BREAKING DEFENSE | eBRIEF

## Cold War Era to Modern Mission Success:

# Digital Engineering Transforms the B-52

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The B-52 Stratofortress is a unique example of how a Cold War-era platform can be updated for cutting-edge advantage and enhanced modern, strategic capability. The Air Force's B-52 Commercial Engine Replacement Program (CERP) is doing just that with the retrofit of new commercial engines originally designed for business aircraft.

The multi-billion-dollar B-52 CERP is part of the Air Force's newly unveiled "eSeries" approach, where systems are designed, built, and tested in a virtual environment before prototype hardware is built. This innovative digital engineering approach will save time and reduce risk on the large-scale upgrade program.

"There are some unique aspects of the CERP in terms of digital engineering, and how we are using digital engineering to do prototyping, risk reduction, and tech maturation for the aircraft integration effort," Air Force Brig. Gen. John Newberry, program executive officer for bombers, said in the trade press September 2020. "There's a lot of other significant modernization efforts underway for the B-52, including radar modernization, to put new capabilities on the aircraft and make it viable for years to come."

CERP is a part of a broader Pentagon modernization of all three legs of its strategic nuclear triad, which includes land- and submarine-based ballistic missiles in addition to the B-52. The Air Force's 76 active B-52H aircraft, which entered service in the early 1960s, still form the backbone of its strategic bomber fleet, however. The engine swap is expected to extend the capability of the B-52 platform to meet this critical mission to 2050 or beyond.

Each B-52 aircraft has eight engines, meaning the replacement program will require 608 new engines plus spares, for a total of about 650. Under the Air Force's Other Transaction Authority (OTA) rules, the Air Force is limiting the competition to three companies, each offering variants of contemporary business jet engines: Rolls-Royce, GE Aviation, and Pratt & Whitney.

The competitors have each developed digital versions of their respective engine offerings, and the Air Force intends to downselect to a single company in 2021 to develop a more detailed virtual design. Most importantly, this will show how its engine integrates with the B-52H airframe, control system, and electronics. That will be followed by an initial contract for a limited number of engines to be integrated on prototype aircraft, with the remaining engines procured in multiple tranches over a 17-year period.

*Photo: An Air Force technician inspects the engine of a U.S. Air Force B-52H Stratofortress. Rising maintenance costs and impending obsolescence of the fleet's engines bring urgency to the B-52 re-engining effort.*

## Cost and Obsolescence Drives the Need for a New Engine

The current fleet of B-52H long-range bombers has been flying since the 1960s. Even at the age of 60 years or more, the Air Force is nowhere near ready to part ways with the storied and versatile strategic bomber, which performs conventional missions as well as the strategic nuclear deterrence role. After all, there are just 20 active B-2 Spirit stealth bombers and 62 B-1 Lancer bombers in the fleet (with 17 Lancers scheduled for near-term retirement). At the same time, the next-generation B-21 Raider is still many years away from deployment in substantial numbers. That, coupled with the limited number and payload of the stealthy B-21s, make the B-52s indispensable.

Accordingly, the B-52Hs have been undergoing several modernization upgrades, including new radars, weapons capabilities, communications, navigation, and other systems. There have been numerous initiatives to re-engine the aircraft dating back to 1969, but these have been deferred due to competing priorities.

But the Air Force can wait no longer if it wants to keep the planes in service. The current powerplant, Pratt & Whitney's TF33, is becoming prohibitively expensive to maintain and has parts obsolescence issues. The last TF33 was manufactured in 1985, according to the Congressional Research Service.

According to Boeing, the B-52H manufacturer and lead integrator for the CERP effort, the cost of overhauling a single TF33 engine has increased from $230,000 in 1996 to $2 million today. "Due to improvements in engine technology, a new engine installed today would not need to be overhauled, ever, for the projected life of the B-52," Boeing said.

*600+ engines will be procured under an Air Force Other Transaction Authority contract. Shown are B-52H Stratofortresses from the 2nd Bomb Wing taxiing down the flight line during a readiness exercise at Barksdale Air Force Base, La., in 2020.*

Because the engine has been out of production for decades, finding spare parts is becoming more difficult. The Air force projects that the engines will become unsustainable by 2030, the service said in documents accompanying its 2021 budget request.

