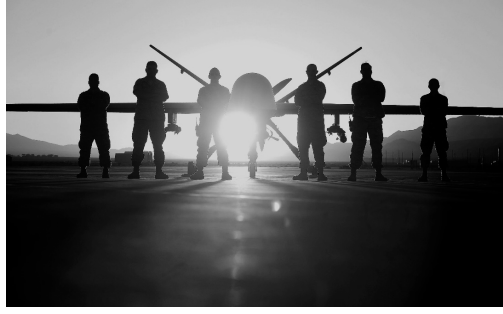


Up to Speed: Developments in the Hypersonic Weapons Industry

Issue 1, Hypersonics Primer



Aerospace, Defense, & Government Services

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This is the first installment in a series that will provide updates and commentary on developments in the hypersonic weapons industry. This issue will set a baseline for the current state of hypersonic weapon development, with more focused reports to follow on topics including hypersonic missile defense, space-based systems, infrastructure, and adversary programs.

Background

Hypersonic weapons – which travel at speeds in excess of Mach 5 (approximately 1 mile per second, or 6,000 kmh) ¹ – have been a part of defense research and development in the United States since the 1960s.² It was during the George W. Bush administration in the early 2000s that the US began to make more targeted investments to develop hypersonic weapons as part of the Conventional Prompt Global Strike (CPGS) program.³

Hypersonic weapons are typically classified into two categories - hypersonic glide vehicles (“HGV”) and hypersonic cruise missiles (“HCM”):

HGVs are unpowered vehicles that are launched from a rocket and then released to glide to its target. These vehicles are maneuverable once they reach the glide phase, therefore holding large areas at risk during flight. Unlike ballistic missiles which can reach upwards of 1,200+ km in altitude, HGVs reach between 40 km to 100 km – flying at trajectories that create significant challenges for existing land- and space-based detection systems and sensor architecture.⁴

HCMs can be launched from the ground, from aircraft, or from ships. These missiles have air-breathing engines that can produce thrust to hypersonics speeds, known as supersonic combustion ramjet (scramjet) engines.⁵ Similar to HGVs, the HCMs combine speed and maneuverability to make them highly effective weapons as compared to conventional cruise missiles.

Hypersonic weapons can be paired with nuclear or conventional warheads, however given their high rate of speed, conventional hypersonic weapons are expected to use only kinetic energy to destroy targets.⁶ The combination of maneuverability, speed, and flight trajectory not only make this first generation of hypersonic missiles very difficult to detect and defend against, but they materially compress timelines for decisionmakers to assess and respond to the threat once the weapon is in-flight, creating urgency among major governments to have offensive and defensive capabilities.

Currently, the United States, Russia, and China are the most active in pursuing hypersonic weapons technology and programs. Additionally, France and India have committed development programs, followed by Australia, Japan, and Germany which are actively pursuing R&D of hypersonic technology.⁷

Russia

In his March 2018 annual state of the union address, Russian President Vladimir Putin touted six new “next generation” weapons, including a new hypersonic weapon called the Avangard – a hypersonic glide vehicle. Citing the US

¹ Approximately 3,800 mph

² Manned hypersonic air vehicles were first flown beginning in 1959, when NASA flew the X-15 hypersonic test vehicle. Source: Richard Speier et al., *Hypersonic Missile Proliferation: Hindering the Speed of a New Class of Weapons*, RAND Corporation 2017

³ Amy F. Woolf, CRS Report R41464, *Conventional Prompt Global Strike and Long-Range Ballistic Missiles*

⁴ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*; Richard Speier et al., *Hypersonic Missile Proliferation: Hindering the Speed of a New Class of Weapons*

⁵ Richard Speier et al., *Hypersonic Missile Proliferation: Hindering the Speed of a New Class of Weapons*

⁶ Richard Speier et al., *Hypersonic Missile Proliferation: Hindering the Speed of a New Class of Weapons*

⁷ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*; Richard Speier et al., *Hypersonic Missile Proliferation: Hindering the Speed of a New Class of Weapons*

withdrawal from the Anti-Ballistic Missile Treaty, US missile defense deployments, and NATO expansion towards Russian borders, Putin sought to justify Russia's development of new strategic arms.⁸

