



GE Power

**ADVANCEMENTS IN H CLASS GAS TURBINES FOR COMBINED
CYCLE POWER PLANTS FOR HIGH EFFICIENCY, ENHANCED
OPERATIONAL CAPABILITY AND BROAD FUEL**

Laurent Cornu, Product Manager, 9HA Gas Turbine

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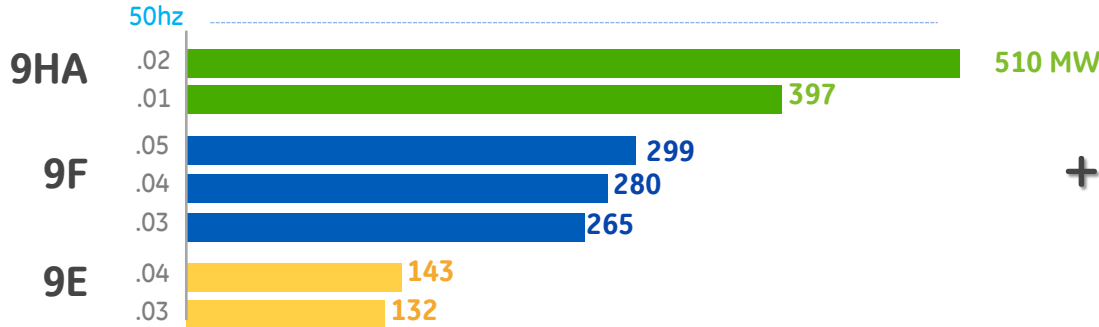
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Gas turbine industry leader

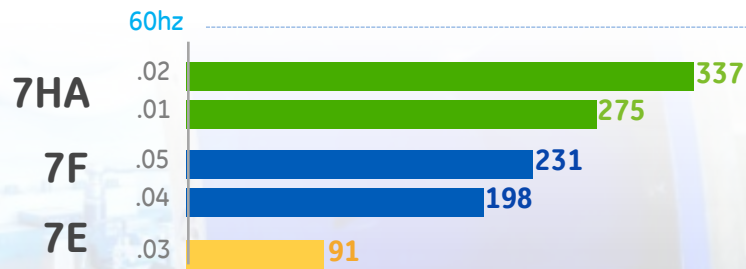
Strongest catalog

- H-class
- F-class
- E-class




+7000 Gas Turbines

+1600 GW



+300M Operating Hours

	GE Fleet (%)	Delta vs. Industry (% pts)
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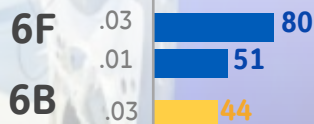
Reliability	98.3	+0.6
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Availability	92.6	+1.0
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Start Reliability	98.1	+0.4
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Source: ORAP®. All rights to underlying data reserved: SPS®. Modified by GE. Rolling 12-month data Apr 2015 – Mar 2016.

