Emerging Trends in Aviation Propulsion

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GE Aviation
October 25th, 2012

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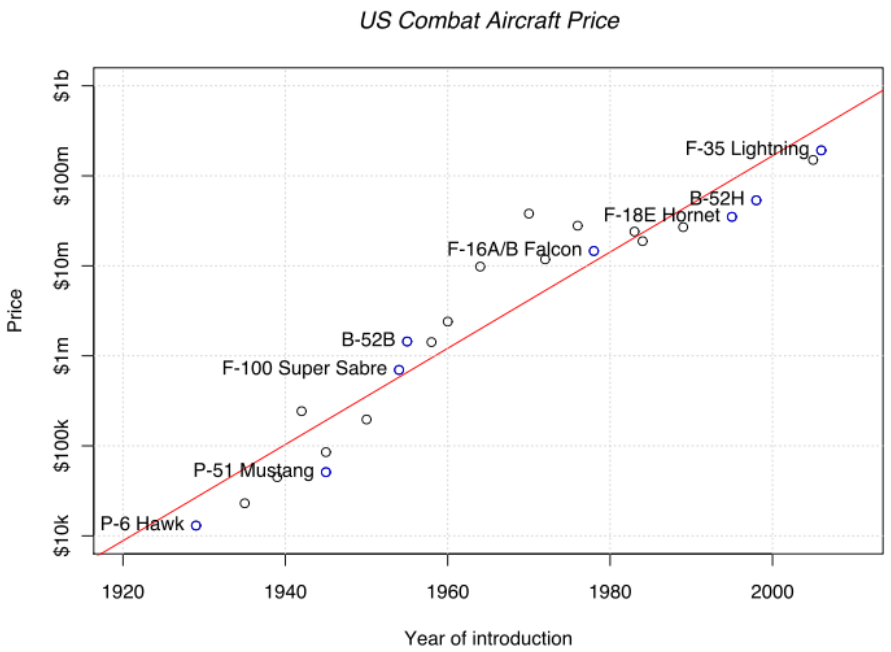
Top Industry Challenges, 2012

- 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 3½ days each per week except for leap year, when it will be made available to the Marines for the extra day." *

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*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

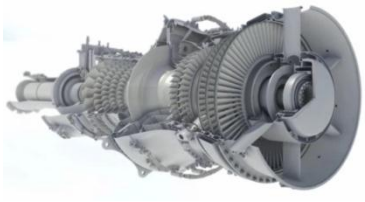
Technologies

Essential technologies

Architecture

New Products

Demonstrators



Non Brayton cycle

cost containment, reduced development times becoming important differentiators

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Processes

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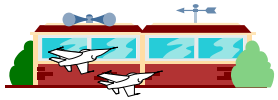
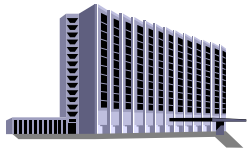
GE Military Services Processes

