Versatile Affordable Advanced Turbine Engine (VAATE)

Outlook

- Titanium matrix composites evaluated
- Intelligent engine control software in development
- The envisioned technologies aim to provide significant capability improvements to military propulsion systems

Orientation

Description. VAATE is the Versatile Affordable Advanced Turbine Engine initiative, a technology cost-reduction program for U.S. military and commercial gas turbine engines, both small and large, whether air-, ground-, or marine-based.

Sponsor. The primary sponsor of VAATE is the U.S. Department of Defense (DoD), Washington, DC, USA.

Participating Agencies. Participating agencies and/or service branches include the U.S. Air Force, U.S. Navy, U.S. Army, National Aeronautics and Space Administration (NASA), and Defense Advanced Research Projects Agency (DARPA).

Status. Running in parallel with IHPTET, the Integrated High Performance Turbine Engine Technology program.

Total Produced. Although developmental engine cores are being produced, VAATE is not an engine production program.

Application. All gas turbine engines, both military and commercial.

Technical Data

Large Versatile Cores (LVCs) and Small Versatile Cores (SVCs) have both been developed under the VAATE initiative as technology testbeds. The LVC is applicable to low- and high-bypass turbofans. The SVC is applicable to expendable turbojets, turboshafts, and small turbofans. Baseline is about year 2000 technology. Improvement ratio goals for each of the cores, by engine type, include:

VAATE AFFORDABILITY METRIC GOALS
CAPABILITY/COST INDEX

Engine Type	VAATE 1 (2010)	VAATE II (2017)	Physics-Based Goal Factors
Large Turbofan/Jet	6x	10x	**x** (Thrust/weight)/**x** SFC **x** Cost (Development+Production+Maintenance)
Small Turbofan/Jet (a)	5x	8x	**x** (HP/weight)/**x** SFC

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			x Cost (Development+Production+Maintenance)

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VAATE AFFORDABILITY METRIC GOALS
CAPABILITY/COST INDEX

Engine Type	VAATE 1 (2010)	VAATE II (2017)	Physics-Based Goal Factors
Turboshaft/Prop	3x	5x	**x** (HP/weight)/**x** SFC **x** Cost (Development+Production+Maintenance)
Expendable	6x	10x	**x** (Thrust/weight)/**x** SFC **x** Cost (Development+Production)

(a) Less than 20,000 lbst.

Variants/Upgrades

Several engine types (turbofans, turboshafts, etc.) are likely being tested using either of the two cores developed, as listed in the above charts.

Program Review

Background. The Versatile Affordable Advanced Turbine Engine initiative succeeds the Integrated High Performance Turbine Engine Technology program, which began in the 1980s. IHPTET is basically a U.S. Department of Defense and turbine industry program to improve military aviation gas turbine capability. It aims to increase operating temperatures and reduce weight through the pursuit (and eventual completion) of evolutionary aero-thermodynamic, structural, and advanced-materials efforts.

VAATE takes on a much broader scope than IHPTET. It focuses not only on aviation turbines, but on marine and power generation turbines as well. In addition, it does not focus on performance improvement, but gives equal, if not greater, consideration to reducing the cost of engine technologies as well as greatly improving engine durability. The result will be the development of engines that cost less to produce, operate, and maintain; are safer; and can be in service longer. An unspoken consideration is the study of enhancements to reduce noise and noxious emissions.

While IHPTET trickled technologies down to civilian engine use, VAATE considers the civil application of its technologies from the start. The program offers a more direct route for technologies to transit from military engine evolution to civilian applications. Power generation turbines in particular are widely used and are an increasingly important part of civilian business for companies that produce military turbines.

Another new R&D facet to IHPTET's successor is that the VAATE program focuses on cost issues, including reductions in development, production, and maintenance costs. The chief thrust is increasing engine affordability by reducing the cost of all applied technologies. Just which technologies are applied are measured against their cost. If the cost is deemed too high, whether in manufacturing, materials, or the projected life-cycle of a given technology, then the technology will not be adopted. This method of measuring the relative value of a technology for possible use in VAATE is termed a capability-to-cost index (CCI). A mathematical formula is used to determine the CCI.

Program Summary: Goals to be achieved include the six major VAATE technology capabilities listed below (as well as the pervasive technology spanning the areas):

1. Strike/Persistent Engagement
2. Air Superiority/Protection
3. Persistent C2ISR (command, control, intelligence, surveillance & reconnaissance)
4. Multimission Mobility
5. Responsive Space Access
6. Agile Combat Support

Development costs will be lowered through the application of virtual design/testing, rapid technology maturation, early engine/airframe integration, and shared system development. Lower production costs will be achieved through the use of multisystem hardware, advanced manufacturing, lower-cost parts (and fewer parts), and innovative assembly. Maintenance costs will be reduced through a maintenance-free, damage-tolerant design; a reduced unscheduled removal rate; health management; increased hot-time capability (i.e., running at high temps); and use of repairable components and improved inspection methods.

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It was hoped that VAATE would increase engine affordability by a factor of four by 2006, using the latest engines as a baseline (cost basis in FY00 dollars). A sixfold improvement was desired by 2010, and a tenfold improvement over the baseline is hoped for by the end of the forecast period.

Ideas regarding high-impact technologies are being generated by U.S. government scientists (such as at the National Energy Technology Laboratory, Department of Energy, etc.), who suggest technologies that can make engines more affordable for research and possible development by the USAF Research Lab's Propulsion Directorate and participating companies.

Rolls-Royce's VAATE Efforts. Rolls-Royce has been a participant in the VAATE effort through the Allison Advanced Development Co (AADC) and LibertyWorks. Its work has included a focus on unmanned air vehicles (UAVs), particularly long-range air platforms.

