[Next generation Engines being developed for Sixth Generation Aircrafts, Future helicopters and commercial aviation]

United States and other countries are now developing sixth-generation fighters, a conceptualized class of fighter aircraft design more advanced than the fifth-generation jet fighters which are currently in service. Russian designers have already started work on the creation of a sixth-generation fighter jet, according to director general of the Foundation for Advanced Research Andrei Grigoryev. Russia has planned for new aircraft that is capable of reaching speeds above 11 thousand kilometers per hour, is super-maneuverable and is capable of maneuvering into the near outer space.

“Since the arrival of the high-bypass turbofan almost 50 years ago, engineers have made huge strides in jet engine efficiency without altering the basic architecture. Two air flows of constant volume either bypass or enter a core section. The core combusts a mixture of compressed air and fuel to generate thermal energy, which is then converted to supply some of the aircraft’s thrust and most of the power,” says AFRL

For combat aircraft in the mid-2030s, that basic architecture is not going to work, according to the US Air Force Research Laboratory (AFRL). USAF has plans to insert laser weapons into future fighters and armed drones, that will overwhelm their power and thermal management capacity. Ever-growing range and endurance standards require another step change in fuel efficiency for thrust, while advances in ground-based air defences will only increase demand for instant acceleration and nimble manoeuvring. “In some ways, you’re going to ask the engine to do things they haven’t been asked to do before,” says Chuck Cross, the AFRL’s chief of the Turbine Engine Division.

The future commercial aviation requires flying cleaner, quieter and using less fuel.

In the AFRL’s vision, the architecture of the jet engine for military aircraft will change dramatically over the next two decades. Bypass ratios will ebb and flow depending on mission need. Key elements of the compressor will change shape in mid-flight, reshaping the air flow as it is squeezed en route to the combustor. Electrical power could be extracted from low-pressure and high-pressure compressor sections, feeding energy to power-hungry lasers and advanced sensors. The heat created by that power will be stored in newly-created systems, such as electrical accumulators or wax-based heat exchangers.

Present jet Engines

Presently jet engines are the workhorses of airplanes carrying millions of people, trillions of miles every year, at supersonic speed and with high safety; the failure rate is only once every million flight hours. NASA explains their principle, “All jet engines, which are also called gas turbines, work on the same principle. The engine sucks air in at the front with a fan. A compressor raises the pressure of the air. The compressor is made with many blades attached to a shaft. The blades spin at high speed and compress or squeeze the air.

The compressed air is then sprayed with fuel and an electric spark lights the mixture. The burning gases expand and blast out through the nozzle, at the back of the engine. As the jets of gas shoot backward, the engine and the aircraft are thrust forward. As the hot air is going to the nozzle, it passes through another group of blades called the turbine. The turbine is attached to the same shaft as the compressor. Spinning the turbine causes the compressor to spin."

There are two main species of jet engines for aviation: low-bypass turbofans, usually called turbojets, and high-bypass turbofans. Turbojets are optimized for high-performance, pushing fighter jets to above Mach 2 (and the SR-71 "Blackbird" to well over Mach 3), but pay for that performance with terrible fuel efficiency. The performance outcome of a conventional turbojet is dominated by the operation of the high-pressure engine core (compressor, combustion, turbine, and exhaust nozzle).

In contrast, high-bypass turbofans are the heavy lifters of commercial aviation, being optimized for subsonic thrust and fuel efficiency, but performing poorly at supersonic speeds. A conventional turbofan adds lower-pressure airflow from an oversized fan which is driven by the jet turbine. The fan airflow bypasses the combustion chamber, acting like a large propeller.

Over the years jet engine technology has developed in leaps and bounds. The target has been to enhance power with reduced size and weight, low maintenance cost and maintenance time, low noise etc. There have been developments in the STOL and VTOL capabilities also. F135-600 engine of Joint Strike Fighter is one such example.

The next generation of military engines will be adaptive, moving from high bypass ratios to low bypass ratios to provide additional performance when necessary, but also optimize performance in cruising modes.

Advanced Turbine Technologies for

Affordable Mission-Capability

The ATTAM Phase I Program is a joint DoD/NASA/DOE/FAA/Industry effort to develop revolutionary and innovative technologies by the 2026 timeframe that will provide an increase in fuel efficiency, propulsive capability and increase power and thermal management goals.

