Aviation Technology Strategy for the 21st Century

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GE Aviation

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THIS IS GE AVIATION...
THIS IS GE AVIATION...

GE AVIATION
38,000+ Employees

Military Engines (MSO)
Installed Fleet, 27,500 Engines

Commercial Engines
Installed Fleet, 23,700 Engines

Systems
Digital, Electric Power, Mech Systems

Marine & Industrial
Installed Fleet, 3,400+ Engines

Commercial Engine Services
50+ locations Worldwide
CURRENT ENVIRONMENT
Mega Trends...

Challenging aviation environment volatile markets...wild commodities gyrations.

Fuel
Better fuel burn & alternate fuels

Materials
Inflation & new capabilities

Emissions
Focus on NOx & CO2
### Strategy For The Next Century

Top Commercial & Military Needs...Common and Complimentary.

#### Commercial

<table>
<thead>
<tr>
<th>Feature</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>50%</td>
</tr>
<tr>
<td>Fuel Burn</td>
<td>20%</td>
</tr>
<tr>
<td>Cost Of Ownership</td>
<td>30%</td>
</tr>
<tr>
<td>Emissions</td>
<td>85%</td>
</tr>
<tr>
<td>Noise</td>
<td>55%</td>
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#### Military

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</tr>
<tr>
<td>Cost of Ownership</td>
<td>30%</td>
</tr>
<tr>
<td>Thrust to Weight</td>
<td>50%</td>
</tr>
<tr>
<td>Thermal Mgmnt</td>
<td>2-5X</td>
</tr>
<tr>
<td>Electric Power</td>
<td>2-10X</td>
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<tr>
<td>Survivability</td>
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MILITARY AVIATION ENVIRONMENT

Common Themes

- Aging Fleets...“Tired Iron”
- Fuel Burn, Budgets, Operating Costs
- Integrated Systems...Electric Power, Thermal Management
- Rationalizing Mix of Legacy Versus New Platforms
- Survivability
- Development of Traditional Turbine AND Variable Cycle Technologies
The Customer Defines the Attributes....GE Develops the Technologies that Deliver.

**Aircraft Mission**
Payload, Range, Endurance...

**Aircraft Capability**
Speed, Maneuvers, Flight Envelope...

**Propulsion System Requirements**
Specific Thrust, SFC, Weight, Installation...

**Propulsion System Technology**
Fuel Burn, Aerodynamics, Noise, Materials...
NEW PRODUCTS
GE38-1B TURBOSHAFT

Engine for the CH-53K.

2-3X payload improvement vs the CH-53E.

GE38 will have 10-20% better SFC than other engines in this power class.

GE38 versus T64...Same airflow, slightly shorter length.

63% fewer parts

57% more power
JOINT STRIKE FIGHTER (JSF) PROGRAM

• Fully Funded

• Demonstrated max A/B thrust.

• Investing in World Class Facilities.

• Building First Engine to Test

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>2008</td>
<td>CDR</td>
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<tr>
<td>2009</td>
<td>FETT</td>
</tr>
<tr>
<td>2010</td>
<td>F136 1st flight</td>
</tr>
<tr>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>First A/C Deliveries</td>
</tr>
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</table>
JOINT STRIKE FIGHTER (JSF) “FLY-THROUGH”
What Does SLEP Bring To The F110 Engine?

• Significant TOW Improvement.
• Increased availability.
• Lower Maintenance Costs.
• Longer Piece Part Lives.
• Lower Engine Operating Temperatures.
• More Durable Materials.
• Ease of Maintenance Hardware Replacement.
GE Aviation

GE9x..the right technologies at the right time

- Composite fan blades
- 23:1 p/p, 10 Stg HPC
- DAC1 combustor
- Thrust links

- 3D aero HPC
- DAC2 combustor
- LPT clearance reduction
- Fan OGV sealing

- Swept fan blades
- 9 stage HPC
- 3D aero HPT
- Low solidity LPT airfoils
- 3rd generation FADEC

- Low emissions combustor
- QC2 noise technology

787
747-8

• 3rd generation composite fan blades (18)
• Composite fan case
• Generation II 3D aero
• TAPS combustor
• Counter-rotating HP/LP
• Advanced engine diagnostics
Lean NPI – Engineering Productivity Integration

