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BACK TO THE FUTURE

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BACK TO THE FUTURE

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON CYBER, INFORMATION TECHNOLOGIES, AND INNOVATION,
Washington, DC, Wednesday, December 6, 2023.

The subcommittee met, pursuant to call, at 2:00 p.m., in room 2118, Rayburn House Office Building, Hon. Mike Gallagher (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. MIKE GALLAGHER, A REPRESENTATIVE FROM WISCONSIN, CHAIRMAN, SUBCOMMITTEE ON CYBER, INFORMATION TECHNOLOGIES, AND INNOVATION

Mr. GALLAGHER. The subcommittee will come to order. We are really lucky to have three incredible witnesses today to talk about a very important topic, military innovation, and how we can learn from the lessons of the past.

The ranking member will forgive me if I have already told this story, but it always is in my mind which is there is this famous scene in William Manchester's biography of MacArthur, no offense, Dr. Herman, I know you wrote a MacArthur book, too, that was great. But in the Manchester book, there is this scene where he is in the Philippines prior to World War II and he is having this debate with his staffers about whether in the midst of war one should suspend democracy. And it becomes this debate about whether dictatorships or democracies are better. And MacArthur, maybe against sort of the caricature of him, argued for democracy and said that the dictator may start off well, but once they encounter friction, they slow down whereas democracy starts slowly, but they activate thousands of flexible and free-thinking minds and over time, ultimately prevail. And I think this is the story we tend to tell ourselves as how America wins and does crisis management. Perhaps in some sense this is the story of "Freedom's Forge."

I wonder though if there are not two problems with that story or whether what I call the MacArthur curve is fundamentally broken when we think about innovation. The first is that in light of the most stressing national security challenge we are trying to solve, which is a PLA [People's Liberation Army] invasion of Taiwan, we might not have time to turn car factories into bomber factories. If they pursue a rapid fait accompli strategy, we may not have time to activate freedom's forge.

And the second thing is and perhaps more obviously is that the defense industrial base and the defense innovation base looks much different than it did at that period of time. We have discovered

many single points of failure. Right now, I think the war in Ukraine has revealed the brittleness of our munitions industrial base and the list goes on and on.

So today, I hope if nothing else, our incredibly impressive witnesses can help us sort of learn the right lessons from past cases of military innovation or even the right lessons from cases where powers failed to innovate and what that meant for their geopolitical position. And as I said at the start, I can't think of three better people to help us think through that.

Oh, one other final note. I think the tendency when you go to one of these defense conferences is there is always like a bunch of panels on the new shiny thing, right? It is AI [artificial intelligence], it is quantum, it is JADC2 [Joint All-Domain Command and Control]. That is all well and good, but I think in light of that, it is incredibly important that we have a conversation like this about looking backward with an eye to preparing ourself for the future because while the sort of essence or nature of war does not change, its character does seem to be changing in light of new technology.

So I want to thank Dr. Andrew Krepinevich, who is the author of a great new book called "The Origins of Victory," many other books, including a book on Marshall and a great study on archipelagic defense. The 2.0 version was just released in September. And then, of course, Dr. Arthur Herman, who as I alluded to, not only wrote a book on the great Wisconsinite Douglas MacArthur, but one of my favorite books, "Freedom's Forge," has written more books than I have time to list.

And then Colonel Mark Gunzinger, who has too many titles to list and wrote the Department of Defense's first transformation strategy. So we have a wealth of knowledge here in front of us and we are looking forward to this discussion.

With that, I yield to the ranking member.

STATEMENT OF HON. RO KHANNA, A REPRESENTATIVE FROM CALIFORNIA, RANKING MEMBER, SUBCOMMITTEE ON CYBER, INFORMATION TECHNOLOGIES, AND INNOVATION

Mr. KHANNA. Well, thank you, Mr. Chairman, for convening these experts on disruptive innovation and ensuring that our military remains the most innovative in the world. As a Representative from Silicon Valley, I can attest that the most disruptive innovations of the past 50 years have come from the Department of Defense. I mean it is DARPA's [Defense Advanced Research Projects Agency's] innovations and others in GPS [Global Positioning System], in the internet, in drones that really led to the commercialization of these technologies in Silicon Valley. So the idea that our Department of Defense and military have not been innovative is just historically inaccurate. They have been incredibly innovative.

But now that we see so much disruptive innovation taking place in the commercial sector, we need a strategy to make sure that the Department of Defense remains the most innovative and also that these technologies are accurately and fully deployed for us in the case of war or combat. And so I appreciate your leadership, Mr. Chairman, on trying to ensure that we integrate and adopt these technologies and use them to make sure that we remain the world's

strongest, most innovative military, and I am looking forward to hearing the experts' testimony.

Mr. GALLAGHER. Thank you to the ranking member. Your written testimony, all three of your written testimony is exceptional. I recognize it is unfair for us to ask you to summarize it in 5 minutes which is not a lot of time. The good news is we will have plenty of time for multiple rounds of questions and the ranking member loves it when I entertain multiple rounds of questions.

So with that, we will start with you, Dr. Krepinevich.

STATEMENT OF ANDREW F. KREPINEVICH, JR., SENIOR FELLOW AND ADJUNCT SENIOR FELLOW, HUDSON INSTITUTE AND CENTER FOR A NEW AMERICAN SECURITY

Dr. KREPINEVICH. Thank you, Chairman Gallagher, Ranking Member Khanna, members of the subcommittee.

By way of background, let me start out by saying I agree with both of you. We are in a period of disruptive change in terms of the military competition and it demands disruptive innovation, as you mentioned, Ranking Member Khanna.

In terms of disruptive change, we are looking at really a geopolitical change that has put us into a period of great power competition that has been absent for about 30 years. But also, in particular the Chinese have caught up to us in what the U.S. military sometimes refers to as precision warfare. We have lost our monopoly, if you will, in the ability to do precision kind of operations of the kind that we demonstrated in the two Gulf wars and in various unconventional warfare operations.

The second aspect of disruptive change is the broad advance of military-related technologies, everything from additive manufacturing, artificial intelligence, drones, quantum computing, directed energy, and so on. That's offering militaries the opportunity to operate in very different and far more effective ways. And historically speaking, typically the military that figures out how to do that first enjoys an enormous advantage over its rivals.

And so one question is how well is the U.S. military prepared and positioned to engage and pursue in disruptive innovation? And to answer this question, as Congressman Gallagher mentioned, Chairman Gallagher, the book that I wrote looks at the histories of four militaries in the industrial information age that engaged in disruptive innovation. They were the first to do so and they realized enormous benefits in adapting and transitioning to a new way of warfare.

And fortunately, when I looked at these four militaries, otherwise there would not have been much of a book, they do demonstrate some common characteristics. So you can sort of look at a military and look at these characteristics and say how well are they positioned to undertake disruptive innovation?

And I will briefly summarize some of these characteristics. One is a guiding vision. What is the new vision of warfare? After we get through this transition period, what dominates warfare? What are its new characteristics? Oh, I should mention that the four militaries were the Royal Navy, the first decade of the 20th century, the transition to the so-called Dreadnought revolution, submarines and so on; the German development of blitzkrieg warfare in the pe-

riod between the World Wars; the American Navy shift from a battleship-based Navy to a carrier-based Navy between the World Wars; and the transformation of the American Air Force between the Vietnam war and the first Gulf war where they introduced what the Russians called a reconnaissance-strike complex.

So, getting back to the characteristics, one is that guiding vision. Second is identifying the key operational challenges that a military confronts. You can look at this as a diagnosis. What are the problems we are trying to solve? What are the key threats? Since we only have limited resources, we have to be very careful about what we choose to focus our efforts on.

Next would be developing an operational concept. How do we plan to address these new challenges? Then there is changes in measures of effectiveness. What worked before, what we valued before, probably we are not going to value in the same set of priorities now as we did before we engaged in our innovation efforts.

Then there is exercises at the operational level of war. And the point here is we are not going to be sure whether our new way of war is valid. And so we conduct operational exercises to try and reduce uncertainty as much as we can wherever we can. There is extended tenure. Some of the key military leaders that guide this effort serve for extended periods of time because typically disruptive innovation takes a decade or more and yet, a lot of senior military leaders typically last 2 or 3 or 4 years in an assignment. This does not occur in periods of disruptive innovation in the four cases that I studied.

Then there is the issue of time-based competition. If you have a military that is world class, a time-based competition that can adapt quickly, they can pursue what I call the first and second move advantages, but they can also adapt very readily and much more quickly than their rivals. And this turns out to be quite an important factor.

This concludes my remarks, Mr. Chairman, although I will say one final point. We are thinking about two things with respect to disruptive innovation. One is we have to get the operational concept, say if we are looking at the Chinese as a threat, how do we plan to defend the first island chain if that is the critical operational challenge. And second, we know we are going to be wrong because there are so many variables. And so if we ever go to war with China, how quickly can we adapt in order to be able to sustain not only the operations, but also adapt to reduce the flaws and eliminate the flaws that our concept has revealed—that is revealed in our concept in conflict. Thank you, Mr. Chairman.

[The prepared statement of Dr. Krepinevich can be found in the Appendix on page 31.]

Mr. GALLAGHER. Dr. Herman, you are recognized for 5 minutes. Is your microphone on? And make sure that it is close to your mouth. It is very formal here. Very far away.

Dr. HERMAN. All set to go?

Mr. GALLAGHER. I think so. Yes.

STATEMENT OF ARTHUR HERMAN, SENIOR FELLOW, HUDSON INSTITUTE

Dr. HERMAN. Great. Our defense industrial base is in crisis. This is certainly the conclusion that our first-ever national defense industrial strategy report has just reached. According to its most recent draft, that industrial base "does not possess the capacity, capability, responsiveness, or resilience required to satisfy the full range of military production needs at speed and scale."

What some of us have been warning about for a decade is now apparent to everyone. One reason I wrote my book, "Freedom's Forge," more than 10 years ago, was to call attention to structural deficiencies in how we arm and equip our military compared to World War II and the Cold War. Now, thanks to the war in Ukraine, the problem has been made obvious and urgent.

The question is how to better incorporate the innovations taking place in our private sector, from AI and robotics to cyber and quantum, into our defense industrial base. Now the industrial base consists of many things: production facilities; supply chains; research and development of new technologies and systems like AI and quantum, hypersonics, UAVs [unmanned aerial vehicles]; industrial and cyber security; and workforce. And we urgently need a strategy for incorporating innovation in all of these areas as part of an overall national security strategy.

But the role of the innovation I think is misunderstood. It shouldn't be treated as if it were a stand-alone category, but instead, as an integral part of the production and productivity process. It is through making things that we learn how they can be made better which is why the most productive companies also tend to be the most innovative. And that is why in creating, for example, the arsenal of democracy in World War II, Washington turned first to the commercial automobile and electronics companies because they had the most engineers and therefore could be counted on to do things and make things better, even if they had never made them before.

For example, when engineers at Pontiac turned their attention to producing the 20-millimeter Oerlikon anti-aircraft gun, they completely redesigned the product to make it faster and also better. And as a result, they managed to cut production time per gun from 3½ hours to 15 minutes. Now there are other examples that are contained in my written testimony. The point is innovation follows productivity, not the other way around.

Another principle that animated the arsenal of democracy was that it was threat-based, not capability-based. The Germans and Japanese made it very plain what was needed from the beginning: the tools to beat the U-boat, the Japanese Zero, and the ME 109, and the German panzer.

One of the problems I think we face today is that the focus has been on the capabilities of high-end technologies like AI and quantum, rather than on the enemy they are supposed to deal with. One could argue that hypersonics is an exception, but this is largely because we sense that we have fallen behind Russia and China in that technology, just as we were behind Germany and Japan when we entered World War II. In short, by focusing on the threat, first

and foremost, we make for a better and more innovative industrial base.

Two points in conclusion. Given the themes of my book and all of the issues and problems confronting our defense industrial base today, people constantly ask me could we do it again? My answer is yes, but not alone. Instead, in addition to restoring our base whenever and wherever possible, we need to build a global industrial network with trusted allies, the U.K. [United Kingdom] and the Five Eyes, NATO [North Atlantic Treaty Organization] members, Japan and South Korea, especially in the advanced technologies like AI, quantum, and space, but also in the traditional and conventional technologies like shipbuilding and like energetics, in other words, the next-generation munitions in which the Chinese are already surging ahead.

I call this the arsenal of democracies for the 21 century and like its 20th century predecessor, it can also overwhelm what I have been identifying as the new axis since 2015—China, Russia, and Iran—and overwhelm them with democracy's innovative output.

Consider this. Today, the United States and the world's most advanced tech countries, 18 of them, 18 of the top 20 are democracies. China, by contrast, ranks 32nd on the list, while Russia and Iran don't even score. All this indicates that if the U.S. and democracies band together, they can overpower China and the new axis with the kind of high-tech focus that is the core of a winning and innovative arsenal of democracies.

Thank you for your attention and I am looking forward to answering any questions you may have.

[The prepared statement of Dr. Herman can be found in the Appendix on page 57.]

Mr. GALLAGHER. Thank you. And I forgot to mention that Colonel Gunzinger has more than 3,000 hours in the B–52. I just try not to give too much credit to West Pointers and Air Force guys, so that is my bias, but I apologize.

Colonel Gunzinger, you are recognized for 5 minutes.

STATEMENT OF COL MARK GUNZINGER, USAF (RET.), DIRECTOR, FUTURE CONCEPTS AND CAPABILITY ASSESSMENTS, MITCHELL INSTITUTE FOR AEROSPACE STUDIES

Colonel GUNZINGER. Thank you, Chairman, and thank you very much for asking us to come testify today.

We are now at a point where urgent action is needed to ensure our Armed Forces will have the technological advantage over the pacing threat. I agree that history should inform this effort and I am going to offer six lessons that I learned and used as a force development planner in the Air Force and in OSD [Office of the Secretary of Defense] as a DASD [Deputy Assistant Secretary of Defense].

My first point is maintaining a technological advantage is a marathon, not a destination. By that I mean we should treat defense innovation as a series of sustained competitions. History teaches us it is a mistake to think that technological breakthroughs will give our military an enduring advantage. Technologies we developed during the late Cold War period like PGMs [precision-guided muni-

tions], stealth, information networks, leapfrogged our military over adversaries and we saw that during Operation Desert Storm.

However, China and other competitors have studied our military successes and have developed capabilities and operating concepts to offset them. So technological inferiority is a very real possibility if our military does not continuously modernize and we cannot treat innovation as episodic and driven by crises.

Second, we should seek asymmetric advantages rather than parity. And that means DOD [Department of Defense] should prioritize new capabilities that will disrupt and impose costs on enemies instead of simply fighting a better war of attrition. Now that is exactly what DOD's Assault Breaker initiative did when it created a reconnaissance-strike complex Andy referred to in the 1980s, to counter a Warsaw Pact threat that could field more combat capacity in Central Europe than NATO.

So today, we are facing a similar challenge with the PLA forces that will have time, distance, and combat mass advantages over our military in a Western Pacific conflict. So our services must pursue breakthrough technologies that will finally change the rules of the game, instead of trying to match the PLA warship for warship, aircraft for aircraft, and weapon for weapon.

Third, new technologies are only as effective as the way they are used. History has shown us that groundbreaking technologies are most effective when they are matched with operational concepts that are designed to take advantage of their attributes. When Predator drones first joined the force in the 1990s, they were restricted to ISR [intelligence, surveillance, and reconnaissance] missions. They were glorified artillery spotters. But when they were modified to carry weapons, it opened up an entirely new approach to using sensor-shooters for precision strikes. So as new technologies like uncrewed CCAs [collaborative combat aircraft] are fielded, our military should develop concepts for using them in ways that will disrupt and degrade the operations of opposing forces instead of simply improving how we plan to operate today.

My fourth and fifth points are capacity matters. Innovation will only make a difference if you procure new technologies at scale. So even as we invest in technologies to offset China's combat mass advantage, numbers matter. An aircraft, ship, tank, you name it, can only be at one place at one time. So in the 1990s and 2000s, many in DOD saw increases in weapon system effectiveness as justification to slash force structure which is part of the reason why our forces are now too small to meet their global requirements. So the solution really is to acquire new technologies at the scale needed to deter and defeat our Nation's enemies and that will require sustained, predictable, budget growth.