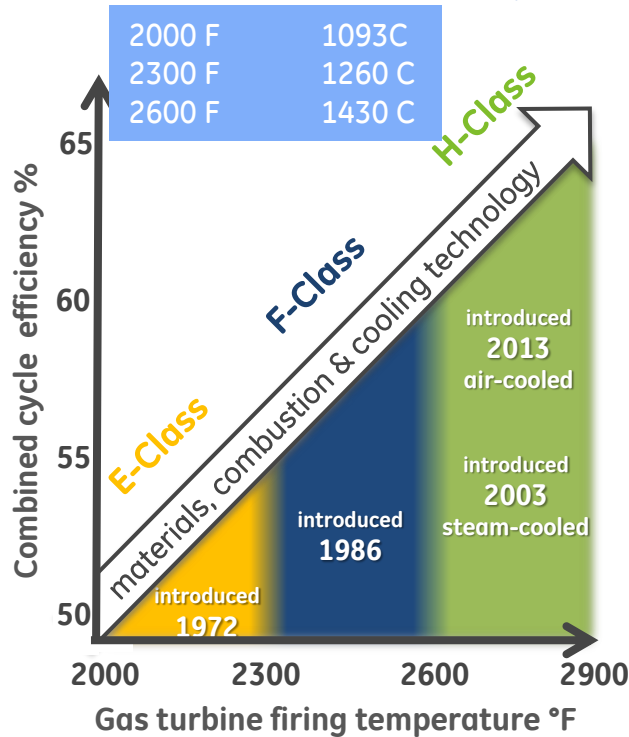
Geared



Comprehensive range of GT offerings

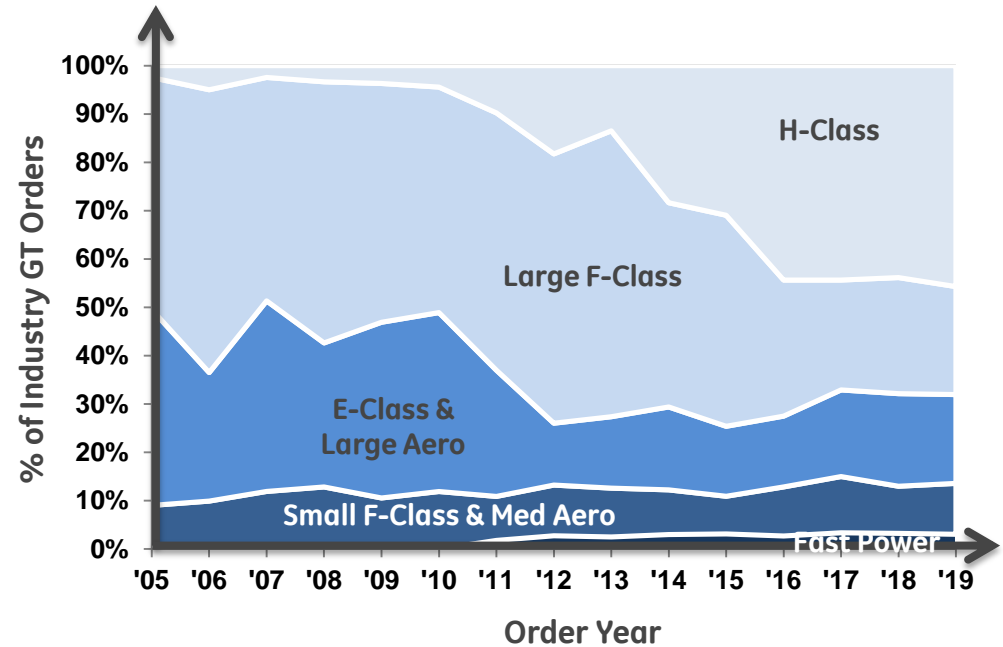
Technology drives efficiency... market transition to H

Technology & plant capability drives the industry



>62% efficiency today for HA technology on Gas Turbine World basis

Industry orders shifting towards H-class (% by MW)