2 Customer – Point of Use



Bases /Squadrons
Forward deployed

Customer

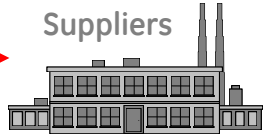


GE REP

1 Material Management/Planning

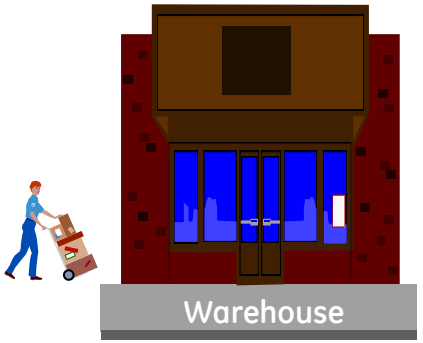
GE Supply Chain

Suppliers

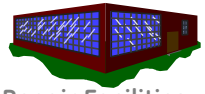


3 Warehouse Management

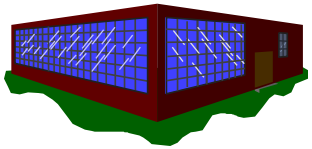
New Parts



4 Depot/Shops – Point of Repair



Repair Facilities
& OEMs



Depot

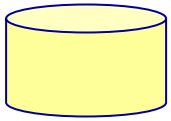
GE REP

6 GE/Customer Engineering & Mgmt

Shared
metrics

Customer

5 Customer Systems

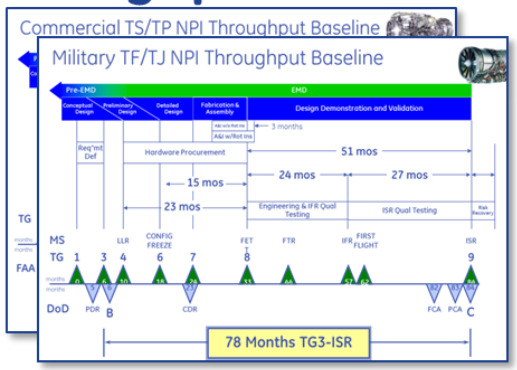


