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PARTICIPANTS:

Moderator:

MICHAEL O'HANLON
Senior Fellow and Director of Research, Foreign Policy
The Brookings Institution

Panelists:

BRENNAN HOGAN
Program Manager
LMI

JIM JOYCE
Specialist Leader
Deloitte Consulting LLP's Manufacturing Strategy and Operations

JAMES KENYON
Director, Advanced Programs & Technology
Pratt & Whitney

DAVE LOGAN
Vice President and General Manager for Technology Solutions in Electronic Systems
BAE Systems Inc.

P R O C E E D I N G S

MR. O'HANLON: Good morning everyone, and welcome to Brookings. I'm Mike O'Hanlon with the foreign policy program here and the Center on 21st Century Security and Intelligence. We've got a wonderful event here today talking about defense technology, and I'm pleased to have a number of members of our national security industrial based working group from a number of America's greatest companies thinking about technology innovation across defense and non-defense sectors.

And I'll introduce the panelists in just a moment. They represent companies that have been part of our group in an important way for a number of years, in some cases more recently than others, but a lot of expertise on several topics.

I'm going to say a brief word of introduction about not only the panelists, but the topics. So, let me actually do that first. What we're trying to do is look at a few specific areas of defense technology and innovation that are ongoing today, and a lot of you have heard of the one we're going to begin with, which is so-called 3-D printing, or additive manufacturing.

But we're also going to talk about propulsion technologies, which in some ways are, you know, a longstanding interest of the U.S. military, and sort of a traditional and in some ways, old fashioned area of technology. And yet, one of very rapid and ongoing innovation. It's very central to the performance of our military forces, as well. And we're going to talk about software and the ways in which systems -- electronic systems, counter-measure systems, other kinds of systems that have a heavy electronics and IT component have to be thought about today; have to be improved.

All of this relates clearly to some big themes in defense budgeting, defense strategy. To what extent is technology changing so fast that we need to emphasize you know, pursuit of a revolution in military affairs perhaps even more than we have been? To what extent do we need to get on top of a new wave of innovation and make sure adversaries don't do it first?

Or, to what extent is this sort of an ongoing evolutionary process? And a lot of exciting and important things are happening, but we don't need to get overly excited or disruptive about our approach towards defense resource allocation. And in the broadest of all senses, this relates to the debate about sequestration or the defense budget, and what's going to happen to some of the programs -- some of the innovations that we're trying to facilitate or promote, if indeed, when Congress returns in a few weeks, it can't figure out some way to stave off this looming budgetary showdown with the president and the possibility of sequester or even shutdown, which these things are -- perhaps in a cosmic sense, they don't look all that horrible to the average observer, because it typically involves 5, 7, 8 percent of the defense budget. But the disruptive effects on programs can be much greater than that.

So, whether we get to all of those topics or not in our opening, we'll hope that you'll raise some of them in the discussion period. So, we're going to speak amongst ourselves for a bit. I'm going to ask each one of the panelists a general question about one of the areas of technology, and then, we'll talk a little bit up here before going to your questions.

Let me now say a bit of a word about each one of these distinguished panelists. Sitting immediately next to me is Brennan Hogan, with the Logistics Management Institute or LMI, and she is going to lead off our discussion of 3-D printing. And I'll ask her, since she's the leadoff hitter, to say a little bit more -- to explain what this area of technology is for those of you who don't know.

But it's an area that's being touted as a remarkable, important area of innovation that according to some people, could change everything, because we could produce technologies, manufacture technologies in ways that are entirely different from ever before, relying less on traditional factories.

To what extent that's partly hype, to what extent that's real, to what extent that applies more to some areas of technology than others, she will help us understand, as will Jim Joyce, who will speak after her and is seated immediately to her right.

And he is with Deloitte, and it's not a great deal about helping the Department of Defense think through how to take advantage of opportunities from additive manufacturing, again, in realistic ways. So, this is not future talk that we're going to do up here for the most part. Maybe a little bit of that.

We're trying to also think practically about what can DOD do in the short to medium term to take advantage of these areas of changing technology. Just to the right of Jim Joyce will be Dave Logan from BAE, another outstanding defense company, and he is going to talk about software and information technology and counter measures. So, he's sort of going to be the electronics guy, and I'll be looking to him to help explain how he defines this area of innovation, what parts of the defense budget, defense sector he is most focused on, and then what he recommends in terms of how we should pursue policy in this domain.

And then, finally, Jimmy Kenyon, to my far right with Pratt & Whitney will talk about engine and propulsion technology, but also, as our cleanup hitter, our Bryce Harper of the team, have a chance to say whatever else he thinks needs to be done to clear the bases and get ready for your questions, as we try to preserve this lead that the nationals enjoy in the National League East, and America still enjoys in defense technology, but we know neither lead is safe if we get complacent.

So, that's the general framing. Thank you for your indulgence as I went through a bit of background, but now I'd like to begin, as I said, with Brennan, and really ask her not only to help us understand what 3-D printing or additive manufacturing is, but to help us understand what its realistic prospects are in the you know, short to medium term for helping the Department of Defense over the years.

MS. HOGAN: Absolutely. So first of all, thank you very much, Mike, for having me. It's wonderful to be here today; beautiful day outside, luckily not too humid. And I appreciate all of the baseball analogies. I'm sure we can keep those going. So, just really quick to baseline. Additive manufacturing is not a new technology. It's been around for over 30 years.

There have been numerous organizations, both in the private and public sector that have been for using it. For those of you that aren't familiar, though, in the audience, how many of you have gone to build sand castles at the beach, either recently or in the past? A few of you. Okay. So, you can build a sand castle two ways. Right?

You can either fill up the bucket with sand and then put it down, and then you have parts of the sand castle or an entire sand castle, if you have one of those big buckets. The other way is, you can put sand and water into a bucket, and then slowly drip it -- a drip castle effect, layer by layer. At the end, you have two castles. They are similar in structure, but they have different makeup, and their components are a little bit different, but basically, the same. And that is what additive manufacturing is to subtractive manufacturing. Your old way of making a sand castle and the new way.

So, with that, what we're looking at at LMI is we understand the DOD, and especially their logistics and supply chain. And one of the things that we recognize is just because a new technology can provide a service, like printing new things, doesn't mean it necessarily should provide that service.

So, we're trying to help the Department of Defense understand at a strategic and policy level, what are all of the implications of applying this technology. And it's not just making sure that you have the machines to print the material or to print the actual parts. It's not just making sure that you have material that is chemically able to produce the part and make it the strength and the heat indices that you need, but it's what are the training and workforce implications of it; what are the policy implications? What are the standards that you need to apply? How are you going to assure quality? How are you going to test these parts? Do you test all of them? One of them? Some of them?

Do you test them in the field? Do you test them before they get to the field? What are the implications on essentially turning this supply chain on its head? In our traditional supply chain, you have the parts that are manufactured, and then you send them to the depot, and then, they go on to a piece of machinery or they go onto the field.

With additive manufacturing, they've already started -- the Army has already started deploying the technology, so you actually can meet the need where it is in the field. Does that work, though? And what are the skills that you need of the workforce that are doing that in the field? So, there are a lot of different implications. Another key area that we're looking at is the security piece of it. So, if you were printing parts using additive manufacturing, you have to have 3-D data. The Department of Defense does not own all of the data for their parts. A lot of that data is actually 2-D.

What is the conversion process for getting from 2-D to 3-D? Is it worth it? And then, who owns the data? Is it the OEMs? Is it the department? Is it someone else in between? And how does that all fit together?

And then, the cyber security aspect of it -- we're all very, very familiar with that. So, if you have all of this data out there that can bring these critical parts to key pieces of machinery or components, how do you secure that, so that it doesn't fall into the wrong hands?

So, that in a very quick nutshell is what we're doing and what we're looking at, and how we're trying to help the department think through the actual application of the technology, whether or not it's disruptive, and whether or not that's disruptive is actually effective.

MR. O'HANLON: So, let me just ask you one quick follow up question, and it will also be a segue to Jim, in a second. Thank you for that background. And by the way, OEM -- original equipment manufacturer.

MS. HOGAN: Sorry.

MR. O'HANLON: No, no.

MS. HOGAN: So many acronyms.

MR. O'HANLON: For our C-SPAN audience. And we're going to try to connect, as Brennan just did very well, some of these very innovative technology areas to the practical conversation. So, let me ask, how much of the DOD budget could realistically wind up in the additive manufacturing realm, let's say by 2020. And just to be clear about what I'm talking about, we all know that the procurement budget for the Department of Defense today is about $100 billion a year.

The research development test and evaluation budget is somewhere around $70 billion, and then, the parts of the operations and maintenance budget that are involved with spare parts and other things that do involve some purchases of hardware, that may be, let's say for round numbers sake, another $30 billion. So, we're talking about roughly, a $200 billion a year total enterprise.