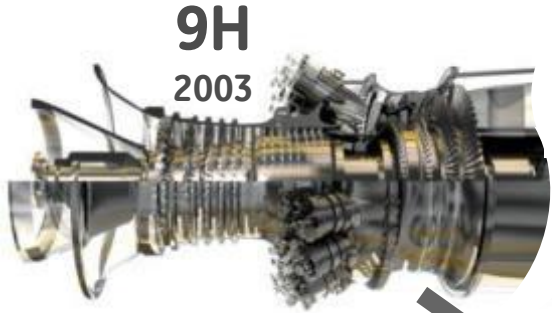
H-class fastest growing segment

Market shifting to high efficiency generation for better economics



HA gas turbine platform evolution

Three generations of gas turbine technology



4-stage VGV
4-stage turbine

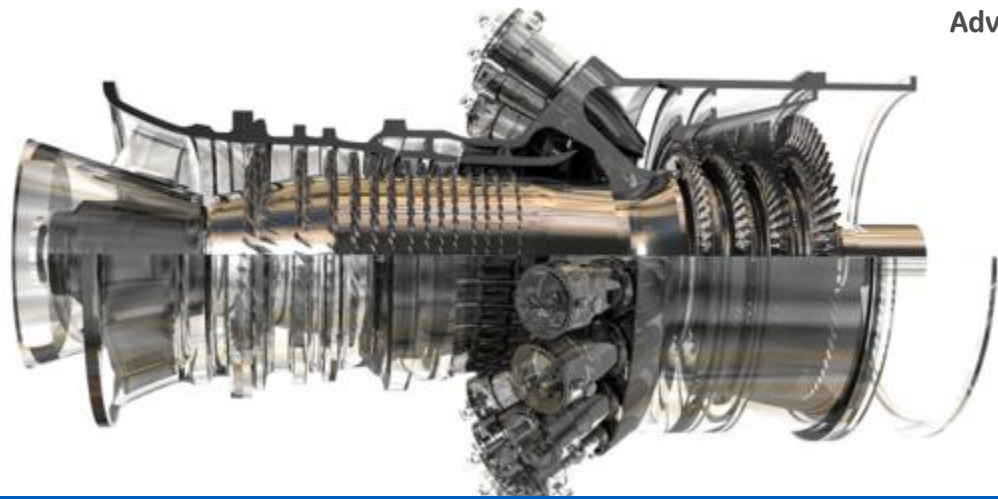


DLN 2.6+



14-stage compressor
Field-replaceable blades
3-stage VGV
Advanced HGP

7/9HA
2014



Note: Year denotes first operation

A decade of technology advances and lessons learned



HA high efficiency gas turbines

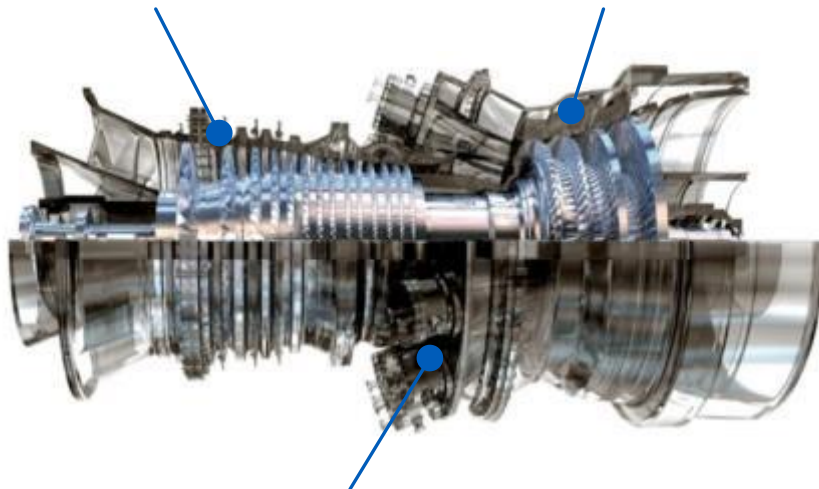
The most cost effective conversion of fuel to power

Compressor

- Field replaceable blades
- 7F.05 validated

Hot gas path

- Air cooled
- Proven super alloys



DLN2.6+ Combustor

- Proven performance
- Broad fuel flexibility

Product performance

	<u>GT</u> <u>MW</u>	<u>1x1</u> <u>CC MW</u>	<u>CC</u> <u>Efficiency</u>
7HA.01	293	435	> 61.5%
7HA.02	346	509	
9HA.01	429	645	
9HA.02	519	774	

Flexibility

Fuel	Ethane, ASL
Turndown	25% GT base load
Ramp rate	15% GT MW/min

HA Gas turbines ... for reliable, cost effective power generation



7 & 9HA power plants around the world



9HA.01 EDF Bouchain

1x1 Single Shaft
GT installed...July '15
Commissioning Feb-May '16
COD ... June '16



7HA.02 Exelon Wolf Hollow

2x1 Combined Cycle
1st GT installed ... May '16
Commissioning ... in progress
COD ... Q2 '17



