Technology Impact On Future Products

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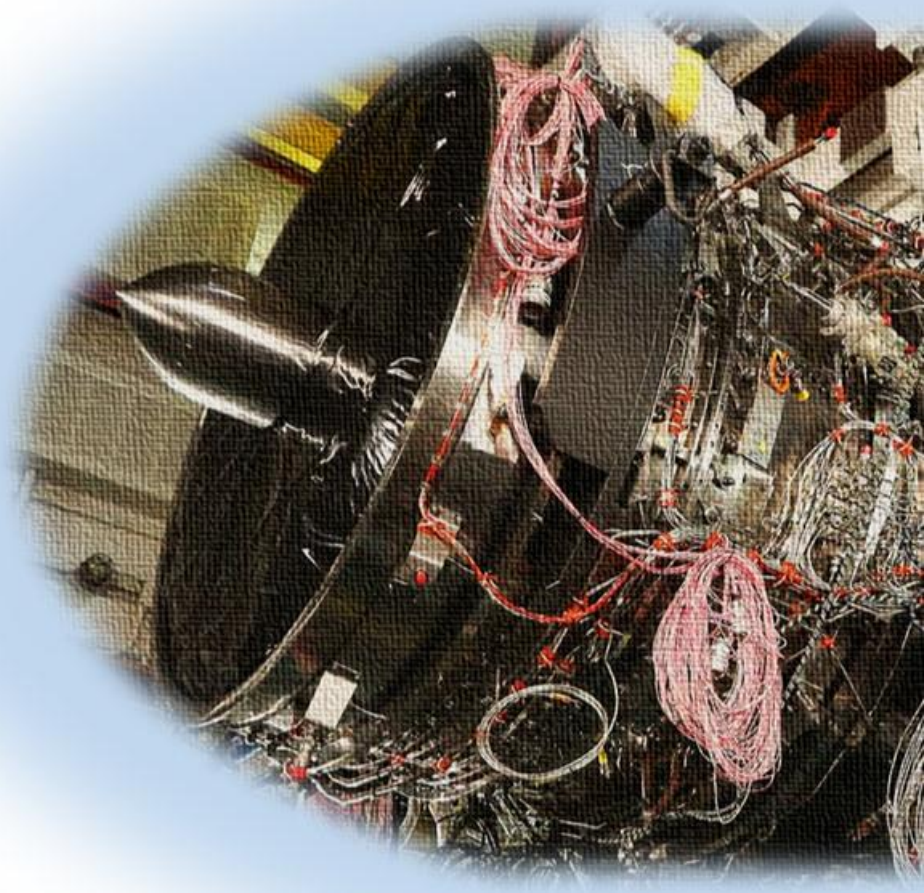
GE Aviation
November 6th, 2014

Imagination at work

Agenda

- Military Propulsion & Power Engineering Organization Update
- GE Heritage of Innovation
- Commercial Technology Synergy
- Military Customer Impact
- Conclusions



The ADVENT Turbofan Demonstrator

Military Propulsion & Power Engineering

Mark Pearson, General Manager

Formerly Three Organizations, Now Under One GM

1. Military Propulsion Engineering
   - Military Systems Engineering, MTES, Operations
2. Advanced Products & Development Programs
   - AETD, ITEP, Bus. Development/Technology Programs
3. Commercial Engines Engineering
   - Marine & Industrial Systems Engineering

MPPE Priorities

- One face to the military customer… technology, NPI, & fielded engines.
- Differentiated product offerings on next gen rotorcraft. Win ITEP.
- Transform the combat segment with adaptive cycle technology.
- Define and execute a differentiated industrial engine strategy.