Out of that, is additive manufacturing so revolutionary that we're going to start to see tens of billions of dollars of DOD acquisition produced through additive manufacturing in the next few years, or is it a much more modest incremental path that you see ahead?

MS. HOGAN: I will not venture to guess a number. I'm not quite comfortable with doing that yet. I think that the most effective way of applying the technology would be in a modest incremental way. And one of the things that we are actually helping DLA, which is the Defense Logistics Agency -- they supply all of the parts to all of the services -- hundreds of thousands of parts every day.

Some of those are very, very high in demand. Some are low in demand. Some of them you don't even need. You might need to replace the part every 10 or 15 years, and at that point, the original manufacturing may not have the tooling to create that part. So, there is a need or a potential use for additive manufacturing, but we're trying to determine where it might be most effectively applied.

Where we think, and this is a project we're actually working with DLA on now, is evaluating which parts can be produced with additive manufacturing, and still actually have the same functionality that they originally had. And with that, is the demand signal appropriate to print those parts? So, and then, again, do you have the data? Can you actually print it? And do you have the type of material and machines and 3-D process to get the part that you need at the end?

So, I think that our recommendation is that it is a modest incremental and more of a 10, 15, 20 year timeframe. But there are a significant amount of parts, you know, in the hundred thousand range, that you could potentially print, if you go through this whole process of evaluating the application of it.

MR. O'HANLON: Excellent. So Jim, if I could just turn things over to you to pick up where we are in this conversation, and you know, with one ongoing question in my mind being, just how big of a deal is this? And what's going to happen over the next 10 to 20 years, as we 3-D printing really come into its heyday?

MR. JOYCE: I would qualify it as an incremental deal for right now, but I would qualify my qualification by saying, a couple of things to bear in mind. The first is that the next hot toy at Christmas in the next two to three years is going to be additive manufacturing, and the sort of democratization of the ability to manufacture things.

The breaking of the tyranny of the scale of capital machinery and people required to manufacturing will be the basis of the profound revolution. It won't be so much a technical revolution as a logistical revolution. And additive manufacturing is a lead technology in that, but cheaper robotics information technology are going to break this tyranny of scale.

Now, what turns the spigot on? What's that hurdle we have to get over in additive manufacturing before we can unlock the sort of logistical revolution? It's really part certification. So, if I make a part on my machine, can I replicate that process and all its detail and result on another machine and be sure that I did it? Can I predict what the finite attributes and functional characteristics of that part are before I make it, and then when I've sent it somewhere else to be made?

Once you crack that code, and it has been cracked for some materials, but not a lot of other ones, you really unleash this technology. And why it will be propelled is because it's a cost saver, number one, and number two, it transfers resources from the tail to the teeth. Though, as an analog, I would say the industrial revolution essentially tethered maneuver units to an industrial base. Railroads, pre-significant supply chains, roads, et cetera.

If you go pre-industrial revolution, and you look at the way a ship of a line operated in the Napoleonic Navy, it essentially, once it was at sea, if it had a good carpenter and a good metalworker, could stay at sea indefinitely, making ports of calls to pick up material to repair the ship, modifying the ship, transforming its abilities. In fact, when a new captain took over a ship, it was sort of axiomatic. The first thing they did was, they talked to the carpenter, redid all the rigging and sails to try and get some more speed out of it.

So, what additive manufacturing starts to do is it breaks that tether to a heavy industrial base required support maneuver units. How does it do that? Well, if you look at a machine shop on board a ship, a field repair depot -- they have a certain envelope of capabilities that they currently have to manufacture and repair things. And what additive manufacturing does, supported by other technologies, is it greatly increases that envelope, because you're working more from raw material than you are from already fabricated parts, that you have to predict their consumption, have them on hand, carry them.

So, the revolution comes when you can certify the results of the additive manufacturing on a repetitive basis. It comes because of the logistical pressure. It takes off newer units. But it also comes, because in an environment of constrained resources, you're likely to see innovation going on in a -- the way that it used to be done, again, which is with the maneuver units in the field.

So for example, with additive manufacturing, many of the SOCOM units will deploy with it. And they've come up with a number of innovations that include things like a dog bone to keep antennas apart, field hospitals needing unique equipment to treat unique wounds are printing specialized clamps and surgical guides to take care of those, as well.

So, you've got this logistical component to it. You have this innovation component to it, which is really, I think, tremendous. And there are sort of first derivatives of both of those, which is there is this notion of hacker -- warfighter as hacker. So you know, I've been around for a while, and I can remember cutting down M79 grenade launchers and putting pistol grips on them, so they could be used as a sidearm.

That sort of innovation, all of the sudden, kind of innovative spirit, not only has a much wider capability of manufacturing options, but also, through social media and communication, can be spread a lot more quickly. So, I think you'll see a lot of innovations start to come from within the maneuver units themselves, within the far fighters and bubble up that way.

MR. O'HANLON: So, let me follow up with you with one quick question before I go to the next subject with Dave. You emphasized, I think in a very vivid way, a very helpful way, the benefit for expeditionary units of additive manufacturing. Is that the primary benefit, or are we also going to see traditional manufacturers here at home move in this direction, just because they can somehow make something more economically, more flexibly with less tooling in their factory? Or is that whole set of changes going to be more gradual and less dramatic than the benefits to the expeditionary units?

MR. JOYCE: I think that sort of change is going to be more gradual, simply because manufacturing accounting systems work against additive manufacturing; that the way you calculate the economic benefits of additive manufacturing runs contrary to the way a lot of additional manufacturer calculate their own economics. They need to take a broader perspective to it.

What I think will happen, though, is you're going to see the rise of imitative individuals and companies that are producing, beginning with obsolete parts, and then frankly, going into mainstream parts as we start to sort out what is protected and what isn't protected legally. And manufacturing increasingly becomes a commodity where folks can just get in. They don't need as much money. They can set up a very capable machine shop and manufacture things that traditionally were done by very large defense companies.

So, I see that change coming as a result of internal competitive pressures within the defense industry as opposed to an evolution and revolution in how large companies act.

MR. O'HANLON: Thank you. And Dave, if I can go to you. I know you're going to now bring to the discussion a little different area of technology. But of course, Jim and Brennan before have been talking about how additive manufacturing is really part of a broader set of changes. So, maybe you can help connect what you're going to talk about to what we've been discussing.

But I know you've got the whole IT, software, and adaptive software world and subject matter to address. So, please help us understand that -- a little bit of introduction, and then, how you see the opportunities going forward.

MR. LOGAN: Sure. So, I think that many of the motivations for these adaptive, sometimes called cognitive, software systems share similar inspiration here. Right? We want to be able to reduce the cycle times. We want to be able to provide capability much more quickly than we've had to in the past.

In the past, we were able to analyze, for example, threats that are out there and design systems that give us a competitive advantage; work through our acquisition cycles and get out there with some of that advantage preserved, based on those time constants. Right? Our adversaries are increasingly migrating to commercial technologies. Like us, they are moving away from intensive, exquisite kind of hardware solutions and driving more of the content than these weapon systems into software, which just makes them inherently more agile.

And so, we are doing similar kinds of things. Right? If you look at radio systems, if you look at electronic warfare systems, we're getting digital closer and closer to the front end of those systems. Right? We're also investing in sort of all the buzz words that you hear, about modular architectures, you know, spiral development.

But that's only going to get us so far. Right? We're still going to get to the point where we are fielding capabilities that are going to run up against environments, threats that are ill characterized at the time of design. Right? And so, the thought here is that you architect systems that draw from the cognitive kind of analogy here, where they have an ability to sense the environment.

Maybe I'll motivate this with a communications example. Right? So, if you were to take a radio of 15 or 20 years ago and crack the lid, even a radio like you have at home, what you'd find in there is circuits, you know, transistors, maybe some ICs in there. If you were to look at the state of the art radios today, most of the functionality that they provide actually lives in the software. They're software defined radios.

And so, we have the ability to upgrade them over time very quickly. Right? But when we put one of those out in the field, and maybe we get exposed to some interference that we didn't anticipate, the desire and the potential of things like, you know, cognitive learning is to go out and figure out mitigation strategies in real time, sense the environment, explore options within the trade space of the as designed system to configure it in different ways and be able to mitigate that interference, whether it's from an adversary's jammer or whether it's just environmental interference that you're running up against, and learn over time, which approaches actually work.

And do that in mission time as opposed to acquisition time. Right? So you know, this probably falls broadly under the umbrella of autonomy and some of the key areas of investment that the DOD is pursuing. We're applying that across many of our products in our portfolio. The radio example is actually one example that's real.

And the idea there is that we can come to the field with systems that are inherently adaptable. Most of that adaptation right now we see occurring within the software base. Right? You can build systems that characterize the environment, understand how they can operate in different configurations, and then optimize their configuration in real time. Right? But you could think about taking that same kind of design pattern and asking, is the limiting factor on the performance of the system an algorithm or configuration, or might it be -- against the radio example -- might it be the antenna that we're actually using that was designed much earlier.