Russia currently has two hypersonic weapons programs. The Avangard, noted above, is launched from an ICBM with "unlimited range" and is reportedly nuclear capable.⁹ Its development dates back to USSR research in the 1980s and it has been tested about 14 times between 1990 and 2018, including a December 2018 test firing where the weapon was reported to have reached a speed of Mach 20 (about the equivalent of orbital velocity).¹⁰ It is believed that the Avangard became operational for combat duty in late 2019.¹¹

The second Russian hypersonic program is the development of the Tsirkon hypersonic cruise missile, which will be ship- and sub-launch capable, and reportedly will travel at speeds of up to Mach 9 with a range of 1,000 km.¹² The Tsirkon was successfully test fired from a ship on December 10, 2018, and according to US intelligence reports, it is expected to enter into combat duty by 2022/2023.¹³

China

In 2020, China deployed its first operational hypersonic weapons system, which pairs the medium-range DF-17 ballistic missile with the DF-ZF¹⁴ hypersonic glide vehicle.¹⁵ The missile has a range of 2,000 km and the DF-ZF vehicle can reportedly achieve speeds of up to Mach 10.¹⁶

In its 2019 annual report to Congress on China's military and security developments, the US Department of Defense noted that China had conducted a successful test of its Starry Sky-2¹⁷, which China described as a hypersonic waverider vehicle.¹⁸ This technology refers to a vehicle that uses "powered flight after launch and derives lift from its own shockwaves."¹⁹ It is believed that the Starry Sky-2 could become operational by 2025.

Most recently, Chinese hypersonic capabilities dominated the headlines after the *Financial Times* reported on a July 27, 2021 test of a hypersonic glide vehicle.²⁰ This was a notable test because the HGV was launched using a Long March rocket as part of an orbital bombardment system (OBS), which places the HGV into orbit before the vehicle slows itself to de-orbit towards its target.²¹ While the missile missed its target by nearly 24 miles, it was first time that an HGV fully orbited the Earth before maneuvering on its own to de-orbit. Of further note, there are reports that the HGV fired a separate projectile mid-flight while gliding at hypersonic speed – an impressive result given the constraints of physics, although it's unclear whether this was an air-to-air missile or a countermeasure designed to challenge missile defense systems.²²

If these reports are true, it provides clear evidence that China's hypersonic capabilities are potentially more advanced than previously thought. In response to the China test, Raytheon Technologies CEO Gregory Hayes said in an interview with Bloomberg Television that "we are at least several years behind." This follows March 2018 comments from then

⁸ Vladimir Putin, "Presidential Address to the Federal Assembly", March 1, 2018; Holly Ellyatt, "Putin reveals new Russian missile that can reach any point in the world", *CNBC*, March 1, 2018

⁹ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

¹⁰ CSIS Center for Strategic & International Studies, *Missile Defense Project*, Avangard, <https://missilethreat.csis.org/missile/avangard/>

¹¹ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*; "First Regiment of Avangard hypersonic missile systems goes on combat duty in Russia", *TASS*, December 27, 2019, tass.com/defense/1104297; "Russia begins serial production of new cutting-edge glide vehicle," *TASS*, March 1, 2018, <http://tass.com/defense/992297>

¹² Vladimir Putin, "Presidential Address to the Federal Assembly", February 20, 2019; CSIS Center for Strategic & International Studies, *Missile Defense Project*, News, February 22, 2019, <https://missilethreat.csis.org/russia-confirms-development-of-tsirkon-hypersonic-cruise-missile/>

¹³ Amanda Macias, "Russia again successfully tests ship-based hypersonic missile — which will likely be ready for combat by 2022", *CNBC*, December 20, 2018

¹⁴ Previously designated as the WU-14

¹⁵ Office of the Secretary of Defense, *Report on Military and Security Developments Involving the People's Republic of China, Annual Report to Congress 2021*, Page 13, et al; Shaan Shaikh, CSIS Center for Strategic & International Studies, *Missile Defense Project*, *China's Hypersonic Future*, December 12, 2021

¹⁶ CSIS Center for Strategic & International Studies, *Missile Defense Project*, DF-17

¹⁷ Also referred to as the XINGKONG-2

¹⁸ Office of the Secretary of Defense, *Report on Military and Security Developments Involving the People's Republic of China, Annual Report to Congress 2021*, Page 44, et al

¹⁹ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

²⁰ Demetri Sevastopulo, "China's leap in hypersonic missile technology shakes US intelligence", *Financial Times*, October 18, 2021