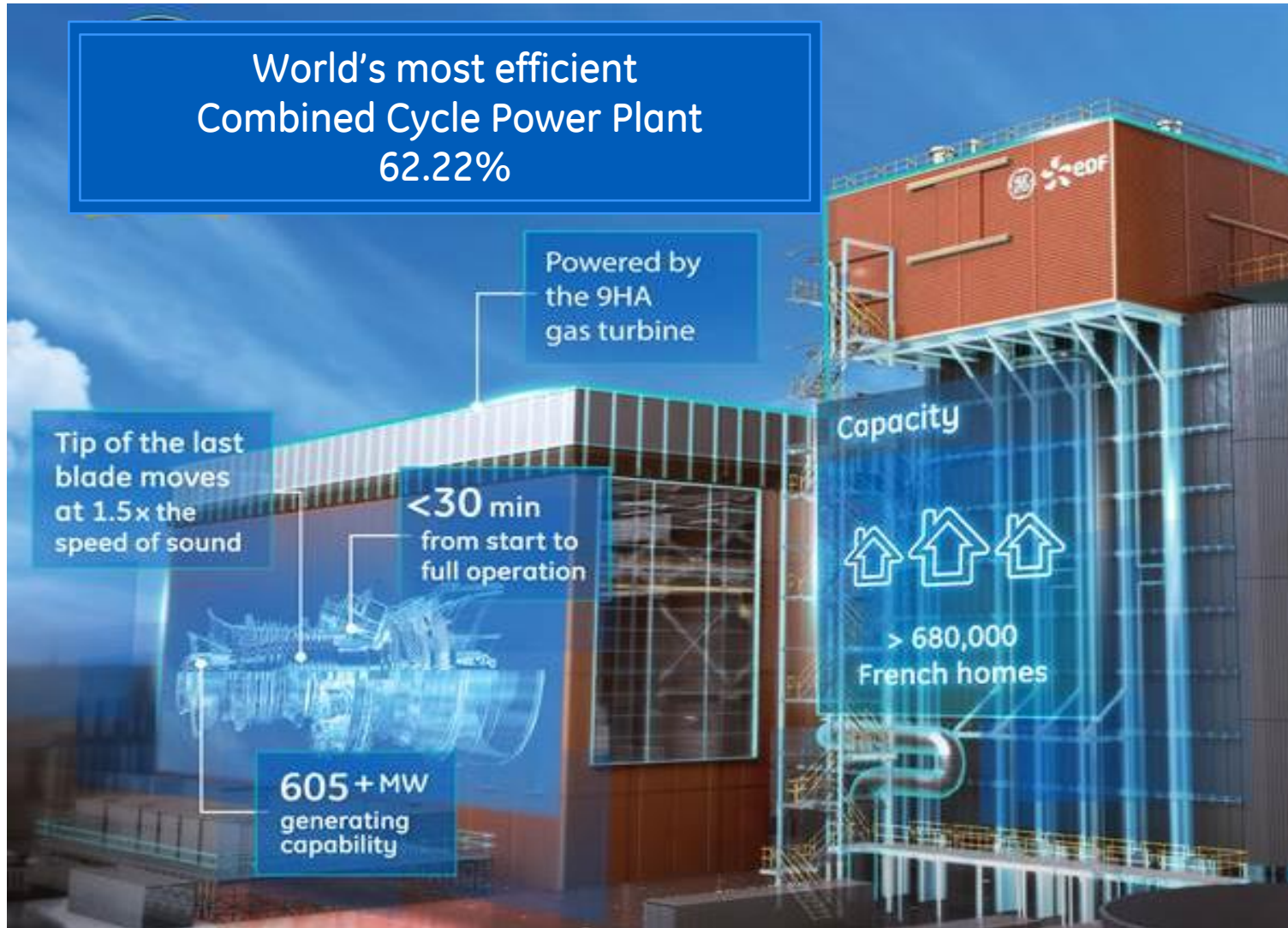
7HA.01 Chubu Nishi Nagoya

3x1 Combined Cycle (2 blocks)
1st GT Installed ... May '16
Commissioning ... in progress
COD ... Q2 '17

