# Termoflores
# Reference D5/D5A Gas Turbine Upgrades

**Siemens Energy, Inc.**
Tony Deal
Gas Turbine Modernizations

**Zona Franca Celsia**
Jose Rafael Serje Polo
Thermal Power Maintenance Leader

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Tony Deal / Siemens Energy, Inc.
Jose Serje / CELSIA

# Project Overview

## Customer

- Zona Franca Celsia

## Location

- Barranquilla, Columbia

## Gas Turbine Frame

- W501D5

## Outages

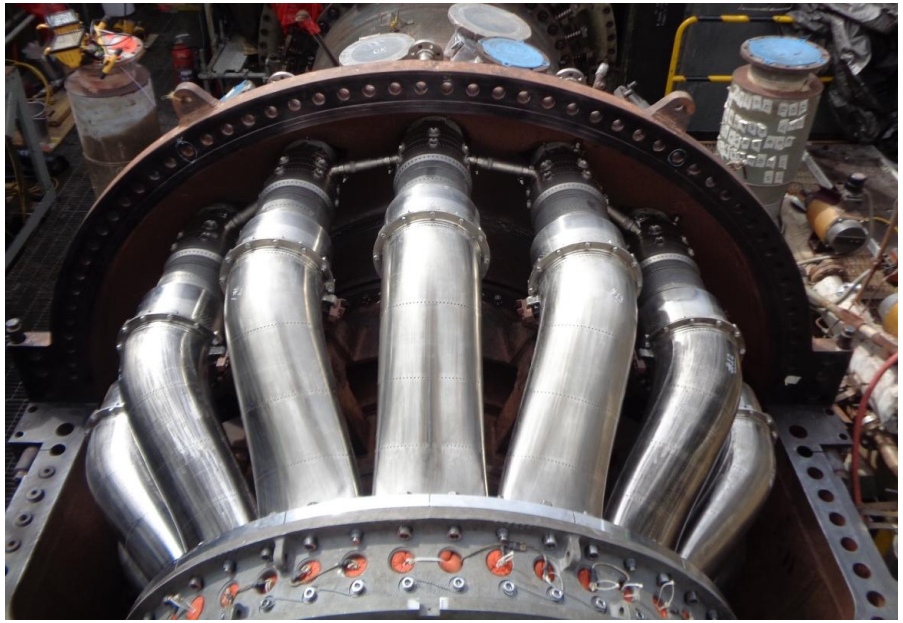
- November 2017 Major
- April 2018 Major

## Modernizations Applied

- Si3D Turbine Modernization
- Bolted Compressor Rotor
- IIEP 2.0 Combustor Hardware

## Customer's Objectives

- Increased Power
- Decreased Heat Rate (increased efficiency)
- Frame Lifetime Extension
- Interval Extension
- Increased Reliability
- Repair Cost Savings



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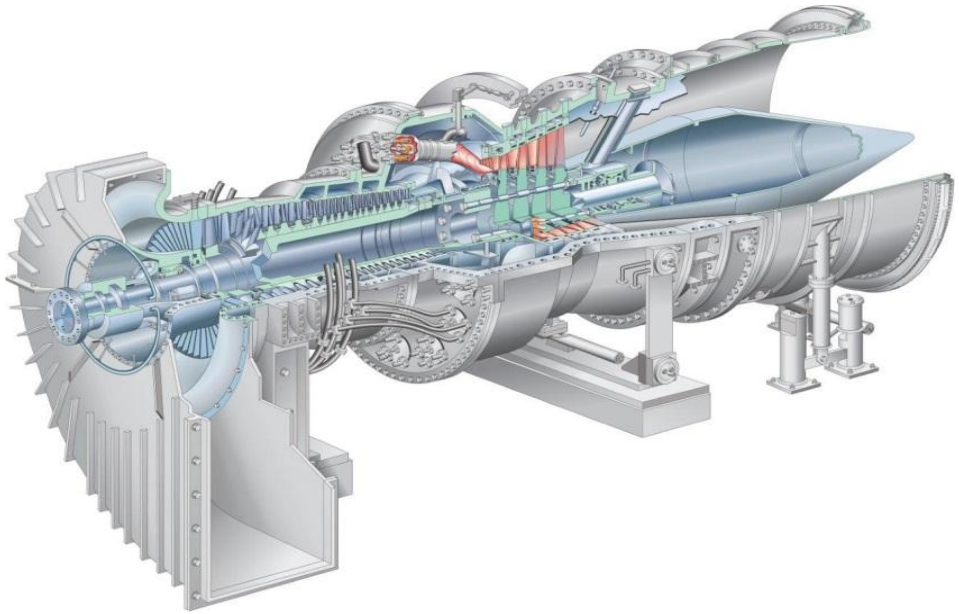





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# Si3D™ Turbine Upgrade

## Package Features

- Aerodynamic redesign of stage 1 blade / vane & row 2 vane
- Cooling air savings – component cooling reduction & sealing improvements
- Leverage advanced frame technology

## Expected Program Benefits

- Improved efficiency / increased power with Si3D re-aero
- Higher firing temp's with IIEP 2.0 Combustors
- D5-D5A interchangeability (D5 requires D5A blade ring)