And finally, new technologies require trained and experienced personnel in volume to use them. DOD must have enough personnel with adequate levels of training to fully exploit the advantages that new technologies will offer. History has taught us that when two opposing forces have relatively equal technologies, the side with the best trained personnel often has the advantage. It is common sense. So fielding new technologies and training personnel to use them, that goes hand in hand. And this is incredibly important today given that it now takes years to develop highly trained,

experienced airmen, sailors, soldiers, and Marines. And like new technologies, we are not going to have the time to surge their training and give them the kind of experience they need in the midst of a peer-on-peer conflict.

And with that, I thank you again. And I look forward to your questions.

[The prepared statement of Colonel Gunzinger can be found in the Appendix on page 70.]

Mr. GALLAGHER. Great. Thank you, all. I am an unabashed fan of military reading lists and a lot of your books have appeared on military reading lists and it is Christmastime and we are all looking for books to give. Imagine you are able to assign holiday reading to the Secretary of Defense and—or rather just assign a case study of military innovation that you think it is particularly important for the Secretary of Defense to understand, what would that be and why?

We will start with you, Dr. Krepinevich.

Dr. KREPINEVICH. At the——

Mr. GALLAGHER. You can't assign your own books, sorry.

Dr. KREPINEVICH. You can't assign your own books?

Mr. GALLAGHER. That is why I said case study.

Dr. KREPINEVICH. I would, I guess, one of the books I would assign would be Dr. Herman's book on freedom's forge, because you can really, in reading that book, get a clear understanding of just how different things were then relative to the way they are now and just how much effort and what kind of organization went into creating the arsenal of democracy or freedom's forge. So that would be a book I would recommend.

A case study I would recommend would be Nick Lambert's book, "Sir John Fisher's Naval Revolution." Basically, it talked about how the world's global power at the turn of the 20th century, Great Britain, was challenged by a rising power in the form of Germany, so there is a similarity there. We are the dominant power. China is the rising power. And Britain faced a number of what I would call operational challenges. So it was how to protect the empire, how to protect commerce throughout the empire, commerce to an island. There were military technologies that were advancing at a rapid rate. Submarines were being introduced, torpedoes, undersea communications, cables, wireless. So you have this combination of a country that has lost its lead in some critical areas of the military competition, as we have done, we have experienced, but also this raft of new technologies, global commitments. So I think the Fisher Revolution, as Lambert calls it, "Sir John Fisher's Naval Revolution" would be a good case study.

Mr. GALLAGHER. Dr. Herman. And you are not allowed to recommend one of his books. No, you are not allowed to, sorry. We will just assume you would have in the interest of time.

Dr. HERMAN. If that is so, then what I will do is mention, I think, two titles that I think bear on the long view with regard to these issues, particularly if you like on the political and economic background within which these sort of patterns of disruptive innovation take place. Andy mentioned Nick Lambert's book. I will mention another Lambert, Andrew Lambert, and his book on maritime states which is about the evolution of sea power over the centuries

and the way in which economic factors and economies and societies become seedbeds for innovation, not just in the military, but also innovation in broader developments of technological progress, of democracy, of a whole range of other areas that I think needs to be part of the wider context in which we think of them.

Then I am going to recommend another book and this is by an economist by the name of Adam Tooze. It is called the "Wages of Destruction: The Making and Breaking of the Nazi Economy." And I mention this because that book, too, is about disruptive innovation, in this case of how Germany's or Hitler's grand designs for dominating Europe and for creating a Europe dominated by a master race had the disruptive effects on the economy and made it really impossible for Germany to sustain the kind of war effort that it eventually found itself drawn into. And some of the statistics and the discussion there about the impact of military strategy on the German economy on the one hand and then on the limitations of that German economy on the way in which the Nazis were able to wage war here is, I think, has a lot of great insights that I would recommend it for reading.

Mr. GALLAGHER. Colonel Gunzinger, in less than 30 seconds.

Colonel GUNZINGER. Absolutely. I hesitate to offer one book, Andrew's "Second Deadly Scenarios" is pretty good. You didn't say I couldn't mention him. But there are a number of books written about the interwar period between World War I and World War II. There was a great ferment of generation of new ideas for amphibious warfare, island hopping, strategic bombing, mechanized warfare, written not just by U.S. authors, of course, but by German authors as well. And that was a fantastic period that reshaped how we conducted warfare for decades. So I think it is well worth investigating some of those.

Mr. GALLAGHER. I will wrap all these up and send them to Lloyd Austin.

Mr. Khanna.

Mr. KHANNA. Thank you, Mr. Chair. I am curious about how we think about the innovation of DARPA versus innovation in battle. So obviously, DARPA gave us Siri, the drones, GPS, internet, the mouse, that all propelled a lot of the Silicon Valley innovation. Is that—has that, have those innovations significantly helped us also in our military capability? And is there something about DARPA that has allowed disruptive innovation in a way that we aren't doing the disruptive innovation militarily when it comes to fighting? Or are we doing it in the same way?

Dr. Krepinevich.

Dr. KREPINEVICH. Dr. Krepinevich. Thank you. I have done some work with DARPA. One of the great advantages that DARPA has is it is unfettered in the sense that it has a lot of freedom to maneuver. I would say that from my perspective one of the challenges that you have with any innovation is whether a military service will adopt it in terms of a new technology or a new technique. A lot of times that will rise or fall on whether or not it sort of fits what a military considers to be its institutional needs. And so if DARPA is offering to the military something that will enable it to do something that it likes to do, enable it to do it better, enable

it to increase its budget share, that is something I think that will increase the odds of DARPA having a success.

The question is is whether the military, its institutional preferences, are actually well aligned with the country's strategic and security needs. And so, for example, I will give an example from history. The U.S. Army trying to introduce tanks and armor units in the 1930s, still had its cavalry arm arguing that horses could do just as good a job and in fact, in some of the field exercises they actually moved horses around the battlefield on trucks and then unloaded them off the trucks and then they went about their business. So a lot of times it is whether there is a receptive home and a lot of times it is whether the military has figured out how they are going to fight. Again, what is their operational concept?

Another example would be the Germans and blitzkrieg. The Germans figured out that they not only needed tanks, but they needed tanks with certain design parameters. So they wanted tanks that had long range and could move fast and they were willing to trade defense in terms of armor plate and gunnery, fire power, in order to get that, because their vision of war was not to go back to World War I and fight trench warfare. It was to break through the trench lines and get so far beyond the trenches, speed, and range, that the allies couldn't re-form that trench line, that they would break into their rear. So again, a lot depends on this relationship between how—what kind of technology is emerging and the extent to which it fits the military's vision about what is the future of warfare.

Mr. KHANNA. I guess the paradox for me is that when it comes to spawning disruptive innovation the military has been way ahead of the commercial sector. I mean, the reality is—I mean, Steve Jobs, all these folks, they went and they saw the technology that DARPA and NSF [National Science Foundation] had created, and yet when it comes to the adoption of that very technology, it seems like they are slower than the private sector.

Dr. KREPINEVICH. Well, it's—okay. Very quickly, if you look at the period between the World Wars, as Colonel Gunzinger was saying, it's been called the aviation mechanization radio revolution because that—those were the sinews of the carrier task force and blitzkrieg. Those were all developed—the leading arm of that was in the commercial sector, and the militaries adopted it or failed to adopt it based upon how they viewed these technologies supporting their vision of how they wanted to fight wars. Some were very innovative; some were—like the French, for example, always our favorite example, basically sought to improve how they fought at—in a sense marginally as opposed to looking at an entirely new way of waging war on a much more effective level.

And you can see this in the commercial sector where you have these big innovations, as you pointed out, which really lead to a different kind of product. And if there's a book to be recommended there, it is Clay Christensen's "The Innovator's Dilemma."

Mr. KHANNA. Thank you.

Mr. GALLAGHER. Mr. LaLota.

Mr. LALOTA. Thank you, Chairman.

Thank you to our witnesses for being with us here today. I represent New York's First Congressional District, the eastern end of Long Island, a couple of hours outside of Manhattan. My district

includes Hauppauge, the Nation's second largest industrial park outside of Silicon Valley, and more broadly Long Island. The greater region is home to 167 defense and aerospace companies comprising over 3 million square feet of industrial and commercial space with over 10,000 full-time employees and $3 billion of economic activity.

And as was noted in some of your opening testimony, with the decline of domestic industrial defense contractors it is important to recognize and promote the existing ones, specifically where I am from, Long Island's industrial defense industry, whose contributions help to keep our Nation's military the greatest the world has ever known.

With that in mind and for any or all three of you, from a warfighting capability development perspective what can our government learn from our partners in the private sector who are constantly working on the next generation of machinery and technology?

Colonel, you seem like you might want to lean into that one.

Colonel GUNZINGER. Yes, I think we can—our military can learn quite a bit. I've noticed in my time when I was on the Air Staff, then OSD—when a chief of service or a senior leader, military or civilian, wanted to know about next-generation technologies, they usually called their own labs. Oftentimes I found there was a better answer out in the defense industry, out in the commercial world. And having the ability to reach out and understand what is being developed, what is the maturity of that technology and how that could be adapted to address many of the challenges our military faces is critically important.

It's both a push-pull. Industry needs to be—have pathways to the government to inform, hey, this is what we've done. We think this can help. But our military needs to pull as well. They've got to be open to asking instead of just looking at their own labs. That's critically important.

Mr. LALOTA. In your mind is that communication, is that collaboration happening at the right level right now?

Colonel GUNZINGER. Increasingly? Yes. Enough? No. And that's why I'm a huge fan of things like war games, which will bring in industry along with operators and planners and strategists, maybe even a couple budget people, and get them together to deal with kind of an operational problem and say—and hear people say, hey, you know, we have a new technology that can do this. We didn't know that. Can you produce that at our next—yes, we can. It's that kind of a dialogue that can really help inform our planners and lead to the creation of requirements which will then lead to actual combat capabilities.

Dr. HERMAN. And I think I would add this, too, that I think one of the other important ingredients for this kind of interaction is including more of the warfighters directly into the discussion instead of having—instead of treating—well, either senior command or the offices of the Secretary or other agencies to be intermediaries between industry and warfighters, bring the warfighters in. Show them what the capabilities are. Let them see. Let them make suggestions. And I think a lot of very interesting and exciting things

will start to happen even with very small companies as well as with the largest.

Dr. KREPINEVICH. I think one thing certainly that I would suggest the military learn from the private sector is the ability to compete based on time. Another book you might check into is George Stalk's book "Time-Based Competition." If you can move faster than your competition, you can adapt more quickly. I think it was—Colonel Boyd mentioned it as getting inside their decision loop.

But look at the—if you want to look at time-based competition, look at the American Navy in the period leading up to World War II. They created the industrial base that enabled them to outproduce the Japanese basically more quickly because you had a bigger base and a more adaptive base.

If you look at the British, they pursued what was called the first and the second move advantage. If you can let your adversary move first, which is what the British did in the 19th century, because you can move faster than they can, then you see all their plans exposed. You know what direction they're going in. So your uncertainty about how to respond to them is much, much lower if you can move faster than they can.

And that's why the British, even though they had the world's best navy, let the French go first in developing steam propulsion and first in terms of ironclad ships, two major innovations. And the British said go first. We're not going to obsolete our own wooden ships until you go first. And once they did, the British out-built them.

Dr. HERMAN. And what we're seeing now is the Chinese have learned how to do that, taking technologies that we developed and using them and scaling them in ways that will make them incredibly effective militarily. We need to reverse that process.

Mr. LALOTA. Thank you. I yield.

Mr. GALLAGHER. Mr. Keating.

Mr. KEATING. Thank you, Mr. Chairman.

As I sit here thinking back to the future and advanced research and the technology that is involved, a disturbing thought I have always had—and I don't know what we could do. Are we missing things? But let's assume some of the greatest threats we have are small terrorist threats. They could be non-state actors or they could be proxies for major competition actors. And with AI they can take biochemicals at very limited cost with only a handful of people doing it and kill millions of people.

So as we are looking at all the technological things that have to happen, technology working at some more basic types of threats that we have present a real problem. Do you see us concentrating and researching what we can do around something like that, just AI to biochemical warfare, millions of people are dead, it cost may be hundreds of thousands of dollars and only a few people. It is an awful thought I have, but as we are looking at our greatest threats, sometimes are we missing some of these things because we are in race, a technological race?

Dr. KREPINEVICH. In my book "The Origins of Destruction," looking at the various technologies, there are oftentimes sections called

the Democratization of Destruction. And it relates to your point, Congressman.

So for example, we see today in the Middle East Hezbollah, Hamas—they have rockets. They have rockets that can fire at extended ranges. If you want to talk about a disruptive shift in the character of the competition, what happens when these rockets and missiles get precision guidance? Again, it's—the cost equation is not in favor of the Israelis when it comes to missile defense against precision weapons. They can use AI and algorithms to detect when these missiles are going to land in an area that they're concerned about or whether they're going to end up—land out in the middle of nowhere.

If you look at the biosciences, a group of Canadian scientists from scratch and $100,000 engineered horsepox, just sort of resurrected it. With $100,000, that's not a lot, and you get a few intelligent scientists, you can do some terrifying things arguably these days.

Look at additive manufacturing. We worry about additive manufacturing, people printing handguns. What will additive manufacturing allow these kinds of groups and organizations to print out in another 10 or 15 years?

And certainly in terms of artificial intelligence there are arguments to be made that spear phishing in terms of basically malware and so on is going to be much more easier to generate using artificial intelligence. And the question is well, are defenses against that going to be enabled by artificial intelligence?

So in a number of ways it looks as though the trends in technology are not only going to enable militaries, standing militaries to operate more effectively, but non-state groups to pose more challenging problems for us as well.

Colonel GUNZINGER. Let me add that back during the 2006 Quadrennial Defense Review, which I helped lead a team for the Secretary of Defense that performed that review, we looked at a number of disruptive threats: bioterror, cruise missile attacks on the continental United States from cargo ships. We didn't really look at AI and so forth at the time. But the problem was people are willing to say this is a challenge. We must do something. We need to invest in analyses to figure out what's the best approach to dealing with this challenge should it ever happen. But when it comes to actually spending resources to counter them or prepare for them, they're not there because there are other requirements that the militaries have established that frankly eat up the trade space, eat up the budget.

And they're valid requirements. I'm not criticizing that. But when it comes to resources my point is it's often not available to deal with those kinds of threats which could kick off the next conflict. And we might not even have thought about what that threat could be yet.

Mr. KEATING. Yes, just in closing I think that sometimes we are caught up in the major power competition to the extent that we are not looking at what some of the more realistic threats could be in that regard. And I think that is a mistake. I think if we are taking away from our ability in the intelligence area to try and scope out some of these things, get the information, be able to prevent it, per-

haps so much of our resources go into this competition, we might miss what was the most realistic and dangerous threat of all.

I yield back.

Mr. GALLAGHER. Thank you. Dr. McCormick.

Dr. MCCORMICK. Thank you, Mr. Chair.

Mr. Herman, in your witness testimony you described the decline of the U.S. domestic industrial capacity and workforce, both defense and non-defense, over the decades. You described the defense industrial base workforce as neglected in terms of national security strategy. Could you elaborate on the neglect and provide the recommendations you may have on how to incorporate workforce as part of our national strategy? And this may be as comprehensive as contracting versus appropriations versus all the inefficiencies that we as Congress are a big part of. How could we streamline that and make it better?

Dr. HERMAN. I think that's an excellent question. It's one that I've been spending a good deal of my time more and more. In fact, right now I'm heading up a commission on workforce development for the space industry, which I think has enormous implications for—not only for our future economy, but also for future national security issues.

And I think that the challenge that we face with regard to workforce—which by the way we faced in World War II as well. There was a lot more plants and shipyards opening during World War II than there were workers available. And this became a major problem of how to recruit and how to train and how to retain workers in that environment, particularly when you had a free market wage environment where if you were working in a defense plant in Detroit and you heard that in the Kaiser shipyards they were paying a lot more, plus you had health benefits, you could just pack up and go. There was no one that was going to say no, you have to stay and keep working on what you've been doing here with regard to producing tank treads or whatever else came up.