Technical Innovation … Military Products

U.S. Jet Engine, I-A

Axial-flow Compressor, J35

U.S. Turboprop Engine, T31

Turbine-powered Helicopter Flight, T58

VSV Compressor, J79

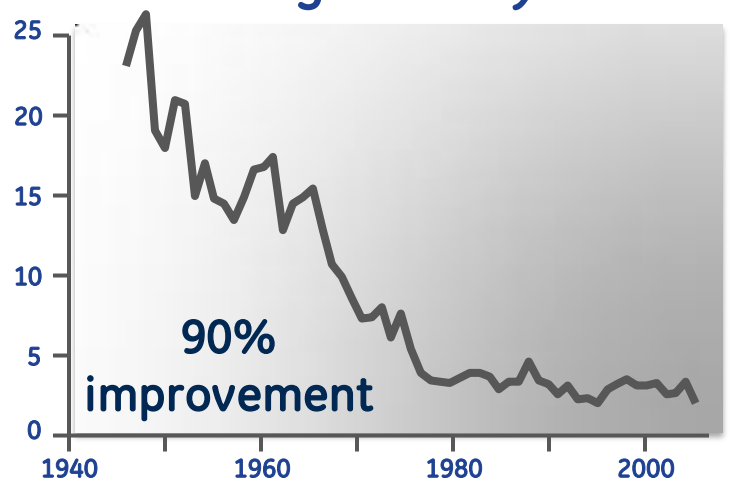
Mach 2.0 Turbojet, J79

High bypass Turbofan, TF39

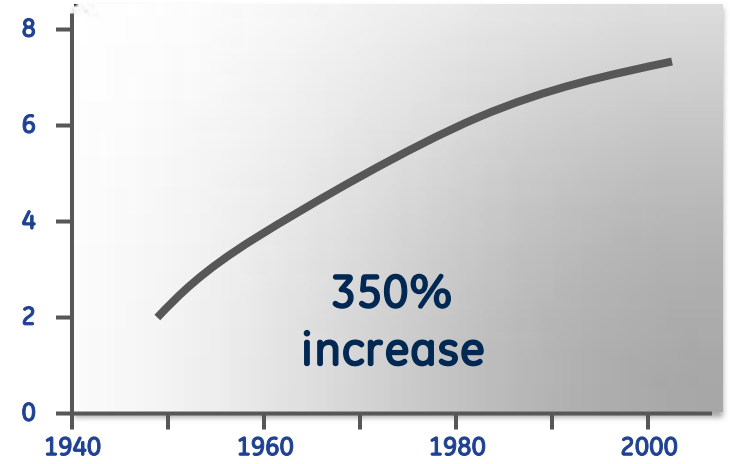
3-stream Adaptive Cycle Engine, ADVENT

50 Years Of Engine Improvements

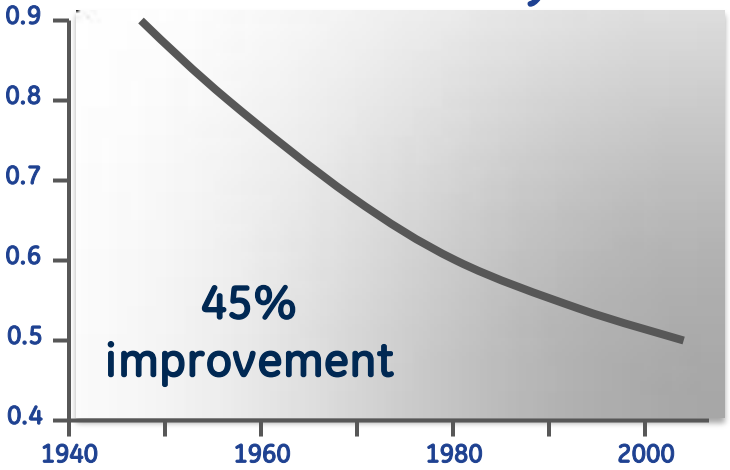
Flight Safety



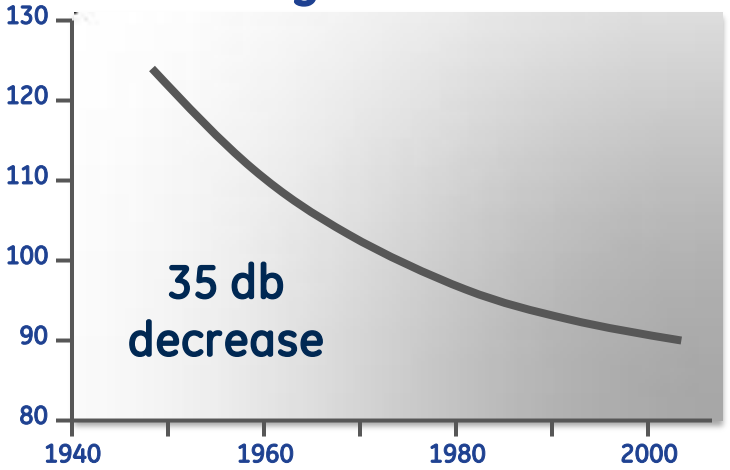
Thrust to Weight



Fuel Efficiency



Engine Noise



The Suppliers' Broader Task …

Delivering customer value with technology - Clean, quiet, affordable, and reliable systems

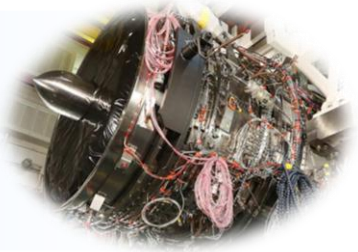
Impact of New Technologies

- Fuel consumption
- Emissions
- Noise
- Ownership Cost
- Maintenance Burden
- Disruptions
- Thrust

R&D investments

- Materials
- Aerodynamics
- Combustion
- Cycles / Planforms
- Architectures
- Fuels

The Future Of Combat Propulsion

Warfighter Need	Propulsion Solution	
Generational Improvement in Range, Loiter, & Combat Performance	Adaptive Engines with Advanced Components	
Enhanced Survivability	Advanced Exhaust Systems	
Demanding Power Requirements	Integrated Power & Thermal Management Systems	

" The best way to predict the future is to invent it." - Alan Kay

The Physics of "Readiness to Serve"