Advanced Turbine Technology for Affordable Mission Capability (ATTAM), is the third in a 29-year-old series of engine development umbrella projects. The first such initiative – Integrated High Performance Turbine Engine Technology (IHPTET) – lasted from 1987 to 2005, yielding a step change in thrust and power performance with the Pratt & Whitney F119 and F135 fighter engines. A second programme – Versatile Affordable Advanced Turbine Engines (VAATE) – sought to deliver another step-change in power, while adding a focus on driving down development and maintenance costs.

The overall goals of the ATTAM Phase I program are to (each goal depends on engine class) are Increase fuel efficiency from 10%-30% , Increase power and thermal management goals by 2x to 20x and Increase propulsive capability by 10%-25%

ATTAM will be inter-connected with the AFRL's aircraft based efforts, including projects called Energy Optimised Aircraft and the Megawatt Tactical Aircraft Initiative, Cross says.

Several VAATE initiatives set the stage for further advances that will be pursued under ATTAM. For example, the AFRL has funded GE Aviation and Pratt & Whitney to demonstrate separate prototypes of a jet engine with an adaptable bypass flow. These adaptive engine technology demonstrators (AETDs) will lead to a follow-on competition to develop a final prototype of an engine that can be inserted into the Lockheed Martin F-35A after 2021, allowing that short-ranged fighter a range boost of up to 25%, writes Stephen Trimble.

Another programme that will transition from the VAATE initiative is a follow-on from the highly efficient embedded turbine engine (HEETE). Originally conceived for mobility aircraft, the advanced compressor developed under the re-named ADAPT programme will feature variable stator vanes inside the compressor, shifting the direction of the airflow as the AETD technology adjusts the amount of bypass flow. Additionally, future engine cores could engage another stage of compression in certain flight modes, writes Stephen Trimble.

As the engines become more efficient, the materials used inside the core must be adapted to endure hotter temperatures, Cross says. So temperature-resistant metallics and ceramic matrix composites now used behind the combustor could migrate to the last stages of the high-pressure compressor, he says.

For ATTAM, however, the key is to integrate the aircraft's propulsion system and onboard power systems.

“The big challenge we see in the future is how do I really design and procure systems that take into account all these different variables, and it may not mean buying the best engine – the most optimised cycle. You may sub-optimise one part for the greater system,” Cross says. “As we work closer with the power and energy community, we start to really investigate those give and takes.”

GE's ADVENT (ADaptive VErsitile ENgine Technology) for future fighter

The Air Force Research Laboratory has been working with GE and P&W on adaptive, “three-stream” engine technology for several years, under a science and technology program called Adaptive Engine Technology Development (AETD). Both companies finished up design review this year, and will continue to build and test individual components under AETD. The follow-on program, AETP, will build and test full-up engines, Kenyon said.

In an ADVENT (ADaptive VErsitile ENgine Technology) engine, the high-pressure core exhaust and the low-pressure bypass streams of a conventional turbofan are joined by a third, outer flowpath that can be opened and closed in response to flight conditions. For takeoff, the third stream is closed off to reduce the bypass ratio. This sends more of the airflow through the high-pressure core to increase thrust. When cruising, the third bypass stream is opened to increase the bypass ratio and reduce fuel consumption.

The extra bypass duct can be seen running along the top and bottom of the engine. This third duct will be opened or closed as part of a variable cycle to transform it from a strike aircraft engine to a transport-type engine. If the duct is open the bypass ratio will increase, reducing fuel burn, and increasing subsonic range by up to 40 percent, leading to 60 percent longer loiter times on target. If the ducts are closed, additional air is forced through the core and high pressure compressor, enabling thrust and speed to increase and providing world-class supersonic performance.

GE's ADVENT designs are based on new manufacturing technologies like 3-D printing of intricate cooling components and materials such as super-strong but lightweight ceramic matrix composites and titanium aluminides, and techniques such as additive manufacturing, to make the engines lighter and more robust while running hotter and providing more power.