²¹ Demetri Sevastopulo, "Pentagon chief admits alarm over China's hypersonic weapon tests", *Financial Times*, October 28, 2021; Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

²² Demetri Sevastopulo, "China missile fired during flight by hypersonic weapon confounds US", *Financial Times*, November 29, 2021

Under Secretary of Defense for Research and Engineering Michael Griffin when he stated that China has conducted 20 times as many hypersonic tests as the United States.²³

United States

The United States is currently developing hypersonic weapons through programs with the Navy, Army, Air Force, and DARPA. All US programs are currently focused on developing and producing prototypes, as the US currently has no programs of record for hypersonic weapons and doesn't have any operational hypersonic weapons currently in service for combat duty.²⁴

The largest disclosed program is the Navy's Conventional Prompt Strike program (\$1.4 billion FY2022 request), which is intended to provide the US military with the ability to strike high-value and time-sensitive targets with conventional warheads. In contrast to China and Russia's nuclear capable hypersonic systems, US hypersonic weapons will be conventionally armed, which is more technically demanding from a development standpoint, as nuclear armed hypersonics require less precision and accuracy. The US focus on conventional hypersonic weapons reflects the strategic goal of complementing its nuclear capability with the capacity to conduct devastating preemptive strikes on Russian and Chinese nuclear arsenals and related targets. From there, US missile defense deployments could then limit any retaliatory strikes against the US.²⁵

The Pentagon's FY2022 budget request for hypersonic research is \$3.8 billion, a 18.8% increase from the \$3.2 billion FY2021 request, and 46% higher than the FY2020 budget request of \$2.6 billion. Additionally, the Missile Defense Agency requested \$248 million for FY2022 to address hypersonic threats, up from \$207 million in FY2021, and \$174 million in FY2020.²⁶

Common Hypersonic Glide Body (C-HGB)

The C-HGB is the glide vehicle that is being developed jointly by the Navy and Army, which will be used across the different services. The C-HGB will comprise the weapon's conventional warhead, guidance system, cabling, and thermal protection shield. Navy is the lead designer, and Army is the lead for production. Each service will use the C-HGB, while individual weapon and launch systems are being developed separately to tailor to specific needs.²⁷

Dynetics (Ticker LDOS.US) is the prime contract holder for the design, development, and production of the glide bodies in collaboration with Sandia National Laboratories. Lockheed Martin (LMT.US), Raytheon Technologies (RTX.US), and General Atomics EMS (private) will work on prototyping, assembly, integration, and testing.²⁸

Navy

The Navy's Conventional Prompt Strike (CPS) system will pair the common glide vehicle with a rocket system designed by Lockheed Martin and Northrop Grumman (NOC.US) to create a common All Up Round (AUR+C) for use by both the Navy and Army.²⁹ The Navy requested \$1.4 billion for CPS RDT&E in the FY2022 request, a 35% increase over the FY2021 request.³⁰

Army

The Long-Range Hypersonic Weapon program (LRHW) will pair the common glide vehicle with the Navy's AUR and is expected to have a range of over 2,775 km. The Army requested \$310 million in LRHW RDT&E for FY2022.³¹ It expects to field an experimental prototype in FY2023 and transition to a program of record by the end of FY2024 for

²³ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

²⁴ Steve Trimble, "New Long-Term Pentagon Plan Boosts Hypersonics, But Only Prototypes", *Aviation Week*, March 15, 2019

²⁵ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

²⁶ Office of the Undersecretary of Defense, United States Department of Defense Fiscal Year 2022 Budget Request

²⁷ US Department of Defense, "Department of Defense Tests Hypersonic Glide Body", March 20, 2020,

<https://www.defense.gov/News/Releases/Release/Article/2119458/department-of-defense-tests-hypersonic-glide-body/>

²⁸ [dynetics.com/hypersonics](https://www.dynetics.com/hypersonics); Leidos company reports

²⁹ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

³⁰ Office of the Undersecretary of Defense, United States Department of Defense Fiscal Year 2022 Budget Request

³¹ Office of the Undersecretary of Defense, United States Department of Defense Fiscal Year 2022 Budget Request

this land-based system. It has been reported that the LRHW could cost \$106 million per missile, with the program adding as much as \$7 billion to the Army’s budget over the next few years.³²

