us, because defense is expensive. These missiles – or our interceptors, we're in the hole. You know, architecture is going to cost more than it costs for them to launch their system, particularly if, you know, they could just overwhelm us with a number of short-range or medium-range ballistic missiles that aren't maneuvering.

So I think, you know, if dust solutions can provide that – you know, that cost benefit, I think we're interested. But, you know, as the S&T person, I have a number of thoughts and questions in my mind. You know, it depends on how you would employ this, if – you know, the way you employ it could, you know, really have a significant impact on command and control or how we actually use it.

You know, there's a lot of technical – you know, kind of niche technical areas that would need to be thought out and analyzed if we were to go down that route. But, I think, there's, certainly, interest just because it has the potential to be asymmetric.

Mr. Trimble: Sure. It's very – big – minute. Yes.

Dr. Lewis: So I love the idea of an asymmetric trade, a low-cost solution on our side that costs them. However, I will point out the most expensive weapon is the weapon that results in your losing.

So we have to pay it, and there are times when we are actually going to have to invest in the expensive weapon because it will prevent us from losing an even more expensive asset or, possibly, the engagement.

Mr. Trimble: I think, you know, today we covered a lot of ground on the interceptor side – the sensors, C2BMC, and just this whole idea of how the threat is evolving and what needs to be done and how to do it. So there's going to be a lot more written and talked about on this topic, I'm sure, in the future, so it's good to have this discussion today.

Thank you. Thanks, everybody, for joining. I think we just have a few seconds left before they turn us off. But it's been a great discussion. Thank you.