$$Range = \left(\frac{V_0}{SFC}\right) * \left(\frac{L}{D}\right) * \ln\left(\frac{W_{initial}}{W_{final}}\right)$$

$$= \left(FHV * \eta_{thermal} * \eta_{transfer} * \eta_{propulsive}\right) * \left(\frac{L}{D}\right) * \ln\left(1 + \frac{W_{fuel}}{W_{payload} + W_{empty}}\right)$$

	$\eta_{thermal}$	$\eta_{transfer}$	$\eta_{propulsive}$	W_{empty}
Today	• Highly Loaded Compressors • High OPR Low Emissions Combustors	• Low Loss Inlets • Variable Low Loss Exhausts	• Very High BPR Turbofans • Ultra High BPR Turbofans	• Novel Alloys / MMC's • Non-metallics
2020-2050?	• Adaptive cycles • Alternate or Compound Cycle • Hybrid Electric Propulsion	• Distributed Power Transmission	• Open Rotors • Distributed Propulsion • Wake Ingestion	• Advanced Engine Architectures

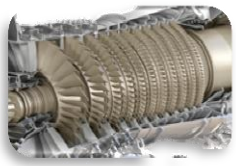
Commercial Technology Synergy


Composites


CMCs


Advanced Coatings


High-Temp Materials


High P/R Compressor


Advanced Combustion


Advanced Cooling


Composite


Additive 3D Printing


Robotic Automation

Materials / Coatings

Turbomachinery Design

Advanced Mfg. Lean Labs

Next generation military product reaping the benefits of heavy GE investment in commercial technology

Next Generation Commercial Products

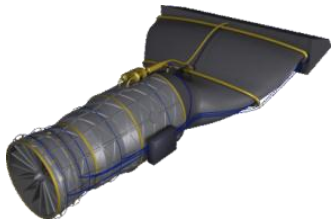

GEnx (2011)


Passport (2016)


Leap (2016)


GE9X (2020)