ENABLE INCREASED NPI, GROWTH, AND BOTTOM LINE

Lean NPI

Technology & Cost Attainment
Global NPI
Design & Analysis FTY=1
Productivity Tools
Cert / Qual Productivity
Cost Modeling
Development Test & Instrumentation

Synergy with other GE Businesses
Common processes & tools.
Design / Analysis FTY

Physical Knowledge
Validated Models and Tools
Component And Rig Testing
Design Process Discipline And Execution

State of the Art 3D Modeling Capability, Correlated/Validated Models
Component By Component Assessment
Strict Process Discipline
Internal and External (USAF, Navy, Army) Reviews

Design Analysis FTY=1

Eliminates costly, recurring, development test events.
Substitution of analysis for test where appropriate.
DEMONSTRATORS
Technology Demonstrator Programs
Strong history leading to benefits today and beyond
ADVENT – ADAPTIVE VERSATILE ENGINE TECHNOLOGY...

PROGRAM GOALS:

50% increase in mission radius.

2X increase in loiter.

10X increase in time at max temperature.

SYSTEMS TECHNOLOGY ADVANCEMENT:

Encompasses entire propulsion system. Highly Integrated.

Multi-use civil & military technologies with emphasis on affordability.

Adaptive fans and cores to improve performance.
HEEETE – Highly Efficient Embedded Turbine Engine

Reduced fuel burn through very high pressure ratio.
- Technology for the Next Gen compressor
- Reduction in SFC, CO2 Emissions.

Addresses technology barriers to high OPR engine.

AATE – Advanced Affordable Turbine Engine

**Demonstrator**: 4 Year Program:
- Decrease SFC
- Increase SHP/Wt
- Decreased costs: O&M & Dev

**Tech Insertion**...Bearings, Combustor, Airfoils & Shrouds, High Work Vaned Impeller, HPT Blade.

Replacement for the T700

10,000+ Engines
TECHNOLOGIES
Advanced Materials...
Ceramic Matrix Composites (CMC’s)

Less weight and better performance with reduced cooling

Introducing composites beyond fan modules

Benefits for higher temperature components:
Turbine airfoils
Combustors

1/3 density of metal for reduced weight
better fuel burn

CMC prototype turbine nozzle

GE Ceramic Composite Products Site
State of Delaware, U.S.
Validated technologies
Surface enhancements for durability

HPC Airfoil Erosion Coatings
Performance retention in high erosion environments

Nitrided Bearings
Improved durability and debris tolerance

Coke Barrier Coatings
Reduced loss of oil flow in high-temp applications
FUELS & EMISSIONS
Alternative Fuels...Economic, Strategic, Environmental

US Defense Science Board Reports Issued in 2001, 2008:

70 percent of the tonnage required to position today’s U.S. Army into battle is fuel

Cost of fuel delivery to the battlefield.

Overriding strategic & economic imperatives:
Diversity of feedstocks.
Dramatically improved fuel efficiency.
Alternative Fuels...Economic, Strategic, Environmental

USAF Has Taken the Lead in Developing an Alternative Fuels Strategy.

Qualification of all Airframes, Engines, Support Equipment by 2011. 50% CONUS Fuel with F-T Blend 2016.

50-50 F-T Blends...a Pathfinder Program

Air Force Has Also Expressed Considerable Interest in Developing Biofuels...Section 526 EISA 2007.
Aviation Alternative Fuels...Framing the Issues & the Path Forward:

70 Billion GPY...About 8-10% of Total Transportation Distillate Fuel Consumption.

Supply chain vulnerability needs to be addressed...fuels & electric power.

Current Consensus: Alt Aviation Fuels... “drop in.”

Gen 1 vs Gen 2 biofuels – Food vs Fuel, Land Use.

Interesting options obtaining DOD & USG funding...

Algae, Bio-oil to Jet-A Conversion, Camelina.

Air Force, DOD, Industry Taking Positive Steps to Address Energy Vulnerabilities
WRAP UP
GE Technology Leadership

Our heritage ... right technology at the right time.

Pipeline for future products ... maturing tomorrow’s technologies today.

Bringing technology benefits ... future innovation.

Developing technology for 2013 and beyond.