If it is the limiting factor -- and then, we can look to things like potentially additive manufacturing, right, to be able to rapidly prototype potentially even you know, in field situations, alternatives that we could then you know, integrate into the system and allow the cognitive processing to figure out how to better exploit a more tailored version, for example, of that antenna.

MR. O'HANLON: So, this sounds like a realm of activity that could influence a large fraction of DOD's systems that are in the field today, even though it may not -- I mean, I'm trying to, as you know, simplify by using sort of the amount of dollars at stake as one of my metrics for the conversation, just to help unify the different themes.

But it sounds like you're talking about the wide array of systems that BAE and other systems manufacture. Right? So, the software and electronics guts of most of our advanced weapons today are the realm of discussion here.

MR. LOGAN: Yeah. I mean, as I said earlier, increasingly, the amount of content is driving towards the software content. Right? I mean, there's no magic bullet here, in the sense that you know, with that adaptation, you inherit other kinds of challenges that you have to address. Right? How do you make sure that these systems, as they're adapting in the field, continue to provide the kind of behaviors and performance that you want? Right?

So, there are some issues that still need to be resolved. You know, predictability of the performance, stability of the performance, those kinds of things. But when we're in an environment where you know, our adversaries are able to you know, increase their cycle times or decrease their cycle times, rather, very quickly, we need to be able to respond just as quickly.

MR. O'HANLON: Could I ask too, one more question that occurs to me as I hear you explain this subject, is the difficulty of writing good software for modern weapons systems -- the complexity -- is what you're talking about a partial response or solution to that, in the sense that, are you -- and maybe I'm getting this wrong, but it sounds like you're talking about an ability to continually modify and adapt, and therefore, not be locked into your system that you started with.

And that could be beneficial if your adversary does things you didn't anticipate. But it could also be beneficial if you made mistakes in the original incarnation -- I don't mean BAE, but I mean in general (Laughter), if there were some software problems or other problems, that we could fix them more easily as we discover them in the field. Is that a fair --

MR. LOGAN: Yeah. I think that we see as many of the software challenges that we find today are just you know, very complex systems that have to be implemented. And I don't really see this as a technology that's going to make our software better, you know, than our coding disciplines. But there is often a challenge associated with how well we've characterized the objectives or the desired performance.

And at some point, we have to look at that down. Often, today, that's locked down in a fairly rigid kind of a way. So, I do see this as an opportunity for us to have a kind of broader ability to adapt, perhaps, to you know, environments that we couldn’t perfectly anticipate.

MR. O'HANLON: Great. Thank you. And Jimmy, Pratt & Whitney, of course, and United Technologies more generally, very important engine manufacturers across the defense and civilian sectors in the United States and around the world today. You folks know as much about engines as anybody, and you're kindly offering to help us understand some trends in engines and propulsion. So, if I could turn that over to you. Thank you.

MR. KENYON: Thanks, Mike. And I think it builds on what we've heard already, because as an engine manufacturer -- that's what we do at Pratt & Whitney -- we make jet engines. As an engine manufacturer, we use things like software, and we work on how we improve our software and make our software more adaptive. We look at techniques like additive manufacturing and how we can make our jet engines faster and better and less expensive.

But at the end of the day, we also see this adaptability, if you will, rolled up at a higher level. But I think to really understand it and to put it in context, I want to talk a little bit about defense strategy, because what we're looking at is in 2012, the DOD released what was, at the time, a very new and different defense strategy that called for, among other things, a smaller, more agile, more flexible, more technologically advanced force.

And now, even as we're transitioning towards a third offset strategy, we still a lot of very consistent themes there, as the department tries to get more and more out of the systems that it buys and fields. We're seeing the same thing in propulsion, in jet engines for aviation. And that's important.

If you follow along -- of course, I do jet engines because I love the thrill of the roar when the jet engine goes, but it is a bedrock of our national military strategy, and then really part of how we do power projection around the world. And aviation has advanced tremendously over the years, but every really significant breakthrough we've had in aviation, especially in tactical, military aviation, has been built upon an advancement in propulsion technology. And right now, as a result of investment in the strategy, we're on the cusp of another breakthrough with the introduction of adaptive engines.

So, what do I mean by an adaptive engine? Let me give you an analogy. It's a timely analogy. If you watched the Tour de France, you've watched cyclists from around the world trying to negotiate a 3,300 kilometer course across France; widely varied terrains. Sometimes it's flat. Sometimes it's hilly. Sometimes it's plain old mountainous. Okay?

And all of these guys have the same goal, which is to get there first. But to get there first, they have to be efficient, because they have to sustain themselves and their bikes for 3,300 kilometers. That's a long way. How do they do that? Well, they manage, if you will, the gears on their bicycles. They change the gears. They optimize the performance of the bicycles and the performance of themselves to adapt to whatever the terrain offers, wherever they are on the course. And that's how they make it work.

They do it, obviously, at a level that we can't, but that's a different discussion. We're trying to do effectively the same thing in jet engines, and we're partnered right now with the Air Force on a major program called AETD, or the Adaptive Engine Technology Development program. But traditionally, a jet engine consists of two main streams of air. You'd have a course stream, which goes kind of through the center of the engine -- and its primary purpose -- it produces a little bit of thrust, but its primary purpose is to power the rest of the engine.

And then, you've got bypass, and that really is what produces thrust. But when you design an engine, it's a single point design. You say, what is the most stressing requirement I have to meet, and you make sure your engine can meet that.

And everywhere else, you take a penalty, usually in terms of efficiency. And efficiency means range, it means payload, it means fuel burn and all of those sorts of things.

What we're doing in this adaptive engine program is introducing a third stream of air that we can modulate. And by modulating it, I can adapt or optimize my performance, no matter what the flight conditions are. And by doing that, I get tremendous improvements in overall mission capability, mission flexibility, range, payload, capability overall. So, it's a big deal to be able to do this.

Now, that doesn't come without challenges, as you can imagine. Adaptive engines aren't new. We've been doing it a long time. We invented or we created the J58 in 1958 -- really, the world's first adaptive engine, and the reason we did that was so that that airplane could take off, mock zero starting off, and then, propel up to incredible flight speeds sustained above mock three.

More recently, we're getting ready to field the F135 to power the F-35 Joint Strike Fighter. And if you're watching that, you know that the Marine Corps version, the F-35B, is able to operate in conventional flight, as well as transition into a short takeoff in vertical landing mode. Well, what happens when you make that transition is you introduce some really profound changes in how the engine operates, but the engine adapts to that, and by adapting to that, is able to seamlessly accommodate those changes in what it's doing.

Well today, what's different about what we're doing is where you look at those two programs or those two engines -- they were meant to adapt to specific parts of flight, whereas this AETD program adapts everywhere. And so, it adapts across the flight envelope and really gives you the full benefit of efficiency throughout, and you can maximize the capability of your airplane.

It has a lot of technical challenges. We've had some design and architecture challenges. We have a very constrained configuration. We have a requirement that it must be three streams and it must fit in a certain size. And by doing that, it forces some tradeoffs you might have to make.

We're pushing the envelope on temperature, so we have technical challenges in terms of how we work on the materials and the coatings and the things we do to withstand those temperatures. We have challenges in software -- much more complex control systems. We have to work on the software challenges in manufacturing.

Some of the parts are very complex. They require some new ways to make components, and we evaluate those. And in the bigger scheme, we evaluate all sorts of advanced manufacturing techniques, including additive manufacturing. And then of course, on top of all of the technical challenges, we're also trying to do this in a time when we have very tight budgets, and we have a lot of things going on in terms of acquisition policies and procedures.

But we're very being very successful. We're being very successful. The program overall is proceeding well. Our design is proceeding well. We're projected to meet all of our performance goals, and we're projected to meet cost targets and those sorts of things. On top of that, we are right now, working with the Air Force to plan the next program, the Adaptive Engine Transition Program or AETP, if you like those kinds of acronyms. And that's a $2 billion investment by the Air Force with ourselves and with GE, to develop and mature these designs even further.

And I think the reason I mention that is that it underscores -- underscores the importance of this technology going forward, and it's a recognition of the importance of adaptive technology at the “how do I make things work level”, all the way up to the system level as part of this overall defense strategy.

So, it's really exciting. There are a lot of great things going on between additive manufacturing, adaptive software and how these play into the systems we field. And I think we're on the cusp of some really big breakthroughs that are part of the defense strategy that emerged just a few years ago.

MR. O'HANLON: Thank you. And this sets up my -- I have one more broad question and maybe a couple of smaller derivatives of that, before we go to all of you. But I'd like to now broaden the scope. You've all done a great job of explaining a certain number of specific technology areas, innovation areas. What I'd like to do is now ask you to reflect on what it all means in terms of the overall character of defense innovation today.

Are we in a period of revolutionary change? Are we in a period where there are a lot of exciting things in various specific domains, but they add up to sort of more or less continuous rapid evolution? That's going to have implications for how to think about the defense budget, whether we should be fundamentally rethinking how we allocate resources, whether we should be -- you mentioned the third offset.