Air Force

The Lockheed Martin developed AGM-183 Air-Launched Rapid Response Weapon (ARRW) is expected to be paired with DARPA’s Tactical Boost Glide technology to create an air-launched HGV capable of travelling at speeds of between Mach 6.5 to Mach 8 with a range of 1,600 km.³³ The Air Force requested \$238 million in ARRW RDT&E in FY2022, and \$161 million for the procurement of 12 ARRW missiles.³⁴

The Air Force recently launched the Hypersonic Attack Cruise Missile (HACM) program in FY2022 that brings together Air Force and DARPA technologies for a hypersonic cruise missile. It is believed that the HACM could be launched from fighter jets and bombers.³⁵ The FY2022 request for the HACM was \$200 million. It has been reported that a design from Lockheed Martin and a design from a Raytheon and Northrop Grumman team are both performing in this program.

DARPA

The Tactical Boost Glide (TBG) is a joint DARPA/Air Force effort that aims to develop and demonstrate technologies to enable future air-launched, tactical-range hypersonic boost glide systems.³⁶ The TBG is a wedge-shaped hypersonic glide vehicle designed by Raytheon that is capable of reaching speeds of Mach 7 and greater.³⁷ DARPA requested \$50 million for the TBG in FY2022.

DARPA Operational Fires (OpFires) program is developing new technologies for a ground-launched medium-range hypersonic boost glide system that can “rapidly and precisely engage critical, time-sensitive targets while penetrating modern enemy air defenses”.³⁸ It is expected that the booster will be able to deliver a variety of payloads at multiple ranges. DARPA requested \$45 million for the OpFires in FY2022. The system is being designed by Lockheed Martin and Aerojet Rocketdyne (AJRD.US).³⁹

In continued effort with the Air Force, DARPA is developing a Hypersonic Air-breathing Weapon Concept (HAWC) with the goal of producing an affordable air-launched HCM that can be launched from a number of different platforms. DARPA requested \$10 million for the HAWC in FY2022. Lockheed Martin is competing against Raytheon/Northrop’s design that uses waverider technology powered by Northrop’s scramjet engine.

Figure 1. US Hypersonic Weapon Development Programs

<i>Weapon System</i>	<i>Service</i>	<i>Industry Contractor</i>	<i>Type</i>	<i>Launch</i>	<i>FY22 Request [1]</i>
Common Hypersonic Glide Body (C-HGB)	Navy/Army	LDOS, LMT, RTX	HGV	---	---
Conventional Prompt Strike (CPS)	Navy	LMT, NOC	HGV	Ground/Sub	1,400.0
Long-range Hypersonic Weapon (LRHW)	Army	LMT, NOC	HGV	Ground	310.0
Air-Launched Rapid Response Weapon (ARRW)	USAF	LMT, NOC	HGV	Air	238.0
Hypersonic Attack Cruise Missile (HACM)	USAF/DARPA	RTX / NOC; LMT [2]	HCM	Air	200.0
Tactical Boost Glide (TBG)	DARPA/USAF	RTX	HGV	Air	50.0
Operational Fires (OpFires)	DARPA	LMT, AJRD	HGV	Ground	45.0
Hypersonic Air-breathing Weapon Concept (HAWC)	DARPA/USAF	RTX / NOC; LMT [2]	HCM	Air	10.0

Source: FON Advisors; Company reports

^[1] Defense Budget Request for FY2022, USD millions

^[2] Raytheon/Northrup Grumman designs and Lockheed Martin designs are reportedly both performing in this program

³² Andrew Feickert, CRS In Focus Report 11991, The US Army’s Long-Range Hypersonic Weapon (LRHW), December 2021

³³ Kelley M. Saylor, CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*

³⁴ Office of the Undersecretary of Defense, United States Department of Defense Fiscal Year 2022 Budget Request

³⁵ John A. Tirpak, “Air Force will try again to launch ARRW hypersonic missile in July”, Air Force Magazine, June 3, 2021

³⁶ Tactical Boost Glide (TBG), DARPA, <https://www.darpa.mil/program/tactical-boost-glide>

³⁷ John A. Tirpak, “The Hypersonics Push”, Air Force Magazine, April 1, 2020

³⁸ “DARPA’s Operational Fires Ground-Launched Hypersonics Program Enters New Phase”, DARPA, <https://www.darpa.mil/news-events/2021-01-21>

³⁹ LMT acquisition of AJRD is pending regulatory approval, with an expected close of Q1 2022.

