Top Industry Challenges, 2012

- Declining defense budgets
- Increased cost of weapons systems procurement
- Increased sustainment costs
- Cost of energy

“In the year 2054, the entire defense budget will purchase just one tactical aircraft. This aircraft will have to be shared by the Air Force and Navy 3 ½ days each per week except for leap year, when it will be made available to the Marines for the extra day.” *

*Augustine's Laws. Source Wikipedia. Creative Commons citation.
Aviation strategy for a volatile world...

Provides a firm foundation for affordable military and commercial products

**Processes**
- Maintenance concepts
- Cost modeling
- Probabilistic lifing

**Technologies**
- Essential technologies

**Architecture**
- New Products
- Demonstrators
- Non Brayton cycle

Cost containment, reduced development times becoming important differentiators
Processes
GE Military Services Processes

1. Material Management/Planning
   - GE Supply Chain
   - Suppliers

2. Customer – Point of Use
   - Bases/Squadrons
   - Forward deployed

3. Warehouse Management
   - New Parts
   - Warehouse

4. Depot/Shops – Point of Repair
   - Repair Facilities & OEMs
   - Depot

5. Customer Systems

6. GE/Customer Engineering & Mgmt
   - Shared metrics

GE REP

GE Aviation
Development cost modeling...

**Throughput**
- Commercial TS/TP NPI Throughput Baseline
- Military TF/TJ NPI Throughput Baseline

**Engine Line**
- Comm TFTJ
- Mil TFTJ
- Comm TSTP
- Mil TSTP

...select template

**Test Plans**
- ...construct test programs

**Hardware**
- ...project hardware costs

**Architecture**
- ...customize the machine

**Tooling**
- ...define support tools

**imagination at work**

GE Aviation
Probabilistic Fracture Mechanics (PFM)

New PFM surface anomaly distributions

- Identifies individual feature contribution to component Probability of Fracture (POF)
- Potential to eliminate depot EC inspections for features that contribute little to overall POF
PFM Implementation Program

Potential to implement PFM for reduced depot inspection requirements.

Appropriate use of EC and FPI provides opportunity for customer cost savings
Technology
## Technology starts with R&D...

<table>
<thead>
<tr>
<th>TRL</th>
<th>Technology Readiness Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE Global Research – 5 locations, New York, Bangalore, Shanghai, Munich, Rio. Approx 3,000 employees</td>
<td></td>
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<table>
<thead>
<tr>
<th>MRL</th>
<th>Manufacturing Readiness Level</th>
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<tbody>
<tr>
<td>Inspection / NDE, Welding / Brazing, Laser Machining</td>
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<table>
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<tr>
<th>MatRL</th>
<th>Materials Readiness Level</th>
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<tr>
<td>New materials, Mechanical Testing, Tribology Composite Processing, Special Coatings</td>
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<tr>
<th>IRL</th>
<th>Integration Readiness Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal management, Inlet particle separators, exhaust systems, IR, special coatings</td>
<td></td>
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</tbody>
</table>
Essential technologies
Keeping the pipeline filled

Adaptable fans  Advanced HXRs  CMCs  Adv. Cooling  High-Temp Materials  Augmentor Technology

2010
Advanced products

Integrated engine and aircraft systems

Adaptive cycles  Advanced architectures 2020

imagination at work
Rapid Prototyping Activities

**Direct Metal Laser Melting:** Laser melts metal powder layer by layer to create complex, 3D components.

**Laser Manufacturing:** Metal powder is introduced directly into laser creating large components layer by layer.

**Dieless Sheet Forming:** Sheet metal is locally and incrementally drawn using stylus above and below work piece.

**Increased speed**

**Early detection of design issues**

**Development tooling costs reduced**

**Catalyst for innovation**

**Electroforming:** Nickel alloy is plated directly onto temporary tooling – creating complex 3D shapes.
Inlet Particle Separator Technology...