And just to explain, this is the idea that now, at this day and age, we need to think about how to take advantage of our technology -- areas or excellence, just as we did with nuclear weapons in the early Cold War period, just as we did with so-called air land battle and precision strike in the late Cold War and Desert Storm period. The third offset would ask to what extent can we do the same kind of thing now with the rise of China and Iran and cruise missiles and other kinds of threats to our systems, and take advantage of a lot of the things we're hearing about today to give America yet another leap forward in technology excellence.

Maybe you would define it differently. I'm going to invite you to in a second. But the question really -- and I'd like to just work down the panel on this and ask anybody who wants to venture an opinion, how do you think about where we are today in

2015 in defense innovation, you know, viewed in a broad, historical sweep?

Is this a period of revolutionary change or is this a period of sort of important but evolutionary change that's more or less continuous with what we've been seeing in the past? I mean, new things are constantly happening, but the pace of change is similar to what's been the case in the past. So, I'm not sure if that's a, you know, overly philosophical question, but I think it has a lot of real world implications, so that's why I'm putting it on the table and turning it over to you, my friend.

MS. HOGAN: So, I think that if we think about just generally the way technology has evolved in the last 10 years, you think of the invention of the telephone and how we've gotten to smart phones. But then the invention of the cell phone and what we've gotten to today, with hand held computers in our pocket, essentially, things are just moving at a much more quicker pace than they did since the industrial revolution.

The other part of it is that I think that there is a recognition that with all of the problems that the Defense Department is facing with constrained resources, a transitioning workforce -- you have a great deal of people who are retiring. There's a knowledge transfer issue. You also are faced with new threats abroad -- the changing landscape of foreign policy and national security, ISIS, rogue foreign states, all of that.

You can't just throw technology at the problem. That's not the solution. You can't throw money at the problem. You also can't throw technology at the problem. So, I think that there is the potential for revolutionary change, but in order for it to be most effective, it should be a thoughtful and considered evolution, and it should take into consideration from a philosophical or strategic level, all of the potential implications across how you support the warfighter and how you support the mission, and how these new technologies, whether it be new jet engines or adaptive software or additive manufacturing or nanotechnology or different ways of securing our cyber systems, and how you do those in a way that is actually considerate to the mission that you're trying to support and the new threats that you see, both internally and externally.

And so, I think there is definitely a potential for revolutionary change, but in order for it to be considerate, it should be an evolutionary change.

MR. O'HANLON: So, the revolution might be what you get when you look in the rear view mirror, but it's not the goal you set out initially.

MS. HOGAN: Right.

MR. O'HANLON: You don't try to make a revolution.

MS. HOGAN: And things like what Jim was talking about -- I mean, I think one of the key factors where it might be revolutionary with additive manufacturing, is the innovation aspect of it. So, when you deploy an additive manufacturing machine in the field and you have the capability at the point of need, so at a FOB, at a forward outpost base, or at a depot or on an aircraft carrier, or on a submarine or in the International Space Station, and you can actually create things that you didn't already have, because you've realized that you have a need for them, and they didn't exist in the supply chain.

And now, you have this new technology so that you can create them and you can actually use them right away. I think that's where the revolution could potentially come from. And that's where we see the greatest potential currently. I think the evolutionary change for things like determining which parts out of the hundreds of thousands of parts DLA provides to the services are the ones that they're actually going to additively remanufacture is more of an evolutionary change.

MR. O'HANLON: So Jim, if I could turn to you for the same question, really. Where do you see the current pace and character of defense innovation in the United States today?

MR. JOYCE: I would characterize it as we are on an evolutionary path, but that we'd better get onto a revolutionary one. There are structural impediments within the procurement process, within the funding process, within the way that we look in R&D that really keep us from the speed and scope of innovation whose potential is there.

Now, that's been recognized among certain corporations -- that GE, for example, saw that their household products were taking too long to develop; that they didn't really exactly fit what customers wanted, so they set up what's called a hacker space, which is kind of a play pen of machines for people to try and innovate.

You'll see these dotted around major cities now. So, there is a sort of democratization of ideas, of manufacturing capabilities innovation that is really driving the next wave in the commercial economy. And the revolution will come, I believe, on the defense side when they start to tap into that. And the best ideas can come from anywhere.

So, one of the ways that I talk about it is, I spent a large part of my earlier life disagreeing with people who thought the workers should control the means of production. Now, the workers do control the means of production, and we have to recognize that and unleash them, so that the best ideas, the innovation, the adaptability isn't coming through traditional hierarchical organizations or structure. It's coming up through a bubbling up of these innovative, very free flowing ideas.

And oddly enough, as I work with these hackers, one of the things that comes up consistently is a lot of them are former military, usually from some kind of a SOCOM background where the value of just getting stuff done is extremely high. So, I think we're on a path which is evolutionary. I think we need to get on one which is revolutionary, and I believe that comes when we start to relook at the way that we are fairly hierarchical and rigid in the way that we innovate and procure. And that needs to change, if we're to really take advantage of the potential of the country's economy and innovative people.

MR. O'HANLON: And this raises the subject of acquisition reform, which as many of you know, is something that Congress is also trying to work on this year. So, I hope we'll come back to that a little later in the discussion. But in the meantime, same question Dave, over to you. How do you characterize the nature of defense innovation today in broad, historical perspective?

MR. LOGAN: Yeah, so I think there's a real opportunity and there's a really compelling need for us to be able to accelerate the way that we're driving new capabilities. I don't -- leveraging the technology, but the challenge is that we need to be more deliberate around the way that we are experimenting with this technology in the hands of the warfighters.

And some of the dialogues I have been with you know, some of the leadership in the DOD, there's a renewed sort of enthusiasm around taking emergent technology and the warfighters, getting together -- pulling that recipe together and doing some experimentation, right? Where we're really trying to figure out what is the potential of the technology whole? But in many ways, the technologists, like myself, I can't anticipate how the operators, how the warfighters want to use it.

And they have far better ways of employing it than I could ever conceive of. Right? And so, it's this sort of iterative, brainstorming process around a structured set of experiments that allow you to adapt the evolution of the technology, the evolution of the con ops and the tactics, techniques and procedures that you're going to use to employ the capability in a way that allows you, then, to feed that back into the acquisition process, and basically, you know, tighten up that cycle time.

So, it's this thought around maybe co-evolution of the solution, where the technology and the warfighters are kind of working together through a set of experiments to kind of drive new capability out into the field.

MR. O'HANLON: Do you have an example of the kind of thing you could be talking about? I mean, just a very practical way to think about?

MR. LOGAN: Yeah. A good example of that. So, one of the other areas of technology that we work on, is multi sensor fusion of data, where you basically take feeds of data from you know, radars, imaging sensors -- you know, all kinds of different sensors, and bring those together.

And you know, typically, the technologist will want to wring every single ounce of information out of every bit of data that comes through those sensors there. And then, what we find when we kind of engage more strategically with the operators is, first of all, that's a fairly intractable problem, to try and get all of that out of the -- all that information out of every sensor, all the time, everywhere. Right?

But there's this nice sort of positive feedback when we're working the operators. They don't think of problems that way. They think about areas where they need more information, where they need a little bit less information, tips and cues from one area to the other. And so, it really drives a different thought process around how you architect things when your customers, the warfighters here kind of visualize and conceptualize the environment differently than just where the technologist would go, which is you know, maximize sort of everything in the system capability.

MR. O'HANLON: Listening to the two of you -- I'll just give another example that occurred to me. I thought of armed drones, because armed drones were something that the Air Force didn't really want to do a lot with in the traditional period of the 1990s. And it took a war environment, which was sort of the real world version of you know, experimentation and evaluating warfighter need, to push, first the CIA, really, and then, ultimately, the Air Force and the services to finally overcome that bureaucratic resistance, to think creatively, bringing together technologists with warfighters.

But we're not going to hopefully have quite as much fighting to do. Let's you know, God willing, in the next five or 10 or 15 or whatever number of years. So, we have to figure out a way to have the innovation without the wartime push. Is that a fair example?

MR. LOGAN: Yeah. Yeah, I think it's a good example.

MR. O'HANLON: Jimmy, same question over to you, but let me precede it with one vignette from an event we had here in April with Bill and also Frank Kendall. And Frank Kendall, as many of you know, the under secretary of defense for Acquisition, Technology and Logistics, Bill Lynn, the former deputy secretary of defense, now CEO Finmeccanica, American branch. And Frank Kendall went first.

And I asked him, how would you evaluate the strength of the American acquisition system today? And he said, it's pretty good. We make the best weapons in the world, and I'd say it's at least a B+, maybe an A-. And he gave a lot of -- obviously, he's pushing reform, and I'm not trying to say he's complacent, but he thought we were still doing pretty well.