## Expected GT Performance*

- D5: Up to ~5 MW; 300 BTU/kWhr
- D5 with FTI Up to ~10.5 MW; 333 BTU/kWhr

**Heat rate and power improvement**

* Performance increases depend on site specific configuration



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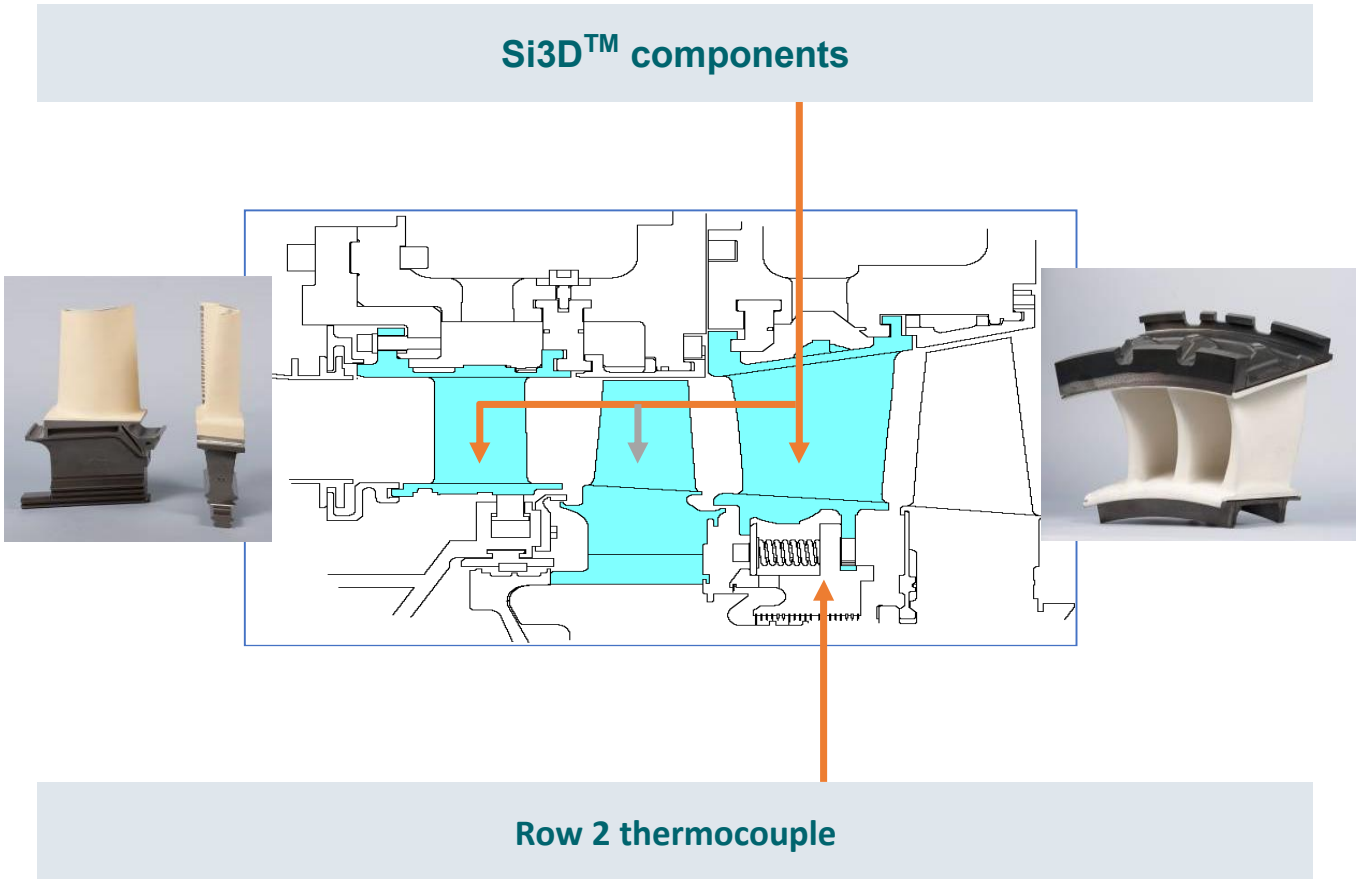
# Si3D™ Turbine Redesign (Stages 1-2)

- Si3DTM row 1 & 2 vanes with riffle seals
- Si3DTM row 1 blades with new sealing hardware
- TBC coated ring segments rows 1 & 2
- Upgraded thrust bearing pads
- Redesigned stage 2 thermocouples
- Row 2 interstage seal housing baffle plate modification
- Features already included in standard D5As:
- Cooling flow modulation rows 2 & 3



