Technology Impact On Future Products

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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**
- 90% improvement

**Thrust to Weight**
- 350% increase

**Fuel Efficiency**
- 45% improvement

**Engine Noise**
- 35 db decrease
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

<table>
<thead>
<tr>
<th>Warfighter Need</th>
<th>Propulsion Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generational Improvement in Range, Loiter, &amp; Combat Performance</td>
<td>Adaptive Engines with Advanced Components</td>
</tr>
<tr>
<td>Enhanced Survivability</td>
<td>Advanced Exhaust Systems</td>
</tr>
<tr>
<td>Demanding Power Requirements</td>
<td>Integrated Power &amp; Thermal Management Systems</td>
</tr>
</tbody>
</table>

"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) \times \left( \frac{L}{D} \right) \times \ln \left( \frac{W_{initial}}{W_{final}} \right)

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

• 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

• Adaptive cycles
• Alternate or Compound Cycle
• Hybrid Electric Propulsion

• Distributed Power Transmission

• Open Rotors
• Distributed Propulsion
• Wake Ingestion

• Advanced Engine Architectures

Today

2020-2050?
Commercial Technology Synergy

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)

Commercial Marketplace Driving Technology Investment

>15M EFH before 2020
Heading Into Our New Shared Golden Age

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

- Investment in US Supply Chain Capacity
- VAATE Technology Portfolio
- Commercial Portfolio Reset

[Diagram showing various aircraft and technologies, including 787, 747-8, A320neo, 737MAX, 777X, Global 7000/8000, 777X, Asheville, NC location, and various technology and supply chain elements.]
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

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

Turbofan Test Highlights
• TRL6 demo for adaptive fan technology
• 60% Flow holding
• Multiple single/double bypass transitions
• Validated 3rd stream heat sink capacity
Driving Combat Engine Revolution

Commercial engines

- GEnx
- LEAP
- GE9X

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

Military engines

- LEAP
- GE9X
- F136
- ADVENT

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

(AETD) Adaptive Engine Technology Development

General Electric
Adaptive Cycle Changes The Game

**Enhanced Combat Options**

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

**Plus:**

- 5\textsuperscript{th} Gen baseline
- Fuel burn
- 25\% lower
- Range: 30\% better
- Thrust: 10\% more
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

- AETD
- ADVENT
- INVENT
- VCAT
- High OPR Compressors
- Augmentors Nozzles
- EPIS Center
- VESIL Lab
- Additive
- CMC's
- Power Gen
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