Development cost modeling…

Engine Line

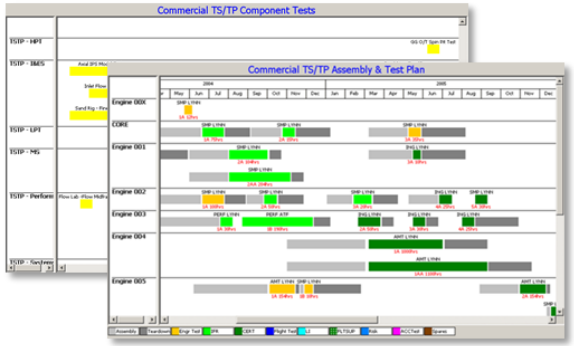
…select template

Throughput



…set program milestones

Test Plans



…construct test programs

Hardware

…project hardware costs

Tooling

…define support tools

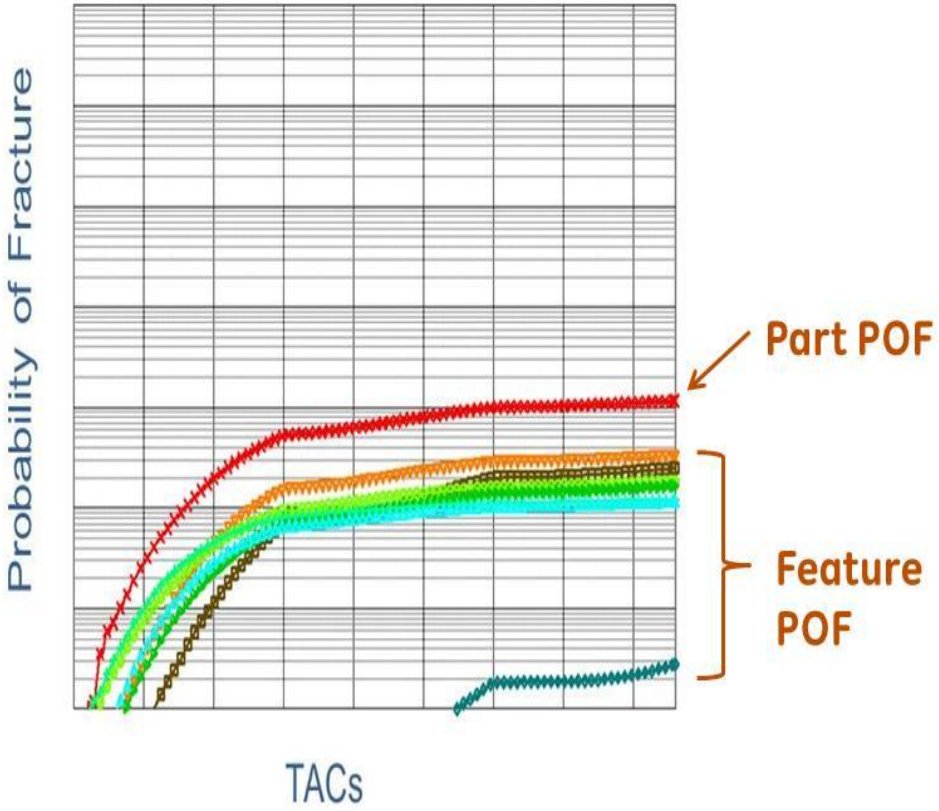
Architecture

…customize the machine

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



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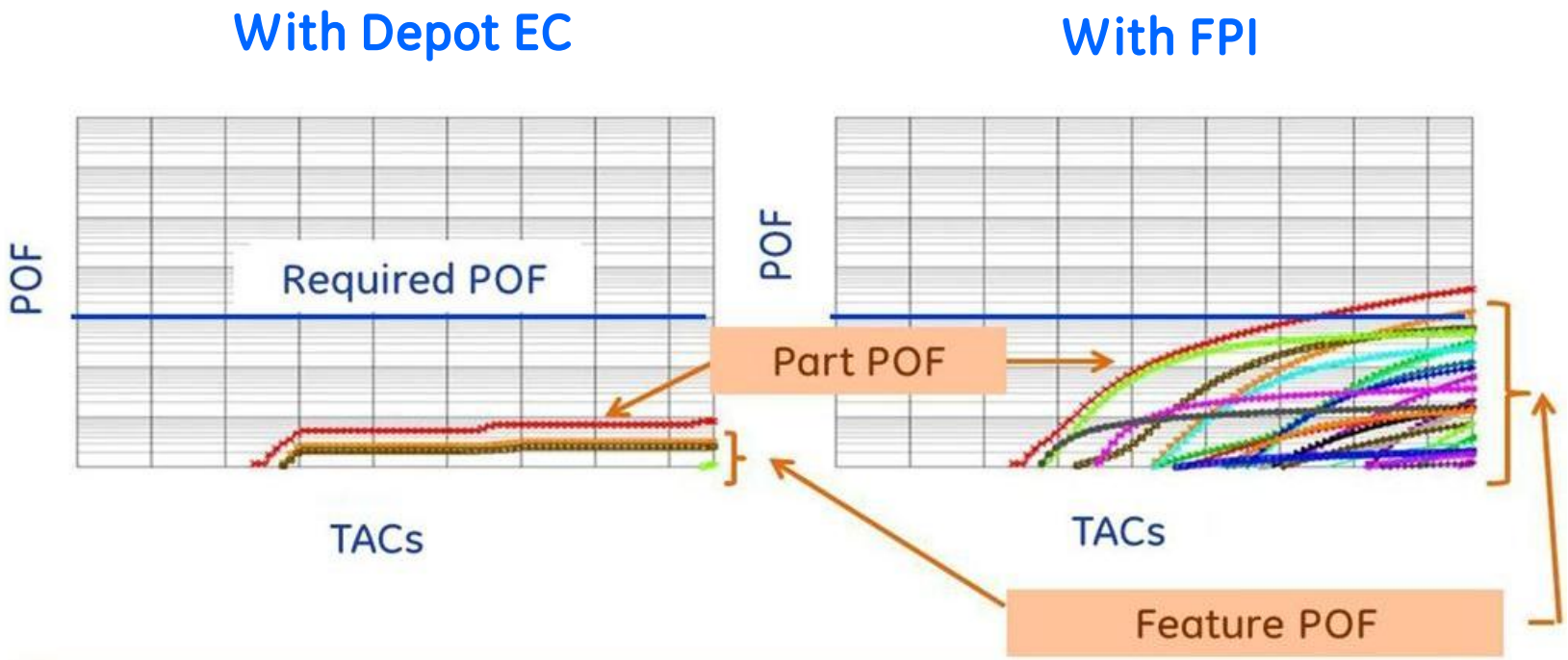
PFM Implementation Program

Potential to implement PFM for reduced depot inspection requirements.