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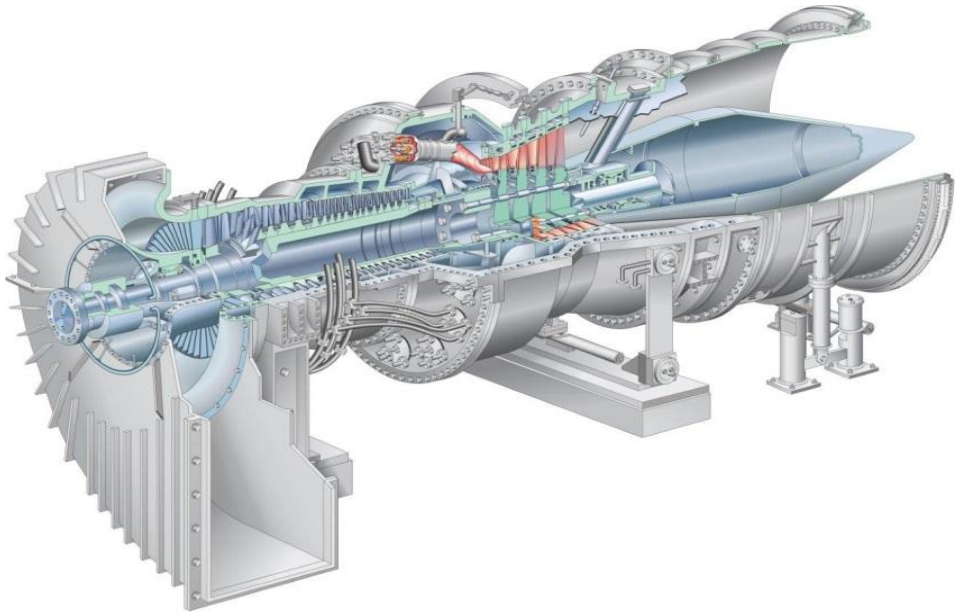





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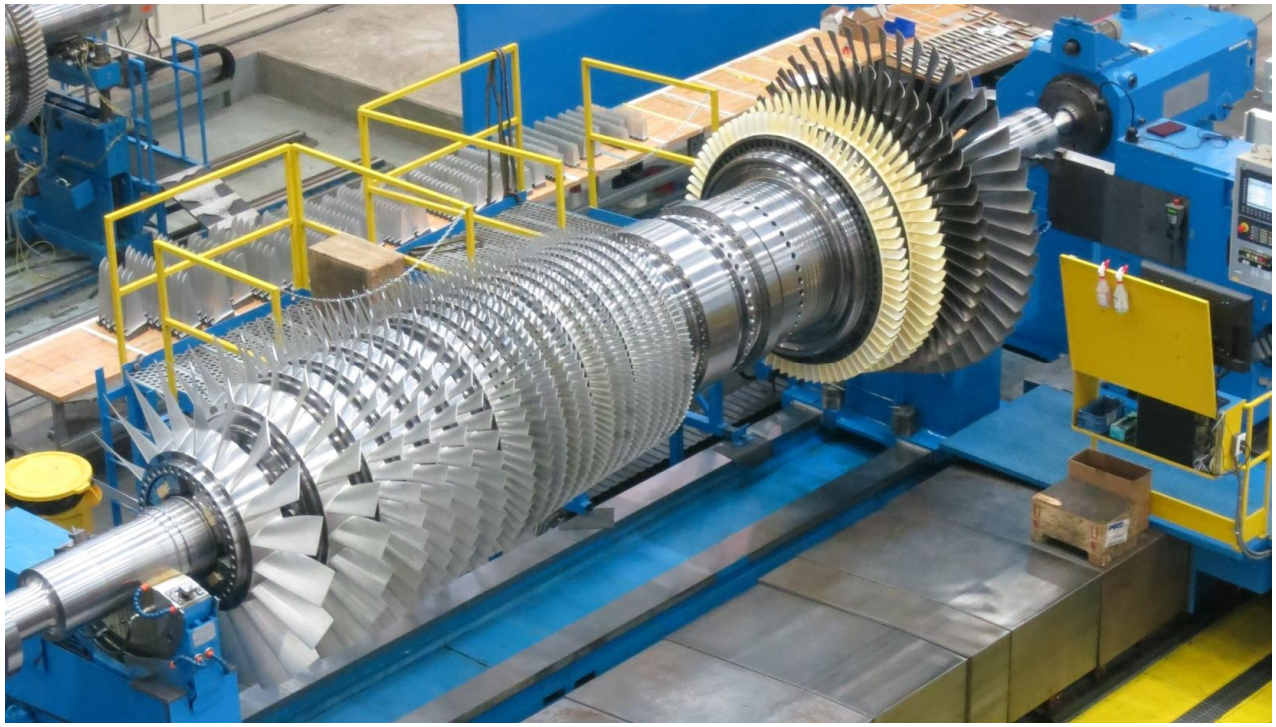
# W501D5/D5A Bolted Compressor

## Enhanced Design Features:

- Visible blade locking keys (no change in blade attachment)
- Retrofit to Turbine spindle (marriage coupling joint)
- Reparability-Individual disc replacement
- Shear pins to transfer torque
- Multiple Spindle bolt design
- Vibratory Response
- Enhanced Air-separator
- Improved Materials result in increased life
- Spigot fits from disc to disc support 10 minute fast start