>15M EFH before 2020

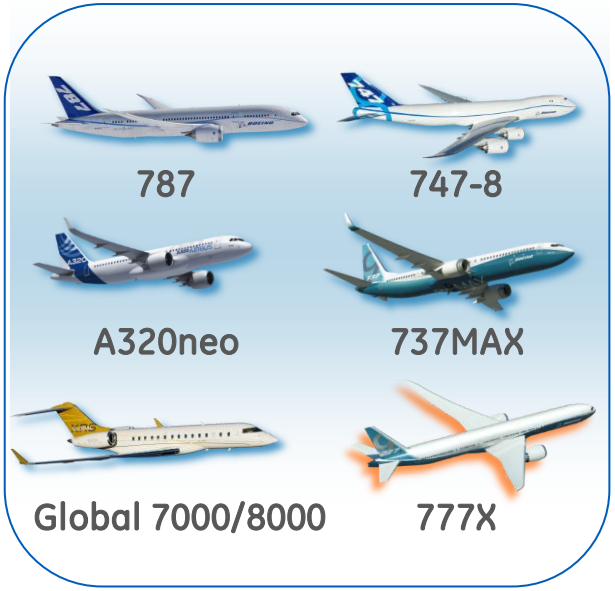

ADVENT / AETD

ITEP


GE38

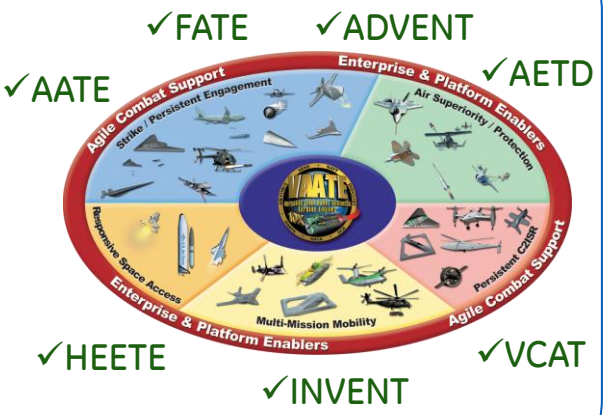
Commercial Marketplace Driving Technology Investment

Heading Into Our New Shared Golden Age



MORRIS TECHNOLOGIES
Precision. Innovation. Ex

RQM
Rapid Quality Manufacturing



Commercial Portfolio Reset

Investment in US Supply Chain Capacity

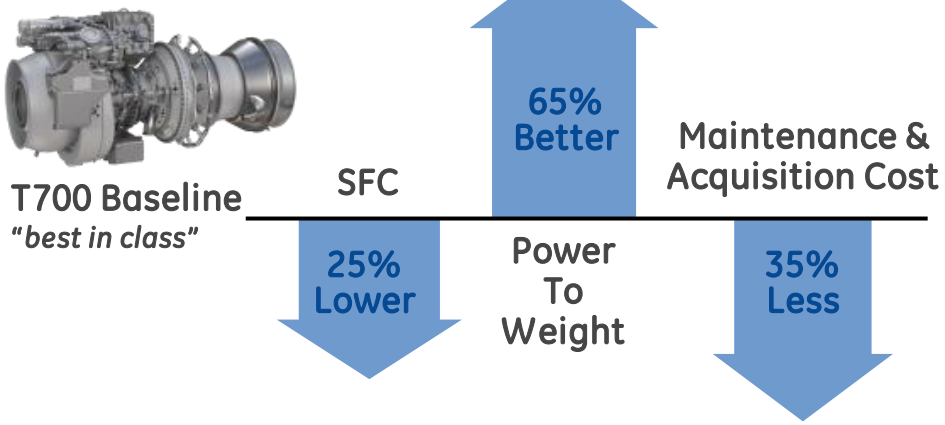
VAATE Technology Portfolio

Prepared To Deliver Revolutionary Capability To The Warfighter At Affordable Cost And Acceptable Risk

Next Generation 3,000 shp Turboshaft

The AATE Challenge

ITEP technology demonstration program



GE3000 … The Solution

- Best in class performance & reliability
- Simple, single spool core design
- Modular architecture
- Affordable … today & tomorrow
- Implements T700 experience
  - 90M+ flight hours
  - 5M+ combat hours
  - 18,000 engines delivered

Improved Turbine Engine Program (ITEP)