A B-52 outfitted with modern commercial-derivative engines will be approximately 30 percent more fuel efficient than those flying today. This provides many critical benefits. First lower operating costs. The re-engining will also provide a 40 percent increase in range and reduce demands on the Air Force's limited aerial refueling tanker fleet. Further, new engines for the B-52 will enable longer loitering times over targets. Another benefit is that new, more efficient engines will have a significantly reduced environmental footprint.

Other features and benefits of the B-52 re-engining include:

- Reduction of ground equipment necessary to start the engines quickly in an emergency, a key requirement for the strategic-deterrence mission.
- A redesigned engine pod with new struts and a modified nacelle that simplifies the engine change-out process.
- Digital engine controls and displays compatible with nuclear-hardened electronics.
- A new gearbox able to accommodate future electrical needs.

The reduced maintenance, lower fuel costs, and other efficiencies associated with the CERP will result in over $10 billion in taxpayer savings between now and 2050, Boeing indicated.

Budget documents show that the Air Force requested just over $299 million for CERP in 2021, with nearly $1.14 in program spending projected through 2025. The service spent $60 million and $175 million, respectively, on the program in 2019 and 2020, the documents show. According to a 2018 report in Breaking Defense, the CERP program could be valued at up to $8 billion over the life of the program.

"This sustainment program will replace the current TF33-PW-103 engine with jet engines of similar size, weight, and thrust characteristics," the Air Force budget documents said. "The use of new technology will increase both the overall reliability/maintainability of the propulsion system and produce additional electrical power-generation capabilities for emerging requirements."


*The B-52 CERP program leverages engines designed for commercial business jets built by companies such as Gulfstream Aerospace. Shown are Gulfstream G500 and G600 aircraft (Photo credit, Gulfstream Aerospace).*

## The Competitors

In the early days of commercial passenger aviation, the aerospace industry piggybacked on military investments, but these days the reverse is often true. In the case of engines, commercial manufacturers have made tremendous advances in money saving fuel efficiency, reliability, and maintainability over the years. In fact, the B-52's current TF33 engine was derived from Pratt & Whitney's commercial JT3, variants of which flew on passenger aircraft including the Boeing 707. The CERP program is merely the latest to take advantage of this paradigm.

The three competitors for the CERP engine contract – Rolls-Royce, GE Aviation, and Pratt & Whitney – are offering variants of commercial business-jet engines whose size, weight, and thrust characteristics roughly match those of the TF33. To minimize integration challenges, the retrofit program will retain the current B-52 propulsion configuration: four twin-engine pods, two on each wing. The Air Force scrapped earlier plans to reconfigure the aircraft with four larger engines, as this would have required expensive modifications to the wings.

The Air Force in 2019 awarded separate contracts to the three companies to develop digital-pod designs featuring their respective engine offerings. Each company worked with Boeing on studies to understand how their respective pod designs and engine characteristics would integrate with the B-52 airframe.

The companies have released some details of their respective offerings:

- **Rolls-Royce** is offering the F130, the Air Force designation for its BR700 family of business jet engines. The F130 already has been integrated into the service's C-37 jet (based on the civilian Gulfstream V) that is used to transport high-ranking U.S. government and Pentagon officials, and E-11 Battlefield Airborne Communications Node (based on the civilian Bombardier Global Express). On its website, the company touts the fuel efficiency, reliability and high mission readiness of the engine, which has logged more than 25 million flight hours.

Rolls-Royce will manufacture the F130 for the CERP at the Indianapolis manufacturing facility of its Rolls-Royce North America subsidiary. "The F130 engine is the affordable option for the B-52, and has already completed early testing at our Indianapolis facilities, confirming the design and performance are an exact match for the aircraft," the company said in a statement.

- **GE Aviation** is offering two engine options: the CF34-10 that flies on the Embraer 190 and the Passport on the Bombardier Global 7500. For the CF34-10, the company cites performance, maturity, and low cost of ownership. For the Passport, the company highlights fuel efficiency, endurance, advanced digital controls and health management, and reduced noise and emissions.

- **Pratt & Whitney** is proposing a militarized version of its PW800 that powers long-range business jets built by the likes of Gulfstream and Embraer. On its website, Pratt & Whitney said the PW800 offers a better than

*A U.S. Air Force B-52 Stratofortress departs after receiving fuel from a KC-135 Stratotanker during a multi-day Bomber Task Force mission over Southwest Asia.*

30-percent increase in fuel efficiency, more thrust and power, and saves 5,400 pounds of engine weight per aircraft compared to the TF33. The engine also features low sustainment costs, with zero scheduled maintenance removals and a robust supply chain infrastructure, the company said.