**Features adapted from 501F style compressor rotor**



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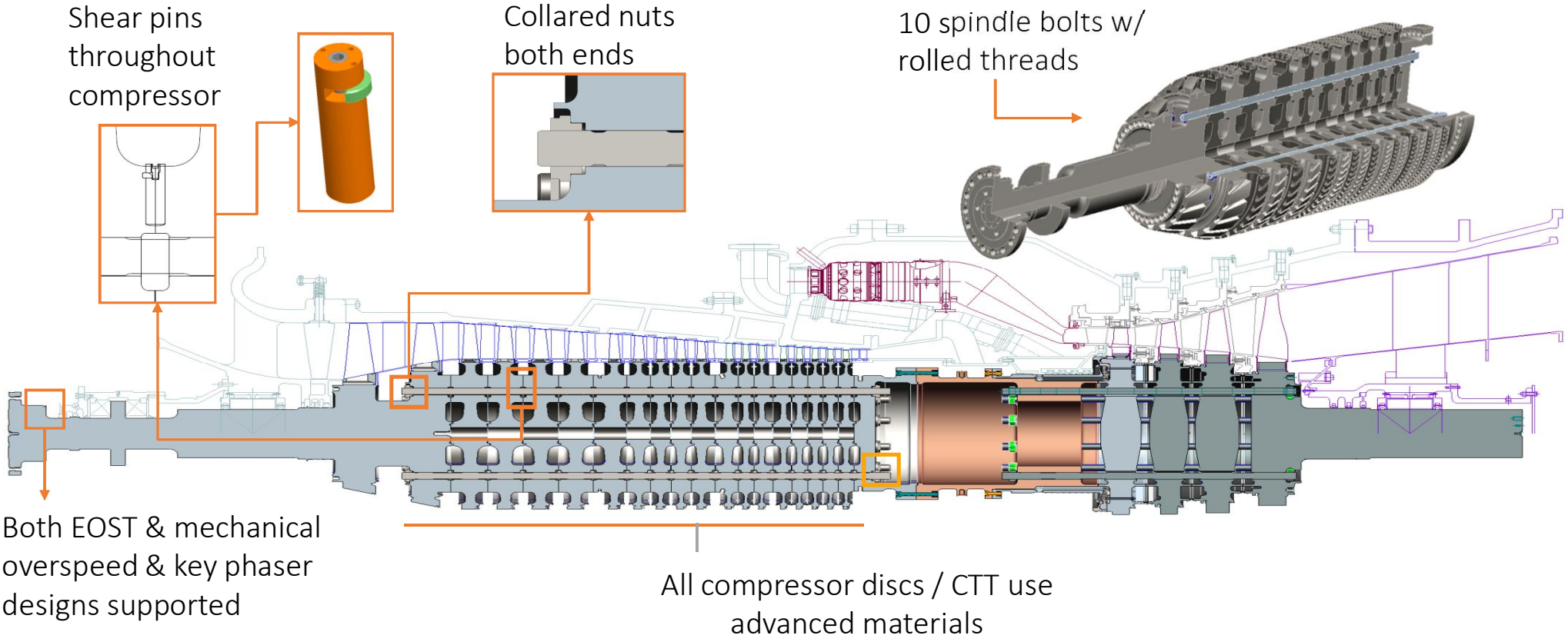
# Bolted Compressor Enhancements



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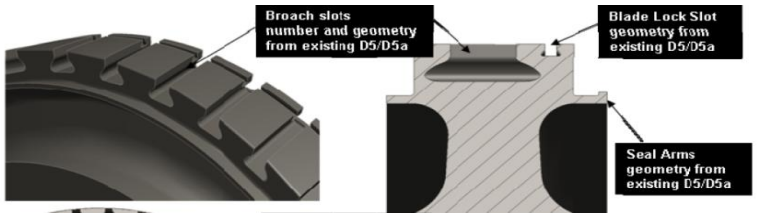
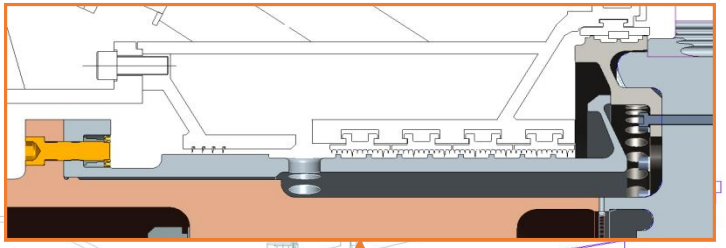
# Bolted Rotor Configuration