So you've got the training and development. You've got workforce. You've got education issues, which we always keep coming back to the question about K–12 and STEM [science, technology, engineering, and mathematics] education and the constant shortfall that we have in terms of both development of skill sets, but also in updating the curriculum in those areas here. We've been talking about this for decades, and yet the trend is still downhill.

So what I'm hoping we'll be able to do with the work that we're doing on the Space Workforce Commission at Hudson is to come up with some answers, to come up with a paradigm about ways in which we can expand workforce in ways that could be a paradigm for talking about it with the rest of the defense industrial base, but then also for our own manufacturing economy as a whole.

But I think part of the issue has been that this has always been an afterthought, particularly on the part of military planners and strategists. And I think there are a number of reasons for that. I think part of it is, if you like—I'm going to say this—I think part of it too is a class issue. I think there's a—there was always been a reluctance to think about the blue-collar aspects of our defense industrial base, of our manufacturing base as a whole, and to think about it as a—as something which will always be there when it's

needed instead of something that needs to be revivified and has to be taking a new direction for the 21st century. And that includes of course our work with foreign countries and with foreign workers as well.

And part of my vision for an arsenal of democracies will be to think about the issue of workforce and the ways in which U.S. workers, workers from our leading democracies can in fact find a way to work together and to become part of a productive whole with those systems which are going to be most important to the future of our national defense.

Dr. MCCORMICK. Thank you. In regards, I only have a short amount of time, but, Mr.—I hope I don't mispronounce your name—Krepenivich——

Dr. KREPINEVICH. Close.

Dr. MCCORMICK. Good. As far as lessons learned from the war in Ukraine with Russia and innovating for the future, do you think it is more important to focus on innovations in technologies versus tactics and surge capabilities when we are talking about not just any war, but looking into the future for lessons learned?

Dr. KREPINEVICH. I think the answer is both. I think we need to look at how both sides are using technologies. There's of course a lot of discussion about the use of drones in that environment and how they've used them. I think in terms of operations though you look at what the Russians have done in particular recently in terms of defenses. And a lot of these defenses are very formidable against even modern weapons, and they aren't especially sophisticated when you just put in enormous numbers of land mines to stop someone.

So a strong lesson.

And that's been a characteristic of military innovation over time. After World War I the Germans lost and they spent several years looking at what went wrong, both from a technological perspective and an operational perspective.

Dr. HERMAN. If I may say something quickly about——

Mr. GALLAGHER. Go ahead.

Dr. HERMAN [continuing]. Can I——

Mr. GALLAGHER. Go for it.

Dr. HERMAN [continuing]. About the Russian industrial base, defense industrial base. What is amazing is is that as an industrial base it's probably one of the least innovative of the major powers. It has been one which has really depended upon foreign export sales in order to sustain itself. And yet what's interesting is that you have a very un-innovative defense base which has managed to sustain this war effort for over these last 2 years. I mean, it's an incredible story of how being able to outlast your enemy and outproduce them even when your resources there aren't really cutting-edge and aren't really sort of moving the military technology paradigm forward.

Mr. GALLAGHER. Mr. Golden.

Mr. GOLDEN. Thank you. You spoke a little bit about the British approach with the French and shipbuilding and alluded to China following this similar tactic more recently. I guess a two-part question for any of you. Are there, part 1, examples where the U.S. has either willfully or out of necessity taken a similar approach? And

part 2, would you advocate that the U.S. look at a similar approach today in any instances, or do you think that would assume too much risk?

Dr. KREPINEVICH. Just a couple of general observations. Since the mid-19th century warfare has moved from two domains to eight. Speed, range, and accuracy have enabled forces operating in each of these eight domains to influence operations in the other seven. So when you sit down and you try and figure out how am I going to defend the first island chain, you have a lot of choices, but you also have a lot of uncertainty because you don't know what is just the exact right mix of these kinds of capabilities and what attributes they have to enable you to maximize your effectiveness.

So because this level of uncertainty is so high, the ability to experiment and exercise what a wide range of capabilities becomes very important to find out, again, to reduce uncertainty at the margins. What capabilities work? What don't? What attributes should they have? And the ability to adapt quickly as you find out what works and what doesn't, this issue of time-based competition—time is a resource. Budgets are resources, technologies are resources, people are resources. Well, so is time.

And the side that figures out first how to operate most effectively, knowing that they're not going to get it perfect, that there's going to be some error, but that does it better than the other side—and then once the balloon goes up, as they say, and you start to see what works and what doesn't, who can move more quickly than the other to field those capabilities that actually matter more, that's the side that's going to have an innovative advantage.

Dr. HERMAN. And can I say something here with regard to those range of choices and the range of domains? This is another role for artificial intelligence, by the way, is in the area of what we call strategic reasoning. In other words, helping planners and strategists work out what's the best combination of priorities involved in a multi-domain conflict, which we're going to have more and more of that as a possibility, but also a multi-front. What happens if you're involved in a conflict in the Middle East, in the Taiwan Straits, and in Central or Eastern Europe all at once? Well, artificial intelligence, and I would also add quantum computing, provide the kind of modeling and the kind of analysis, optimization analysis that will allow planners to get through and understand and have a range of feasible choices as opposed to being—having to sort of grope their way through the possibilities that go with it. Yet another example where again innovative—the disruptive innovation in this case can be really important at the very top, as well as what happens on the battlefield or what happens in an industrial base.

Colonel GUNZINGER. I would caution because we can do something technologically doesn't mean we should. And because an adversary is doing something doesn't necessarily mean we should follow suit.

When I was in OSD Policy as a DASD I often heard Policy people, very smart individuals, talk about, well, look, China is imposing costs on us because they're fielding these medium-range, intermediate-range ballistic missiles that can attack our bases along the first island, et cetera, et cetera, et cetera. We should do the same to them. Well, not necessarily.

They have a very different target set than we would. They're attacking bases, our bases and our allies' bases that are undefended. They're not hardened. We can't disperse yet because we don't have the resources to do it. We lack kinetic and non-kinetic defenses, whereas China has the PLA air force. Very different kinds of targets. Very different—their bases are hardened. They're ready to disperse. They have decoys, et cetera. That takes a different mix of weapons and a different mix of capabilities to attack effectively.

So as an operator you have to think through those differences to establish requirements that will make us the most effective against them rather than just say, well, we should do what they're doing.

Mr. GALLAGHER. Mr. Luttrell.

Mr. LUTTRELL. Dr. Herman, you mentioned artificial intelligence, strategic advantages, machine learning and how that gives us an operational strategic advantage over our enemies. I got to tell you I don't know an AI computer that's ever been shot at. And when a round goes downrange that has your name on it and is hollering at you, things change.

I think my question is as we push for this industrial footprint, Colonel, you rattled off about a half-dozen issues that we are facing in the country that push us way, way to the rear. And I don't know if I could—it may be a fair assessment to say the Iraq and Afghani war may have pushed us to the rear because we were front sight focused on that engagement while our adversaries took our inventions and ran with them. And now they are that far ahead of us.

The majority of my colleagues sitting on this panel with me served in combat and the one thing that you can't argue is a fighter on the ground with his or her finger on the trigger, period. I mean, one of the most formidable forces I fought against was the Afghanis and they have been fighting their whole lives. They love every second of it and I don't think they have ever lost a war, if I remember correctly.

We hear in the committees up here all the time about how we need to advance the technological space in order to defeat our adversaries. Doctor, you mentioned that there needs to be—it needs to be weighed accordingly. Does the Hudson Institute—is their stance more in the technological space in order to combat China, Iran, or do you have an opinion on are we losing our footprint with the forces and how does that play out? Anybody.

Dr. HERMAN. Well, I think that's one of the key issues that we're not empaneled right now to talk about, but it's the big question, isn't it? I mean, you can equip your people with all the advanced technologies you want and back them up with those technologies, the whole works—unmanned systems, AI, space, and all that—but are they ready to go into combat? Are they ready and are they dedicated enough and are they willing to risk their lives for what is coming?

And one of the things that concerns me is that our—is that the cost of being—the cost of the United States being the leading superpower of the free world is a heavy one. It's a heavy one in human terms as well as economic terms and technology terms.

And all of this—in my view all of this discussion that we've been having here is moot if we don't have a commitment on the part of Americans, and our allies—but particularly Americans because

people look to America to lead—we don't have a commitment to defend freedom to the last measure. And that is still going to be the most fundamental, the most fundamental advantage we have against any opponent we face, against any scenario, war or—warfighting scenario, deterrence scenario we have. We need to make the sacrifice that those and you and others made and were willing to make, otherwise we're just wasting our time.

Mr. LUTTRELL. The forces that we fought alongside the biggest—one of the largest statements they ever made is like you SOBs, you all volunteer to fight. It is in your blood. We don't have to do that where we are from. They make us do it. But you guys——

Dr. KREPINEVICH. At one of the hearings after the first Gulf war I think it was General Powell was asked would you have basically traded your troops for the Iraqi troops or your equipment for the Iraqi equipment? And Powell said I'd trade my equipment, take theirs, but I'm not going to trade my troops for theirs. And there's an old saying about Bear Bryant that he'd "take his'n and beat your'n, and then he'd take your'n and beat his'n." And so leadership, the quality of troops, counts for an enormous amount.

That said, technology counts, too, because——

Ms. LUTTRELL. It does, but there comes a point in time—and I am not arguing. In fact, I am a tech guy. But there was a point in time later in the war that couldn't drop a bomb, couldn't fly the plane over the top of us to help us out, couldn't do none of that. And I know that with the advances in AI, a push of a button is a very valuable threat to everybody that has the advancements ahead of us. I just wanted to get your opinion on that.

Mr. Chairman, I yield back.

Dr. KREPINEVICH. Well, two quick points about AI. I've worked a lot in missile defense and there's a point at which—if you're say an air defense battery, you're going to be overrun and you can't figure out—and same thing if you're in a carrier strike group. How do you defend against all the stuff coming in? How do you prioritize it? And how do you sustain it? If it's a sustained attack over 10 or 15 or 20 minutes, a human being's mind starts to go to Jell-O.

Same thing with a pilot that had to be tanked twice to get from the Arabian Gulf to Afghanistan on these 8, 10, 12 hours. After about 8 hours a pilot's mind starts to go to Jell-O. You can only keep your keen sense of being on the fighting edge for so long. And in those cases artificial intelligence in the form of a drone might be the answer.

Mr. GALLAGHER. Mr. Deluzio.

Mr. DELUZIO. Thank you, Mr. Chairman.

Hello, everyone. Focus my questions on defense industrial base, consolidation there, and impacts on innovation. And so, look, the consolidation that has happened since the 1990s is obvious. It is pretty drastic. The primes have gone from 51 to 5 in that timeframe. We have seen consolidation impact the number of bids from everything from weapon systems, components, parts, you name it. Senior leadership at the Pentagon, civilian and uniform, has raised the alarm. I think my colleagues in both parties on this committee—subcommittee have expressed different concerns around the impact of consolidation on readiness and otherwise.

Oftentimes we focus on, and I have talked about us, as the public, overpaying for weapon systems, the industrial base's ability to deliver on time. The Wall Street Journal today or yesterday talked about the inability to surge excess and extra capacity.

My question though is about the impact on innovation. Has this decrease in competition hurt the industrial base's ability to innovate? Is it too hard for smaller newer entrants to come in and compete? So I open the floor to all three of you.

Dr. Krepinevich, start with you. How are you seeing this decrease in competition impact innovation?

Dr. KREPINEVICH. Well, obviously the more primes you have, the more opportunity you have for competitive bidding and for different ideas as to how to meet a particular need of the military's.

I would also say that when it comes to innovation a big part of what the industrial base can also do is respond to a military sense of how it—again how it plans to fight. I keep coming back to this. Until we decide how we're going to defend the first island chain, it becomes very difficult to know what we're going to ask of the industrial base.

And the other point is not just with respect to innovation, but in this context—and I'll go back to the—some of the lessons of previous periods of disruptive innovation. The British were very keen to maintain an industrial base that could outproduce its rivals and do it more quickly. So that was a key metric for the British when they looked at their industrial base. Can we produce at scale more quickly than our rivals?

The other issue that came out in one of the cases was with respect to the American Navy prior to World War II. Didn't quite know whether carriers were doing to be the answer. Didn't even know what kind of carriers. So they built different classes of carriers. They built small carriers, big carriers, Goldilocks carriers.

Same thing. We didn't quite know what the best form of air attack was going to be. What was the best form of strike? They built horizontal bombers that again dropped bombs vertically. They built dive bombers. They built torpedo bombers. And then they had the industrial base—and again you had to have a fairly broad industrial base—be able to produce that faster and larger quantities than our adversaries could do in order to keep up with us.

Dr. HERMAN. I would say that, from my point of view and from what I—and also from a World War II point of view by comparison, yes, there are certainly lost opportunities when you have reduced competition and when you have fewer numbers of primes, as Andrew was just saying.

But I think it operates—the issue operates in a slightly more subtle way, and that is is that what I would see as even bigger obstacle, both to innovation but also to a productive, really productive and scalable industrial base is FARC [Federal Acquisition Regulatory Council], is just the Federal regulation and the enormous labyrinth and the hoops that companies have to jump through in order to negotiate that.

And what you've ended up with then with regard to the big contractors are the ones who can negotiate that labyrinth and who have become—know how to work the system in ways in which so many other companies, including midsize and startup, and even

commercial companies who would love to be involved, love to help out and bring their technology and their ideas and their products to our national defense, who simply take a look at the size of the Federal regulations and say there's no possible way.

But we've been here before. In 1940, summer of 1940 the U.S. Army decided they need a light utility vehicle, right, a new one. And they sent out—with a range of specifications they sent out a request for proposals to 286 companies in America. Two of them answered. None of the big companies, not Ford, not Packard, not—none of them, General Motors, none of them answered because none of them wanted to do any business with the Federal Government. They knew it was a loss leader. They didn't want to get involved with it.

The two who answered, one of them, Bantam, was about to go bankrupt. And it was like we'll just roll the dice one last time. We've never made anything like this, but what the hell. The other one was Willys. And it was of course the Willys Jeep model that came out of that. It was almost by happenstance because those two companies were thinking like we haven't got—we don't want to get involved with the Federal Government, but we have to. Their backs were to the wall and that's why they involved—that's why they did it.

What we really need and what we're working on, what is happening in places like the PPBE [Planning, Programming, Budgeting, and Execution] Reform Commission, with which I've been working over this last year—one of the things we need to do is to find ways to ease in and continue the involvement of small companies, of startup companies with great ideas and great technologies and to enable them to reach the point where they become part of programs of record and part of the mainstream with it. There I think even more than trying to change the balance between the big primes and the smaller players and the competition issue that's where the thrust is going to have to come.

Mr. GALLAGHER. Thank you. Mr. Fallon.

Mr. FALLON. Thank you, Chairman.

Well [inaudible] just piggybacking on what you were saying before, invention sometimes comes to pass because it is necessary. Like World War I and we saw a lot of the things that came out of that, and how to use the airplane. We didn't really know how to use it. It was there, but it was in its infancy. And then same thing with World War II.

I wonder how long it would have taken to develop nuclear weapons if World War II had never—it is kind of counterfactual history and alternate history, but it was kind of a necessity at the time and the race was on between us and the Germans and—then Yom Kippur in 1973. You see a lot of what the Soviets were fielding and then what we were fielding and then what came out of that: the Abrams, Bradley, Apache, Black Hawk, Patriot Systems.

So the question really becomes does DOD want to innovate? And I'm of the humble opinion that nothing will change unless really everything does. So I wanted to ask the three of you on the panel what do you think the role of venture capital can play in the future of innovation? And we'll go with Dr. K. first.

Dr. KREPINEVICH. Well, actually there is a—I think a room for venture capital. If you look at—and I think this particular period is similar to the interwar period between the World Wars because then most of the technology that was being pulled into military capabilities—aviation, mechanization, radio—was from the commercial sector. If you look at some of the technologies today—artificial intelligence, additive manufacturing, synthetic biology, right on down the line with some exceptions, for example, like directed energy and hypersonics—a lot of that is in the commercial sector.

And I'm familiar with one organization, Shield Capital, that has set its mission to identify in the commercial sector those gaps that it sees in the commercial sector that would be useful to the military and to fund business in those gaps because they think down the road the military's—not only will this be useful in a commercial sense, but ultimately it will be in demand by the military.