As the prime integrator for the re-engining project, Boeing Defense, Space & Security, which built the B-52 fleet, worked with the three engine makers to complete virtual engine prototypes and perform integration risk analysis, according to Air Force procurement documents released in May 2020. Boeing also is responsible for the interface between the engine and the B-52 airframe. Despite its oversight role, Boeing will not be selecting the engine provider; that responsibility falls to the Air Force.

## New Procurement Practice Addresses The Urgency

Rapidly rising maintenance costs and impending obsolescence of the TF33 engines on the current B-52 fleet have lent a sense of urgency to the CERP re-engining effort. Accordingly, the Air Force in September 2018 designated the program as a Middle Tier Acquisition (MTA), a new procurement category authorized in the Section 804 of the 2016 National Defense Authorization Act that facilitates rapid system prototyping and acquisition.

According to Air Force charts prepared for the Defense Acquisition University (DAU), the need for MTA authority is driven by the accelerating pace of technological advancement and the agility of U.S. adversaries fielding new capabilities. As of April 2019, the Air Force was well ahead of the other military services in MTA-designated programs, with 17 underway valued nearly $19 billion combined, according to the DAU.

"The primary thing [MTA] allows us to do is to streamline our decisions and reporting, take smart risks and to deliver capability to the warfighter faster," said Abby Pogorzelski, the Air Force's CERP program manager, during a DAU presentation. She said there are two pathways to MTA. "The first one is rapid prototyping, which is to field a demonstration or prototype within five years, and the second is rapid fielding, which is to initiate production within six months, then complete fielding within five years.".

CERP currently is a rapid prototyping effort, Pogorzelski said, adding that the Air Force has yet to decide whether it will pursue a rapid fielding MTA or revert to a more traditional acquisition for the next phase of the CERP effort.

## Prototyping in a Virtual World

Working closely with Boeing, the competing engine manufacturers developed virtual designs, or Virtual Power Pod Prototypes (vPPPs), which were delivered in late 2019. Sometime this year, the Air Force will downselect to a single design to develop into a Virtual System Prototype (vSP) that shows how the engines and pod will interface and interact with the full aircraft.

According to an Air Force CERP program summary for fiscal year 2020, the vSP will be completed in October 2021. "The vPPP and vSP digital design models will provide detailed information to support physical modification of two B-52 prototype aircraft" with the selected engine, the Air Force said.

After limited operational testing of the prototype aircraft, the Air Force will begin more comprehensive testing using 11 low-rate initial production aircraft, the service said. The remaining aircraft in the fleet will be modified in six full-rate production lots, the Air Force said, adding that it continues to evaluate options to accelerate production and fielding, including the MTA rapid fielding pathway.

"Initial engine quantities include 16-64 engines to integrate onto prototype aircraft, plus additional spares," the Air Force said in its May 2020 CERP request for proposals. "The remaining quantity of engines will be acquired over the course of multiple ordering periods, for a total

contemplated period of performance of up to 17 years. The 17-year period of performance includes a basic period and option periods as follows: one six-year basic period, one five-year option, and six one-year options."

## A New Class of Virtual Program

In a September 2020 speech at the virtual Air Force Association's Air, Space and Cyber Conference, then-service secretary Barbara Barrett unveiled the new eSeries class of development programs that would be digitally designed and virtually tested before taking physical form. The B-52 CERP initiative is one of only a handful of programs to receive the eSeries designation.

*Will Roper, former assistant secretary of the Air Force for acquisition, technology and logistics, included the B-52 CERP in the service's new eSeries of programs whose hardware is designed and tested virtually before taking physical form.*

"Digital engineering enables companies to design, build, and test aircraft, satellites, or weapon systems completely online," Barrett said. "Imagine iterating thousands of potential designs, developing composite materials without mixing chemicals, testing with countless sets of conditions in air or space, and delivering the product for manufacturing as a digital file no larger than an email attachment."

The result is compressed timelines, reduced infrastructure requirements, lower barriers to entry, and reduced costs, Barrett said.