Bill Lynn got up later -- same question. And he said, I agree with Secretary Kendall for major platforms and maybe for engines. He didn't say that, but I'm surmising maybe that's the kind of thing he's thinking about. But I don't think that we do very well with electronics, wherever Moore's Law is relevant, wherever adaptive software may be relevant, and on that kind of a thing, we need the revolutionary acquisition reform that Jim was talking about earlier. So, I'm blending here and paraphrasing.

But to put the question to you, is it fair -- because we're hearing a couple of different things. We're hearing some people say you know, this is a period of rapid innovation in some sectors, and it should be even faster, perhaps. But you're also talking about ongoing improvements in propulsion that your company has been doing for decades.

MR. KENYON: Mm-hmm.

MR. O'HANLON: That struck me as still very impressive, but maybe not any more rapid today than they were five or 10 or 15 years ago. So, help me understand. Is the pace of innovation very fast in some areas, slower in others? How should we think about this holistically?

MR. KENYON: I would argue that the potential for revolutionary advancement is absolutely there, and I think we've heard that already, with some of the things we've talked about. Where we are, though, is that we have a system, an acquisition system that is ill suited to deal with that. Why? You can sum it up in one word, and that's complexity.

All of the things that we talked about this morning introduce complexity, and there are other things that introduce complexity. We'd heard about the various things that you can do with additive manufacturing. Okay. How do you manage that strategically? That adds complexity to it.

Everybody would argue that the more software you have, the more complex a system is, and so therefore, software means complexity. The engines we're talking about are more complex. And when you look at all of these things together and a whole myriad of other technologies and other things that we're doing, it adds complexity.

Now, add to that globalization of the industrial base, globalization of the supply base, globalization of the customer base and all of these various things. All of that adds complexity. Add to that many of the new threats and things that are moving at different paces around the world. That all adds complexity. And then, when you put all of this together, and then, oh by the way, add the budget environment we're in, and the uncertainty of funding from year to year, and the uncertainty of requirements from year to year, that all adds complexity.

And what happens there is, as you begin to add complexity, we have a system that doesn't really handle complexity very well. It's very risk averse in that sense. And why? Because these things cost money, and these things cost taxpayer money, which the department is trying very, very hard—to manage as effectively as it can. But what that does is, it adds a risk aversion into the acquisition process that makes it very hard to introduce some of these more complex, but much more revolutionary capabilities very rapidly.

We have no tolerance for failure. We have a system that is more willing to tolerate a budget increase than a performance shortfall, and we just keep adding this and adding this. And so, things take longer and they cost more. And as a consequence, we end up, instead of getting the revolutionary things out there more quickly, we take more risk averse approaches, we go for more off the shelf type of technologies, because they are theoretically less risky, and we take more incremental approaches, because I have a lot more confidence that I'll get there. But even at that, I end up taking longer and costing more because of the complexity of what we're dealing with.

MR. O'HANLON: Thank you. And that's going to lead -- I have one question that's derivative of that before we go to all of you, and it does relate to the ongoing question of acquisition reform as it's being considered on Capitol Hill. And this will give a chance for anybody who wants to weigh in on this, to please do so.

But I'm going to put the question in the following terms. As it's been explained to me, one way to think about the debate on Capitol Hill and why the problem is hard to solve there, as well as for the broader defense community, is that there are at least two competing ways to think about the number one priority of acquisition policy. And one is to make sure the taxpayer doesn't get ripped off, and we minimize any kind of potential for the $600 you know, hammers of the Chuck Spinney days of the 1980s. And we want to have as much oversight to make sure that doesn't happen.

Another strand of thinking says no, if you overdo that, you're just going to have so much regulation and so much sort of dead weight sitting over corporate America, that a lot of companies aren't going to want to even work for DOD, and those that do are going to spend most of their creative juices figuring out how to comply with regulations, rather than designing new technology.

I think I just heard you say that you would probably concur with the school of thought that says we'd better be careful about over regulating and over monitoring, not that we're trying to encourage a lax environment, but if we put too much regulation, too much restriction on companies, they're going to fail to innovate. So, I want to make sure I heard you right, give you a chance to say anything else you want to about where we stand with acquisition reform today, and then, work down the panel for others' comments.

MR. KENYON: Well Mike, I think the truth is somewhere in between. I think if you deregulate too much, you do run the risk of the taxpayer getting ripped off. I'd like to think, certainly on behalf of my own company, but I like to think most defense contractors are very mindful of their responsibilities to our ultimate customer, the warfighter and the American people. We take that commitment very seriously.

But by the same token, we don't always agree on a business basis with what our customer wants to do. And that's a natural thing that's going to occur in any sort of relationship like that. But that being said, you clearly don't want to create -- the government has a responsibility to the taxpayer to be fair and to be transparent. You have to do that.

Now, the question becomes, how can you do that, but at the same time, give industry the flexibility to do what they need to do? I don't know that there's a good answer, which is why acquisition reform has been a buzz word for decades, and continues to be something that we continue to strive for and continue to struggle with. But I would say that that's probably the hard problem of the century.

But nevertheless, it's something we have to continue to strive to get better, because there is a balance there. There is a balance between letting industry innovate, letting industry take responsibility and put goods into the hands of the warfighter that meet the warfighter's needs, but then, making sure that the responsibility to the taxpayer is upheld.

MR. O'HANLON: So, before I go any -- Dave, let me just follow up with a very specific question. Is there one word -- based on your current understanding of where Congress has left this debate as it's leaving town now, July 31st, 2015, is there one word of advice you would give them to push this process to the next realistic level, knowing we're not going to have a silver bullet; we're not going to solve it once and for all, but based on your understanding of where the debate is right now, one thing you'd like to see people do, one word of advice you would provide.

MR. KENYON: The one thing I would suggest is to understand the difference between business and government. And in understanding the difference between business and government, understand that you can't run government as a business and you can't run business like a government. And if you can understand the differences between the two, and draw the differences between the two, that helps to settle that relationship.

MR. O'HANLON: Thank you. Dave, any thoughts on acquisition reform policy where we should be going?

MR. LOGAN: Yeah. So I think likewise, we take our responsibility there very seriously, as well as I think most of our peers do. I do think also, it's about balance. Right? At either extreme, you get the kinds of behaviors that none of us want. Right? So in addition to finding where that right balance is there, I think we also need to step back and reflect a little bit on the kind of acquisition objectives that we want to have as we see the cycle times and the kind of technologies coming in. Right?

Being able to acquire things that you know, incrementally add capability over time. Right? It's a different kind of acquisition that you do there. So, in addition to kind of getting that set point right, and we have a joint responsibility to our customers to help make that happen, it's also sort of reflecting a little bit more on how these iterative incremental enhancements help us with our budget pressures, help us get capabilities into the hands of the warfighters more quickly. But there's challenges associated with how you acquire those kinds of systems.

MR. O'HANLON: And where does that have to happen? Where is the number one roadblock now? Is it in existing law? Is it in the culture of the military services? Is it in the nature of the acquisition workforce? I'm sure you're going to say it's a little bit of all of the above, but if there's one community, one part of the process that's most in need of fixing today, or innovation, what would that be in your mind?

MR. LOGAN: Yeah, I mean, I think it is in a little bit of all of those areas there. I think that you know, the technology and the future capabilities don't necessarily respect the organizational constructs that we have right now. So, increasingly, you know, technology is forcing us to think about acquiring things that involve you know, varied stakeholders in ways that we haven't had to bring them together in the past. It's just the way it is. Right?

And so, part of it is just the communication across folks both in industry and government that form that stakeholder community that have not regularly actually been working to acquire those kinds of systems.

MR. O'HANLON: Jim, you called for more revolutionary change. Do you see a way to make that happen, to catalyze that in the context of this conversation?

MR. JOYCE: Yeah. I think we just heard a million dollar comment here, which is the technology doesn't respect the current kind of organizational structures and the way that it was adapted. So, I don't know when I -- you know, you could have a pretty good argument about what era our procurement system harkens back to, and some people would say it's a civil war, essentially model, and it's about mass and resources.

Well, we need a procurement system which isn't about mass. We need one that's about the adaptability and knowledge continent effectiveness of what we're procuring. And to do that, I think what we really need to do is look at the procurement system not so much in terms of whether we have enough regulation to protect the taxpayer or not, or you know, are we acquiring the right weapons systems?

We should look at it in terms of how do we widen the base of the sources and the resources being used for developing and delivering these systems? So, when I talk to some of the leading folks in private industry about their technology and how it's being used by the Department of Defense, they repeatedly say to me, you know, there are a lot of folks out there, folks like the Chinese, that are much better at taking innovation wherever it is and effectively militarizing it--bringing it in.

So, I think that our system is one of -- in some ways, our kick procurement. It's about programs. It's about acquiring large capital expenditures. It's not driven by innovation or adaptability. So, if I were to counsel the folks that are going home on vacation, I might tell them not to come back (Laughter), but I would also say, the game has changed here. Okay?