- State-of-the-art component test capability
- Extensive IPS geometry experimental development
  - Rapid Prototyping Techniques
- Latest in aerodynamic CFD and particle physics modeling
  - Collaboration with GE GRC
Technology Demonstrator Programs
Strong history ... military/commercial benefits today & beyond

CFM International is 50/50 joint venture with Snecma (SAFRAN Group)
LEAP is a registered trademark of CFM International
## Architecture: Technology Demonstrators

### Military/Commercial Technology Synergies

<table>
<thead>
<tr>
<th>Customer</th>
<th>Program Goals</th>
<th>Technologies</th>
<th>Segments</th>
</tr>
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<tbody>
<tr>
<td>US Army</td>
<td>25% better SFC</td>
<td>3D aero, materials</td>
<td>Attack/utility Helicopters</td>
</tr>
<tr>
<td></td>
<td>65% ↑ hp/wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US Army</td>
<td>35% better SFC</td>
<td>3D aero, efficiency</td>
<td>Heavy lift Helicopters</td>
</tr>
<tr>
<td></td>
<td>80% ↑ hp/wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US Navy/US Air Force</td>
<td>20-200+% better SFC</td>
<td>Variable cycle, 3D aero, FLADE™</td>
<td>Combat aircraft</td>
</tr>
<tr>
<td>US Air Force</td>
<td>35% better SFC</td>
<td>3D aero, efficiency</td>
<td>Tanker/Transport</td>
</tr>
</tbody>
</table>

### Technologies
- **AATE** (Advanced Affordable Turbine Engine)
- **FATE** (Future Affordable Turbine Engine)
- **ADVENT** (Adaptive Versatile Engine Technology)
- **HEETE** (Highly Efficient, Embedded Turbine Engine)

### Program Goals
- 25% better SFC, 65% ↑ hp/wt
- 35% better SFC, 80% ↑ hp/wt
- 20-200+% better SFC
- 35% better SFC

### Segments
- Attack/utility Helicopters
- Heavy lift Helicopters
- Combat aircraft
- Tanker/Transport

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**Blackhawk**, **NextGen heavy lift**, **6th Generation**, **KC-135**
Adaptive Engine Technology Development

- AETD...new class of engines with up to 25% better fuel efficiency
- Variable cycle technology
- Technology demonstration that builds on ADVENT
- Foundation for future generation of combat propulsion
F110 Product Family...Common Core
Service Life Extension Program Benefits

- SLEP exceeding program goals....record setting time on wing. 2X base or better
- NRIFSD rate at zero
- Provides reduced cost of ownership and improved readiness
- Incorporation of SLEP critical to long term affordable supportability of all F110 family engines
- Enables affordable upgrade to the 6000 TAC configuration

Over 200 Million Accumulated Flight Hours on 15 Different Aircraft Applications
GE38 Development...Heavy Lift
Power for the Sikorsky CH53K

- GE38 Versus T64:
  - 18% Improved SFC
  - 57% More power
  - 63% Fewer Parts

- All ground test vehicle engines installed. A/C rolled out.

- Successfully completed 1,000 hr missionized durability test. Performance retention excellent.

- Submitted 90% of required test reports for first flight.
Vision for 2030 – 2050 Propulsion Systems
Revolutionary Ideas Required To Support Future Aviation

Key Technologies to Bridge The Gaps
- High OPR Cores
- Advanced Propulsors (FLADE™, Open Rotor, etc.)
- Electrical Systems (Fuel Cells, Batteries, Superconductivity, Electric Motors, etc.)
- Distributed Propulsion Concepts
LNG as a transportation fuel...

**Marine** – Emissions regulations driving change to littoral vessels

**Rail** – LNG is “the next big thing”

**Trucking** – OEM conversion kits, new make.

**GE Oil & Gas** – RAPID mini LNG equipment growth

Huge price disparity and LNG build-out creating opportunity to dramatically reduce cost of energy for aviation
Summary...

**Process** – Maintenance concept selection can have multi billion dollar impact to the bottom line.

**Technology** - is the lifeblood of the business - From materials to advanced cooling. Near term to 2050+ architectures.

**Architecture** – Leverage commercial & military. Over-the-horizon...non Brayton cycles. Must rethink energy.
We invent the future of flight, lift people up, and bring them home safely.