Ceramic matrix composites

Condition-based maintenance

Advanced 3D aerodynamics

Sand-tolerant technologies

GE Technology Pipeline

$1.8B Annual Investment In Aviation Technology

GE3000

UH-60 Black Hawk

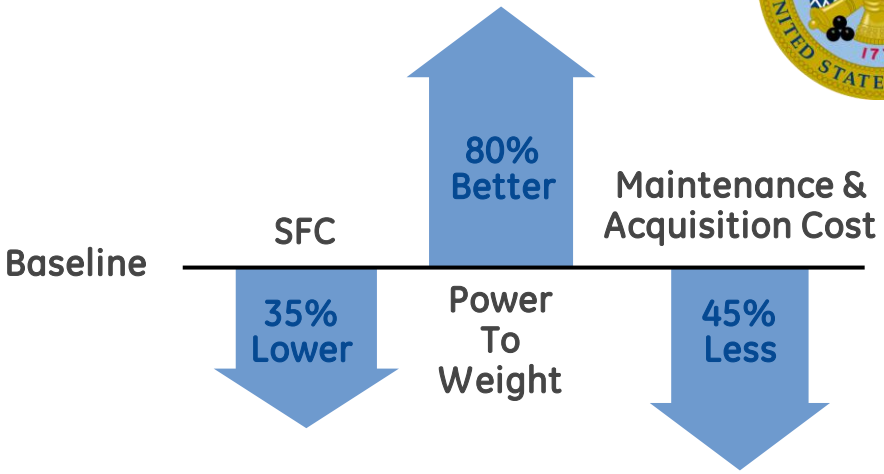
- Enables internal & external lift at hot & high conditions
- Improved range

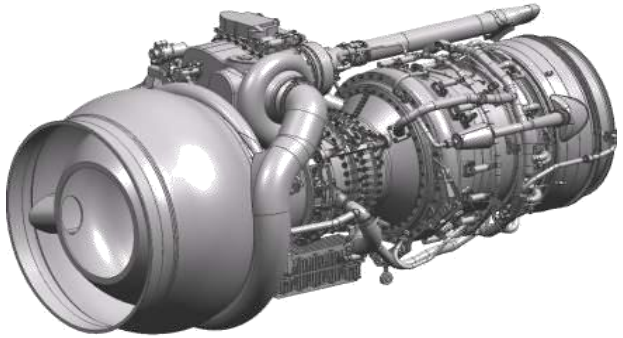
AH-64 Apache

- Allows full payload at hot & high conditions
- Improved time on station

Future Affordable Turbine Engine (FATE)

Program Objectives





- 5 year U.S. Army S&T demonstrator program started September 2011
  - 5,000 – 10,000 shp turboshaft
- Future turboshaft engine technology
  - Applicable to medium-heavy lift rotorcraft and turboprops
  - FATE technologies applicable to ITEP, JMR/FVL & upgrades to existing engines

ADVENT … The Future Is Now!

Core Test Highlights

- TRL6 demo for key core technologies
- World record T3/T41 combination
- 1800+ Instrumentation sensors

ADVENT Core Engine

Turbofan Test Highlights

- TRL6 demo for adaptive fan technology
- 60% Flow holding
- Multiple single/double bypass transitions
- Validated 3rd stream heat sink capacity

ADVENT Turbofan Engine

Driving Combat Engine Revolution

Commercial engines

GEnx

LEAP

GE9X

- ✓Advanced aerodynamics & cooling
- ✓High temperature alloys
- ✓Ceramic Matrix Composites (CMC)
- ✓High efficiency core

Military engines

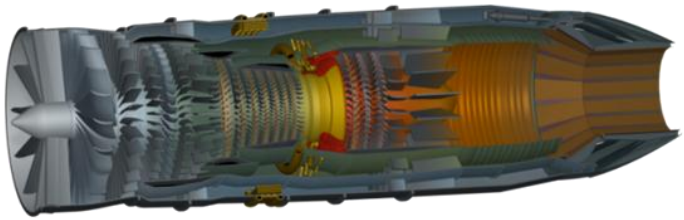
ADVENT

F136

- ✓Adaptive cycle & 3rd stream
- ✓High pressure ratio
- ✓Survivability technologies
- ✓Augmentor/exhaust nozzle