Gas turbine Full-load validation supports fast site schedules



9HA plant record performance achievement

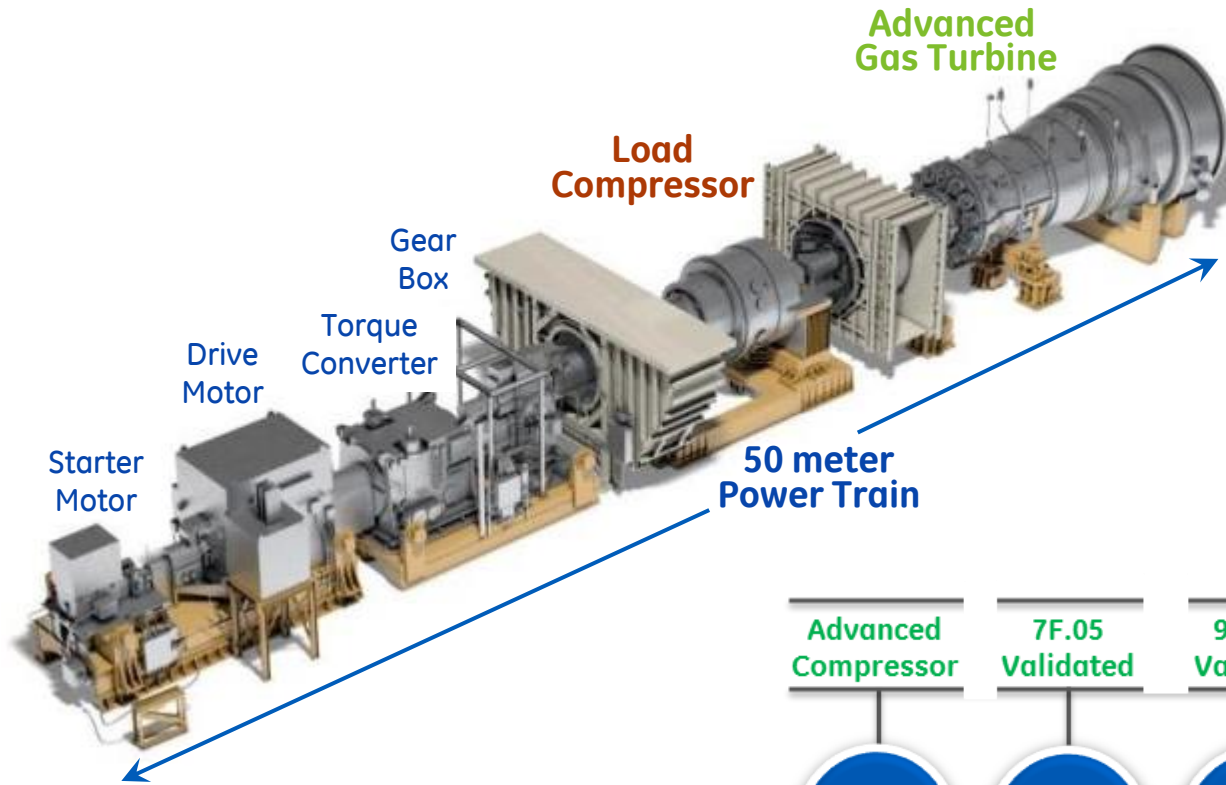




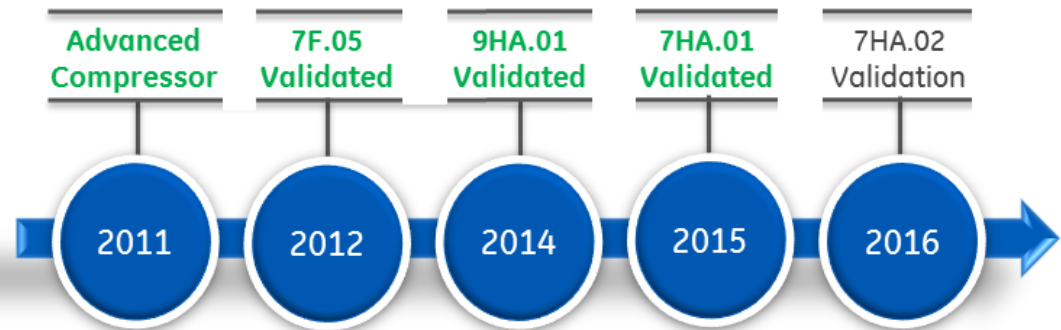
HA validation



Advanced technology validation milestones



- Off-grid, full load
- 50Hz & 60Hz
- Gas & liquid fuels
- Gas turbine commissioning & digital twin assessment
- Installation & maintenance routine

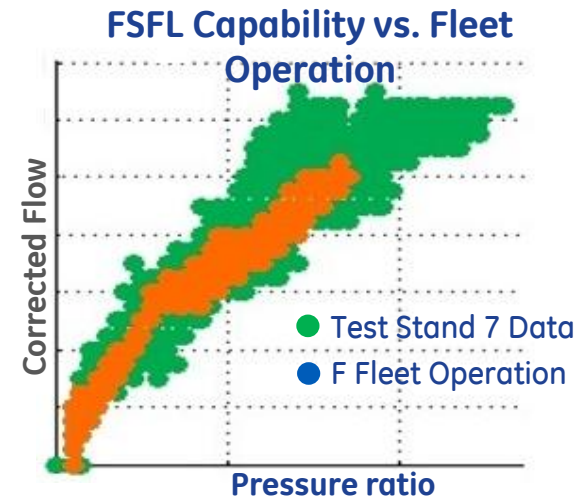
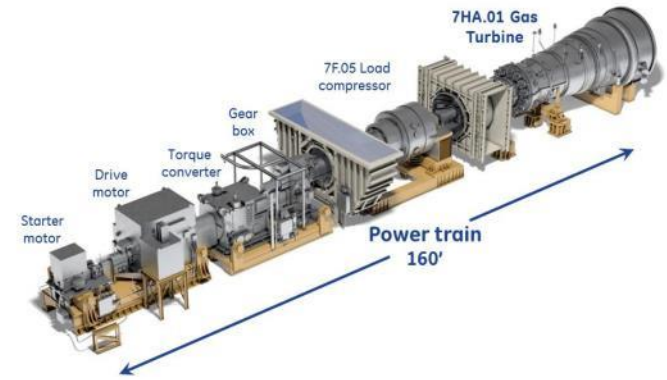


\$500M investment to validate technology reliably



TS7 Off-Grid Testing Benefits

- **No grid restrictions ... no frequency or load limitations**
 - Testing at all load ranges on-frequency (50 and 60hz capable)
 - Testing at load ranges off-frequency for variation and grid events
 - Testing at transient conditions
- Deliver thorough product mapping **beyond field operation** ... insurer and customer acceptance
- TS7 has **permanent data collection system**
 - Capable of 7000 data streams
 - High quality data due to permanent data and scanner rooms.