US Industrial Activities

The hypersonic weapon industrial ecosystem in the US is dynamic, sharing technology and processes from the space and existing missile programs to support full life-cycle production, from design and development to manufacturing and integration. Although it maintains many similarities to the traditional missile ecosystem, there is a demand for greater incorporation of advanced materials sciences and leveraging of artificial intelligence and other advanced computing capabilities to support command and control, as well as intensive modeling, simulation, and analysis.

The key players in the US hypersonic weapons market are Lockheed Martin, Raytheon, and Northrop Grumman. Dynetics, which was acquired by Leidos in early 2020, also plays an important role as they are leading the development and production of the common glide vehicle to be used across services. Boeing, which has a long history of hypersonic technology development, has recently re-entered the market to complete a preliminary design review (PDR) and ground testing for a dual-combustion ramjet on the HyFly2 program.⁴⁰

Lockheed Martin

Lockheed Martin is the largest player in the US hypersonic weapons industry, with over 30 years of experience in the research, development, and demonstration of hypersonic technologies. The Company is currently expecting to generate approximately \$1.5 billion in revenues in 2021 related to hypersonics work. On the Q3 FY2021 earnings call in October 2021, CEO James Taicet highlighted that the top area underpinning future growth for the company was hypersonics. Lockheed is currently performing on six hypersonic programs across the company and following the successful completion of ongoing testing and evaluation activity, multiple programs are expected to enter production between 2023 and 2026. On the same earnings call, acting CFO John Mollard noted that assuming many of these projects do move into production, that \$1.5 billion revenue figure could grow to \$3 billion by 2026.⁴¹

In March 2021, Lockheed won a prime award of \$1.54 billion by the Navy for the CPS program, which was a modification contract that covers design, development, build, and integration of equipment for missile flight test demonstrations and fielding.⁴² This follows a February 2019 award of an \$846 million contract modification for the design, development, build, and integration of large diameter rocket motors for the CPS program.⁴³

Lockheed is the prime contractor for the LRHW systems integration project, where they were awarded a \$347 million multi-year contract in Aug 2019 to integrate the LRHW with the C-HGB. Lockheed is also a subcontractor to Dynetics on its \$352 million contract to prototype and produce the C-HGB system.

Additionally, Lockheed won a \$988 million contract modification in December 2019 for critical design review, test, and production readiness support for the ARRW program⁴⁴, which follows a \$480 million ARRW contract award from August 2018. The ARRW program has seen a number of recent setbacks including a December 15, 2021 test failure which was the third test failure of the ARRW when the launch sequence was aborted before the booster was released from a B-52 bomber, following a similar failure on April 5, 2021.⁴⁵

Lockheed is working with Aerojet Rocketdyne on a number of these programs, as AJRD is a leader in solid propellant boost rocket motors and has successfully developed and tested a number of hypersonic scramjet and dual combustion ramjet engines. Lockheed announced in Dec 2020 that they have entered into definitive agreements to acquire AJRD for \$4.4 billion. During the M&A conference call, Lockheed CEO stated that “Aerojet is a critical partner across our portfolio already, and this helps position us for even greater growth in hypersonics, missile defense, and space, which are key elements of the national defense strategy.”⁴⁶

Raytheon Technologies

Raytheon Technologies is the combination of Raytheon Corporation and United Technologies, which merged in 2020, creating what United Technologies CEO Tom Kennedy described at the time as a “true powerhouse, a true leader in

⁴⁰ Steve Trimble, “Boeing Wins Chance to Reenter Hypersonics Weapons Race”, *Aviation Week*, November 5, 2020

⁴¹ Lockheed Martin FQ3 2021 Earnings Call, Oct 26, 2021

⁴² <https://www.defense.gov/News/Contracts/Contract/Article/2534571/>

⁴³ “Lockheed Wins U.S. Navy’s \$1.54B Conventional Prompt Strike Weapon Deal”, *defenseworld.net*, March 12, 2021

⁴⁴ <https://www.defense.gov/News/Contracts/Contract/Article/2030017/>

⁴⁵ Valerie Insinna, “Air Force hypersonic weapon runs into trouble after a third failed test”, *Breaking Defense*, December 20, 2021