It's not about massing resources and allocating budget. It's about accessing the full continuum of innovation and effectively militarizing it as required. You know, ultimately, the responsibility is not around protecting taxpayer money or executing big programs. It's about winning. And a lot of folks in private industry will say the transition of civilian technology or technology wherever it is into military use -- we're losing our lead on that, just because of the sheer weight and the wrong model. The model doesn't respect the technology.

MR. O'HANLON: So Brennan, over to you for any thoughts you've got. But I guess one question that occurs to me is, you know, is the glass half full or half empty, because we've got contending themes in our conversation. Not really debates, one person against another, but there are themes that are saying, we're making the best stuff in the world. We've got the best stuff in the world. We're doing interesting things across the domains that you all have been discussing this morning.

And yet, at the same time, we're bureaucratized. We're ossified. We don't really innovate, especially in peace time very well. You know, do you have a bottom line view on whether the glass is half full or half empty, and what we should do about it?

MS. HOGAN: That's actually a perfect segue, because I was trying to think of one word I would apply, and I think it's two words. And I would counsel Congress on being realistically optimistic, which is a way of life that I try and ascribe to. You can't have everything all of the time, and you can't think that everything is going to be going well all of the time. But you can be realistic about the potential.

And I think that all of the organizations that we represent, we really do have the taxpayer in mind, and there seems to be a struggle between those of the current leadership on the Hill and their understanding of what the industrial base is trying to do, and whether or not they have actually the warfighter's best needs in mind.

LMI was founded, actually, because Secretary McNamara recognized the need that someone outside of the Pentagon needed to look at the logistics issues that were facing the military 50 years ago, and see it in a different light and try and solve those complex problems. And we have since continued to support that mission.

And one of the things that we continue to try and do is look at innovation as a way to support the mission constantly. And there is a great spirit -- not to get philosophical, but I will -- in this country of entrepreneurship and innovation. And that is what will drive the potential solutions and the potential evolution and revolutionary opportunities that there is. And I think that trusting that entrepreneurial and innovative spirit is actually going to be okay.

And if you fail and at least fail forward and learn from those mistakes, it is an accurate and efficient investment in the technology. Then it's all worth it. But the process and the structure, as everyone -- the gentleman to my right have recognized, it does not facilitate that process. It ties up that process to the point that people who actually might have the solutions don't want to even participate.

So, I would counsel Congress to be optimistically realistic about the future, and to have a little bit more trust in the private sector in bringing these technologies to bear on the public sector problems.

MR. O'HANLON: One follow up. In what way is the Congress not trusting the private sector enough right now? Is it because it pushes DoD to use the traditional bureaucratized, regulated methods of procurement, and needs to encourage Congress to take advantage of the federal code and the options for a commercial acquisition style, you know, procurement? I mean, what's the specific way in which Congress gets in the way?

MS. HOGAN: I think that the acquisition process is so cumbersome, and their requirements don't actually meet the needs of what things are being proposed. So, a lot of times, the questions that come out of the problems that are trying to be solved, if there is a new way of solving them, there isn't a recognition that you have to look at it and evaluate it in a new light.

You're trying to apply old regulations and old acquisition policy to new solutions, and there is a disconnect between how you do it. And there is also, I think sometimes, a fear of the unknown. If you don't have all of the answers at the beginning, or if the evaluation process isn't educated enough, or the individual evaluators that are part of the acquisition process don't understand it, instead of asking questions again and again to better educate the acquisition policy process, there is a fear and just a shutdown of the process.

So, I think it's just the general bureaucracy. And Jimmy said it. Complexity. I would characterize it more as red tape, and the amount of complexity in the actual acquisition process that prevents these new solutions from being applied.

MR. O'HANLON: Great. Well, let's go to all of you. We've got about a half hour left. I'm going to take two questions at a time. Please wait for a microphone and identify yourself. And if you can pose a question specifically to one person, that would help. It's not obligatory, but it's preferred. So, we'll do two at a time. The woman here in the fourth row, and then gentleman, I guess in about the seventh row, both on the aisle.

MS. COPE: Good morning. Thank you for your comments. My name is Margaret Cope. I'm an independent consultant. I have a background in life cycle management in the Air Force.

My question has to do with PMA, Product Manufacturer Approval. Where is that with regard to this whole process? I know when you talk budget constraints, that was an area that we were looking significantly at, and I would just like to know if you have an update. Probably, Jimmy, you're the one that would know most about that.

MR. O'HANLON: Well, then before we do, let's take -- we'll get two on the table. That way, we can just pick and choose.

MR. WERTMAN: I'm John Wertman with the Association of American Geographers. My question is probably for Brennan. We've been real big advocates for STEM education here in the United States.

As we talk about things like agile systems, complexity, revolution, evolution, what are the implications for the 21st century warfighter? How has the Defense Department been thinking about what warfighters are going to need to be able to do with these new technologies in mind?

MR. O'HANLON: Well Jimmy, we'll start with you and go to Brennan.

MR. JOYCE: Sure. Well, so, PMA becomes a very interesting discussion, especially in light of things like what we heard earlier, with additive manufacturing. I can take apart and I can figure out how to do it in the field, and there you go. The problem you run into, particularly with aircraft systems, is that there are certain characteristics of those parts that you have to have.

It's material properties as well as qualities such as surface finish and dimensionality and things like that. If you don't have them, that part can fail, and when it fails, it will be spectacular, and not in a good way. And so, one of the things you worry about, when you go through the PMA process, the whole idea is that you've proven that you can produce that part to have the right quality, so that you have the quality part that can do what it has to do.

If you decentralize that and take away -- that's an authority that you're given. Things like additive manufacturing can challenge that, because then how do you maintain that authority? The challenge for us as manufacturer is that we stand by the quality of our products. And if you start flying around products that have parts that we can't stand by, then it makes it very difficult for us to stand by our products anymore.

So, I think right now, where we are on PMA, it's a bureaucratic, authoritative process and things like that. Where you can successfully do it, it can drive competition. It can drive cost improvements. But you have to be very, very mindful of the quality issues. And I think looking ahead, as we look at things like additive manufacturing, that may become yet even more complex.

MR. O'HANLON: Brennan?

MS. HOGAN: Sure. So, with regard to STEM education, we actually work very close with universities in our research and development program. We do internal R&D, and then we do academically funded R&D projects. And one of the things that we've been looking at with regard to additive manufacturing is how do you provide the workforce that can actually use the technology.

And a key component of that is what are the skills and capabilities that they need. And there is, I think in some areas, a misconception that when you use a new technology, you can kind of throw all the other stuff -- baby out with the bath water, and you don't need to know traditional engineering aspects. Physics is not changing. It is the same.

The technology that is going to have to withstand those physics when you produce a part and put it on a plane or an aircraft carrier or a submarine, you have to understand the traditional engineering aspect, because you have to know how you produced that part in that past, and then, how you've used this new technology to create a new part, whether it's the same part or whether it's three parts that you can now print as a singular part.

But you have to have that background in engineering, and you have to have that capability to understand how to use it. With regard to how that applies to the warfighter, it is a question that continues to need to be answered, and that's what we're working with the DOD on the training and workforce perspective.

If you put additive manufacturing in the field, if you put it at a forward operating base or a combat outpost, and you have an infantry unit that is 30 guys, who within that team has the capability to actually take the software, print the part, to create a part as it's needed, to use CAD files and 3-D data to actually print the part? So, what are those skill sets?

And I think the STEM piece of it continues to be an area that there is a growing need, and I think that there will be a need for having specialists and generalists who can facilitate the process, so that the technology can actually be applied in a forward or a deployed setting.

MR. O'HANLON: Thank you. Let's take two more. These two gentlemen here.

MR. HARPER: Thank you. Jon Harper with National Defense Magazine. I guess this question is probably for Brennan and Jim. Can you give some examples of the way in which the services are using additive manufacturing now and what some of their plans are for utilizing that technology in the coming years?

MS. HOGAN: Sure.

MR. O'HANLON: Then?

MR. DOYLE: I'm Randall Doyle from Georgetown University. I'd like to kind of look at this from a different angle. Listening to the process and the acquisitions and everything, I want to talk about external factors with the advancement of fighter planes and missile technology and so forth in China.

I'm wondering how much pressure is on you to be able to produce these products for the military, and so forth, and whether maybe because of China's vast advancement in weaponry and so forth, maybe that will be part of the process of breaking down some of this red tape that you talked about, and maybe it would make you happier with Congress.

MR. O'HANLON: Great. You know, I'm going to add one more, and that way, we potentially have a question for everybody. So, we'll see here -- at least that's what I'm hoping.

MR. HURWITZ: Thank you. I'm Elliott Hurwitz, a former member of the intelligence community and the State Department and the World Bank. For Mr. Kenyon, I have a question. What is the rate of progress of our major adversaries, People's Republic of China and the Russian Federation, in terms of adaptive propulsion?

MR. O'HANLON: So, why don't we begin with Jim this time? And then, we'll work across the panel.