GE's AETD design improves fuel consumption by 25 percent, increases thrust by 20 percent, and extends aircraft operating range by 30 percent

US Army Engine Program Advances to Design

Phase

The US Army's effort to improve the operational capabilities of its rotorcraft fleet through the Improved Turbine Engine Program (ITEP) is heading for preliminary design requests in May as it aims for a 2023 production goal.

Advanced Turbine Engine Co. (ATEC), a 50-50 joint venture of Pratt & Whitney and Honeywell, is competing with GE Aviation to develop a drop-in replacement for the legacy GE T700 engines that power the Boeing AH-64 Apache and Sikorsky UH-60 Black Hawk fleets. The engine is also expected to power light rotary-winged aircraft expected to emerge from the service's nascent Future Vertical Lift (FVL) program, according to Jerry Wheeler, vice president of programs at ATEC.

The Army's new engine will be designed to save 25 percent on fuel consumption at 3,000-shaft horsepower, as well as boost the horsepower-to-weight ratio by 65 percent and engine-design life by 20 percent.

ATEC is offering the HPW3000 turboshaft engine for the ITEP competition, which uses a two-spool gas generator architecture that improves specific fuel consumption, according to Madden. The engine successfully completed performance and durability tests and its new inlet particle separator proved effective in sand testing, Madden said. An engine that can cope with dusty, sandy environments is a requirement stemming from the wars in Afghanistan and Iraq.

Aviation and Missile Command's chief, Maj. Gen. Jim Richardson, recently highlighted the engine's potential to allow the Apache and Black Hawk to, "carry more armament and more troops further and more efficiently.

"The ITEP will allow our future aircraft to operate with more flexibility while increasing effectiveness on the battlefield. ITEP, when paired with FVL aircraft, provide us the opportunity to see the future of Army aviation," Richardson told Army Technology magazine.

GE's Future Affordable Turbine Engine (FATE) program

The FATE program set its goals at 35 percent reduction in specific fuel consumption, 80 percent improvement in power-to-weight, 20 percent improvement in design life and a 45 percent reduction in production and maintenance costs relative to currently fielded engines.

GE also successfully tested a FATE inlet particle separator, compressor, combustor and turbines that validated advanced technologies like 3D aero designs, ceramic matrix composites and additive manufacturing, in which the company invests $1.8 billion annually to develop.

"The FATE engine is the world's most advanced turboshaft engine, incorporating technologies for the next generation of propulsion," Harry Nahatis, GE Aviation's general manager of Advanced Turboshaft Programs, said. "We're very encouraged by the test results thus far and are incorporating the lessons learned into our ITEP offering."

Rolls-Royce's UltraFan

A geared design with a variable pitch system, UltraFan™ is based on technology that could be ready for service from 2025 and will offer at least 25 per cent improvement in fuel burn and emissions against the same baseline.

UltraFan will utilise the new advanced core architecture, enhanced with further technologies and the broader application of innovative high-temperature materials to push the core overall pressure ratio to more than 70:1. UltraFan features a new geared architecture to meet the challenges of the future.

A power gearbox is introduced between the fan and intermediate pressure compressor to ensure the fan runs at its optimum speed. In common with three-shaft architecture, the engine compressor and turbine continue to run at their optimum speed to deliver optimum performance. The carbon titanium fan system is further developed to allow the deletion of the thrust reverser, enabling a truly slim–line nacelle system.

Super Quiet Progress Eagle Concept Plane

Aircraft in the future could feature three decks, generate their own power and be 75 per cent quieter than current aircraft, according to designs for new concept plane. The Progress Eagle would have capacity for around 800 passengers and would run on hydrogen fuel rather than the high-grade aircraft fossil fuels used today.

The aircraft has solar panels on its wings and carries a wind turbine that can generate electricity while it is in flight. Futuristic AWWA-QG Progress Eagle concept aircraft was dreamed up by Barcelona-based designer Oscar Viñals.

NASA’s 18-Engine Electric Concept Plane for Future Aviation

NASA is testing an experimental 31-foot aircraft wing with 18 electric motors placed along the leading edge. The wing is made of carbon composite, while the electric engines are powered by lithium iron phosphate batteries. NASA says the unusual setup, called Leading Edge Asynchronous Propeller Technology (LEAPTech), could result in more energy-efficient and greener aircraft.

