RE- ENGINING A LE

GEND

The U.S. Air Force's strategy for ensuring the nuclear deterrence and conventional firepower of its bomber forces through the 2050s and beyond will require installing commercial jet engines onto its B-52s. Jan Tegler spoke to the Air Force and industry managers who must pull off this re-engining on time and on budget.

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U.S. airmen work on a B-52 Stratofortress engine at Barksdale Air Force Base, La.
Credit: U.S. Air Force

Dennis Thibodeau, a retired Pratt & Whitney engine assembly line technician, knows as well as anyone the lengths that the U.S. Air Force has gone over the decades to keep its iconic B-52 bombers flying in their strategic bombing and deterrence roles. Visiting the famous aircraft boneyard at Davis-Monthan Air Force Base in Arizona in 2004, Thibodeau recalls seeing Lockheed C-141 Starlifter transport aircraft being scrapped.

"They were cutting the 141s' fuselages up but the Air Force officer escorting us told us the engines were being saved" for overhaul as spares for the B-52 fleet, he says.

Thibodeau had done his part three decades earlier as a U.S. Air Force B-52 crew chief in Thailand to keep the planes flying over Vietnam. After joining Pratt in 1974, Thibodeau went on to help assemble many of the TF33 turbofan engines that continue to power B-52s today but can't much longer, largely because of the cost and difficulty of finding replacement parts.

In fact, the Air Force now estimates that by 2030 the engines will be "unsustainable."

That timing is a problem, because the Air Force announced last February in its 2019 budget request that it plans to continue flying B-52s "through 2050-plus," because of their favorable operating costs and utility compared to the B-1Bs and B-2s.

A sizeable portion of the U.S. nuclear deterrence and conventional bombing capabilities, therefore, will be riding on a re-engining program that will begin unfolding this year with selection of a company or companies to supply engines under a program called CERP, short for Commercial Engine Replacement Program, the word commercial referring to engines of a kind that also power commercial jets.

The re-engining program must roll out smoothly despite lofty fuel efficiency and militarization goals. By the mid 2030s, the Air Force plans to fly just two kinds of bombers for conventional and nuclear-deterrence missions: The Big Ugly Fat F - - - -r, or BUFFs, as the B-52s are known, and a planned fleet of 100 sleek B-21 Raiders, the Northrop Grumman-manufactured stealth bombers.

"The bomber fleet is bifurcating between a penetrator and a bomb truck," explains Richard Aboulafia, a military aviation analyst for the Teal Group in Virginia. "With a penetrator, if you have maybe 100 B-21s, then the B-2s look not as good and more expensive to operate, and the B-1 has always been an expensive problem child."

The re-engine winner or winners must improve fuel efficiency by 20 to 40 percent without sacrificing performance; cope with the B-52's unusual design of two engines on each of four wing struts; and conquer an array of electrical and aerodynamic challenges. There is little margin for delay, with the B-1s and B-2s poised for retirement by the mid 2030s.

The 2019 National Defense Authorization Act (signed by President Trump in August) provides funding for CERP for the period of the current Future Years Defense Program, meaning through 2023, says Air Force Lt. Col. Gavin Berne, Global Strike Command's deputy chief of bomber requirements.

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The time has come

The idea of switching B-52 bombers to a new kind of engine has been around nearly as long as the Air Force has been flying the famed aircraft.

"The oldest suggestion of a potential re-engine for the B-52 that I've seen was from 1969," says James Kroening, Boeing's B-52 program manager.

That's not that long after U.S. Strategic Air Command began flying the B-52B in 1955, carrying nuclear bombs to deter the Soviet Union. Now, after starring roles in the Cold War, the Vietnam War, the Persian Gulf War and the wars in Afghanistan and Iraq, equipping the B-52 fleet with new engines is a $1.56 billion idea whose time has finally come.