So I do think there is a role and historically there has been a role as well.

Dr. HERMAN. The process that you were just talking about, that phenomenon is what I call emergence through emergency, and where you suddenly find yourself in a situation where your back is to the wall and you have to think innovatively and differently and come up with a new paradigm. But as our chairman was just saying earlier, we may not have such a time for that kind of reflection and retooling if we find ourselves in a conflict in the Taiwan Straits.

This issue about venture capital is one I've thought about a great deal because I think it is a missing advantage that the United States have all of that private capital, equity capital which is looking for opportunities for investment in innovation. And a lot of it is—and I think we'll agree a lot of it is people who are involved not just in terms of making a profit, but also who do want to support our national security, who become involved in these technologies for patriotic reasons, as well as for return.

The challenge is I think that we have two different cultures with what happens at DOD and what happens in the venture capital realm. And I think DOD, the Department has been looking at ways to encourage more venture capital and bring it on board, setting up offices, et cetera.

But I think in some ways they think of venture capital as substitute capital. In other words, this is money we don't have to spend from our budget because we'll find private investors who will do it. But of course that's not the case. Venture capitalists are looking for something else. They're looking for return on their investment. They're looking for a long-term fostering of a growth from the technology or product that has national security uses, but which will ultimately pay off in the commercial realm and is commercializable as well as a national security asset.

So I think finding a way in which to bring those two communities together involves bringing a mindset shift on DOD on the one hand, which is venture capitalists are very—can be a useful ally, but they're not thinking the way you do about money and about investment. And on the other side, on the other side of making venture capital feel like this is a—we're going to create an in-

vestment and an acquisition environment which will be conducive to bringing on your best ideas and your best company.

Colonel GUNZINGER. Let me jump in very quickly, if I could. Yes, DOD must innovate. It knows it must innovate. And to answer the last three questions on a point, but there have to be programs to offer VCs [venture capitalists] opportunities. There has to be opportunities for different companies to actually fund development of technologies that will lead to innovation.

During the Cold War period our Air Force bought a new type combat aircraft, one every 2 years. After the Cold War it was one new aircraft every decade. Now that's not the kind of promise that VCs are going to pony up money for to fund technologies that can lead to new aircraft. That also hurts the workforce because they want to work on programs that are going to succeed and actually end up in the field, in warfighters' hands.

So VCs have a role, but they must have some promise on return, and that's going to take new capabilities like CCAs, collaborative combat aircraft, which more—we see VC money pouring into different companies coming up with new ideas for this family of CCAs because there's some promise of actual programs and actual return.

Mr. FALLON. Thank you, Mr. Chairman. There's a lot of difference between SpaceX and NASA [National Aeronautics and Space Administration] I think in a lot of ways, too, but necessity. All right. Thank you very much. I yield back.

Mr. GALLAGHER. Thank you. I want to ask another question, which means you all will have an opportunity to ask another round, if you want. Just let us know. You can get in the queue.

Dr. K., describe to me your recommendation for a national training center, potentially in collaboration with some of our closest allies.

Dr. KREPINEVICH. To put this in context, I think if I were Defense Secretary one of the short list of questions I would ask is tell me how you're going to defend the first island chain.

And during the Cold War we had a set of operational concepts that said this is how we're going to defend NATO. The Army and the Air Force developed something called AirLand Battle that described not only to stop the Soviet advance, but also how to conduct deep-strike operations to break up the second and third wave coming out of Eastern Europe.

The Navy said we're going to keep Soviet submarines north of the Greenland-Iceland-U.K. gap. This is how we're going to do it. We're going to send our submarines up there. We're very good at submarine warfare. We're going to keep their bombers from coming down and bombing our transport ships trying to get across the Atlantic by something called the outer air battle. And there was this chainsaw concept they had as part of that.

The Marines said we're not going to let them flank our troops in Germany by coming into Norway. And so the Marines pre-positioned equipment in Norway, they moved in very—the plan was to move in very quickly, seize the airfields, keep the Russians from getting to the airfields. We have nothing like that with respect to how you're going to defend the first island chain.

When I was the special assistant to the Defense Secretary for Special Projects during the Cold War we had multiple mobilization

scenarios. What is our mobilization scenario for Chinese military buildup in the Western Pacific? We looked at at least three different contingencies with the Soviets and we learned lessons from that. One of the lessons was we put four entire division sets of equipment in West Germany because we knew we could only—we couldn't match them unless we flew the troops in and not all the equipment with them.

So the idea is what are the operational concepts for defending the Western Pacific, the first island chain? When I wrote "Archipelagic Defense," to give you an example to set up the issue of exercises, I said, well, one way we might defend some of these islands is what I call turtle defenses, basically taking the lessons of what the Japanese did in World War II, basically going underground. In fact, when the Marines hit Iwo Jima in World War II, one Marine said the Japanese aren't on—they're under Iwo Jima.

So would that work? Is that a viable concept? And this is where you get to the issue of exercises. In the 1970s we pioneered high-fidelity training, getting back to the earlier question about how well trained are your troops, and we established an opposing force. Back then it was the Soviets. Where is that kind of training center today? Where is the training center that says here comes the People's Liberation Army. They're waging systems destruction warfare. They're invading your island. How are you going to defend it successfully?

Until you come up with an answer to that how do you establish defense priorities? How can you say this is what we ought to buy? And this is a wasting asset here. This might have been good in counterinsurgency or Desert Storm, but it's not going to be very helpful against the Chinese in defending an island along the chain.

And so this—I've talked to, for example, Australians. The Australians say we've got a lot of land in Australia. We could develop a combined training center in Australia. You can instrument it. We could develop a combined Chinese opposing force just the way we did during the Cold War. Where is this?

Exercises not only reduce uncertainty by helping you find out what works and what doesn't. It also builds up support. So for example, the Brits, their big problem around the turn of the century were submarines and torpedoes. The way they went to war was they would blockade the enemy's naval base. Well, now you can't do that because these people are firing torpedoes at you. Well, what's the answer? Part of the answer was conducting these kinds of exercises. So the Brits—the British naval officers and establishment realized they couldn't operate that way anymore. That's the first step to realizing innovation.

And the other example I'll mention would be the German field exercises in the fall of 1937 where they actually had a panzer division for the first time, this armored division. And it just blew everybody's socks off. I mean, they just couldn't believe what this division was doing in the field. And that's not something you can replicate with a war game or with a study. It's visceral. And so the need for these kinds of exercises I think is crucial.

Mr. GALLAGHER. Yes. I am out of time.

Ranking Member, you have any more questions?

Mr. KHANNA. Thank you, no.

Mr. GALLAGHER. Anybody?

I have one more then. Sorry. Hey, rank has its privileges.

Dr. Herman, your comments about—I don't want to mischaracterize it, but it seemed to be that like innovation can't be its own separate thing. It needs to be part of like everything going on. It made me think of Elting Morison's famous book "Men, Machines, and Modern Time," where she talks about innovation is often just iterative. But it also involves like unique human beings with unique personalities. At times these are like very—the type of human beings that would not necessarily get promoted in the military, right? John Boyd was mentioned earlier, right? I mean, that is probably a great example of it.

I guess what I am driving at is we talk about innovation, we talk about like the org [organization] chart of DOD, we talk about funding, but ultimately I think it comes down to like a cultural issue of do we have—are we promoting and empowering humans that can take intelligent risk and rewarding them for taking intelligent risk? I don't know what the precise question is there, but maybe you can comment on that, even if it is just to push back on my analysis.

Dr. HERMAN. Sure. I think you can probably get excellent comments from everybody here——

Mr. GALLAGHER. Yes.

Dr. HERMAN [continuing]. On the panel on that one. I guess my view would be when I'm thinking about innovation and productivity and production is that you have a—you have on the one hand you have the commercial sector in which innovation is a necessity in order to compete in the marketplace. You always have to make things better and make things faster and make them cheaper. It's the nature of the business you're in.

In the military I think confronting the issue of innovation is when things go wrong, right? It's when you're in the field and suddenly you realize something is not working and you've got to try something else, maybe a new technology, maybe a new tactics, maybe an entire new strategic rethink. This is why so often the winner of the last war becomes the loser of the next, right? World War I, the French and the British; World War II, the French were looking forward. They were actually looking forward to the German invasion, you know?

Mr. GALLAGHER. Yes.

Dr. HERMAN. General Gamelin was rubbing his hands with glee when he learned that the Germans were going to attack because he had thought he had figured out exactly how to beat them based on the experience of the first war, right?

Mr. GALLAGHER. Yes.

Dr. HERMAN. This is how innovation comes in. So in both cases you just put your finger on the common factor for both: risk taking.

Mr. GALLAGHER. Yes.

Dr. HERMAN. Risk in business, which sometimes leads to failure. Your business goes under and you start a new one. In the military or in—I'm not going to—I going say the military—defense industrial base, there is risks.

Mr. GALLAGHER. Yes.

Dr. HERMAN. Projects will fail. One of the great virtues I think with DARPA is precisely that. They do know that a lot of their projects are going to fail. And it's understood from the beginning that some of these are just not going to work out.

I think the challenge is is to bring a similar mindset, an openness to risk, a willingness to embrace failure on the small scale in order to bring about success on the large scale that remains the next big cultural cliff to climb at our current Department of Defense.

Mr. GALLAGHER. Well, let me put a finer point on it and invite your comment, Colonel Gunzinger. I just wonder if John Boyd, who is as much of a Marine Corps hero as an Air Force hero—whether he would have made it past the rank of captain in today's military.

Colonel GUNZINGER. Probably not.

Mr. GALLAGHER. Yes.

Colonel GUNZINGER. Although I hear it's pretty easy to make major these days.

Mr. GALLAGHER. Is your microphone on?

Colonel GUNZINGER. I apologize. It is now. One of the things we cannot do is turn innovation over to a bureaucracy. We've seen that in the past. We saw DOD establish the Transformation Office during the time Secretary Rumsfeld was in charge. And actually I took over that office as a DASD.

But you put—you turn bureaucracy loose on innovation and you get anything but more often than not. That's why we have Rapid Capability Offices, a Strategic Capabilities Office. That's why we have DARPAs. Because they work outside the current processes to bring good ideas to the fore to the operators and planners who hold the money.

But there has to be resources and a promise of some transition. And that requires leadership. You have to have leaders saying I agree we must take that risk. This is transformational. We need to break through the resistance of current programs and actually put money behind this and fund it. If it doesn't work, I'll take the hit, but I think we need to do this. And that takes leadership.

Mr. GALLAGHER. Final comments on the human dimension from Dr. K.

Dr. KREPINEVICH. One is at each of the four studies key figures that are leading the innovation have extended tenure. So I'll give you—I was on the Joint Forces Command Advisory Board. Typical tenure for a commander there was a year, maybe two. You can't give somebody a tenured job and give them 2 years to do it.

Mr. GALLAGHER. Yes.

Dr. KREPINEVICH. And when General Mattis—he called me in around 2008 and said, you know, Andy, I'm thinking of shutting this down. And part of the conversation was to really get this to work what you'd want to do is find a Jim Mattis, give him 3 years at Joint Forces Command. If he was making progress, give him another 3 years. And then fleet him up to Vice Chairman of the Joint Chiefs for a 4-year tour. That's 10 years to see something through.

Mr. GALLAGHER. Yes.

Dr. KREPINEVICH. And so it's—part of it is identifying these people.

Mr. GALLAGHER. I'm thinking Naval Reactors.

Dr. KREPINEVICH. Naval Reactors. Yes, certainly Rickover's. General Creech, who headed TACAIR [Tactical Air Command] during the revolution in basically the Air Force, headed TACAIR for 6 years, from 1978 to 1984. And General Dixon before him was like-minded. Jackie Fisher in the Royal Navy had something called the Fish Pond because they were all trying to institutionalize. They realized that after they left, if they hadn't done that, there was going to be a backfill. And in each case there's this—if you want to know if a military is really engaged in disruptive innovation, there's going to be blood on the streets. Okay?

Look at the Marine Corps. General Berger. Whether he had the right idea or not, you knew he was trying to do something.

If you look at for example Fisher—I'll just give you the best example—he ends up defending himself in a session, in a series of hearings at the Committee on Imperial Defense, headed by the prime minister, because the syndicate of discontent has come out against him: admirals, politicians, and so on.

Same thing with the American Navy in the period between the World Wars. Knife fights going on basically between the gun club, the battleship admirals, and the aviation advocates.

So people matter. People matter a great deal.

Mr. GALLAGHER. Thank you, all. This has been phenomenal. I guess more than anything else we need our warriors to read and write so that our fighting isn't done by fools, as the old saying goes. And they have a good place to start with all of your testimony and the books you have written that informs it. And this has been a really enriching conversation, so thank you for joining us.

Thanks to the ranking member.

And with that, the subcommittee hearing is adjourned.

[Whereupon, at 3:26 p.m., the subcommittee was adjourned.]

A P P E N D I X

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PREPARED STATEMENTS SUBMITTED FOR THE RECORD

DECEMBER 6, 2023

Back to the Future

The Challenge of Disruptive Military Innovation

Testimony Submitted to the Subcommittee on

Cyber, Information Technologies, and Innovation

Armed Services Committee

United States House of Representatives

by

Andrew F. Krepinevich, Jr.

December 6, 2023

Victory will smile upon those who anticipate changes in the character of war, not upon those who wait to adapt themselves after changes occur.

General Giulio Douhet

He who will not apply new remedies must expect new evils.

Sir Francis Bacon

Chairman Gallagher, Ranking Member Khanna, Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the challenge of disruptive military innovation,[1] with an eye to the lessons learned from successful efforts in the Industrial/Information Age.[2]

Background

The world is in a period of disruptive change in the character of warfare. This is primarily the result of geopolitical and military-technical change. The return of China and Russia as active, revisionist great military powers finds the military competition escalating to a level not seen since the Cold War. Simultaneously, the advance of a

[1] As used in my testimony, "innovation" refers to efforts designed to develop and introduce new capabilities and ways of operating that yield an increase in military effectiveness within an existing way of waging war. Such an innovation may be the result of an advance in technology, such as the proximity fuse invented by the British and developed along with the Americans in World War II. It could also emerge from a new way of operating, such as the "Thach Weave" to deal with Japan's superior Zero fighter during the Pacific War, or from a novel way of organizing or structuring one's forces, such as in the U.S. Army's concentration of large numbers of helicopters into an Airmobile Division in the early 1960s. "Disruptive innovation," on the other hand, involves efforts designed to realize a discontinuous leap in military effectiveness, thereby introducing what is sometimes referred to as a military revolution. Examples of disruptive innovation are found in the U.S. Navy's shift between the world wars from a fleet centered on the battleship to one centered on the fast carrier task force, and the introduction of nuclear weapons. Or consider a notional example of innovation in the transportation industry at the turn of the 20th century. An innovation would have involved developing a better horseshoe, one that lasted twice as long as those then in use. A disruptive innovation would see the introduction of the automobile. The former effort would have marginally improved the effectiveness of the *existing way* of "doing business," while the latter effort realized a dramatic boost in effectiveness by introducing a radical *new way* of doing business.

[2] This testimony is based on findings from my new book, *The Origins of Victory*, published by Yale University Press.

range of new military-related technologies offers the promise of waging war far more effectively than ever before.[3]

This situation finds the U.S. military especially challenged, as it has spent most of the last three decades focusing on waging war against minor powers like Iraq, Libya and Serbia, and on counterinsurgency and counter-terror campaigns against non-state groups. On the other hand, during this time its great power rivals, China and Russia, devoted intense effort to offsetting the United States' dominant position what some call precision warfare, and others refer to as employing a reconnaissance-strike complex.[4] Their efforts have paid off. The United States no longer enjoys a near monopoly in this form of warfare, and must therefore adapt to compete effectively under new and very different circumstances.

This dramatic change in the competitive environment presents a compelling need to pursue disruptive innovation. As history shows, militaries that succeed in leading the way into a new and far more effective way of waging war can realize an enormous benefit over their rivals. Correspondingly, those that fail to keep pace can find themselves operating at a severe disadvantage.