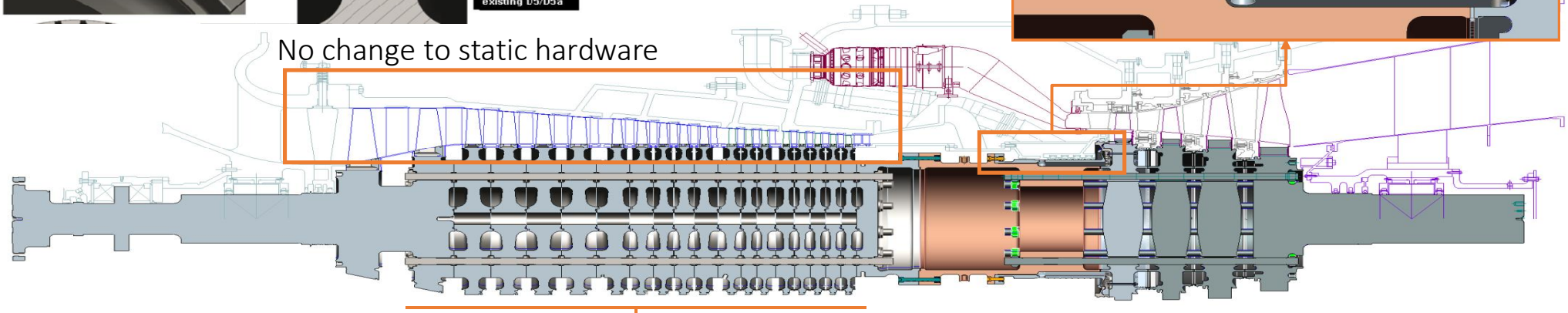
Standard D5/D5A blade locking




2-piece air separator to reduce potential imbalance, and less thermally sensitive



No change to static hardware



Intended Benefits:

- Bolted configuration produces straighter rotor
- Improved materials results in increased life
- Bolted / spigot configuration supports 10 minute fast start



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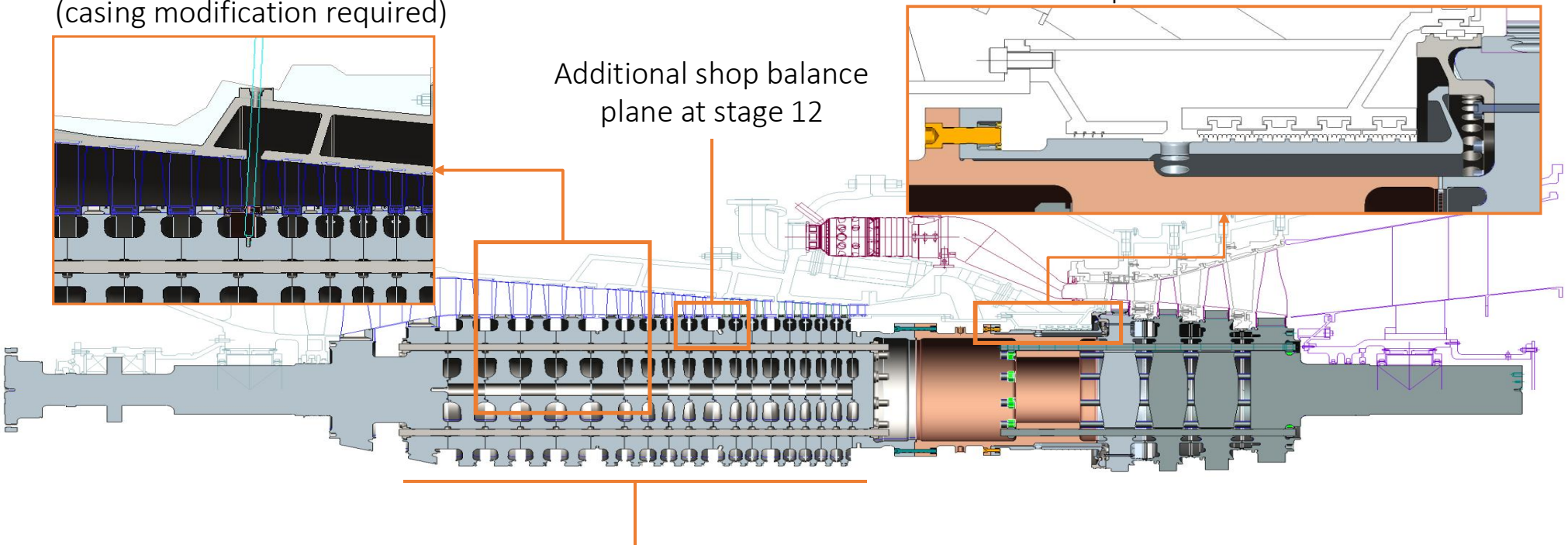
# Rotor Dynamic Enhancements

New stage 7 field balance plane
(casing modification required)