The first program to receive the eSeries designation was the Air Force's eT-7A Red Hawk advanced trainer aircraft. According to the Air Force, the use of model-based engineering and 3D digital design tools reduced Red Hawk assembly hours by 80 percent and software development time by half. "The aircraft moved from computer screen to first flight in just 36 months, the Air Force said in a September 2020 press release.

In addition to the eT-7A and B-52 CERP, the list of programs receiving the eSeries designation has expanded to include: Next Generation Air Dominance (a secret program to develop a sixth-generation fighter), the A-10 Warthog Re-wing Program, and Ground Based Strategic Deterrent to replace the LGM-30 Minuteman III intercontinental ballistic missile.

The eSeries concept turns the time honored "fly before you buy" acquisition paradigm on its head. As laid out by Will Roper, the outgoing assistant secretary of the Air Force for acquisition, technology and logistics, in a pair of recent papers on digital manufacturing, the new concept should be "eCreate before you aviate" through digital engineering and virtualization.

Every system virtualization has a starting point, a set of building blocks that must be understood, Roper wrote. "For the B-52 Commercial Engine Replacement Program, that starting point was the podded mount for the digital engines to 'attach' to the physical wing, as well as the measured center of gravity and airflow properties of the jet."

B-52 CERP hopeful Rolls-Royce sees digital engineering as a core strength. The company is a founding member of Manufacturing x Digital, a Defense Department/industry consortium with more than 300 partners dedicated to advancing the state of the art in U.S. manufacturing. Other prominent consortium members include Boeing, Lockheed Martin, and Microsoft.

"We've been an industry leader for years across many aspects of digital capabilities," Darryl Roberson, senior vice president at Rolls-Royce North America Defense and a retired Air Force lieutenant general, told Breaking Defense in a February 2021 interview. "We've demonstrated our strong digital engineering pedigree in digital design and virtual reality on the F130 engine, which is our proposed engine for the B-52, as well as numerous other engines to include digital twin capabilities. We enjoy a proven track record in the area of digital test, as well as in reducing risk by combining digital and test-cell capabilities to speed up the overall process."

The digital engineering of the B-52 engine replacement represents a unique bridge between an increasingly distant past, the present, and the fast-approaching future. One that will help carry one of the nation's most storied 20th Century aircraft through the first half of the 21st. The B-52 is a remarkable and enduring success story. Already one of the longest-serving military aircraft in history, the B-52 will, by the time it finally retires, have outlived its designers, thanks in large part to engineering technologies they could scarcely have imagined when they did the original B-52 work.

*VIEWPOINT FROM ROLLS-ROYCE*

# APPLYING RISK REDUCTION AND DIGITAL ENGINEERING: THE AIR FORCE'S B-52 RE-ENGINING PROGRAM

Craig McVay, senior vice president Strategic Campaigns for Rolls-Royce Defense.

With hundreds of thousands of hours of digital engineering work done, Rolls-Royce is well ahead of schedule for the F130 engine development.

The Rolls-Royce F130 engine, based on the commercial BR725 powerplant, is the company's candidate for the B-52 CERP program.

Craig McVay is Senior Vice President of Strategic Campaigns for Rolls-Royce Defense. He is a retired Marine Corps fixed-wing aviator and in this Q&A discusses how the company is bringing advanced technology and support to the USAF B-52 re-engining program.

**Breaking Defense:** Why is the B-52 re-engining program so important for the Air Force?

**McVay:** The B-52 fleet will play a critical role in the U.S. Air Force's strategic plan for decades to come and the Commercial Engine Replacement Program (CERP) will enable these iconic aircraft to remain in service. The fleet will need new, improved engines to extend the lifespan of the aircraft – highly reliable powerplants that match the airframe well, offer a modern design, and provide highly fuel-efficient operation.

**Breaking Defense:** Which engine has Rolls-Royce offered for the CERP?

**McVay:** Rolls-Royce will offer the F130 engine, a military version of our commercial BR725 powerplant. The F130 family of engines is already operating in the Air Force fleet on other aircraft, so it is known to be a proven, reliable product. The Rolls-Royce BR700 family of engines, from which the BR725 derives, has been extremely reliable in commercial business aviation operations and the entire fleet has amassed over 27 million engine flight hours. That's an impressive record of dependable service. It's so dependable that once an F130 engine makes it onto the wing of a B-52, the engine may never require removal during the remaining lifetime of the aircraft.