Given the implications for U.S. security, senior defense policy-makers should be particularly interested in knowing how to exploit disruptive shifts in the competition to their advantage. Simply put, they should want to know: How well is the U.S. military, and those of its principal rivals, positioned to exploit the "next big thing" in warfare?

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[3] For an overview of these technologies and their potential to support disruptive military innovation, see Andrew F. Krepinevich, Jr., *The Origins of Victory* (New Haven, CT: Yale University Press, 2023), pp. 85-140.

[4] The Precision Warfare Revolution was introduced by the U.S. military in the form of a nascent reconnaissance-strike complex in the First Gulf War. The precision-warfare regime has matured in the sense that there are other militaries, China's People's Liberation Army (PLA) in particular, that have fielded their own version of a reconnaissance-strike complex. Thus, while once the U.S. military held a rough monopoly in precision-warfare operations, this is no longer the case. For its part, the PLA has come to view modern warfare as a competition between opposing "operational systems," supplanting the paradigm of war between opposing mechanized military forces. This is similar to Russian descriptions of reconnaissance-strike complexes and American views of "multi-domain warfare." China's operational system (or reconnaissance-strike complex) comprises five subsystems: the *information-confrontation*; *reconnaissance-intelligence* (scouting or ISR); *command*; *integrated support* (or battle network); and *firepower-strike* (strike) systems. The PLA sees the military competition centering on deconstructing the enemy's reconnaissance-strike complexes—what it calls "systems destruction warfare."

The answer to this question may be found, in part, by studying militaries that led the way in generating quantum leaps in military effectiveness through disruptive innovation. With this in mind, I assessed the experiences of four militaries, encompassing different time frames, national military organizations, and branches of the armed forces:

- Britain's Royal Navy during the so-called Dreadnought Revolution of the late 19th and early 20th centuries;
- The U.S. Navy during the period between the world wars that saw it position itself to shift from a fleet centered on battleships to one built around fast carrier task forces;
- Germany's military that, during the interwar period, developed mechanized air-land operations ("*Blitzkrieg*"); and
- The U.S. Air Force during the period between the Vietnam and First Gulf Wars that saw it developing a rudimentary reconnaissance-strike complex.

This assessment revealed characteristics common to these militaries relating to disruptive innovation. The balance of my testimony provides a brief summary of these characteristics, with emphasis on the U.S. military's experience.

A Guiding Vision

In each case where a military organization led the way to a disruptive shift in the competition, it enjoyed the benefit of a clear understanding of it was trying to do, how it would go about accomplishing it, and the anticipated end state.

The vision of the end state is relatively brief and unambiguous, serving to focus and inform the organization's efforts. The U.S. Navy was blessed with its own visionaries in the years between the world wars. One was Vice Admiral William Sims, who, in 1925, nearly a decade before the United States launched its first purpose-built aircraft carrier, asserted "A small, high-speed carrier alone can destroy or disable a battleship alone . . . . [A] fleet whose carriers give it command of the air over the enemy fleet can defeat the latter. [Consequently], the fast carrier is the capital ship of the future." Sims'

vision was shared by Rear Admiral William Moffett, head of the Navy's newly established Bureau of Aeronautics (BuAer), who proclaimed, "We can hardly visualize today the potential power of aircraft, not so much for scouting and spotting, but for bombing and torpedoing. It may readily be the deciding factor in a war."

The U.S. Air Force's leading visionary in the decade following the Vietnam War was General Wilbur ("Bill") Creech. The general was convinced that a different way had to be found to address the integrated air defense system (IADS) threat that had inflicted such high casualties on the Air Force and Navy during the Vietnam War, and on the Israeli Air Force in the 1973 Yom Kippur War. Creech's vision was of an all-day, all-night, all-weather, integrated force that could wage a campaign whose goal was to suppress enemy air defenses, not "fly past" them.

Emerging Technologies: Key Enablers

In each of the four cases, disruptive innovation was either driven or enabled by significant advances in military-related technologies. Advances in aviation technology were fundamental to the shift from a battleship-centered fleet to one organized around the carrier as its capital ship, and the fast carrier task force as the successor to the line of battle. Long-range radio and radar further transformed war at sea by providing the carrier task force with early warning of approaching enemy aircraft and a means to coordinate friendly aircraft operations over extended ranges. In a similar vein, advances in mechanization, aviation and radio enabled Germany's military to transform its World War I era "storm troop" tactics to *Blitzkrieg* operations.

In the quarter century prior to the First Gulf War, the U.S. Air Force's dramatic change in the character of air operations found it relying heavily on the information technologies (IT) revolution, which was just then gathering momentum. The introduction of solid-state electronics, enhanced sensors and laser technology in the late 1960s made effective precision-guided weapons possible. The IT revolution also proved crucial in fielding stealth aircraft. Nascent battle networks were enabled by the GPS satellite constellation and by advanced scouting and airborne command-and-control systems, such as the Airborne Warning and Control System (AWACS) and Joint

Surveillance and Target Attack Radar System (JSTARS) aircraft that provided U.S. forces with an enormous boost in situation awareness.

Operational Challenges: "What Are We Trying to Do?"

Each of the four military organizations examined addressed this fundamental question: What key operational challenges do we confront? As used here, "operational challenges" are *compelling real-world problems posed by adversaries at the operational (or campaign) level of war.*

Success in disruptive military innovation is closely associated with the particular challenge a military sets for itself, as operational challenges can vary widely. This is important, as disruptive innovation that enables a military to meet one operational challenge will not necessarily prove as effective in addressing others. Moreover, since a military organization does not have unlimited resources, it cannot prepare for every significant threat. Thus hard choices must be made as to which will be accorded priority, for as Frederick the Great warned, "He who defends everything, defends nothing."

The four militaries engaged in disruptive innovation examined were focused on addressing specific problems, or challenges, at the operational level of war. These problems were overcome thanks to their ability to identify, develop and exploit major new sources of competitive advantage. That being said, the new forms of warfare that emerged from their innovations, while remarkably effective in certain aspects of the overall competition, were considerably less effective in other situations.

These limitations appear in *form* and/or *scale*: either the form of military challenge was materially different from the one that was the focus of disruptive innovation, or the magnitude of the challenge was so great that the new form of warfare could not be executed at the necessary scale to address it successfully.

For example, *Blitzkrieg* operations proved enormously successful in defeating Poland and France in short campaigns. Having succeeded, the German military was confronted with a challenge quite different in *form* from that which it was designed to address—conducting a seaborne invasion of the British Isles. When, in 1941, Adolf

Hitler declared war on Soviet Russia, the German armed forces achieved great initial successes against the Russian forces. Yet Germany proved unable to prevail in large measure because its military lacked the size to defeat a modern military on the *scale* the Russians could field. Nor could Germany's army adequately secure an area an order of magnitude greater than that of Poland or France.

There should be no more than five or six core operational challenges—not every challenge can be a "core" challenge. And even core challenges must be prioritized to inform resource allocation choices.[5]

In brief, each of the four militaries examined were the first to engage in disruptive innovation to realize a major boost in its competitive advantage for *a particular operational challenge*. Hence the importance of military organizations focusing on addressing the questions: What is it we are trying to do? What is the particular challenge at the operational level of war that we are trying to address?

To use a medical analogy, pinpointing the key operational challenges is akin to arriving at a correct "diagnosis." The more accurately and precisely a military can define it, the greater the chances that it will be able to arrive at the right "prescription" of how to address it successfully.[6]

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[5] Given the current geopolitical environment, a contemporary set of core operational challenges for the U.S. military might include the following:

- Deterring and, if necessary, defending the U.S. homeland and its treaty allies from catastrophic strategic attack, to include by weapons of mass destruction, as well as by advanced conventional and cyber weapons (i.e., against technically advanced, numerically comparable enemies).
- Deterring and, if necessary, defending U.S. allies and security partners in the Western Pacific, especially those along the First Island Chain, from Chinese aggression and coercion (i.e., against a technically advanced, locally numerically superior enemy) without resorting to nuclear weapons use.
- Deterring and, if necessary, defending NATO's Eastern European frontiers from Russian aggression and coercion (i.e., against a technically advanced, locally numerically superior enemy) without resorting to nuclear weapons use.
- Deterring and, if necessary, defending against attempts to sever lines of communication via the global commons linking the United States to key overseas theaters of operation and essential trading partners/resources (i.e., against technically advanced numerically comparable enemies) without resorting to nuclear weapons use.

Innovative Operational Concepts: The New "Way of War"

The particular operational challenge identified informs thinking about operational concepts, which provide the basis for planning at the theater or campaign level of war, to include describing how forces will operate to achieve strategic goals. As such, they offer possible solutions to existing and emerging operational challenges. Dramatic shifts in the character of military competitions, such as described in the four cases examined, find successful military organizations developing and refining operational concepts that are very different from those that characterize the existing warfare regime.

These concepts guided analysis, war gaming, field and fleet exercises and experiments, and were in turn informed by them. The effect was to create a "virtuous cycle" that enabled candidate operational concepts to be evaluated, refined, and enhanced or, in some cases, discarded. Those that "made the cut" shaped their military's doctrine, as well as its size, force mix, organization, structure and investment priorities. Absent a clear statement of the operational challenge and an operational concept that describes how it will be addressed, it truly is a case of "If you don't know where you want to go, any road will get you there."

During the Cold War, for example, Central Europe was the location of the key military competition between NATO and the Soviet-led Warsaw Pact. Consequently, the U.S. military's principal operational challenge was *defending NATO's Central European frontiers against a technologically advanced, numerically superior foe (Soviet Russia and its Warsaw Pact allies) in a high-intensity conflict environment while avoiding employing nuclear weapons.* This clear statement of the problem enabled the U.S. military, over the course of the forty-year standoff between the two superpowers, to develop a series of integrated operational concepts that informed the crafting of military doctrine. These concepts were adapted and, at times, even abandoned, as circumstances required.

One such concept, AirLand Battle, envisioned the U.S. Army and Air Force defeating successive "waves" of enemy forces advancing out of the Soviet Union through Eastern

Europe. Generally speaking, the Army, supported by the Air Force, sought to block the advance of Soviet frontline forces while a combination of U.S. air and ground-based forces—combat aircraft, missiles, and rocket artillery—attacked the second and third waves of enemy ground forces advancing toward NATO's borders.

Simultaneously, the U.S. Navy planned to employ attack submarines beyond the Greenland-Iceland-United Kingdom (GIUK) maritime gaps to protect allied shipping moving across the Atlantic from commerce-raiding Soviet submarines, while the fleet's Outer Air Battle concept set forth how its aircraft carriers' air power would be used to defeat Soviet strike aircraft. To preclude the Soviets from using Norway as an advance base, the U.S. Marine Corps prepared to deploy quickly to that country and secure its airfields. Not only did these concepts guide U.S. and allied military thinking and planning; they also helped establish clear defense program and budget priorities. Yet no comparable set of operational concepts exist today with respect to defending the First Island Chain from aggression by China.[7]

In each of the four histories examined, innovative operational concepts enabled the militaries to realize far more effective ways of fighting at the campaign level of war. For example, after World War I the U.S. Navy was focused on addressing the operational challenge of conducting a campaign extending across the Pacific Ocean to Japan's home waters, where it envisioned fighting a decisive battle against the Imperial Japanese Navy. Lacking forward bases, Navy leaders knew the fleet would need to bring its own air power with it. The Navy exploited advances in aviation and radio, as well as radar, in developing the fast carrier task force that would, in the months following the attack on Pearl Harbor, see the line of battle rendered obsolete and the carrier emerge as the fleet's new capital ship.

In the 1960s and 70s modern air forces confronted the growing challenge of rapidly improving enemy integrated air defense systems (IADS). At the time, the U.S. and Israeli air forces were conducting offensive air operations, but at a high cost in actual

[7] A point-of-departure set of operational concepts to address the threat posed by China to U.S. allies and security partners along the First Island Chain can be found in Andrew F. Krepinevich, Jr., *Archipelagic Defense 2.0* (Washington, DC: Hudson Institute, 2023).

and virtual attrition, even against minor powers like North Vietnam and Egypt, respectively. General Creech envisioned a campaign centered on suppressing the enemy's IADS, not bypassing it. In addition to introducing high-fidelity training, the Air Force drew upon the IT revolution that enabled advances in guided weapons, fielding stealth aircraft, conducting effective night operations, and achieving advanced situation awareness. The combination of capabilities that emerged from this effort formed the foundation of the nascent reconnaissance-strike complex that made Creech's concept a reality.

Different Measures of Effectiveness (MOEs)

In each of the four histories examined, new problems at the operational level of war and the novel operational concepts developed to overcome them changed thinking about what mattered most with respect to military capabilities, or their "measures of effectiveness."

Dramatically altered MOEs characterized the U.S. Navy's shift from a battleship-centric to a carrier-centric fleet. In the battleship era, emphasis was on the weight of a broadside that could be fired at the maximum range of the largest guns. As long as this measure of merit prevailed, the battleships would always compare favorably with carriers.[8]

Those naval officers who envisioned the carrier as the fleet's capital ship advocated different metrics. They valued the carrier air wing's advantage in *extended-range* fires over the battle line's superior *volume* fires. They conceded that a carrier's planes could only deliver a fraction of the firepower inherent in the line of battle—but argued that this was trumped by the fact that they could do so at a range ten times greater.

Moreover, during the 1930s it was also becoming clear that, in carrier warfare, the key to success was to find and sink the enemy's carriers before it found yours. This led the Navy to emphasize long-range scouting aircraft (to find the enemy carriers) and

[8] As late as 1940, the Naval War College was informing its students that "it takes 108 planes to carry as many large torpedoes as one squadron of destroyers and 1,200 to carry as many large bombs or large projectiles as one battleship."

various types of strike aircraft (to sink them). Consequently, the Navy sought to maximize the number of aircraft on its carriers, and their launch and recovery speed.

The First Gulf War yielded a major shift in several key MOEs used by the Air Force to determine military effectiveness. The combination of stealth and guided weapons produced a shift away from "mass"—large strike packages where a majority of aircraft were in support roles (such as jamming)—and toward small numbers of stealthy aircraft armed with guided weapons. Thus the MOE for strike operations shifted from the number of aircraft that could be assigned to strike a target, to the number of guided weapons employed on stealth aircraft. Similarly, emphasis on bomb tonnage dropped gave way to bomb accuracy. This can be seen by the rapidly growing percentage of guided weapons relative to unguided bombs employed in Air Force operations following the First Gulf War. Precision-guided munitions comprised less than 10 percent of the munitions employed by the U.S. aircraft in the First Gulf War. This figure grew to roughly 30 percent in the 1999 Balkan War, exceeded 50 percent in air operations in Afghanistan in 2001-02 (Operation Enduring Freedom), and surpassed 60 percent in the Second Gulf war.

Exercises and Experimentation

Although important in their own right, professional analysis, simulations and war games can only go so far in identifying, developing and validating new concepts of operation and military system requirements. They lack the level of detail provided by well-designed and executed field exercises and maneuvers conducted at the operational level of war. This is critical since, in war, the "devil is often in the details," and Murphy's Law is often the order of the day. For example, war games conducted at the Naval War College in the early 1920s identified the importance of maximizing the number of aircraft on a carrier, as well as aircraft sortie rates. It was not, however, until the Navy's first carrier, *Langley* (actually a converted collier), was launched and participated in exercises that the Navy could determine precisely *how* this goal was to be achieved (or, indeed, *whether* it could be achieved at all). The *Langley* conducted a series of exercises and experiments that led to such innovations as crash barriers and

the deck park, enabling the ship to more than double its aircraft complement while dramatically increasing its sortie rate.

Field and fleet exercises also proved indispensable in maintaining an awareness of significant shifts in the character of military competition that sometimes occur during periods of disruptive change, but which are not themselves revolutionary. This was the case with the American Navy and Air Force. The U.S. Navy's fleet problems and experiments identified several such shifts. Tests with the battleship *Texas* in 1919 showed that aircraft acting as spotters greatly enhanced the battle line's gunnery accuracy at extended ranges. Ten years later, Fleet Problem IX revealed that carriers could function as an independent strike force by conducting raids, even though they still had not displaced the battle line as the arbiter of sea control. In the absence of fleet exercises and experiments, it is doubtful the Navy would have either identified these shifts in the military competition as soon as it did, or adapted to them as quickly or as well as it did. Similarly, the U.S. Air Force benefitted considerably from its own experience and that of the Israeli Air Force (IAF) in several wars—the ultimate "field exercises." The Vietnam War showed that guided weapons could enable the existing form of air operations—large strike packages focused on individual missions at the tactical level of warfare—to be executed more effectively. The IAF's 1982 operation in Syria's Bekaa Valley demonstrated the boost in effectiveness that operations employing unmanned aircraft could provide.