At least four formal proposals to re-engine the bomber and more than twice as many studies on the subject date back to the 1970s. Better fuel efficiency, lower maintenance costs and diminished need for aerial refueling were cited as economic and operational benefits. But each proposal failed, primarily because the Air Force always believed the B-52 would be replaced by newer bombers, including the B-1 and B-2. The potential life of the B-52 was "perceived to be much shorter than 2050," Kroening notes. "So the business case didn't result in the same economic benefit they might realize now."

Pratt & Whitney stopped building the TF33 engines in 1984. The first TF33s entered service in 1960 with 936 produced in total. Every B-52H, the version flying today, is powered by eight TF33 engines. The Air Force has kept these engines in service with the aforementioned ingenuity and by strictly adhering to routine maintenance practices buttressed by periodic overhauls at a cost of nearly $2 million per engine, according to Boeing.

The turning point came in a 2017 memo circulated by Air Force Materiel Command's Propulsion Directorate. The memo stated that the TF33 engines would be unsustainable in just over a decade. By that time, the Air Force had decided internally that it would extend the B-52's lifespan, though the announcement was still seven months away.

The memo was a "game changer," says Berne, the bomber requirements deputy. "It wasn't just about saving money anymore. It was about keeping the aircraft flying."

The Air Force's reference to flying through 2050 "plus" has contractors thinking. "If you want to sustain the basic TF33 through 2030 or 2040, we certainly can do that," says Pratt & Whitney's Mike Moeller, a former B-52 instructor pilot and retired Air Force lieutenant general. Keeping the planes "viable beyond 2050, that's a different challenge," says Moeller, the vice president for business development and integration at the company's Military Engines unit.

The Air Force views B-52s as more versatile than B-1Bs or B-2s, because each can carry a wide range of conventional munitions as well as the nuclear-capable Long Range Standoff cruise missile that could debut in 2030. Plus, B-52s are cheaper to fly and require fewer maintenance man hours than the 1970s-designed B-1B and 1980s-designed B-2. The Air Force also suspects that the stealthy advantages of the B-2 will have waned by the 2030s, noting in its "Bomber Vector," as it calls the bomber plan released along with the 2019 budget request, that the B-2 "will see its technological advantages diminish in the not-too-distant future."

▼ A U.S. airman checks the eight J57 engines on the aircraft at Tinker Air Force Base, Okla., in the late 1950s. TF33 turbofan engines powered the B-52H variant when it began flying in operations in 1961.

U.S. Air Force

Bomber-bizjet fusion

"Speed and simplicity" are behind the Air Force's desire to marry commercial engines and the BUFF, says the Air Force's Jim Noetzel, a former commander of the 96th Bomb Squadron and now the requirements lead at Global Strike Command for the re-engining program. "This will not be a developmental engine," he stresses. "We looked at the benefits of refurbishing the TF33, compared that to commercial off-the-shelf engines and asked what would be the fastest, cheapest? That led to our requirement for new commercial, in-production engines."

Noetzel and Berne refer to CERP as a "modification" built upon recent and previous re-engine studies, including proposals for a four-engine configuration. Boeing and Rolls-Royce advanced a four-engine concept in 1996, proposing four RB-211 turbofans with 40,000 pounds of thrust (178 kN) apiece.

But now, Boeing, as the engine integrator for CERP, says any deviation from the B-52's eight engines arranged in twin nacelles on the four struts would necessitate a host of expensive changes to the bomber's airframe. So eight engines it is.

"Struts and nacelles will be replaced but it is our intent that the size, weight, thrust capacity, etc., of the engines are such that handling characteristics that are impacted won't be a significant actor," explains Kroening, the Boeing B-52 manager.

The Air Force hadn't released detailed requirements at the time of this writing but enough basics were in place for engine manufacturers to suggest commercial engines that might be retrofitted to the B-52. The engines they have proposed power a range of business jets and regional airliners. Some also power Air Force transport and communications aircraft.

Pratt & Whitney plans to offer its PW815 turbofan, says Moeller. Currently on the new Gulfstream G600 business jet, the engine was also selected to power General Atomics Aeronautical Systems' unsuccessful contender for the Navy's MQ-25 Stingray refueling drone.