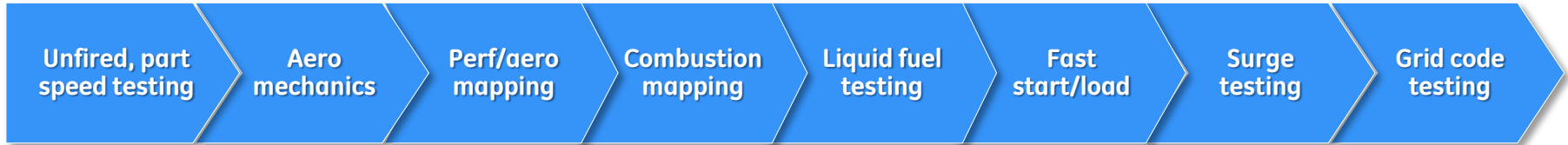


FSFL provides data far beyond field operation

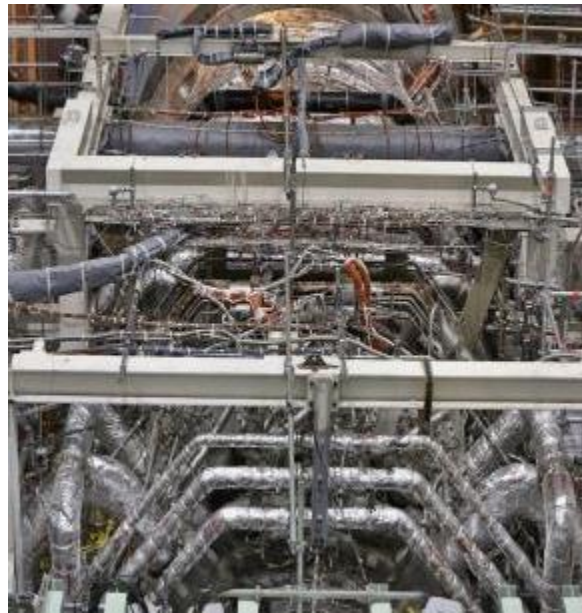


Unprecedented facility and operations

Test sequence



- Start-ups, shut-downs, re-starts
- Speed sweeps at varying load conditions
- Low load mapping (0 - 30%)
- Emission compliant load range (30–100%)
- Extreme conditions ... over-fire, over-speed, under-speed at load