Investment Strategies: Options and Hedges

To various degrees, through serendipity or design, each of the four military organizations examined pursued investment strategies emphasizing "hedging" against the uncertainties inherent in a highly dynamic competitive environment. They did this in part by creating options in potentially revolutionary capabilities that could be exercised quickly if they proved out, while also avoiding, to the degree possible, locking themselves in to major investments in existing capabilities that might rapidly depreciate in value, or new capabilities whose value was as yet unproven.

To the maximum extent possible, a hedging strategy avoids locking-in, via large production runs, to current or emerging military systems. Two of the four military organizations avoided locking in to large production runs of major military systems that would greatly depreciate in value, or in systems that visionaries believed would enable a major boost in combat effectiveness.[9] In the case of the U.S. Navy this was facilitated in part by treaty obligations. The Washington Naval Treaty prohibited the construction of battleships and placed a relatively low ceiling on carrier tonnage. Nevertheless, with respect to naval aviation, the Navy consciously tried to limit its purchase of large numbers of aircraft that, since the rapid advances being made in aviation technology, ensured they would become quickly outdated.

The four militaries examined also recognized, to a lesser or greater extent, the dangers of "false starts" and "dead ends," as well as the value of "wildcatting."

False starts occur when systems or capabilities are purchased in quantity before they have reached the point where they prove themselves. In the American Navy's case, the Washington Naval Treaty and the Great Depression kept it from investing heavily in the *Ranger*-class of carriers, which proved a false start—the right *kind* of ship, but the *wrong ship design* for the operational challenge posed by the Imperial Japanese Navy in the Pacific.

Dead ends are those systems and capabilities that may appear attractive, but never fulfill their promise within a military's planning horizon. Admiral Moffett's proposed flying-deck cruisers—half cruiser and half flight deck—were "dead end" ships that, despite the admiral's affection for them, fortunately were never built.

Wildcatting prioritizes exploring a wide range of potentially attractive systems and capabilities that have the potential to advance disruptive innovation, but producing them in limited numbers. In so doing wildcatting expands opportunities for exploring

[9] The two great power militaries that did produce large quantities of major systems were the Royal Navy and the U.S. Air Force. Both confronted immediate threats from other great powers and thus had to maintain large standing forces. (Both, however, also incorporated "hedging" into their investment strategies.) The German military between the world wars also faced similar threats, but for most of this time was severely limited in size and capabilities by the Versailles Treaty.

new operational concepts in joint exercises, enabling military organizations to buy options, or "insurance," against an uncertain future, thereby reducing risk.

For example, despite the limits imposed by the Washington Naval Treaty and the severe fiscal austerity imposed by the Great Depression, in the years prior to World War II the U.S. Navy successfully pursued a wildcatting procurement strategy of sorts that saw it introduce four different carrier classes into the fleet: two converted cruisers (the *Lexington* Class at 33,000 tons), the *Ranger* (13,800 tons), three carriers of the *Yorktown* Class (roughly 20,000 tons), and the *Wasp* (14,900 tons). The Navy also hedged against the uncertainties associated with the development of air power, investing in various types of attack aircraft, including those designed for horizontal- and dive-bombing attacks, as well as torpedo bombers.

In the two decades preceding the First Gulf War, the U.S. Air Force fielded the basic elements of its battle network and missiles that would enable a shift to beyond-visual-range (BVR) air-to-air engagements, while enhancing its counter-scouting efforts by fielding a wing of stealth aircraft—the F-117 Nighthawk. It also created a major alternative to its "smart pilot-dumb bomb" strike arm in the form of precision-guided munitions.

Time-Based Competition: The First- and Second-Move Advantage

Like manpower, money and materiel, time is a resource and, as such, can play an important role in determining military advantage, especially in periods of disruptive change that require a far greater degree of adaptation than is the case in periods of evolutionary change. The ability to compete based on time involves employing time more efficiently and effectively than one's rivals. Militaries that develop a world-class competence in time-based competition are more agile than their rivals. They introduce new capabilities more rapidly, and can alter their force structure and doctrine more quickly than their competitors. The faster a military can introduce new capabilities into the force, the less need it has to field a large standing military.[10] This is particularly

[10] Of course, in order to maximize their effectiveness the troops that operate military systems must be familiar with them and the operational concepts they are intended to execute. The four militaries

important in periods of disruptive change, when existing military capital stock is prone to depreciate at an accelerated rate.

Military organizations enjoying an advantage in time-based competition are well placed to adopt strategies based on exploiting the first- and second-move advantage. This was a significant factor in several of the military histories examined.

As the term suggests, the first-move advantage involves shifting to a new, more effective way of competing before rivals can react and keep pace. The U.S. Air Force offers a good example of a military organization pursuing the first-move advantage. In the 1970s the American military under Defense Secretary Harold Brown explicitly sought to leverage the country's IT advantage over Soviet Russia by developing stealth and battle management aircraft, precision-guided weapons, advanced sensors, and a space-based positioning, navigation and timing system. In combination, they enabled the Air Force in particular, and the U.S. military more broadly, to exploit the first-move advantage and gain a dramatic boost in effectiveness, as revealed in the First Gulf War.

An even better example is found in the Royal Navy in the 20th century's first decade. Britain's First Sea Lord, Admiral John Fisher, oversaw the building of the first modern battleship—*HMS Dreadnought.* With its uniform complement of big guns and new age turbine engines, the ship possessed far greater firepower and was significantly faster than any battleship afloat.

But Fisher wanted to do more than effect a major shift in the character of fleet engagements—he wanted to shape it. Fisher leveraged Britain's advantage in time-based competition to dramatically compress the *Dreadnought's* construction time. A year and a day after construction start, *Dreadnought* began her sea trials. Fisher had

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examined, however, suggest this does not necessarily require a lengthy period of time to achieve. Within five years the U.S. Navy, which until the late 1930s had a carrier force comprising a converted collier, two converted cruisers, and one undersized purpose-built carrier found itself operating over 80 carriers of all types while waging a fundamentally new type of war at sea on the way to destroying the formidable Imperial Japanese Navy. The same can be said of the German military prior to World War II. It began openly rearming in 1935 and did not field test the first Panzer Division until 1937. Yet it mastered *Blitzkrieg* in less than five years.

cut the normal building time for a battleship—in this case, *a radically different and more powerful battleship*—by more than half.

As he intended, Fisher's gambit *Dreadnought* disrupted the plans of Britain's principal naval rival, Germany. As *Dreadnought* was emerging from the drawing board, the German Navy was launching *Deutschland*, the first in a class of five new German battleships—ships that *Dreadnought* made obsolete. Consequently, as news of the planned size, speed, and armament of *Dreadnought* reached Germany, near panic ensued. Fisher's German counterpart, Admiral Alfred von Tirpitz, secluded himself for months with his most trusted advisors to determine how best to respond.[11]

The second-move advantage finds a military organization confronting a situation where a rival has begun fielding new capabilities, forces and operational concepts with an eye toward effecting a disruptive shift in the competition in its favor. If the lagging military enjoys an advantage in time-based competition, it can use it to catch up—and surpass—the rival that is seeking to exploit the first-move advantage.

The benefits associated with the second-move advantage are several. For one, it allows the "second mover" to see with relative clarity the "first mover's" plans for gaining a competitive advantage. This reduces considerably the uncertainty confronting the second-mover. Another benefit accruing to the second mover occurs in situations where it enjoys a dominant position in the existing competition, and thus has no need to introduce new capabilities that would lead to the premature depreciation of a considerable portion of its existing military capital stock.

The U.S. Navy found itself enjoying a second-move advantage when following in the Royal Navy's wake after World War I. At that time the British enjoyed a monopoly on

[11] To Fisher, disrupting the naval plans of his rivals was not intended to be a one-time affair, but an ongoing practice. He hoped his successor battle cruiser ships would continue promoting chaos in his adversaries' shipbuilding schemes. Later, Fisher would summarize his thinking on "plunging" (as he termed it) to Winston Churchill, who became First Lord of the Admiralty in 1911. By launching ships that were substantially superior in quality to anything then afloat, Fisher declared, the Admiralty could compel other navies to reconsider their own ship building plans. If the Admiralty's plans were not revealed until the last possible moment, the disarray produced among Britain's rivals could enable the Admiralty to slow its own naval construction program for a year and perhaps longer, providing economies to the naval estimates. The "secret" of successful naval administration, Fisher declared, "is 'plunging'—it stupefies foreign Admiralties." Krepinevich, *Origins of Victory*, pp. 218-21.

aircraft carriers. This conferred a near-term advantage for the Royal Navy, but it proved ephemeral, as aviation technology was advancing at breakneck speed. This found the Royal Navy's carriers' value depreciating at an accelerated rate. Moreover, tight budgets, combined with a desire to get full value out of the relatively new carriers, found British political leaders reluctant to fund additional flattops. The U.S. Navy, on the other hand, was better able to keep pace with advances in naval aviation owing to its late arrival to the competition.

Interestingly, in the mid-19th century the Royal Navy exploited its world-class competence in time-based competition to pursue a second-move strategy during a period of disruptive change in the character of war at sea, in this instance the shift from wooden ships propelled by sail to ships with iron hulls and steam engines. Then, as during Fisher's time, Britain possessed the world's largest, best-equipped and most technically advanced warship industry. It enabled Britain to build ships of cutting-edge design, faster and in greater numbers than her rivals. Thus, it was France, not Britain, which first moved to launch steam-propelled warships and ironclads. Even though Britain was fully capable of leading the transition it held back so as to maximize its advantage in existing warships. Once the French acted, the British quickly offset their efforts by launching more (and better) of the new style warships before their adversaries could realize an advantage.[12]

Extended Tenure and Institutionalization

In each of the four cases examined the senior leaders most associated with disruptive innovation enjoyed what in today's U.S. military would be considered an unusually long tenure. This makes intuitive sense, as disruptive innovation is not accomplished overnight; rather, it requires an extended period of time—typically a decade or longer—to bring about.

Admiral Moffett, arguably the key figure in the development of U.S. naval aviation, served as head of the Navy's Bureau of Aeronautics for an astounding twelve years,

[12] Similarly, the Royal Navy "ignored" the development of submarines until a major naval rival introduced this new form of war at sea.

from its inception in 1921 until 1933.[13] General Creech headed the Air Force's Tactical Air Command for six years, from 1978 to 1984. Both leaders also cultivated officers who shared their vision and worked to advance their careers. Admiral Moffett succeeded in ensuring that all aviators were officers, and that certain commands, such as those of naval air stations and aircraft carriers, were reserved for pilots, creating a pathway to senior rank for naval aviators. The BurAer staff provided slots for aviators and a place for them to gain experience. During the 1920s future Navy admirals such as Marc Mitscher and John Towers found a home in BurAer. The chief of naval operations during World War II, Fleet Admiral Ernest King, whom Moffett convinced to transfer to naval aviation, succeeded Moffett as head of BurAer in 1933.

Similarly, a remarkable number of Air Force future leaders worked for General Creech during his tenure as head of the Tactical Air Command. All six of the Air Force chiefs of staff that served from 1986 through 2001 were either a wing commander or served on Creech's staff during the time he headed the Tactical Air Command. Over time 21 of the officers Creech had a hand in developing rose to the rank of full general.

Little Things Mean A Lot

The shift from one warfare regime to another that marks the success of disruptive innovation often occurs after a relatively small shift in a military's structure and equipment. Put another way, the phenomenon is highly nonlinear: even a relatively small percentage of the total force capable of waging the new form of warfare can achieve levels of effectiveness far greater than much larger forces fighting within the construct of the passing regime.

With the possible exception of the Royal Navy, each of the militaries examined in the case studies brought about a disruptive shift in the military balance with a small shift in the composition of its capital stock. For example, only around 12 percent of the German Army that defeated the combined Belgian, British, Dutch and French forces in a campaign lasting but six weeks was mechanized or motorized. In late 1941, the U.S. Navy comprised 352 major combatants, of which only seven were aircraft carriers,

[13] His tenure would have been even longer had he not perished in an airship crash.

which proved the key to turning the tide of war in the Pacific and introducing a new form of war at sea. During the First Gulf War the U.S. Air Force's 59 F-117 Nighthawk stealth aircraft represented less than 3 percent of combat aircraft in the theater, and flew only 2 percent of the sorties Yet they struck roughly 40 percent of the strategic targets. And while less than 10 percent of the bombs dropped by the Air Force were precision-guided weapons, they produced over 75 percent of the damage inflicted on Iraqi targets.[14]

The Incomplete Revolution

In all of the instances where a military organization's disruptive innovation produced a dramatic boost in its effectiveness, significant parts of its vision of future warfare remained unfulfilled.

For example, the U.S. Navy's carriers had limitations. Carrier aircraft dominated the daylight hours, but at night surface combatant engagements were the norm. Following their devastating success against Japanese carriers in the Battle of Midway, the American flattops withdrew during the night, while Japanese surface ships pressed ahead, attempting to engage them. Although the carrier had clearly displaced the battleship as the capital ship, the latter did not quickly go the way of the horse cavalry. In a number of maritime engagements during World War II, the battleship dominated.

The U.S. Air Force's introduction of precision-warfare in the First Gulf War also had its limitations. The stealthy F-117 aircraft only operated at night. Its laser-guided bombs were generally ineffective in poor weather, including conditions involving rain, smoke and cloud cover. Furthermore, in early 1991 GPS coverage was limited, and there were times when it was unavailable. Finally, the Air Force's ability to strike mobile or "time-sensitive" targets in near-real time was exceedingly modest.

[14] The Air Force concluded that "Two raids of 300 B-17 bombers could not achieve with 3,000 bombs what two F-117s can do with only four [PGMs]."

In summary, while war provides the ultimate validation of the vision of a dramatically new and more effective form of military operation, it typically also reveals gaps in the vision that remain to be addressed. The need for innovation is enduring.

Concluding Thoughts

The histories of our four militaries that led the way in effecting disruptive innovation yield valuable insights for contemporary military organizations anticipating discontinuous shifts in warfare. That being said, the findings are not definitive. At best, they are highly suggestive. We are well served by remembering Richard Feynman's injunctions that, even in the hard sciences such as physics, the "laws" stated in textbooks are really approximations, and are always subject to revision. So, too, with the study of war and military innovation. Still, as conditional as these findings are, they are arguably more useful than simply "awaiting events," or "muddling through."[15]

[15] Indeed, the characteristics derived from the four militaries examined here also correlate remarkably well to those identified as resident in business organizations that successfully pursued disruptive innovation. While military and businesses organizations have important differences, research reveals that corporations, like their military counterparts, are constantly on the lookout for new sources of competitive advantage while maintaining a vigilant eye on products, services and other sources of existing advantage that risk becoming wasting assets. Krepinevich, *Origins of Victory*, pp. 423-27.

Andrew F. Krepinevich, Jr.

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Dr. Krepinevich has served in the Department of Defense's Office of Net Assessment, and on the personal staff of three secretaries of defense. He has also served as a member of the National Defense Panel, the Defense Science Board Task Force on Joint Experimentation, the Defense Policy Board, the Congressional National Defense Strategy Commission, the Army Special Operation Command's Advisory Board, the Army Science Board, and as chairman of the Chief of Naval Operations Executive Panel.

Dr. Krepinevich has taught on the faculties of West Point, Georgetown University, the Johns Hopkins School of Advanced International Studies and George Mason University.

His most recent book, *The Origins of Victory: How Disruptive Military Innovation Determines the Fates of Great Powers*, was released in March. He also authored *The Last Warrior: Andrew Marshall and the Shaping of Modern Defense Strategy; 7 Deadly Scenarios: A Military Futurist Explores War in the 21st. Century;* and *The Army and Vietnam*.