Each motor can be operated independently at different speeds for optimized performance. Key potential benefits of LEAPTech include decreased reliance on fossil fuels, improved aircraft performance and ride quality, and aircraft noise reduction.

LEAPTech is a key element of NASA’s plan to help a significant portion of the aircraft industry transition to electrical propulsion within the next decade. For now, NASA will test the new wing by mounting it on top of a truck and driving across a lake bed at up to 70 m.p.h.

Hybrid electric engine

Researchers from the University of Cambridge, in association with Boeing, have successfully tested the first aircraft to be powered by a parallel hybrid-electric system. An electric motor and petrol engine work together to drive the propeller. The demonstrator aircraft uses up to 30% less fuel than a comparable plane with a petrol-only engine. The aircraft is also able to recharge its batteries in flight, the first time this has been achieved.

During take-off and climb, when maximum power is required, the engine and motor work together to power the plane, but once cruising height is reached, the electric motor can be switched into generator mode to recharge the batteries or used in motor assist mode to minimise fuel consumption.

“Until recently, batteries have been too heavy and didn’t have enough energy capacity. But with the advent of improved lithium-polymer batteries, similar to what you’d find in a laptop computer, hybrid aircraft – albeit at a small scale – are now starting to become viable,” said Dr Paul Robertson of Cambridge’s Department of Engineering, who led the project.

XCOR Engineers Announce Major Breakthrough in Engine Technology

XCOR Director of Engineering and acting CTO Michael Valant announced today that his team has reached an important milestone in the development of the reusable 5K18 Lynx main propulsion rocket engine. His engineers were able to ‘close the loop’ of the thermodynamic system under test conditions, a key technology for the Lynx sub-orbital vehicle.

This technology includes a novel method to drive essential engine parts using waste heat from the rocket engine, thus eliminating the need for adding large, heavy compressed gas tanks to the vehicle. This propulsion system is an essential part of the Lynx “instant reusability” because it allows the vehicle to be flown multiple times per day without costly servicing of components. In addition, XCOR engine technology could be used to benefit other rocket-propelled vehicles in the same way.

Boeing patent reveals radical ‘fusion’ engine powered by lasers

Recently, US Patent and Trademark Office approved an application from Boeing’s Robert Budica, James Herzberg, and Frank Chandler for a laser-and-nuclear driven airplane engine. According to the patent filing, the laser engine may also be used to power rockets, missiles, and even spacecraft.

High-powered lasers will be used to vaporise the radioactive material producing fusion a reaction. The by-products of the process would be hydrogen or helium, which would leave the back-end of the plane creating thrust.

Meanwhile, the inside wall of the engine’s thruster chamber will react with the neutrons created by the nuclear reaction. The resulting heat can then be harnessed by placing a coolant on the sides of the combustion chamber. The idea is to use this heat to produce electricity that can then drive the engine’s lasers.

Boeing claims energy-efficient thrust can be produced by firing lasers at deuterium and tritium and then having the neutrons activate uranium 238 to generate more heat.

* Hot gases produced by the laser induced fusion are pushed out of a nozzle at the back of the engine, creating thrust.
* a neutrons hit a shell of uranium 238 which causes fission and generates lots of heat
* a heat exchanger uses the heat from the fission reaction to drive a turbine that generates the electricity that powers the lasers

They have different configurations
* one configuration generates ISP of about 2000 to 5000 seconds
* another configuration has an ISP of about 5000 to 25000 seconds
* another configuration an ISP of about 100,000 to 250,000.

Several energy conversion technologies have been identified or proposed that may have potential for application in commercial aircraft e.g., solar power, nuclear power, battery/fuel cell power, and hydrogen engines. However, these advanced concepts would require major innovations, development, and changes in infrastructure before they could serve as viable alternatives to hydrocarbon-powered gas turbine engines.

“The future will continue to see different and diverging requirements for the military and commercial sectors. Variable mission and adaptive capabilities will drive military programs, while time on wing and efficiency will continue to be the drivers for commercial aircraft. Material choices will differ with the technological and engineering trade-offs

within each sector, and the portfolio of materials for aircraft engines will continue to grow with additional research and development, says Ernest ," said Arvai at Pratt and Whitney

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