Appropriate use of EC and FPI provides opportunity for customer cost savings

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Technology

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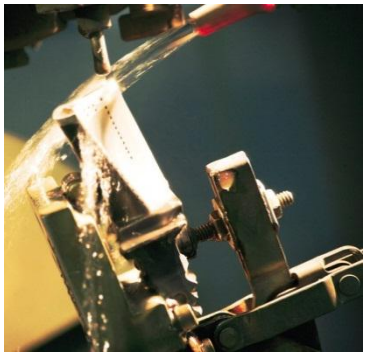
Technology starts with R&D…

TRL — Technology Readiness Level

GE Global Research – 5 locations, New York, Bangalore, Shanghai, Munich, Rio. Approx 3,000 employees

MRL — Manufacturing Readiness Level

Inspection / NDE, Welding / Brazing, Laser Machining



MatRL — Materials Readiness Level

New materials, Mechanical Testing, Tribology
Composite Processing, Special Coatings

IRL — Integration Readiness Level

Thermal management, Inlet particle separators, exhaust systems, IR, special coatings

Essential technologies

Keeping the pipeline filled

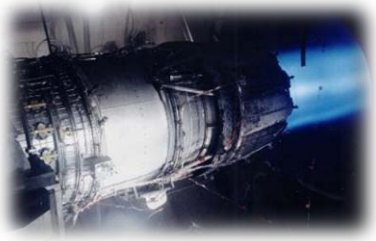
Adaptable fans

Advanced HXRs

CMCs

Adv. Cooling

High-Temp Materials



Augmentor Technology

2010 → Advanced products → Integrated engine and aircraft systems → Adaptive cycles / Advanced architectures → **2020**

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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