2-piece air separator intended
to reduce potential imbalance

Additional shop balance
plane at stage 12



Bolted configuration intended to produce
straighter / improved run-outs



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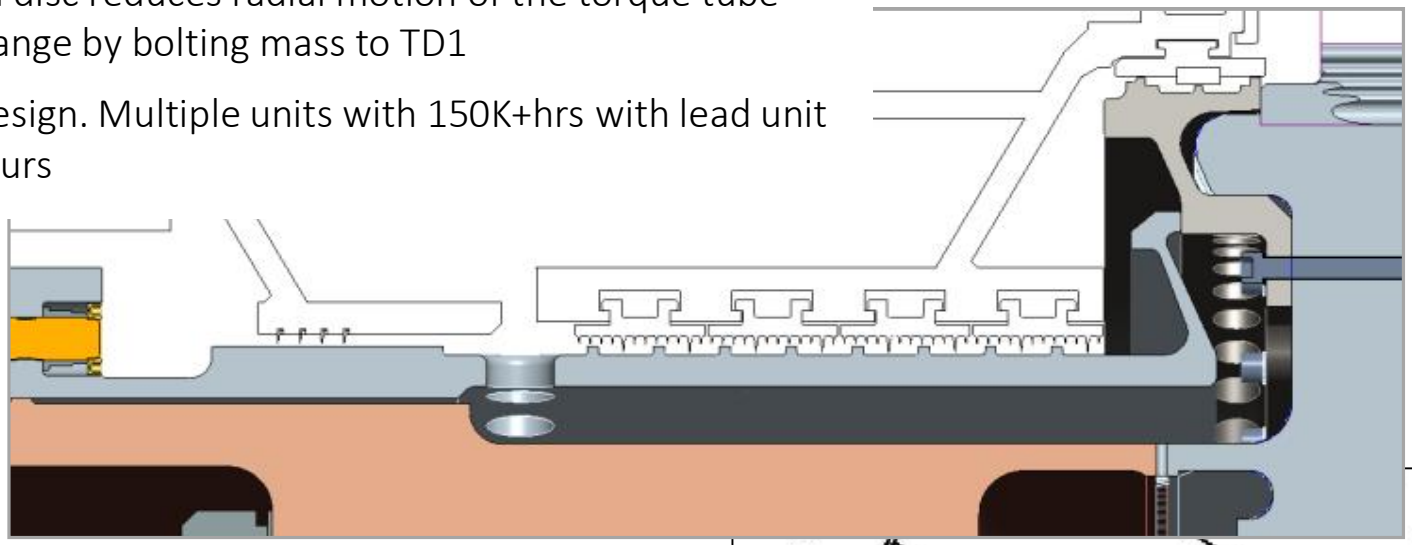
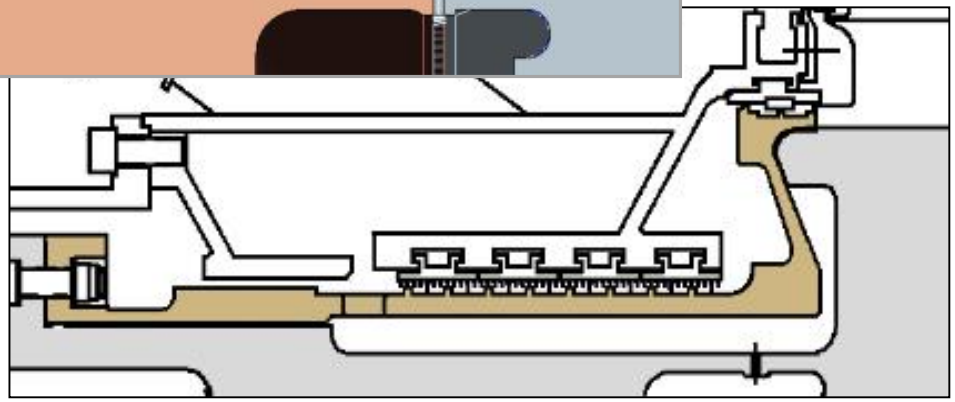
# Design Features
# Two Piece Air-Separator

- Bolted on disc reduces radial motion of the torque tube mating flange by bolting mass to TD1
- Proven design. Multiple units with 150K+hrs with lead unit ~200K hours



Old design



New air separator designed to reduce potential for shifting / source of vibration

- Reduced mass of forward section
- Aft section bolted to rotor



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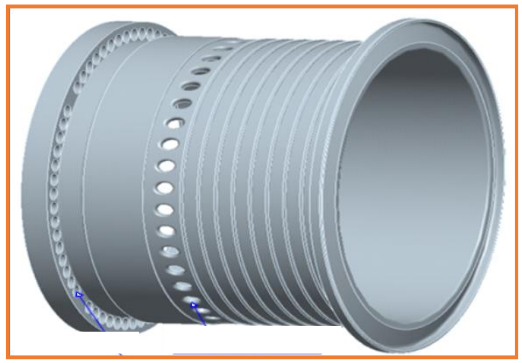
# Two Piece Air Separator Details

**Torque Tube**

New Sealing Surface with reduced free-rotating mass is much stiffer



Blade 1 cooling supply holes

**Bolted Disc**

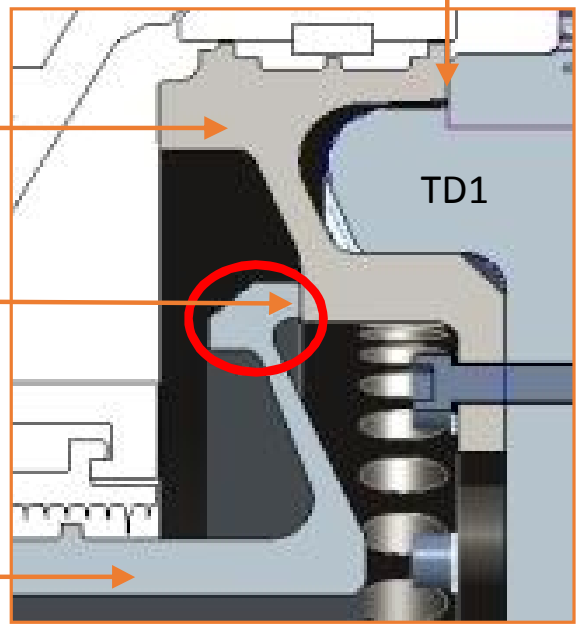
Slots to clear TD1 cooling holes

Previous Sealing surface

Bolted Disc

New Sealing Surface

Torque Tube




**Assembly View**



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# W501D5/D5A Bolted Compressor Rotor Design – Fast Start Implementation