VAATE I: 6x AFFORDABILITY BY 2010

Legacy	
AE 3007 (Global Hawk)	50% increase in payload or 65% increased time on station Greater than 2x increase in aircraft available power
Pipeline	
F119 (F-22)	10% thrust increase 5% range increase Potential $1.25 billion life-cycle cost savings with technology insertion
F414 (F/A-18E/F)	55% longer range 20% increased thrust, or $1-2 billion total ownership cost savings Increased time on wing Improved readiness
F136/F136 (F-35 JSF)	Weight reduction of at least 244 pounds Thrust increase of at least 10% More than a $315 million production cost savings per engine More than a $6 billion life-cycle cost savings
Future	
Common Engine Program (H-60/AH-64)	20% reduction in acquisition, operation, and support costs Increase in engine life of 20% 80% increase in payload at equivalent operational radius Double the mission radius with same payload

VAATE II: 10x AFFORDABILITY BY 2017

Future	
Advanced Supersonic Cruise Engine	Mach 2-4 cruise capability 30% increased mission radius Potential $9 billion life-cycle cost savings with technology insertion 3x increased sortie generation rate Fast response to time-critical targets
Large Commercial Passenger	33% range increase 17% reduction in seat cost per nautical mile
Future Cargo Helicopter	Future combat system transport capability 4x range or 2x payload increase Global self-deployment
USTOL Intra-Theater Transport	1.3x C-130 cruise speed increase 30% increase in mission radius STOL capability

Funding

The following funding data for the VAATE, which supports IHPTET, have been extracted from the U.S. Air Force and U.S. Navy Biennial RDT&E budget estimates as of April 2014. No budgetary data are currently available for newer contracts.

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U.S. FUNDING

	FY11(Act) AMT	FY12(Act) AMT	FY13(Est) AMT	FY14(Est) AMT
RDT&E				
PE#0602203F, 3066	198.88	207.76	232.55	197.55
PE#0603216F, 4921	129.93	120.92	151.15	153.22
PE#0603236N, 2915	10.38	7.27	0.0	0.0

All $ in millions.
Note: For PE#0602203F and PE#0603216F, funding includes several engine-related efforts, not just VAATE.

Contracts/Orders & Options

Contractor	Award ($ millions)	Date/Description
Boeing Co	20	Jul 2003 – Indefinite delivery/indefinite quantity (IDIQ) contract to provide VAATE Phase I.
Allison Advanced Development Co	150	Aug 2003 – IDIQ contract to provide VAATE Phase I.
Honeywell	70	Aug 2003 – IDIQ contract to provide VAATE Phase I. The U.S. Air Force Research Laboratory, Wright-Patterson Air Force Base, OH, is the contracting activity. (F33615-03-D-2355)
Pratt & Whitney	200	Aug 2003 – IDIQ contract to provide VAATE Phase I. The USAF can issue delivery orders totaling up to the maximum amount indicated, though actual requirements may necessitate less than this amount. At this time, $51,846 of the funding had been obligated; further funds will be obligated as individual delivery orders are issued. Work under this contract was to be completed by Aug 2011. Solicitation began Nov 2002, and negotiations were completed Aug 2003. The U.S. Air Force Research Laboratory, Wright-Patterson Air Force Base, OH, was the contracting activity. (F33615-03-D-2354)
Rolls-Royce	185	Jan 2009 – Rolls-Royce says its Indianapolis-based research arm LibertyWorks was awarded the contract from the U.S. Air Force Research Laboratory. Under the Phases II and III deal, worth $185 million if all options are exercised, LibertyWorks will continue to develop VAATE propulsion engine technology for the Air Force.

Timetable

Year	Major Development
1997	Formulation of IHPTET successor program begun
2000	Agenda for VAATE program announced
2005	VAATE formally begun
2006	Fourfold increase in engine technology affordability goal
2010	Sixfold increase in engine technology affordability goal
2012	Completion of the VAATE Phase I demonstrator engine test with Pratt & Whitney that includes STOVL clearance testing of turbine components
2017	Tenfold increase in the affordability of engine technology to be realized

Worldwide Distribution/Inventories

The vast majority of VAATE work is conducted in the **United States**. Work is also assumed to have been conducted in the **United Kingdom**.

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Forecast Rationale

VAATE's objective is to develop and demonstrate durable and "intelligent" engine technologies for existing and developmental military aircraft, rotorcraft, missiles, and UAVs. The program's stated goal is to achieve a tenfold improvement in turbine engine affordability by 2017, with an interim goal of sixfold by 2010. VAATE has been running in parallel with IHPTET, which is a joint DoD, NASA, and aero-turbine industry initiative to focus turbine propulsion technology on national requirements.

The initial phase of VAATE concentrated on developing core turbofan engine components (i.e., compressors, combustors, and turbines). Testing was then conducted of advanced control system hardware using component life models with the intent of transitioning the new technology to a demonstrator engine program. In 2006, advanced materials were tested, including gamma titanium aluminides, metal matrix composites, ceramics, and advanced metallic alloys.

These advanced materials were applied in the testing and evaluation of two combustor configurations: a trapped vortex combustor and a compact recirculation combustor. Testing modalities included high cycle fatigue, computational fluid dynamics, cycle analyses, and component life modeling.

Front-end component testing has included advanced fan designs constructed of titanium matrix composites, while hot section testing identified metallurgical issues such as oxidation, blade creep, and thermal fatigue. The application of advanced materials is intended to reduce component wear and improve load capacity and thermal resistance. The counter-rotating fan-on-blade, or FLADE, concept was evaluated for aerodynamics and acoustic characteristics as a component of an engine's high-pressure turbine.

Development of a universal Full Authority Digital Engine Control (FADEC) continues; the goal is to produce a unit that will ultimately be employed on all commercial and military gas turbine engines.

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