Among his recent works are *"The Eroding Balance of Terror,"* and *"The New Nuclear Age,"* both published in the journal *Foreign Affairs*, and *"Modernizing the Nuclear Triad: Decline or Renewal?"*

A graduate of West Point and the Naval War College, Dr. Krepinevich holds an M.P.A. and Ph.D. from Harvard University. He is a member of the Council on Foreign Relations.

In 2020 Dr. Krepinevich received West Point's Distinguished Graduate Award.

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Hearing Date: 12/6/2023

Hearing Subject:

Back to the Future

Witness name: Andrew Krepinevich

Position/Title: Senior Fellow, Hudson Institute, Adjunct Senior Fellow, CNAS

Capacity in which appearing: (check one)

● Individual ○ Representative

If appearing in a representative capacity, name of the organization or entity represented:

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2022

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
HQ003422P0027	OSD/Net Assessment	$199,128.00	Disruptive Military Innovation

2021

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

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2023

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2022

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2021

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2020

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

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2023

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

2022

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

2021

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment
#2021-2623	Smith Richardson Foundation	$162,250	Archipelagic Defense

2020

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

Testimony for the House Armed Services Subcommittee on Cyber, Information Technologies, and Innovation, Rep Mike Gallagher (R-WI), Chairman

By

Arthur Herman, Senior Fellow, Hudson Institute and Director, Quantum Alliance Initiative; author of *Freedom's Forge: How American Business Produced Victory in World War Two*

Thank you for this opportunity to speak to you on one of the most important issues we face regarding our national defense, namely how to better incorporate the innovations taking place in our private sector, from AI and robotics to cyber and quantum, into our national defense strategy, specifically our defense industrial base.

Our defense industrial base is in crisis. This is certainly the conclusion that our first-ever National Defense Industrial Strategy report has just reached. According to its most recent draft, that industrial base "does not possess the capacity, capability, responsiveness, or resilience required to satisfy the full range of military production needs at speed and scale."[1]

What some of us have been warning about for a decade, is now apparent to everyone. One reason I wrote *Freedom's Forge* more than ten years ago, was to call attention to structural deficiencies in how we arm and equip our military with the latest and most decisive technologies and systems, compared to World War Two or the Cold War. Now, thanks to the war in Ukraine, this problem has been made obvious, and urgent.[2]

Reasons for this decline are various. One is the decline of the manufacturing sector in the U.S. in general, including its labor force, including a sharp decline after 2000.[3] Another has been the shrinkage in the number of competitive defense

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[1] "Pentagon: US arms industry struggling to keep up with China," Politico, Dec. 2,2023 https://www.politico.com/news/2023/12/02/draft-pentagon-strategy-china-00129764

[2] Freedom's Forge: How American Business Produced Victory in World War II; Random House, 2012; A. Herman, "By Arming Ukraine, We Arm Ourselves," The Dispatch (December 23, 2022) https://thedispatch.com/article/by-arming-ukraine-we-arm-ourselves/.

[3] J.R. Pierce, "The Surprisingly Swift Decline of U.S. Manufacturing Employment, "Institute for International Economic Policy, Feb. 3, 2013: https://iiep.gwu.edu/2013/02/05/the-surprisingly-swift-decline-of-u-s-manufacturing-employment/

contractors after the Cold War: from roughly a dozen major military contractors in 1990 to only four.[4]

But there has also been a general benign neglect of our defense industrial base for several decades, in large part because it has been so good, and performed so magnificently, in enabling us to dominate sea, air, land and space; that we came to take it for granted. Instead of being the subject of intense and serious study as part of a national security strategy or being addressed in broader strategic terms, it was treated as an afterthought (especially workforce), and relegated to the attention of separate agencies like the Industrial Base Policy office (inside the OUSD A &S) and the Industrial Base Analysis and Sustainment program.[5] These are offices which have been traditionally underfunded and understaffed, and underappreciated, at least until now.

So what is the Defense Industrial Base?

First, it's production facilities and capacity from factories to shipyards to warehouses—which is how we usually picture it when we thought it at all.

Second, it's supply chains. This component has changed dramatically; during World War Two virtually everything it needed came from the 48 states. Now its supply chains are global and increasingly a matter of urgency, since we understand now how vulnerable those chains are-and how many terminate in China.[6]

It's also research and development; i.e. incorporating new technologies and systems, e.g. AI, quantum, hypersonics, UAV's, into our warfighting capabilities and sustaining those systems so they can be decisive in warfighting or deterrence.

It's innovation and design within those systems as part of the production process, i.e. making them better, faster, and cheaper—much as we did with nuclear weapons and ballistic missiles during the Cold War, and with munitions during World War Two.

It's security. This was barely a concern during the World War Two era, now we have to address security as a top priority in everything from cybersecurity and industrial plant security to IP and personnel security clearances. Zero-trust

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[4] Those being Boeing, General Dynamics, Northrop Grumman, and Lockheed Martin. Lockheed Martin alone was made of 17 different firms and divisions of defense companies.

[5] See "Annual Industrial Capabilities Report to Congress," FY 2020-1.

[6] E.g. A.B. Abrams, "Chinese Parts in the F-35 Highlight Concerning Trend in the US Defense Sector," September 17, 2022 https://thediplomat.com/2022/09/chinese-parts-in-the-f-35-highlight-concerning-trend-in-the-us-defense-sector/Note to F35 component.

initiatives now have to be baked into any national strategy for assessing our defense industrial base.[7]

Last but hardly least, it's workforce—from the factory floor and drivers and warehouse employees to engineers and managers. I'd have to say, this is the aspect of our defense industrial base that has been the most neglected of all, in terms of a national security strategy—and the most unforgiving.

We need a national action plan for incorporating innovation in all these areas, as part of a national security strategy—but workforce perhaps above all, since nothing moves or is made unless the people are there, who know how to do it—or operate the machines that execute it (including AI: I predict that the growth of AI/ML will actually increase the need for a larger secure workforce for defense industrial needs).

At the same time, the role of innovation is deeply misunderstood. It shouldn't be treated or studied as if it were a stand-alone category of input for the industrial base, but as an integral part of its production and productivity process. It's through making things that we learn what can be made better: which is why the most productive companies also tend to be the most innovative.

That's also why, in creating the Arsenal of Democracy during World War Two, Washington turned to the auto and electrical companies first, because they had the most engineers and therefore be counted on to do things and make things better, even if never made them before. A classic example is what happened when engineers at Pontiac turned their attention to producing the 20 mm. Oerlikon antiaircraft gun. In doing so they completely redesigned the product, to make it faster but also better. As a result, they managed to cut production time per gun from 3 ½ hours to 15 minutes.[8]

Or take the case of Saginaw Steering Gear Company, a GM subcontractor. When the time came to deliver on their contract to produce 280 30. Caliber machine guns based on the Browning design by March 1942—even though they had never made a firearm in their lives—they delivered 28,000 instead.[9]

In other words, innovation follows productivity, not the other way around.

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[7] "Executive Order on Improving the Nation's Cybersecurity,' May 12, 2021 https://www.whitehouse.gov/briefing-room/presidential-actions/2021/05/12/executive-order-on-improving-the-nations-cybersecurity/

[8] Freedom's Arsenal: The Story of the Automotive Council for War Production (Detroit, 1950), 101.

[9] Freedom's Forge, 147.

Another lesson of World War Two was that government needs to understand its proper role better. The usual linear model is that government, i.e. DoD, decides what's needed, contracts with industry to produce how much and when; then delivers the final product to the warfighter, on whose input government has relied in the first place.

The alternative is to change government's role into that of a broker, a middleman, between industry and the warfighter. This would have government start by saying to the private sector, show us what you have that could meet our needs, and the warfighter's. If we like it, then your task will be to tell us how you are going to meet our specific production needs and in what time frame—a time frame which our warfighters, not bureaucrats, have set.

It's an entirely different dynamic. Instead of a linear top-down process, the dynamic flows from one end to the other in a constantly renewing feedback loop, with government in the middle. That is what happened-had to happen-- in World War Two. Lacking any reliable defense industrial base to start with, Washington was entirely dependent on private industry, to demonstrate how it was going to make the weapons that were most urgently needed—tanks, planes, aircraft engines, ships, submarines, trucks, artillery and machine guns. Government's job was finding the raw materials to make them (i.e. supply chain management), and then distributing the finished products across two oceans in time to enable the warfighters to prevail.

That touches on a third principle of the Arsenal of Democracy model worth emphasizing; it was entirely threat-based, not capacity-based. The Germans and Japanese made it very plain to everyone in 1940-1 what was needed in terms of armaments; i.e. weapons that could beat the U-boat, the Japanese Zero and the Me 109, and the German panzer. Because of this need to deal with a specific threat, innovation was automatically built into the process, e.g. when the P-51 Mustang designers added a British Rolls Royce engine in order to raise its performance level above competing Axis aircraft.[10] The race to build the first atomic bomb, in order to have a nuclear weapon before the Germans did, also illustrates the same process.

The same happened with the Army's so-called Big Five during the Cold War in the 1970's. Every component of the Big Five arsenal-the M1 Abrams tank, the Bradley Fighting Vehicle, the AH-64 Apache and UH 60 Blackhawk helicopters,

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[10] Freedom's Forge, 104-5.

and the Patriot missile battery, were all developed and produced to deal with specific Soviet threats in case of a war in Germany and Central Europe. As a result, the Army had the tools that would enable it to be the dominant military in the world for the next two decades, culminating in Desert Storm.[11]

One of the problems we face today is that the focus has been on the capabilities of the high-end technologies themselves, i.e. AI and quantum, rather than the enemy they're supposed to deal with. One could argue hypersonics is an exception; but this is largely because we sense that we've fallen behind China and Russia; just as we were behind Germany and Japan when we entered World War Two.[12]

In short, by focusing on the threat first and foremost, we make for a clearer industrial base strategy.

Let me make two points in conclusion.

Given all the issues and problems confronting our defense industrial base today, people constantly ask me ever since *Freedom's Forge* was published; could we pull off the Arsenal of Democracy again.

My answer is yes—but not alone. Instead, in addition to reshoring our base whenever and wherever possible, we need to look to building a global defense industrial network with trusted allies, UK and Five Eyes, NATO members, Japan and South Korea; and particularly in the advanced technologies: AI, quantum, space, hypersonics, i.e. those technologies where supremacy provides a future decisive edge. But the same model should apply to traditional and conventional systems, such as naval shipbuilding and energetics, the next generation munitions where again China is busy surging ahead.[13]

I call this network the Arsenal of *Democracies*, for the 21st century. Like its 20th century predecessor, it can overwhelm its New Axis opponents with its output, in ways that will force them to reconsider their own strategies—which is exactly what an offset strategy is geared to do.

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[11] David Trybula,"'Big Five'" Lessons for Today and Tomorrow," Institute for Defense Analyses, May 2012 . .

[12] Arthur Herman, "The U.S. Needs a Hypersonic Capability Now, " Wall Street Journal, December 6, 2021 https://www.wsj.com/articles/america-needs-a-hypersonic-capability-china-xi-beijing-missile-weapons-attack-defense-budget-11638827597

[13] Nadia Schadlow and Braydon Helwig, "Ukraine War Shows America Could be Outgunned Without Investing in Energetics," Breaking Defense, April 30, 2022 https://www.hudson.org/national-security-defense/ukraine-war-shows-america-could-be-outgunned-without-investing-in-energetics.

Because the fact is, economically and technologically the world's democracies have the New Axis surrounded.

Even as China is still poised to become the world's second-largest economy after the US, its New Axis Russia and Iran barely register on the list of world's economies in terms of GDP. By contrast, the US together with the other democratic nations in the top ten (Japan, Germany, UK, India, France, Italy, Canada, and South Korea) total more than twice China's GDP.[14]

We can push this point further. According to Global Finance magazine's 2022 estimates, the US and its fellow democracies occupy 18 of the top 20 slots of the world's most advanced tech countries. China meanwhile ranks 32nd on the list, while Russia and Iran don't even score.[15]

All this indicates that if the U.S. and other democracies band together, they can overpower China and its New Axis allies not only in terms of economic muscle, but with the kind of high-tech focus that will be the core of a winning Arsenal of Democracies.

There are several steps already in place, on which we can build to speed production and innovation forward. The National Technological Industrial Base (NTIB) which includes the U,K., Australia, and Canada is a good start; there are also existing Defense Trade Cooperation Treaties (DTCT's) which set aside ITAR requirements for trusted allies like UK and Australia, but which are under-utilized.[16] But even more important than government to government agreements, however, will be company-to-company collaboration, in terms of incorporating innovation for achieving that decisive edge.

This leads me to a final thought. At a time when everyone is concerned about the US encouraging allies to share the defense burden, and about NATO and others paying their fair share, this Arsenal of Democracies model can be part of the answer. Instead of trying to squeeze out an additional ½ percent or ¼ percent above existing defense budgets, why not ask these allies to open up their advanced tech companies and defense contractors to work with their US counterparts, to

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[14] https://www.worlddata.info/largest-economies.php

[15] https://www.gfmag.com/global-data/non-economic-data/best-tech-countries

[16] Arthur Herman, "Breaking the Defense Trade Barrier: Defense Trade Cooperation Treaties and the Future of the U.S.-Japan Alliance." Hudson Institute, 2018.

develop and build the systems we will all need to defend freedom, now and in the future.

The future could well depend on well we ask that question.

Thank you for your attention, I'll be pleased to answer any questions you may have.

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Arthur Herman
Senior Fellow
Hudson Institute

Arthur Herman is a senior fellow and director of the Quantum Alliance Initiative at Hudson Institute. His research programs analyze defense, energy, and technology issues.

Dr. Herman is the author of nine books, including the New York Times Best Seller How the Scots Invented the Modern World, the Pulitzer Prize Finalist Gandhi and Churchill: The Epic Rivalry that Destroyed an Empire and Forged Our Age, Freedom's Forge: How American Business Produced Victory in World War II (which the Economist named one of its Best Books of 2012), To Rule the Waves, Douglas MacArthur: American Warrior, and 1917: Lenin, Wilson, and the Birth of the New World Disorder.

Dr. Herman is a frequent contributor to Commentary, Mosaic, National Review, the New York Post, and the Wall Street Journal. He was also the first non-British citizen to be named to the Scottish Arts Council from 2007 to 2009. He received his BA from the University of Minnesota and PhD from Johns Hopkins University in history and classics.

DISCLOSURE FORM FOR WITNESSES
COMMITTEE ON ARMED SERVICES
U.S. HOUSE OF REPRESENTATIVES

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the House of Representatives for the 118th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants), and contracts or grants (including subcontracts and subgrants), or payments originating with a foreign government, received during the past 36 months either by the witness or by an entity represented by the witness and related to the subject matter of the hearing. Rule 11, clause 2(g)(5) also requires nongovernmental witnesses to disclose whether they are a fiduciary (including, but not limited to, a director, officer, advisor, or resident agent) of any organization or entity that has an interest in the subject matter of the hearing. As a matter of committee policy, the House Committee on Armed Services further requires nongovernmental witnesses to disclose the amount and source of any contracts or grants (including subcontracts and subgrants), or payments originating with any organization or entity, whether public or private, that has a material interest in the subject matter of the hearing, received during the past 36 months either by the witness or by an entity represented by the witness. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number), will be made publicly available in electronic form 24 hours before the witness appears to the extent practicable, but not later than one day after the witness's appearance before the committee. Witnesses may list additional grants, contracts, or payments on additional sheets, if necessary. Please complete this form electronically.