As exciting as a win would be, Moeller cautions that Pratt & Whitney's "job one" is to sustain the

▼ U.S. airmen check a B-52 Stratofortress' running TF33 engines for leaks. In-depth inspections like this one at Barksdale Air Force Base, La., are required after every 450 flying hours. The Air Force estimates the engines will be "unsustainable" by 2030.

MODERNIZING THE U.S. BOMBER FLEET

AIRCRAFT	NUMBER	FLYING WHEN	MADE BY	PRODUCTION	FIRST COMBAT
B-52H	76	Through 2050s "plus"	Boeing	1961 - 1962	Vietnam, 1965
B-1B	63	To be retired by mid-2030s	Rockwell*	1984 - 1988	Iraq, 1998
B-2	20	To be retired by mid-2030s	Northrop Grumman	1987- 2000	Kosovo, 1999
B-21	100	First planes are projected to enter service in 2025	Northrop Grumman	Production has not started yet as far as is known.	Unknowable

* Boeing acquired Rockwell's aerospace and defense businesses in 1996.

current TF33 fleet. "There are going to be TF33s flying deep into the 2030s. So our primary responsibility is the operational readiness of the TF33."

Craig McVay of Rolls-Royce Defense, senior vice president for military strategic systems, says his company will put forward the BR725, an engine currently flying on the Gulfstream G650. The Air Force employs the BR700 family of engines — which it calls the F130 — to power its Gulfstream C-37A transport aircraft and the Bombardier E-11 Battlefield Airborne Communications Node airborne communications relay aircraft, a military version of Bombardier's Global Express business jet.

McVay is keen to point out that United Kingdom-based Rolls-Royce Defense would assemble and test the BR725 in the U.S. if the Air Force selects it. "It will be a U.S.-made engine with a high U.S. part content."

Karl Sheldon, GE Aviation's vice president and general manager of large military engines, reports that GE plans to offer a version of its CF34 turbofan engines that power Bombardier's Challenger business jets and CRJ regional airliners, as well as Embraer's E-Jet series of regional airliners. The company will also propose its new Passport 20 turbofan, which is now entering service on Bombardier's Global 7500 business jet.

Matching commercial engines with military requirements

Noetzel says the Air Force wants candidate engines to be in the same 17,000-pound thrust (75.6 kilonewtons) class as the TF33 and produce "no change to current minimum control airspeed" of the B-52 while "maintaining the aircraft's current combat ceiling and takeoff performance."

New engines must also "be compatible with current B-52 electrical, hydraulic, pneumatic and fuel systems" and be capable of being changed quickly if necessary. External weapons carriage should be "unaffected" by the new engines and they must have a quick-start capability to allow the B-52 to "maintain its current capabilities for nuclear and operational missions," according to Berne.

Each of the engine makers told me they were confident their commercial powerplants can meet the Air Force's requirements for performance. The challenge they say is integrating their commercial engines with the B-52 and adapting them for military use.

▼ Eight throttles control the engines of a B-52.

U.S. Air Force

▲ U.S. Air Force aerospace propulsion technicians practice repairs on a trainer B-52 engine at Barksdale Air Force Base, La.

For example, military engines and control systems must be nuclear-hardened. The radiation associated with a nuclear blast can physically damage semiconductors in electronics causing a variety of aircraft systems, including engines, to malfunction. Nuclear hardening makes electronic components resistant to radiation by using different manufacturing techniques and radiation-tolerant materials in the production of semiconductors.

They must also perform in circumstances commercial engines are not designed for, including aerial refueling. There are also issues to be solved with packaging commercial engines in a form that doesn't deviate too much from the current pod configuration that houses two TF33 engines. "We've already started to do some work on our own," GE's Sheldon explains, "thinking about how the engines fit on a pod, how they would be closely coupled together, what kind of distortion tolerance we have on each fan to take in some worst-case scenario, refueling distortion, all of that in advance."