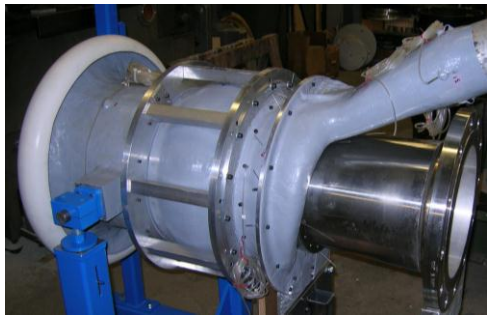
Development tooling costs reduced

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



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Architecture

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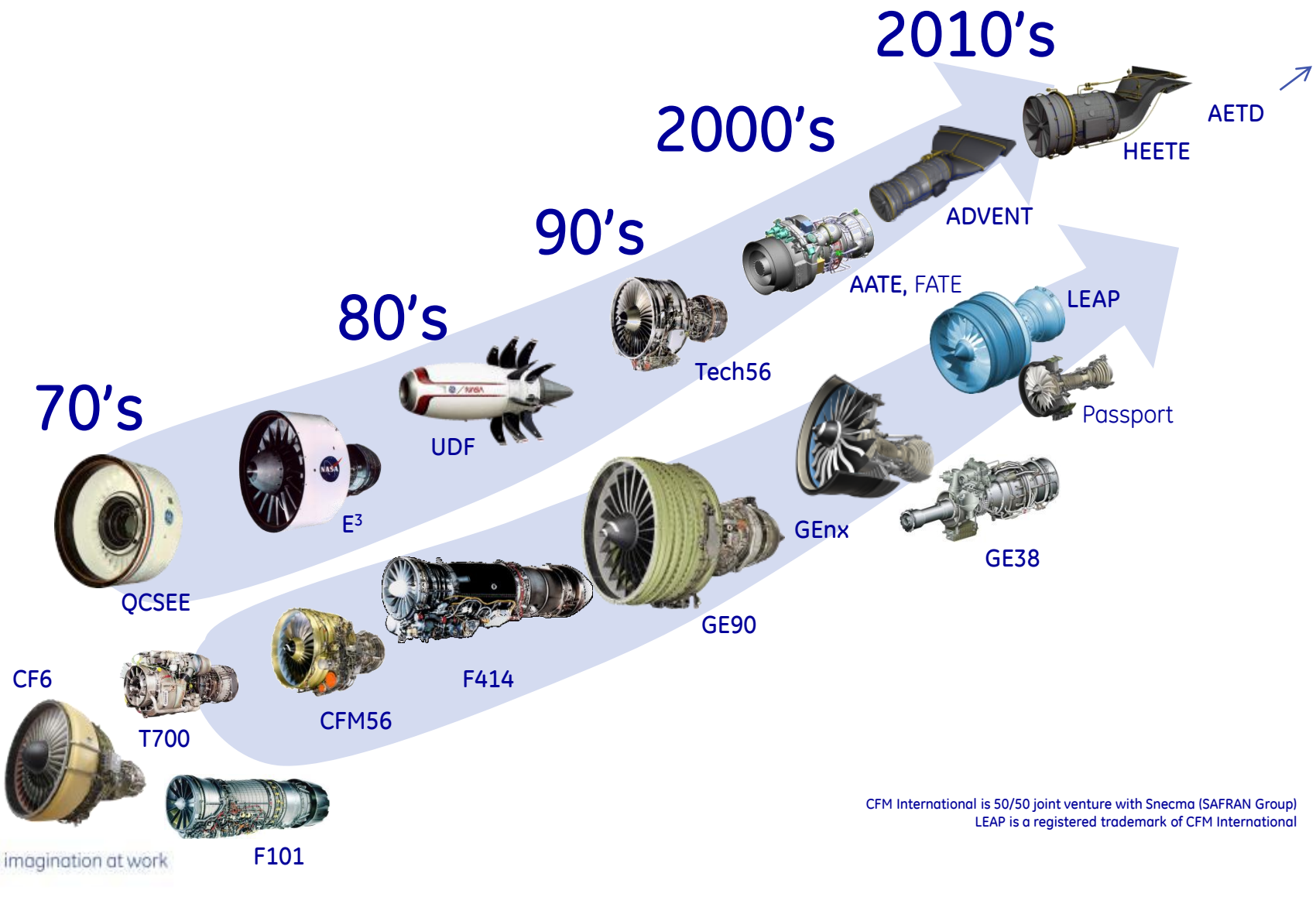
Technology Demonstrator Programs

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

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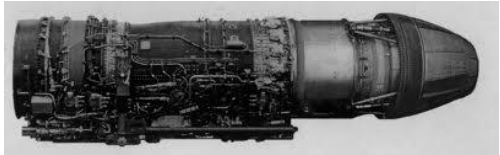
Architecture: Technology demonstrators

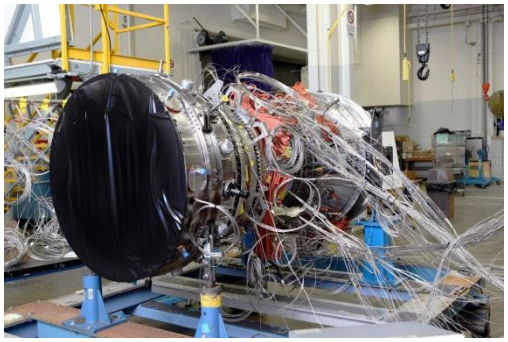
Military/commercial technology synergies

	AATE (Advanced Affordable Turbine Engine)	**FATE** (Future Affordable Turbine Engine)	**ADVENT** (Adaptive Versatile Engine Technology)	**HEETE** (Highly Efficient, Embedded Turbine Engine)
				
Customer	US Army	US Army	US Navy/ US Air Force	US Air Force
Program goals	25% better SFC 65% ↑hp/wt	35% better SFC 80% ↑hp/wt	20-200+% better SFC	35% better SFC
Technologies	3D aero, materials	3D aero, efficiency	Variable cycle, 3D aero, FLADE™	3D aero, efficiency
Segments	Attack/utility Helicopters	Heavy lift Helicopters	Combat aircraft	Tanker/Transport
	 Blackhawk	 NextGen heavy lift	 6th Generation	 KC-135