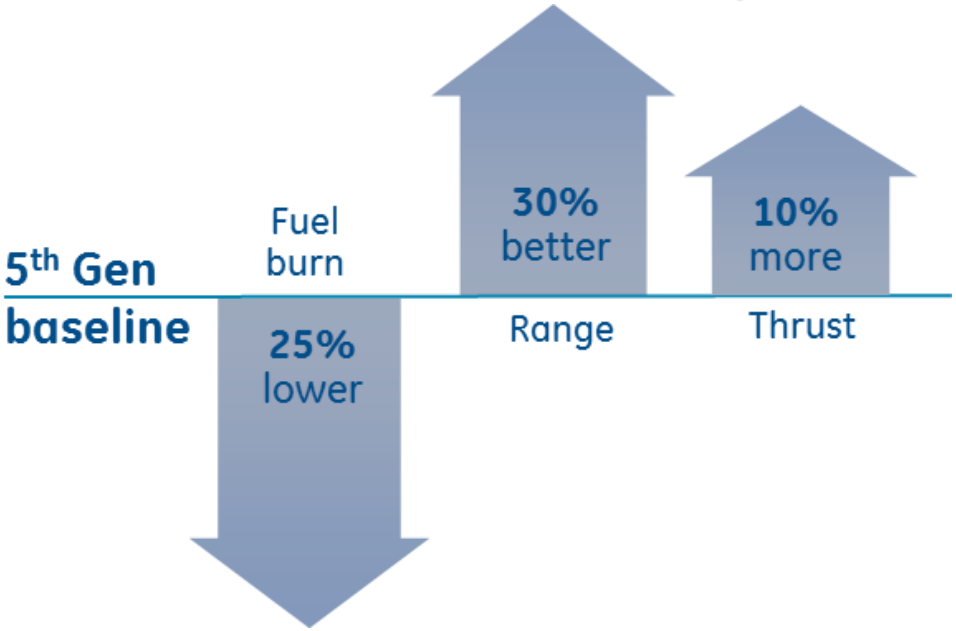
AETD

(Adaptive Engine Technology Development)



Adaptive Cycle Changes The Game

Enhanced Combat Options



Plus:

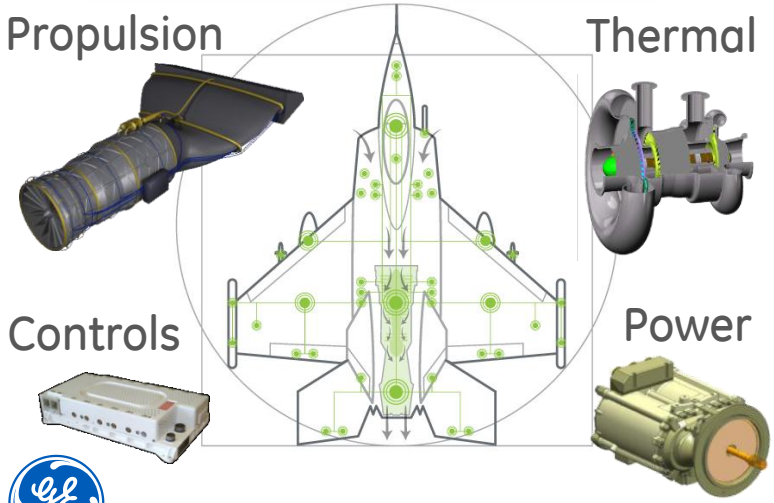
- ✓ Increased thrust
- ✓ Improved cooling capacity
- ✓ Enables advanced weapons
- ✓ Enhanced survivability

Integrated Systems – Building Capabilities

Electrical Power Integrated Systems Center (EPIS Center)