MR. JOYCE: Well, I'd characterize the use of additive manufacturing amongst these services as islands of experimentation, in many ways, driven by either individuals or programs -- not necessarily -- units that have an inherent interest in innovation.

Though, we're -- sort of concrete examples of how it's being used in the field would be the deployment of additive manufacturing machines with SOCOM. I mean mentioned the dog bone for the antennas. There's been no auto modification of weapons, so that they are -- rather than being mass produced, they're more custom fit to individuals, and there's been -- there's an example of something that was used for a sling underneath a helicopter that was made in the field.

Again, I would say that this is not in any way new, and in fact, when you start talking about the Navy, it's inherently in the Navy's DNA to do this kind of stuff. The ship is out there in the middle of the ocean. It's going to keep going, and the machine shop will come up with a solution. And what this particular technology does is it widens the envelope with possible solutions that that machine shop can execute on.

So, the adoption path within the services is really a function of need and frankly, immediate need. There's nothing like having to solve a problem that causes you to propel a technology forward. Now, in the industrial base, the adoption of the technology is really kind of bi-fluctuating. These machines and the material -- the price performance envelope on them is crashing, and effectively within that class of machines, there are commoditizations going on, both the material and the machine.

There's also a group of machines and materials that are becoming highly specialized and regarded as a competitive advantage, so that if I would turn to Jimmy and say, hey, would you tell me how you've locked down your processes and keep -- and have limited your variability -- well, how do you guarantee your finite element analysis, he wouldn't tell us, because that is the competitive advantage.

So, there's a limited number of folks, usually with a lot of capital that are truly differentiating themselves in additive manufacturing. And frankly, they're having to build the machines themselves. The machines that are available just aren't up to snuff. So, in the commercial industrial sector, it really is playing out as a, is this a commodity type capability with commodity materials, or is there an opportunity to create a distinct competitive advantage?

And what we're seeing so far is, it takes a lot of money to lock down the processes on the metal side and create parts. But when you do, you have an advantage over other companies that is significant and justifies that capital investment.

MR. O'HANLON: Brennan, do you want to add an example or two before we go to Jimmy and then Dave?

MS. HOGAN: Sure. I think there's two key examples that are helpful. To Jim's point, the Navy has been using additive manufacturing for a number of years. The Naval and dental school has been printing bridges for people in their mouths for many years -- probably almost 30 years.

With the addition or additive manufacturing, the customization to an individual person's physiology, there's a great opportunity there, and the medical services continue to provide that. There's a lack of infection when you have customized prosthetics or skull caps when you have traumatic brain injuries. And so, that's a growing area.

The other example that I like to use pretty often is the rapid equipping force that I mentioned earlier, SOCOM special operations command that was deployed. In Afghanistan, infantry units were given flashlights, and there was an exterior button the flashlight. So, they would put the flashlight in their pocket or on their pack, and every time they would walk, it would click on and off.

Any of you that are familiar with night patrols know that's kind of rule number one. Don't turn the lights on. So, they came back to the rapid equipping force, and they said, we need a cover for this. So, they actually produced a cover -- they came up with a cover for the flashlight, and they printed them in the field and provided them immediately to the infantry units. And so, that is a key example of the innovative aspect of it.

And there is that. It's continuing to go on. And again, to Jim's point earlier about the services, at the services, they are pushing the envelope constantly, because they are primarily there to support the warfighter, and sometimes, luckily they don't want to put up with the impediments that I mentioned earlier about supporting that mission. And so, they are just pushing the technology.

From a strategic perspective, that's where we're trying to help DoD see, as you push that down into the services and across the services, having a comprehensive strategy for how you apply the technology.

MR. O'HANLON: So Jimmy, I don't know if you're comfortable talking about global trends in propulsion, but if you are --

MR. KENYON: Oh, so that is a little bit hard to answer directly. But here's what I will say, and I'll actually touch on both of those questions. There's been a lot of investment, a lot of work going on both in Russia and China, and that's been fairly public.

There have been a lot of articles in the press lately regarding in particular, China's desire on the commercial side to develop propulsion capability. And so, clearly that's something that bears watching. If you were to watch Secretary Kendall's remarks, we have a $2 billion investment in propulsion, even while we're struggling in other areas. And why is that?

Propulsion is recognized as a differentiator for the United States. It's something that sets us apart. And so that's why keeping that technological lead is a big reason for that. That's an interesting thing. And looking at your bigger question, it's remarkable. In this nation, historically, we've been able to rise to the occasion when we have a national imperative.

When you go back to World War II, we had this thing going on in Europe and this thing going on in Japan, and the result of that was just a tremendous blossoming of the defense industrial base, and particularly, the aviation base. We produced airplanes, punching them off the production line day after day after day, because we needed them in the fight. And we found ways to do that -- both the government and the industrial base.

Fast forward a little bit, and once Sputnik was launched and detecting, boy, we took off. And not that long later, we were putting people on the moon. And that was just one part of what turned into the Cold War in the technological advancement that was the Cold War, because of a compelling national imperative. Where are we today, when we consider what we see going on in Russia and what see going in China?

And when we look at the defense strategy that we hear about, is it a compelling national imperative? Well, when you look at our defense acquisition system today, you might argue not yet. But are we headed in that direction? Maybe.

MR. O'HANLON: Thank you. Dave, anything you want to add to this discussion?

MR. LOGAN: So, maybe I'll hit on both of those, as well. From the additive manufacturing kind of perspective, you know, I spend my organization, a lot of our time in the R&D spaces. Right? But we're using that very extensively. And there, it's really about being able to re-spin you know, prototypes very quickly and far more cost effectively.

I was in a proposal review just a couple of weeks ago, and you know, we're talking about how we're going to modify a system going to phase two, and you know, and they walk with an aluminum version of what we're actually going to be using as the infrastructure there. And we're also experimenting with far more sophisticated materials, as well, beyond the aluminum instance in that particular case.

When it comes to the pace of our adversaries and what we're doing technology wise and capability wise, I'm actually very optimistic, in the sense that some of the dialogues that I think are occurring right now, you don't have to be more than a few minutes into a conversation with Secretary Kendall on this kind of a topic before he asks you the question, are you getting the data that you need. Are you in the conversations with our folks about where our adversaries are going; where our deficits are and what we're doing to potentially overcome those?

All right, the same thing -- you know, Mr. Stackley in the Navy. They're very keen on making sure that those conversations are occurring, and that those are substantial conversations around data and scenarios and the like. Right? And they’re not just operating within stovepipes, either. You know? I've seen good conversations coming across services.

So, you know, I'm not suggesting that those conversations weren't occurring before, but they're occurring now with a sense of intensity that I can actually see the difference.

MR. O'HANLON: And we're going to do one more round of questions, and then we'll allow everyone to make final comments, too. While I look for hands, I'm also going to say that we have General Campbell coming from Afghanistan to be here Tuesday at 3:00pm, to talk about the state of play there. But that also is an opportunity, and I'm sure everybody in the room would probably want to join me.

We may or may not have another opportunity in short order on C-SPAN to say thank you to a departing group of military leaders that as many of you know, are leaving now en masse. So, we're seeing the chairman and vice chairman of the Joint Chiefs of Staff, as well as the chief of staff of the Army, and probably the chief of naval operations, and a number of others, too.

But certainly, those four all appear to be changing in coming weeks. The Navy part is still in transition, as I understand it, but I'm sure we all want to thank not only General Dempsey, General Odierno, Admiral Winnefeld and Admiral Greenert, but all of the men and women who have served with them and through this intense period of military activity and service for our country.

So, I won't ask you to join me now, but when we thank the panelists in a few minutes, let's keep the round of applause, also, for all of these wonderful military leaders, because it is sort of an historic moment, as the United States makes this transition out of war. And seeing those four leave more or less simultaneously, brings it home, at least for me. Anyway, sorry for that little aside.

But let's get three last questions, and then we'll do a final wrap up. So, I'm going to take the question at the very back, and then you two here, and then we'll just go across the panel.

MR. JONES: Hi. Matt Jones from the Boeing Company, and I want to thank the panelists for a very informative session here. Thank you very much.

My question is related to -- I guess I'll aim it at Jim. You've talked about the application of additive manufacturing to logistics and other aspects of it. Do you see much evidence of how additive manufacturing is changing designed philosophy? In other words, are people starting to really design for additive manufacturing?

MR. O'HANLON: Okay, and the gentleman here in the fourth row, and then --

MR. STURGILL: Ryan Sturgill with the Cohen Group. I wanted to ask what initiatives you see either DOD funding, or potentially, even other departments for additive manufacturing. And for example, the White House has you know, moved to set up this national network for manufacturing innovation, and the first center is on additive manufacturing, I think based in Youngstown, Ohio.

And I think DOD kicked in a fair amount of money to fund that, initially. And maybe you can comment on sort of how that's going. But are there other initiatives like that sort of coming down the pipeline that we might see?

MR. O'HANLON: Thank you. Over here?