**Breaking Defense:** But what about installing new Line-Replaceable Units?

**McVay:** Like any modern commercial Rolls-Royce engine design, the F130 significantly increases engine time-on-wing for the B-52. Longevity is a given and the engines are designed to easily last for the remaining life of the B-52 fleet. The F130 design includes quick, flightline access to Line-Replaceable Units, or LRUs, on the engine – no engine removal required. The F130 engine is a maintainer's engine, and a pilot's engine – all with unprecedented time-on-wing and the resulting high level of readiness.

**Breaking Defense:** What makes the F130 engine design a good fit for the B-52?

**McVay:** It's not only a good fit, but we consider the F130 the perfect fit. It operates at similar thrust levels to the aircraft's current engine. It is also the right physical size for the aircraft, which will reduce drag, as well as reduce wing / nacelle design and stress risk. In addition, the F130 has the perfect balance of proven reliability and the benefits of a modern design. The Air Force will enjoy all of these key attributes with Rolls-Royce's B-52 CERP propulsion solution.

**Breaking Defense:** What has Rolls-Royce already done to reduce risk for the CERP program?

**McVay:** To begin with, the F130's design will considerably reduce risk for the engine integration onto the airframe and the B-52 mission. Beyond that, we have gone 'all in' on the digital engineering side. That brings efficiency and speed to the design process, and completes required tasks more quickly. The significant amount of design time we have

already performed has complemented the physical and digital testing already completed to de-risk the program. With hundreds of thousands of hours of digital engineering work behind us, we are well ahead of schedule for the F130 engine development at this point of time.

**Breaking Defense:** Does this apply to the maintenance and training side as well?

**McVay:** Absolutely – Rolls-Royce has already developed virtual reality training software for the engine to be used by B-52 maintainers. This will prove invaluable in training new maintainers while reducing cost and risk, and increasing safety. But even more importantly, the virtual reality system will provide real-time, 24/7, global-support capabilities for maintainers around the world. No matter where the aircraft are deployed, maintainers will be able to connect with Rolls-Royce technical experts via the VR training system – so our techs can 'see what they see'. This will enhance communication, increase efficiency, and improve aircraft availability. A similar training software system for Rolls-Royce engines on Air Force C-130J aircraft is already in operation and has been well received by airmen.

**Breaking Defense:** Where will Rolls-Royce manufacture the F130 engines if the company wins the competition?

**McVay:** The F130 will be an American-made engine – engineered, produced and supported at our primary U.S. facilities in Indianapolis, IN. We just completed the significant modernization of our Indianapolis facilities, creating a manufacturing site tailor-made for this engine line. Our facilities are among the most efficient and high-tech of any Rolls-Royce site worldwide. In fact, visitors to our new facilities tell us that our new Supercell robotic manufacturing unit is the most advanced technology they have seen in any aerospace facility anywhere in the industry. Needless to say, we're very excited and quite proud to offer this advanced manufacturing capability to the U.S. Air Force; our facilities will be the perfect solution for efficiently producing F130 engines.

In addition, Rolls-Royce is one of the founders and leaders in the DoD-industry high-tech consortium known as Manufacturing x Digital (MxD), which is acutely focused on digital manufacturing. This puts Rolls-Royce at the forefront of the latest developments in advanced manufacturing. Rolls-Royce continues to utilize a value-driven approach in implementing digital technologies. The aim is to reduce risk, cost, and delivery time.

**Breaking Defense:** Environmental impacts from aviation continue to be of growing concern both globally and from the Department of Defense and the Air Force. How is Rolls-Royce addressing these concerns?

**McVay:** Rolls-Royce is absolutely committed to the environment and aims to achieve net-zero carbon use, in our operations, by 2030. There are two key elements of this, and both are important and linked to each other. First, Rolls-Royce has been focused on improvements in fuel efficiency and reduced environmental impact for a long time. Every new generation of our commercial engines, for example, includes reductions in fuel burn to lower the environmental impact. We are also championing electrification – developing, testing, and innovating technologies and systems together with partners to create the electric propulsion and energy systems for tomorrow. Second, these advancing electric capabilities will benefit the warfighter because electric motors are inherently quieter – translating to more lethality for special missions. While there are no specific requirements from the Air Force at this moment, our company will continue to pursue these capabilities for the future.