Most comprehensive validation in GE's history

160 accelerometers

120 clearance probes

330 light probes

750 strain gages

3,300 thermocouples

1,890 pressures probes

300 thermal Crystals



GE's HA gas turbine exceeds expectations

9HA.01 & 7HA.01 validated, 7HA.02 testing on-going

Test Stand

1 Unit
200 Hours

more
valuable
than

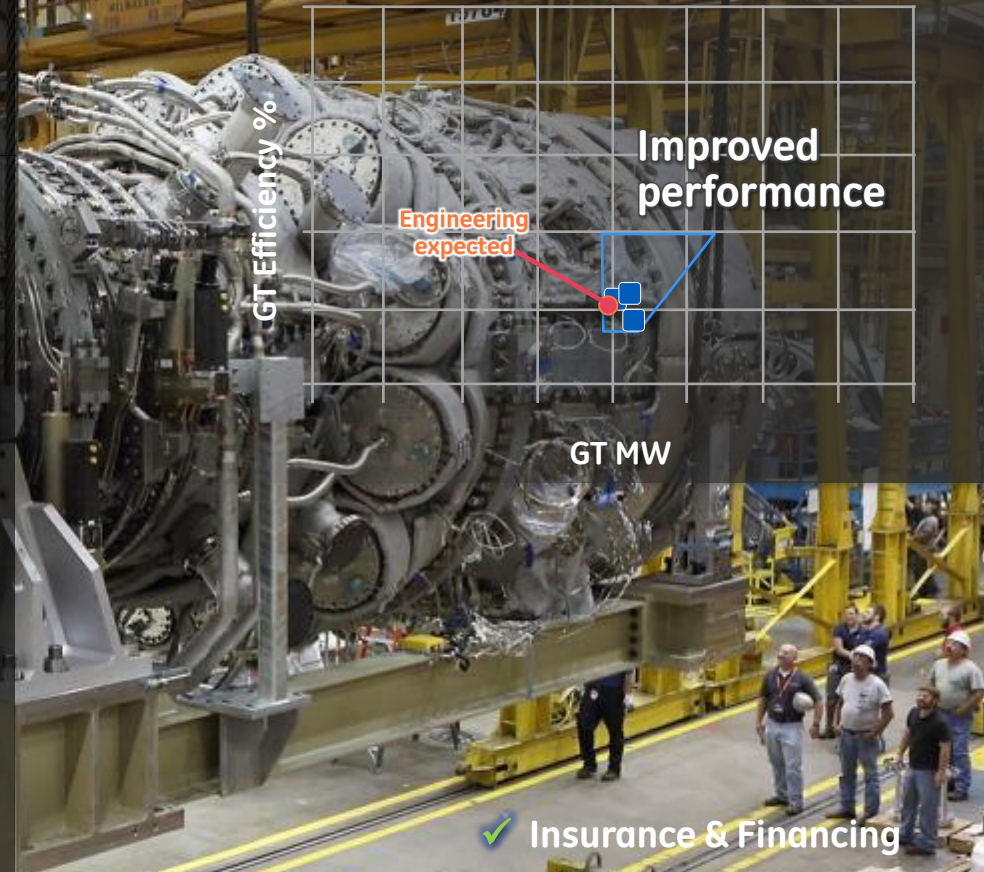
Field Operation

500 Units
1 Year

- Off-grid full speed, full load test capability
- Able to operate beyond "real world" limits
- Comprehensive validation before FF in field
- Enabling rapid acceptance by customers, insurers & lenders

Proven Results

- ✓ Baseload performance achieved
- ✓ +110% output / high flow demonstrated
- ✓ +75°F overfire demonstrated
- ✓ Emissions & operability verified
- ✓ <25% turndown achieved
- ✓ <10 min fast start demonstrated
- ✓ 80 MW/min ramp rate demonstrated
- ✓ Gas variation – doubled (to $\pm 15\%$ MWI)
- ✓ Cold fuel to base demonstrated



Comprehensive understanding of design processes, technology & capability



Pre-engineered and packaged accessories

Enhanced construction, maintenance & reliability

Up to 25% faster installation than 7F.03

- ✓ Customer connections ↓ 40%
- ✓ Field welds ↓ 40%
- ✓ Electrical terminations ↓ 80%
- ✓ Field installed valves ↓ 98%



Field installed valves	7F.03	7HA
Cooling & sealing air	13	0
Gas fuel	2	1
Atomizing air	1	0
Inlet bleed heat	2	0
Lift oil	4	0
Water wash & false start DRN	17	0
Gas fuel purge	6	0
Total	45	1