SIEMENS
Ingenuity for life

**Current** D5 Startup schedule: TG > FSNL= 20 min; Synch = 0.5 min ; Load = 8.5 min

**Total = ~29 min**

- **Rotor** design is intended to allow "fast start"= 10min to full load
- Improved GT acceleration rate
- Improved GT loading rate = 24MW/min
- Controls modifications - "fast start button" added and firing curves modified
- Fast start factors (Equivalent starts) - 10x per fast start

**Fast Start** D5 Startup schedule: TG > FSNL= 8 min; Synch = 0.5 min; Load = 5.5 min

**Total = ~14 min**

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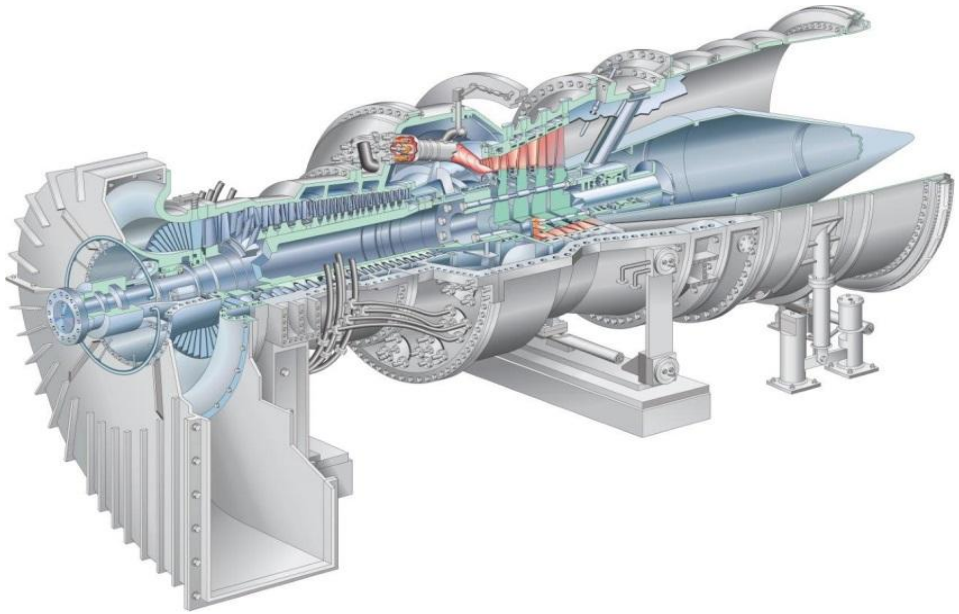
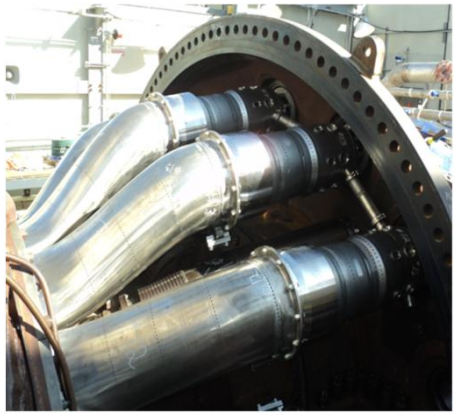