Adaptive Engine Technology Development

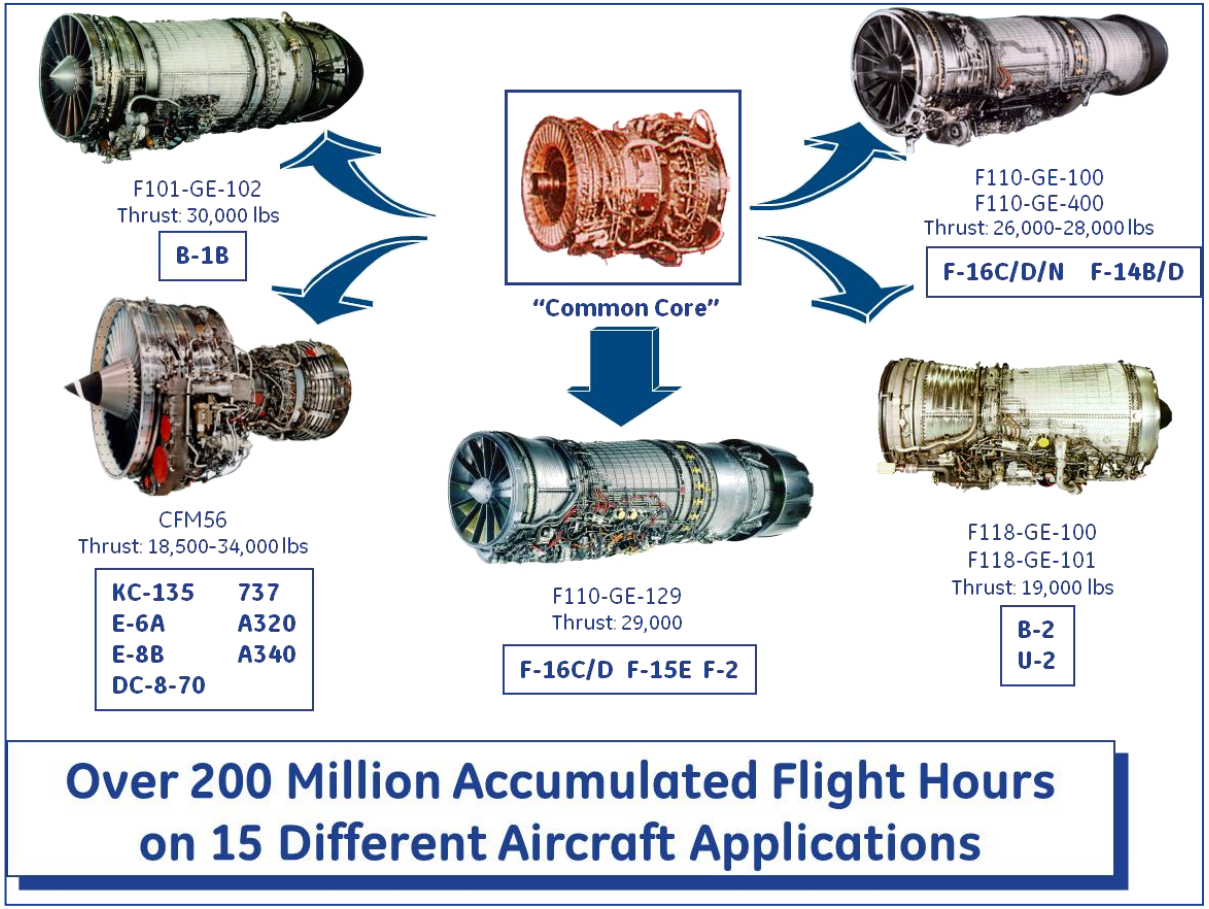
- AETD…new class of engines with up to 25% better fuel efficiency
- Variable cycle technology
- Technology demonstration that builds on ADVENT
- Foundation for future generation of combat propulsion