CERP will complement the work already being done to bring the analog B-52 into the digital age. This includes new combat network communications technology, a weapons bay improvement program that will enable the B-52 to carry smart weapons internally, Link-16 tactical data link capability and upgraded GPS interface units for the aircraft's computers.

Analog-to-digital transformation will be a major feature of CERP. Commercial jet engines come with electronic engine controllers. Kroening says Boeing's role as integrator will be to provide the interface between those controllers and the airframe and the cockpit, and control mechanisms in the cockpit.

U.S. Air Force

"IF YOU SAT IN THE COCKPIT OF THE B-52 TODAY, YOU WOULD SEE DIAL GAUGES THAT SHOW ENGINE INSTRUMENT STATUS. WE'LL BE REPLACING THOSE WITH LCD DISPLAYS THAT DEPICT THAT STATUS. WE'LL HAVE TO REPLACE THE THROTTLE STATION ITSELF AND CREATE THE ELECTRONICS THAT REPLACE THE PHYSICAL CABLE TYPE CONNECTION BETWEEN THE ENGINES AND THE THROTTLES."

— James Kroening, Boeing's B-52 program manager

"That's a significant part of the modification," Kroening stresses. "If you sat in the cockpit of the B-52 today, you would see dial gauges that show engine instrument status. We'll be replacing those with LCD displays that depict that status. We'll have to replace the throttle station itself and create the electronics that replace the physical cable type connection between the engines and the throttles."

The Air Force's quick-start requirement is another integration challenge. The B-52 lacks onboard starting capability. The bomber's TF33s are started in two ways currently. For normal operations the B-52 starts pneumatically. A ground crew wheels a cart-mounted auxiliary power unit, or APU, to the airplane and attaches a hose to a fitting on the inboard pod on the left wing that houses the No. 3 and No. 4 TF33s. Activating the APU, compressed air is supplied via the hose to rotate engine compressor spools. With sufficient pressurized air in the combustion chamber, fuel is introduced to the engine, ignited and the turbofan starts. Once these engines are stabilized, bleed air is sent from them to start the others. In addition, APUs supply electric and hydraulic power to the aircraft without the need to start the engines.

Alternatively, explosive cartridges can provide quick engine starts for B-52s assigned to the nuclear alert mission. Gunpowder cartridges are inserted into breaches on the engines. Firing each cartridge ignites fuel supplied to each engine and starts all eight simultaneously.

Berne says that for the nuclear mission, B-52s must be able to start without external equipment.

In addition to producing engines, Pratt & Whitney has a division that supplies a range of auxiliary power units to start the engines on commercial airliners. That gives the company an edge, Moeller says, because it can integrate an APU with the PW815 in-house to provide a quick-start method none of the competitors can offer. "We believe Pratt & Whitney is uniquely positioned because we have the ability to provide the PW815 as well as an APU solution."

That said, Boeing and Paris-based engine manufacturer Safran (a partner with GE Aviation on the CFM-56, which now powers most KC-135 tankers) entered into a partnership last November to produce APUs. It's not known if Safran will vie for CERP but if it did, it could also offer an integrated quick-start approach.

While the Air Force has touted fuel savings and lower maintenance costs of new engines, it has been less vocal about another CERP requirement: the capability of a new engine to generate significantly more electrical power than the TF33.

"If you step back and look at this re-engine program, electrical power is probably the single biggest area of improved performance that is a requirement," says Kroening, Boeing's B-52 manager.

At this writing, the engine manufacturers hadn't been told how much extra capacity the Air Force wants, but greater electric power could support a host of future improvements to the B-52, from defensive directed energy weapons systems and hypersonic weapons to new sensors and avionics.

Global Strike Command's Berne says that having a modern propulsion system to keep the B-52 flying is the central element of CERP but that improved electrical power generation capability is critical for future viability.

"We don't really know what's out there that we'll be integrating with the airplane 20 or 30 years from now," he says. But we've got to start to provide the electrical power margin to take on those new systems." ★