Key features

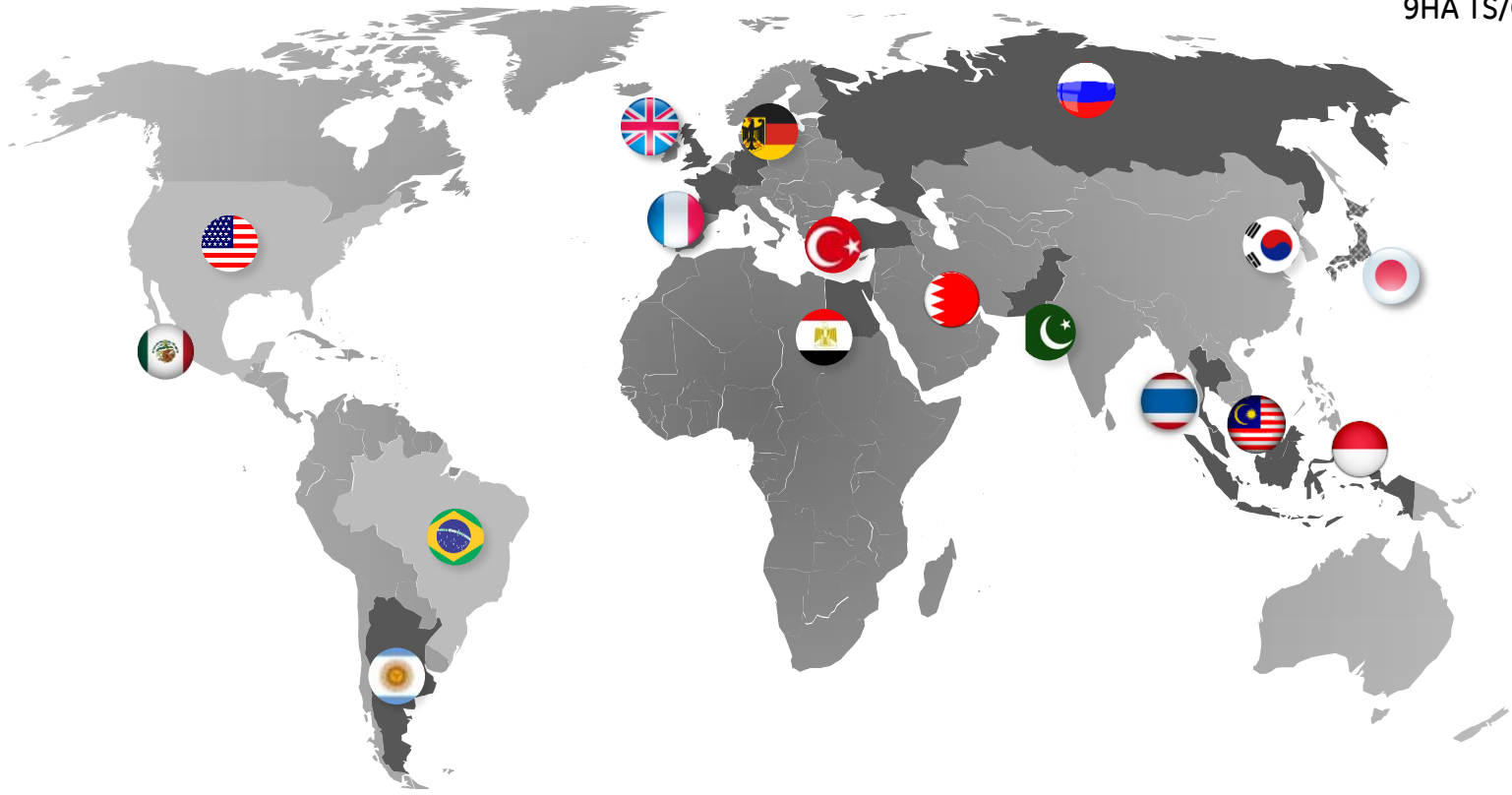
- ✓ Elimination of hydraulics
- ✓ Quick roof lift off – no equipment
- ✓ Simplified combustion piping
- ✓ Water purge eliminates oil coking
- ✓ Increased access space
- ✓ Reduced outage time ... up to 20%

7HA construction ... 10,000 man-hours less than 7F



Winning with the HA Gas Turbine

7HA TS/Orders
9HA TS/Orders



103

Technology Selections

7HA: 60
9HA: 43

47

Orders

7HA: 28
9HA: 19

40

Gas Turbine GW

7HA: 19
9HA: 21





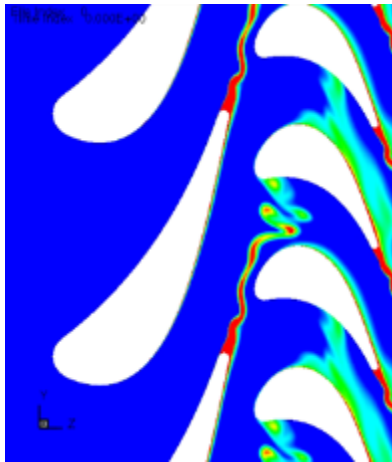
Future Evolutions



Enabling >65% combined cycle efficiency

Technology pipeline for the next decade:

UNSTEADY PHYSICS



Supercomputers unlock improved aero layouts

ADDITIVE MANUFACTURING



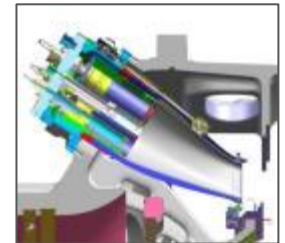
Complex layouts enabled by advanced manufacture

CERAMIC MATRIX COMPOSITE



Durability 500F hotter than metals, uncooled

COMBUSTION



Low emissions at 3000F

Leveraging GE's aero engine heritage and F-fleet experience



HA gas turbine power plants ... reliable, cost-effective power generation

- ✓ Strong technology heritage
- ✓ FSFL validation
- ✓ Wide gas & liquid fuels capabilities
- ✓ Simplified & packaged systems
- ✓ 103 units selected ... 47 ordered



Technology pipeline for sustained product & industry leadership