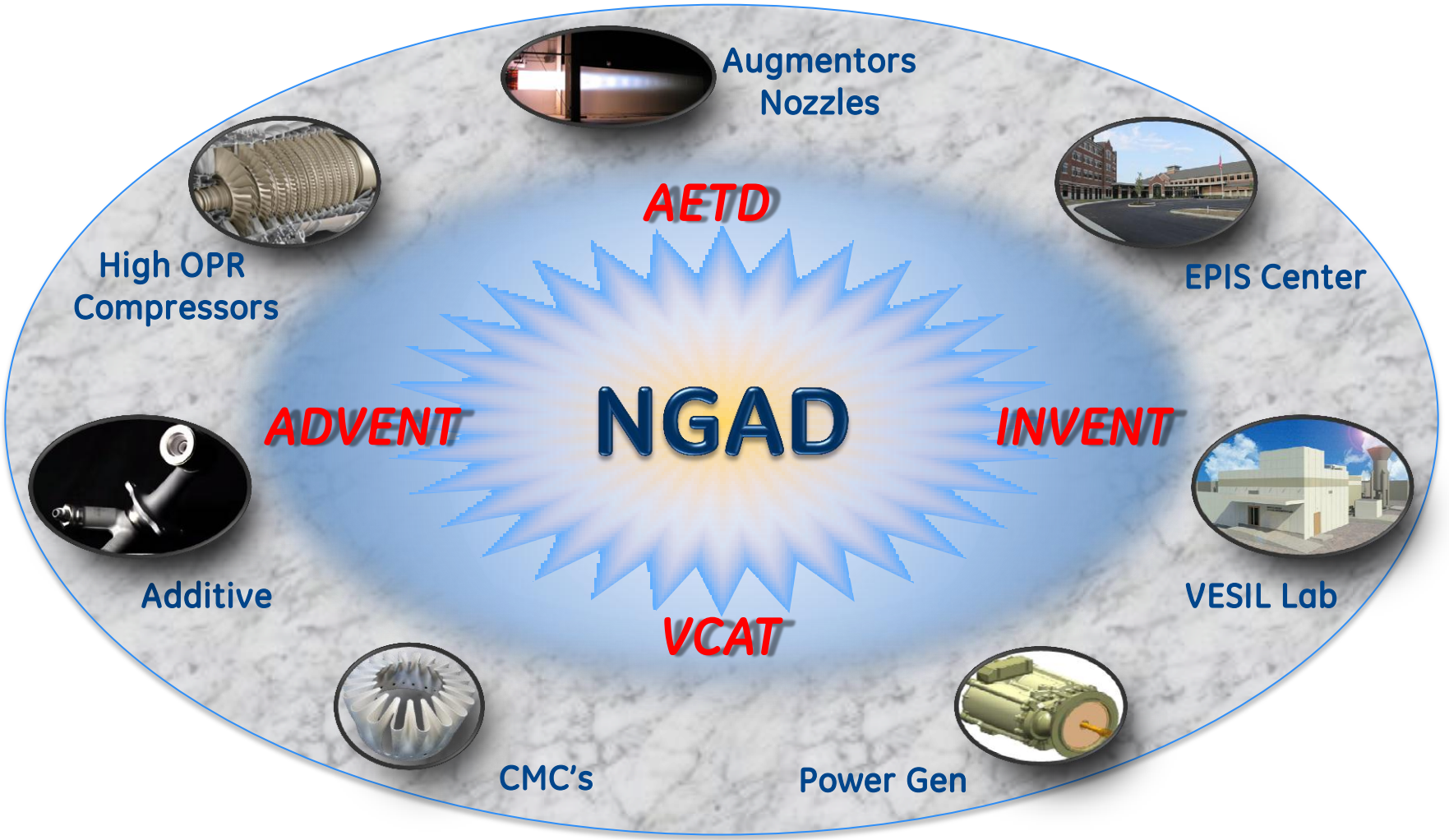
Integrated Propulsion Power & Thermal Management

- Full scale aircraft power systems
- Integrated thermal management
- Adaptive cycle engine interface
- Real time hardware in the loop
- INVENT test and demonstration



Vehicle Energy Systems Integration Lab (VESIL)

A Complete Technology Portfolio … Unique



In Conclusion, GE Is…

- a proud partner with our military customers, promoting and advancing cutting edge propulsion technologies
- organized to address the integrated power-thermal management-survivability needs of future aircraft propulsion
- leveraging our commercial technology investments for advanced military propulsion
- excited and well positioned for helping to define the next generation of military propulsion

"What is chiefly needed is skill rather than machinery."

- Wilbur Wright, 1902