⁴⁶ James Taicet, LMT CEO, *AJRD M&A Call*, Dec 21, 2021

hypersonics. We bring together Raytheon's capability in missiles, in seekers and payloads, and UTC's expertise in exotic high-temperature materials, nickel-based alloys, [and] silicon carbide-based composites.”⁴⁷

Raytheon doesn't currently break out its hypersonics revenue, however on Raytheon Corporation's Q2 2019 earnings call (pre-merger), CFO Anthony O'Brien stated that the company was expecting to generate about \$300 million in aggregate hypersonic revenue for the year.⁴⁸ In its 2021 Investor Day presentation (post-merger), Raytheon highlighted hypersonics as a core next-generation solution to deal with evolving threats, with hypersonics and missile defense representing a combined lifetime value to RTX of over \$50 billion, with a greater than 15% CAGR for future sales in these areas.⁴⁹

Raytheon has developed a strong market position within offensive strike hypersonics, working on the HAWC and TBG programs, as well as participating in the CPS, LRHW, and other classified programs. However, Raytheon stands out currently as the leader in counter (defensive) hypersonics. In fact, Wesley Kremer, President of Raytheon Missiles & Defense, noted that the company “believes that the counter hypersonics market will exceed the [offensive] hypersonic market... we also believe we are very well positioned to capture that... missile defense, the defense capability has been a hallmark of legacy Raytheon for decades.”⁵⁰ The rationale that the company has highlighted regularly is that the defensive market includes the weapons to counter the hypersonic threat, but it also includes the entire integrated kill chain, including communications and sensors. We will be focusing on hypersonic missile defense and related space-based systems in future reports.

Northrop Grumman

Northrop has a broad portfolio of hypersonic weapon capabilities that it offers through six different government programs, providing propulsion, fuses, and warheads. Northrop is also active in counter hypersonics which is part of its space business to detect, track, and target hypersonic weapons from adversaries. During an investor conference in November 2021, CEO Kathy Warden noted that the revenue contribution from hypersonics is small to start, accounting for just a “single-digit” percentage of projected \$36 billion in total company revenues for the year.⁵¹

Northrop's core hypersonic capability on current programs involves development and testing of its scramjet engine, which is made almost entirely of 3D-printed parts using advanced materials.⁵² In June 2019, Northrop and Raytheon signed a teaming agreement to develop, produce, and integrate Northrop's scramjet combustors to power Raytheon's air-breathing hypersonic weapons. The companies are working together on the \$255 million HAWC Phase 2 program and the HACM program for DARPA and the Air Force. The companies noted in their 2019 teaming press release that they will continue to collaborate on HAWC and future air-breathing hypersonic missiles programs.

Northrop accelerated its entry into the hypersonic market through its \$9.4 billion acquisition of Orbital ATK in 2018. Northrop had capabilities with large space systems, but the addition of Orbital's portfolio that included small space systems, launch vehicles, propulsion, missiles, and munitions provided them with nearly \$4.5 billion of revenues from these new capabilities and \$15 billion in contract backlog.⁵³

Closing Remarks

With reports that both China and Russia have fielded hypersonics weapons for combat duty, the urgency for the US to field operational systems is expected to drive an increase in spending over the next few years as we move from research to production. This is evident in the Pentagon's growing budget requests for hypersonic research, but also confirmed by comments from the major defense primes. This should create significant opportunities for contractors across many different verticals, especially those that touch hypersonic missile defense and the related space-based systems, which will be the topic of the next report.

⁴⁷ United Technologies, Shareholder and Analyst Call, June 17, 2019

⁴⁸ Raytheon Company Q2 2019 Earnings Call, July 25, 2019

⁴⁹ Raytheon Technologies Analyst/Investor Day Presentation, 2021, Page 49

⁵⁰ Raytheon Technologies Analyst/Investor Day, May 18, 2021

⁵¹ Source: CapitalIQ; Northrop Grumman Corporation Presentation at Baird Global Industrial Conference 2021, November, 09 2021

⁵² John Wilcox, Northrup Grumman VP of Advanced Programs and Technology, quoted at Paris Air Show in June 2019, reported by Valerie Insinna, [defensenews.com](https://www.defensenews.com)

⁵³ Northrop Grumman/Orbital ATK M&A Presentation, September 18, 2017

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