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

GE38 Development…Heavy Lift

Power for the Sikorsky CH53K

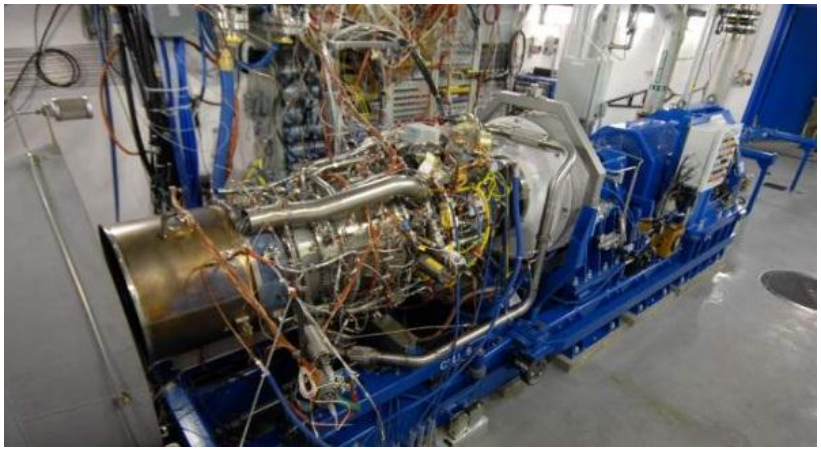
- GE38 Versus T64 :

  18% Improved SFC
  57% More power
  63% Fewer Parts

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

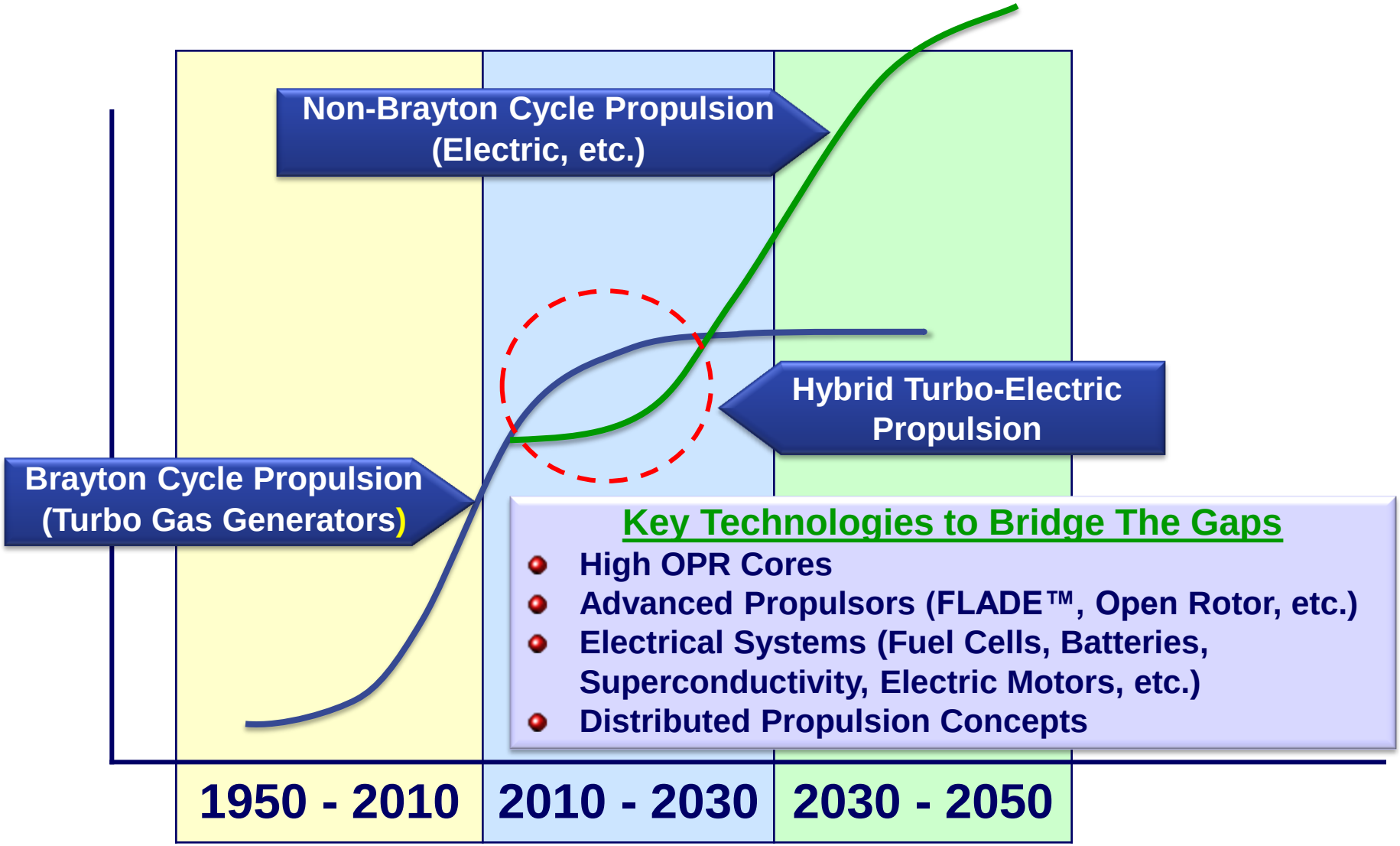
- All ground test vehicle engines installed. A/C rolled out.