MR. LYNGAAS: Hi. Sean Lyngaas with Federal Computer Week Magazine. Dave, you mentioned that adversaries are kind of moving away from a hardware laden approach to more software to having digital things earlier in the cycle. That's kind of a maybe a crude summary of what you said. But can you elaborate on that, what you mean by that? And the implications for how the U.S. does business in that field?

MR. O'HANLON: Because those three questions were put so succinctly, I'm going to go ahead and -- there was one more hand, and I'll bring that it into the mix, and then we'll just wrap up.

MR. BARAN: Hi. My name is Steve Baran. I'm a soldier and a defense fellow, though my remarks are my own here. I'd like to see if I can get remarks specifically as they relate to 3-D printing and energetic materials. So, as we look forward, we heard a lot of discussion about componentry and parts.

If I could look towards you know, individual cartridges for soldiers, weapons being produced forward, air-drop munitions, so that they can be tailored, more flexible, more adaptable, as well as more efficiently placed in the hands of the warfighter. So, to kind of zero in, opportunities and efforts; what's going on right now that you know of; the merits of this kind of research and effort.

And then lastly, you know, defense industry and academic partnerships -- things that we can leverage our graduate students to do a lot of lifting on? What are the opportunities there? Thank you.

MR. O'HANLON: Why don't we just work from Brennan downward, and we'll see if we can cover most of these questions as we conclude?

MS. HOGAN: Okay. I think I can kind of speak to three of them. With regards to logistics, the key part that we see in terms of applying additive manufacturing, I mentioned earlier, is you're essentially turning the supply chain on its head.

So, you create the parts at a manufacturing base, and then you send it to a depot, and then, it gets put on a component or it gets sent out into the field. If you push the entire supply chain forward and you actually put the machine in the field and you're printing in the field, you're actually just truncating the entire process and meeting the need exactly where it is.

So, the potential there is great and significant in condensing the whole supply chain and all of the logistics that support it, and looking at reduction of inventory, reduction of all of the money that is spent on the space where all of these parts are housed. But again, it has to be a thoughtful process. Which of those parts actually -- is there a business case to truncate that logistics and supply chain?

And then, with regard to the question about academic partnerships -- so, a lot of the universities work with organizations like myself, and then the Youngstown Ohio organization, it's America Makes that you were referring to -- it is an initiative that was borne out of the DoD, and it brings together industry academia and the services and Department of Defense to have a conversation and continue to push the technology forward, and to facilitate the process, the acquisition process and introduce that entrepreneurial spirit that you have in these small organizations that focus primarily just on the technology of the 3-D printing and the potential implications.

They may not have a familiarity with the DoD contracting process like most of us do, and so, America Makes and organizations like it are helping to facilitate that conversation. There are a number of investments that DoD is making directly with schools. So, Penn State and Virginia Tech are two of those schools that we work with.

CIMP 3-D is the lab up at Penn State, the Dreams Lab at Virginia Tech is 3-D arm, and there are investments that different organizations within DoD are making to work with them collaboratively to look at what the potential implications are, what the processes are, where you could find efficiencies, what parts or components might be able to be printed.

And then, we do a lot of work sort of -- we also facilitate that conversation. So, taking the questions and investing our own funding in answering those questions and using the academic expertise. The graduate students that are in those programs again, still have that traditional manufacturing and engineering background, and then, are advancing it to understand better how do you design in 3-D. How do you look at a part that was subtractively (sic) manufactured, or three or four parts, and put them together and look at how they could be printed?

And so, those are some of the things. And I think I hopefully covered all three of those.

MR. O'HANLON: Jim?

MR. JOYCE: Yeah. I'd like to address the question around design for additive manufacturing. I would characterize it right now as being an art, and not an engineering science; that the software -- design software needs to take a jump forward before it catches up with the technology; that there's a lot of lack of understanding or just frankly, knowledge about how you design the digitally optimal part, as it's sometimes referred to.

So, in many ways, I compare it to when composites came in to aerospace, and everybody was a metal person. There was just an incredible adoption cycle -- a cycle -- had to totally orient themselves. A cycle of getting composite education out to engineering schools before it really flourished. That took decades, really.

So, there's some of that going on with design for additive manufacturing. I would say there's two really interesting things, though, I think, in the design for additive manufacturing space. The first is where designs are coming from, though we've all heard about competitions being run on jet engine brackets, or parts coming from design and art schools used in industrial applications. So, there is this democratization of designs already occurring. Where do you go for ideas and solutions to include the actual users of the product?

The second thing is that my experience is that folks that embark on the design for additive manufacturing paths often veer off and start designing for their own supply chains, because as they lay out the economics and the needs, they revert back to, I don't want to change the part. I just want to be able to build it at the point of use because of what that does to my logistical requirements, my inventory requirements; what it does for a disappearing source of parts, et cetera.

MR. O'HANLON: Thank you. Dave?

MR. LOGAN: So, sort of what's the implications for more and more software content, closer and closer to the sort of front end of these systems? So, maybe I'm looking at that with an example. I'll take you back a couple of decades or more.

So, there's a set of enthusiasts that sort of have these scanners, and they listen to things that are going on on the radios. And if you had one of those 20 or more years ago, what you would do is, you would figure out what you want to listen to. You'd go down to your local electronics store, and you'd buy a crystal.

You'd open the back of the radio up, and you'd plug the crystal in there, and you had four slots for crystals, so you could pick four, if you wanted four. And if you changed your mind, you'd go back to the store and you'd get a different crystal and put that in. Right? And then, you could use that device to listen to the radio frequencies that were the most interesting to you.

So, we kind of take for granted today, that that same kind of a product -- you get it, you enter in the frequency that you're interested in, hit enter, boom, you're listening to it. Right? As new formats come out, in large part, that new system is able to address and receive and understand those.

And the reason is can do that is because we're actually converting from the radio frequency that comes over the air into a format where we do a lot more of the processing and software much, much earlier. And so, the change to accommodate a new system in this case, a new radio that you want to be able to listen to is an upload of software into that system. It isn't going down to the local store and buying a crystal.

So, you can sort of extrapolate from there to systems where we're not listening, but maybe we're communicating. Right? And systems where perhaps we want to bridge across different radio formats. Right? And in the past, you might have to have different sub-radios for each of those formats that you want to bridge. And now, you can ingest all of those and in software, make that connection occur. And so, the real implication is one of you know, efficiency, cost, extensibility, all those kinds of things.

MR. O'HANLON: Excellent. And Jimmy, Bryce Harper --

MR. KENYON: Sure.

MR. O'HANLON: -- Jimmy.

MR. KENYON: And I appreciate that relationship there, because my son is a huge Bryce Harper fan. (Laughter)

MR. O'HANLON: And we can't yet make him with 3-D manufacturing, can we?

MS. HOGAN: No.

MR. O'HANLON: We can't make a replica if we needed one.

MR. KENYON: Not yet.

MS. HOGAN: A little one.

MR. KENYON: Yeah, a little one (Laughter). So, there are a lot of key ideas here. I think going back to the question on design for additive manufacturing, at the end of the day, that's the real opportunity. That's the real opportunity, because it opens up a whole new way of making things that can cost less because I need less material; that can take less time because I can eliminate some processes out of my manufacturing line.

There are a lot of things I can do with that, that frankly just make the product better. I can take weight out of products, because I don't put things in other places where I can't remove it later on. I have design flexibility. Right now, I've got a program where I've got a major component of a military engine on test, and we made parts of it using additive manufacturing, and I was able to lay in instrumentation leads. And by doing that -- or ports for instrumentation leads.

By doing that, I don't have to add things that disrupt the aerodynamic performance. It just makes it a lot better. So, that really is ultimately where we need to go. But what's the catch? What we have to do learn how to do is, as Jim alluded to, it's kind of an art right now.

We get used to thinking of physics the way we think of physics. Physics is physics. F equals MA and you can't push on a rope. But the way we think about it, the way we pose our problems, that's how we do our analysis. We have to rethink not only how we make things, but how we design things and how we analyze them with those physics to take full advantage of that.

The opportunity there are things like the America Makes Initiative, like STEM initiatives that tap into additive manufacturing. America Makes was intended to catalyze the industry. It was intended to get this started. And well, apparently, it's worked, because we're here talking about it. Companies like my own, like others are really heavily engaged in it, and we're working and taking it forward very quickly.

The other part of that though, is STEM. Universities are a huge part of that. How do I think differently about the physics? We have a relationship we heard about at two universities, earlier. We have a relationship, naturally, being a Connecticut based company, with the University of Connecticut where we're working on additive manufacturing with them.

And if you go and you talk to different companies, you'll hear similar stories about the relationships they're forming with their universities that they have relationships specifically for that reason. So, I think there's a huge opportunity there, and I think it's only a matter of time before we get there.

MR. O'HANLON: Well, wonderful. Well, listen, thank you all for being here, and please join me in a big round of thanks and appreciation (Applause) for the panelists.

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