Hearing Date: 12/6/2023

Hearing Subject:

Back to the Future

Witness name: Arthur Herman

Position/Title: Senior Fellow

Capacity in which appearing: (check one)

● Individual ○ Representative

If appearing in a representative capacity, name of the organization or entity represented:

Federal Contract or Grant Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) or grants (including subgrants) with the federal government, received during the past 36 months and related to the subject matter of the hearing, please provide the following information:

2023

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
contract	PPBE Commission	$243,000	Senior Technical Writer

2022

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
conract	PPBE Commission	$22,000	Senior Technical Writier

2021

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2020

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
contract	OSD Office of Industrial Policy	$20,000	Review of Industrial Capacity report

Foreign Government Contract, Grant, or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or grants (including subcontracts or subgrants), or payments originating from a foreign government, received during the past 36 months and related to the subject matter of the hearing, please provide the following information:

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2022

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2021

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2020

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

Fiduciary Relationships: If you are a fiduciary of any organization or entity that has an interest in the subject matter of the hearing, please provide the following information:

Organization or entity	Brief description of the fiduciary relationship

Organization or Entity Contract, Grant or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or grants (including subcontracts or subgrants) or payments originating from an organization or entity, whether public or private, that has a material interest in the subject matter of the hearing, received during the past 36 months, please provide the following information:

2023

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

2022

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

2021

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

2020

Contract/grant/ payment	Entity	Dollar value	Subject of contract, grant, or payment

Statement of Mark Gunzinger
Director of Future Concepts and Capability Assessments
Mitchell Institute for Aerospace Studies

Before the
Subcommittee on Cyber, Innovative Technologies, and Information Systems
House Armed Services Committee
U.S. House of Representatives

Hearing on December 6, 2023

Chairman Gallagher, Ranking Member Khanna, and members of the House Armed Services Subcommittee on Cyber, Information Technologies, and Innovation, thank you for allowing me to testify today on the critical importance of defense innovation and how history should inform investments in defense technologies. I am honored to provide perspectives from my experience in the defense policy and force planning communities.

We are in a decisive decade: one that demands urgent action to regain our military technological advantage over the pacing threat. China's rapid military modernization has eroded the United States' ability to deter and, if necessary, defeat aggression in the Western Pacific. While no rapid, easy fixes exist to redress these circumstances, rebalancing America's military capabilities and capacity to reduce risk created by a decades-long failure to modernize our forces demands new foundational principles. Toward that end, I spotlight six lessons from history that should shape the planning for, and continuous modernization of, our nation's military forces.

1. Maintaining the technological advantage is a marathon, not a destination.
Treat defense innovation as a series of sustained competitions.

Meeting present and foreseeable national security challenges will demand a long-term, sustained focus on military innovation and modernization. I could argue that we are in a conflict today—or at least an intense competition for military advantage, with peer and near-peer adversaries. History teaches us that competitors constantly seek to displace the leader, as is the case in any race.

In the case of national defense, it is a mistake to think that a single technological breakthrough will provide a permanent advantage. Eventually, useful ideas and tools proliferate beyond their initial creator into the hands of other competitors. Consider that gunpowder was first invented in China as early as 142 AD. Other Asian and European powers gained access to the material and steadily learned how to advance and refine its employment. Over the next two thousand years, competitors developed new ways and means to use gunpowder that were increasingly cheaper, faster, accurate, and more lethal.

Similarly, the revolution in military technologies and operational concepts that the United States pioneered during the late Cold War period leapfrogged all other nations' warfighting prowess. The effectiveness of stealth, precision strike

systems, 4th generation aircraft technologies, and networks stunned the world during Operation Desert Storm in 1991 and set the stage for unrivalled U.S. military dominance in regional conflicts over the next two decades. At the same time, however, competitors studied these successes and sought to aggressively match and supersede the technologies and operating concepts that created them. China in particular has reshaped its military and warfighting strategy to defeat the "American way of war" and the U.S. military's aging capabilities. U.S. military inferiority is a very real possibility if we do not seek to advance our capabilities from the performance thresholds that were last set at the end of the Cold War.

2. Seek asymmetric advantages rather than parity. *Prioritize developing and acquiring asymmetric capabilities that will disrupt and impose costs on adversary forces instead of thinking in terms of fighting a better war of attrition.*

This approach is not new. It is exactly what American leaders in the 1970s and 1980s pursued as they faced a Warsaw Pact with more combat capacity in Europe than NATO. These leaders realized they needed to out-think the Soviets, which led to DOD's Assault Breaker initiative, which yielded the reconnaissance-strike complex that matched enhanced battlespace information awareness with precision strike technologies and stealthy aircraft.

Today, facing similar challenges, the United States must prioritize new technologies like 5th and 6th generation stealthy aircraft for both air-to-air and air-to-ground missions; uncrewed collaborative combat aircraft (CCA) to augment these highly capable crewed aircraft with affordable yet capable mass; a new generation of munitions that are both mission-effective and cost-effective; and new systems that will harness the attributes of directed energy, artificial intelligence, and quantum computing.

However, there is a risk that new technologies will initially be used in mass-on-mass approaches to warfare, in which each side seeks to land more punches on the other. That risks U.S. forces engaging in a tactical "whack-a-mole" operation. We need a strategic approach that pursues breakthrough technology that fundamentally *changes* the rules of the game. Otherwise, we risk simply repeating the stalemate and slaughter we saw during the First World War. In a more modern example, the attrition-dominant warfighting approach underway in Ukraine is not how the United States should ever seek to fight.

Instead, we need to emulate lessons learned about how new technologies like mechanized armored forces restored maneuver to armies in the first half of the 20th century and how long-range air forces enabled strikes deep into an enemy's heartland to impose costs and disrupt the adversary's means of sustaining an offensive. Efforts and resources must be focused on thinking in a smarter, more prudent fashion than the opponent, not just who can absorb the most losses over an extended period of time.

3. Technology is only as effective as the way it is used. *Pair emerging technologies with novel concepts for their use in realistic threat environments. Stop doubling down on new technology just to do the same things better.*

Ground-breaking technologies are most effective when they are matched with insightful operational concepts that seek to optimize the ends, ways, and means of securing desired effects in the battlespace. Too often throughout history, nations have ceded the full potential of new technologies by harnessing them to legacy ways of fighting. Consider that during the First World War, the U.S. Army initially employed aircraft as artillery spotters—a linear interpretation of "better high ground" to provide support to surface forces. Over time, the use of airpower expanded to include new missions like close air support, strategic attack, and air superiority, as well as long-range reconnaissance and surveillance. Similarly, when uncrewed MQ-1 Predator drones were first developed and fielded in the 1990s, their role was restricted to intelligence, surveillance, and reconnaissance. Eventually, when combat circumstances demanded enhanced effects, they were weaponized. This led to an entirely new approach of using sensor-shooters for precision strikes in Afghanistan, Iraq, Syria, and beyond.

As new technologies like uncrewed CCAs are developed, there is a risk they will be used in ways that will linearly augment the Air Force's crewed aircraft and compensate for the service's combat air inventory shortfalls. While the Air Force needs more combat air capacity, it would be better to use CCAs in new ways to disrupt and degrade China's warfighting strategy in a Pacific conflict. Insights from recent wargames at Mitchell Institute for Aerospace Studies indicate uncrewed CCAs used in novel ways could be a means to disrupt China's air and missile defenses, opening the path for follow-on forces to gain the degree of air superiority needed to defeat a PLA offensive against Taiwan.

4. It still requires adequate capacity. *Recognize that force capacity still matters. Stop the caustic cycle of attempting to do more with a diminished force.*

Even as the United States invests in technology to offset China's combat mass advantage, it is crucial to remember that numbers still matter. An aircraft, ship, tank, or satellite can only be in one place at a time, and operations in a region as large as the Pacific will require a force that is sized to conduct multiple dispersed operations across thousands of square miles simultaneously.

The capacity multiplier effect afforded by new technology is undeniable. During the first night of Operation Desert Storm, 20 stealthy F-117 fighters used precision-guided munitions to strike 28 separate Iraqi targets. By comparison, it required 41 non-stealthy aircraft with non-guided "dumb" bombs to destroy a single target during the same time frame. However, many in DoD saw this revolution in effectiveness as a justification to slash force structure inventories in the 1990s and 2000s. Moreover, since the end of the Cold War the United States has yet to complete the full buy of a new manned combat aircraft. The B-2 was canceled at 21 aircraft delivered, not the 132 initial requirement. F-22 production was stopped at 187 fighters, not the 381 planned—and that number was already a reduction from the force of 781 aircraft originally envisioned. Force cuts and inadequate modernization have left U.S. combatant commanders without the capacity required to support their war plans. Given the need to deter and possibly respond to aggression in Europe, the Middle East, the Indo-Pacific, and in defense of the U.S. homeland, force structure numbers matter.

Consider basic combat aircraft mission rotation math—one-third of a deployed inventory of a combat aircraft will be executing missions while another third is returning to their airbases, and the remainder will be getting ready to launch on their next missions. Applying those numbers to the B-2 inventory illustrates how a U.S. combatant commander could have only a handful of stealthy bombers ready for missions at any given time—assuming the entire B-2 force is deployed, no bombers are down for maintenance, and there is no combat attrition. With roughly 100 combat-coded F-22s in the force, those numbers work out to approximately 30 F-22s on station in the battlespace at any given point in time—again, using unrealistically positive force planning assumptions. Stretch 30 F-22s across a region as vast as the Western Pacific, and it is clear that force capacity cuts in the past were far too radical.

The solution to these capacity shortfalls demands DOD acquire stealthy B-21s, F-35s, KC-46s, CCAs, NGAD systems, and other modernized capabilities at the scale needed to deter, and if necessary, defeat threats in multiple theaters. This will require sustained, predictable budget growth that balances the pace of modernization with increases in force capacity. The U.S. military simply cannot prepare for tomorrow's fight if it's forced to operate with yesterday's budget under a series of continuing resolutions.

5. Innovation only matters if you procure it. *It's not enough to innovate new technology, DoD and the services must also be empowered to surge acquisition and procurement with ample funding to meet operational requirements. Stop the practice of increasing research and development spending without follow-on aggressive procurement.*

It is important to recognize that military innovation is only worthwhile if it results in a leap-ahead in capabilities and sufficient force capacity. There is nothing more costly or inefficient than investing in research and development without following up with funding to acquire new technologies at the scale needed to make a difference in warfare. This problem has plagued the Department of Defense over the last 30 years and caused the services to extend many of their major weapon systems well past their original design lives, all at great expense to taxpayers and yielding only diminished returns.

DoD's 1992 decision to cap B-2 procurement at only 21 aircraft rather than the 132 planned resulted in what is now the oldest and smallest bomber force in the Air Force's history. That is also why the aircraft is often cited as the most expensive aircraft ever procured at $2 billion per unit. Similarly, slashed purchases of the Zumwalt class destroyer resulted in the program's $12 billion of research and development costs being spread across just three ships. As a result, the Zumwalt now has a per-unit cost of $9 billion rather than the initial 1998 estimate of $1.2 billion. Consider what would happen if private industry adopted this approach: how much would a Tesla EV cost if they stopped production at only 21 vehicles? It would obviously be a disastrous course of action, yet it is one that U.S. leaders have pursed repeatedly across the defense modernization portfolio over the past three decades. If the need for a new technology remains valid, the most effective, efficient path available to defense leaders is to procure it in large quantities to meet their operational requirements.

6. New technologies still require training experienced people in volume to use them. *DoD must ensure it has enough personnel with adequate levels of training to fully exploit the advantages of new technologies in the capacity required for major theater combat operations.*

Finally, it is crucial to remember that a high-tech military needs highly trained service members in sufficient numbers to meet requirements and anticipate realistic attrition factors in warfighting operations. The Air Force has been carrying an annual 2,000 fighter pilot shortfall for many years. That is placing tremendous strain on operational units, depriving headquarters staff of essential expertise, and drives overtaxed pilots and their families to separate from the service. This peacetime shortfall would spiral out of control in a peer conflict that results in significant losses. It takes at least five years to train a moderately experienced fighter pilot, and far longer to give crews the depth of experience needed to maintain a combat edge over a competent adversary. That means that even if a solution is implemented today, it would take five years for the problem to diminish. The Air Force lacks such a solution, so the risk compounds. This is not the only shortfall—maintainers and other experts are likewise spread thin across the force.

Further personnel complications are arising as the Air Force sunsets worn out airframes like the E-3 JSTARS and the E-3 AWACS without operational follow-on systems due to excessive modernization delays. Air battle managers—the experts on those platforms—take years to cultivate and will be the key actors with the new Joint All Domain Command and Control (JADC2) enterprise. Extreme risk exists that these experts will depart the service for want of the tools to do their job. The Air Force, Department of Defense, and Congress must pay particular attention to stewarding these career fields through these difficult transitions. Regenerating this talent from scratch would take years—and regenerating truly seasoned experts even longer. Consider the challenges the Air Force faces in the electronic warfare field. It cut systems and personnel too aggressively in the 1990s as a budget savings measure and is now struggling to grow capacity for this mission area at a time when the threat is expanding.

Learn from history or risk losing. *We know what needs to be done to ensure our nation's security. It is time to stop admiring the problem and implement solutions.*

As U.S. leaders seek to address the threat posed by China, it is especially important to recognize that defense innovation and modernization at scale is needed now, not in some distant 2030s future. U.S. leaders learned this as they anticipated the onset of the Second World War, with Secretary of War Harry Woodring writing to President Roosevelt in 1938 that, "We are not prepared for conflict. Billions appropriated today cannot be converted into preparedness tomorrow." Woodring was right: of course money is crucial, but so is time. Despite an overwhelming surge after Pearl Harbor to boost wartime production and training, it took nearly all of 1942 and 1943 to ramp materiel production and personnel training to meet wartime demand. It was not until 1944 that the United States could fight the war decisively.

China will not afford us that time. They have too much at risk to consider any other course of action aside from achieving rapid knock-out blows and then prepare for an extended conflict if necessary to attrit U.S. forces to a point of insolvency. Avoiding that fate requires U.S. leaders to develop new technologies and procure them in operationally viable quantities that anticipate attrition, the scale of the Indo-Pacific theater, and concurrent operational demand in multiple theaters. It is time to be realistic about owning the problem we face, acknowledge where capacity gaps exist, and play a smart, long-term plan to net future success. Those who question the expense should consider the lessons from history presented here. Ignoring them will risk incurring far greater costs that result from suffering a major defeat.

MARK GUNZINGER serves as the Director of Future Concepts and Capability Assessments at the Mitchell Institute for Aerospace Studies.

BACKGROUND: USAF Col (Ret.) Gunzinger was a command pilot with more than 3,000 hours in the B-52. As a member of the Air Staff during the 1990s, he conducted research on behalf of the Air Force Chief of Staff and Secretary of the Air Force on future warfighting operational concepts. In the late 1990s, he was a co- author of DoD's first transformation strategy that prioritized the development of new technologies to sustain the U.S. military's ability to project power into contested areas. As Director for Defense Transformation, Force Planning and Resources on the National Security Council staff, The White House, Mr. Gunzinger co-led the development of strategic plans focused on offsetting emerging of anti-access and area-denial (A2/AD) challenges in the Western Pacific. He was then appointed Deputy Assistant Secretary of Defense for Forces Transformation and Resources with oversight of DoD's conventional capabilities. Acting as project leader for government-sponsored wargames that examined the challenges of emerging A2/AD threats in the Persian Gulf region, he developed elements of a new operational concept for U.S. military operations, which informed the development of DoD's Air-Sea Battle concept.

AREAS OF FOCUS: Mr. Gunzinger's recent studies have focused on future directed energy capabilities, such as ship-based lasers and high-power microwave weapons, operational concepts and technologies needed to maintain the U.S. military's dominance in the electromagnetic spectrum, and capabilities to create new advantages in precision strike salvo competitions with China and Russia. He has led multiple U.S. and international wargames and workshops to assess future concepts and systems-of-systems for joint and combined military operations in contested environments.

ACADEMIC AND PROFESSIONAL TITLES: Mr. Gunzinger has an MS in National Security Strategy degree from the National War College, a Master of Airpower Art and Science degree from the School of Advanced Air and Space Studies, a Master of Public Administration from Central Michigan University, and a BS in Chemistry from the U.S. Air Force Academy. He is the recipient of the Department of Defense Distinguished Civilian Service Medal, the Secretary of Defense Medal for Outstanding Public Service, the Defense Superior Service Medal, and the Legion of Merit Medal.

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Hearing Date: 12/6/2023

Hearing Subject:

Back to the Future

Witness name: Col Mark Gunzinger

Position/Title: Director Future Concepts and Capability Assessments

Capacity in which appearing: (check one)

● Individual ○ Representative

If appearing in a representative capacity, name of the organization or entity represented:

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2023

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2022

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2021

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2020

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

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2023

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment
Payment	Japan (Japan Air Self Defense Force)	$2,339	Air fare for speaking engagement in Tokyo

2022

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2021

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract, grant, or payment

2020

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2020

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