- Submitted 90% of required test reports for first flight.



Vision for 2030 – 2050 Propulsion Systems

Revolutionary Ideas Required To Support Future Aviation



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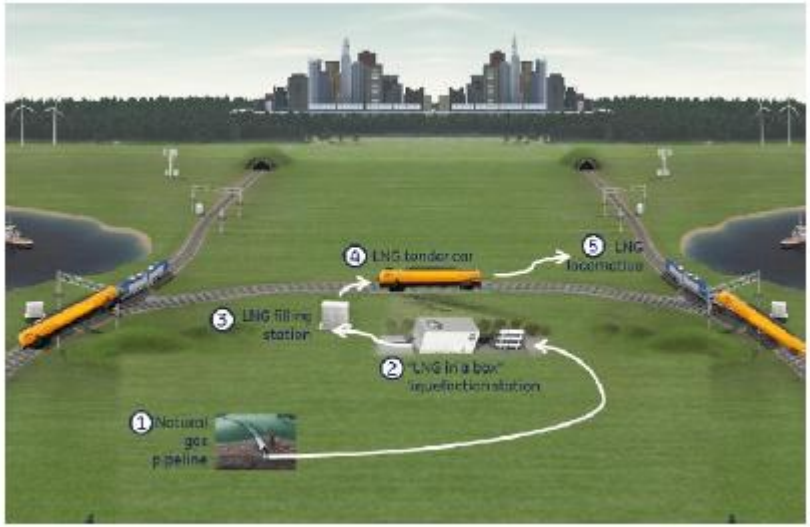
LNG as a transportation fuel…

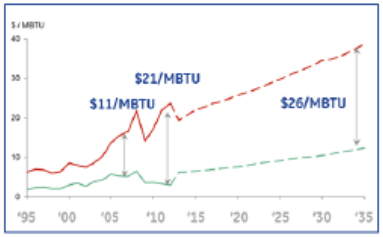
Marine – Emissions regulations driving change to littoral vessels

Rail – LNG is "the next big thing"

Trucking – OEM conversion kits, new make.

GE Oil & Gas– RAPID mini LNG equipment growth



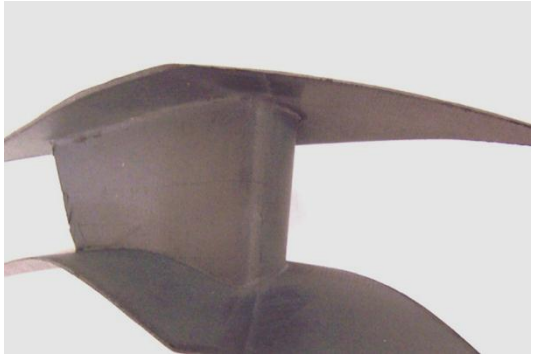


Huge price disparity and LNG build-out creating opportunity to dramatically reduce cost of energy for aviation

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.

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We invent the future of flight, lift people up, and bring them home safely