# D5/D5A Redesigned Combustion System
# IIEP 2.0 Combustor Hardware

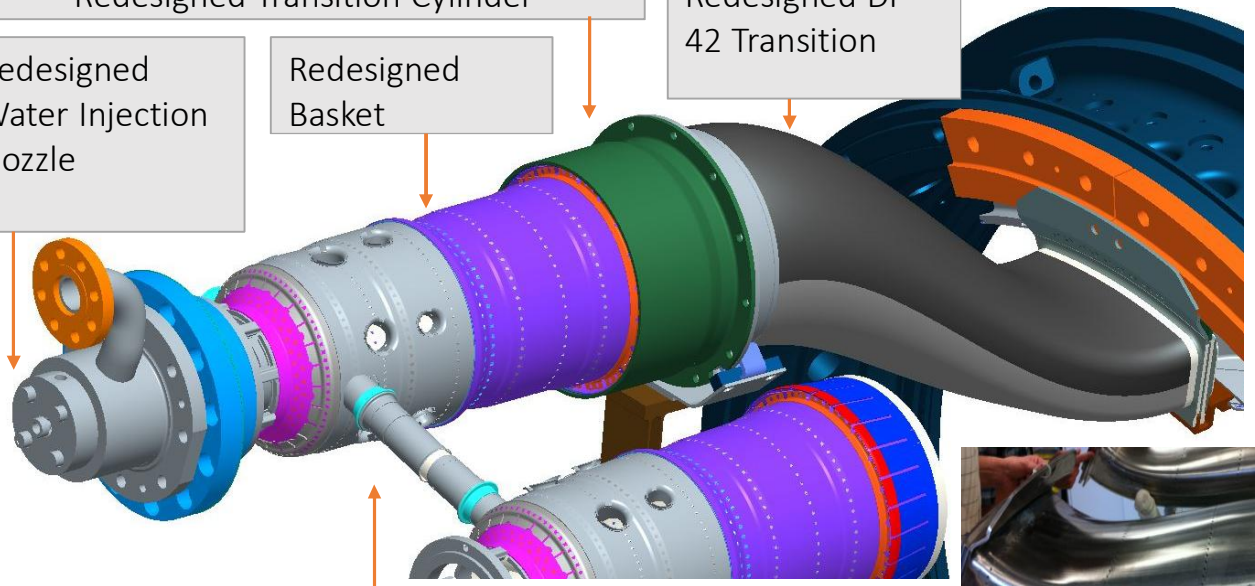


Redesigned Transition Cylinder

Redesigned Water Injection Nozzle

Redesigned Basket

Redesigned DF-42 Transition



Redesigned Cross Flame Tube

Outer Transition seal eliminated!

**Improved LCC / designed to address identified distress modes, improve water spray and maintain current emissions and dynamics le[illegible] / 16k EBH / 1,600 ES inspection interval**

JRSP1



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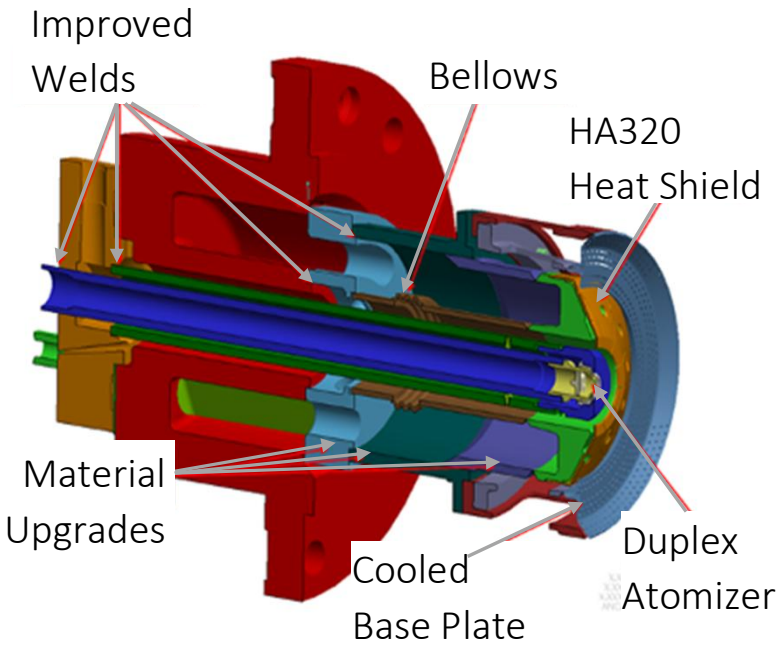
**JRSP1** Is 1600 ES equal to 16kEBH?

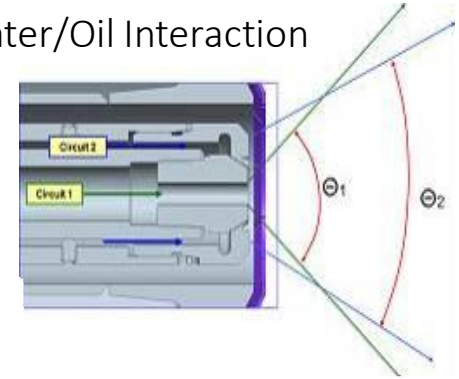
Jose Rafael Serje Polo, 10/1/2018

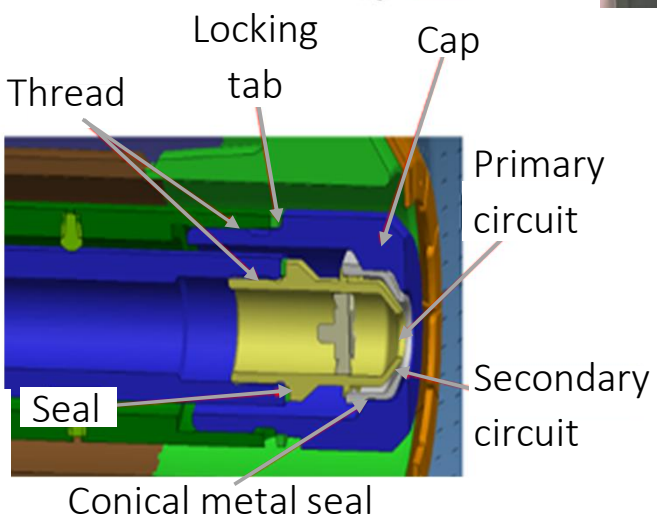
# IIEP 2.0 Combustor Nozzle Details

- Improved Materials
- Heat shield added
- Improved water spray
- Improved oil spray




Water/Oil Interaction




Baseline through oil tip

New Water Spray

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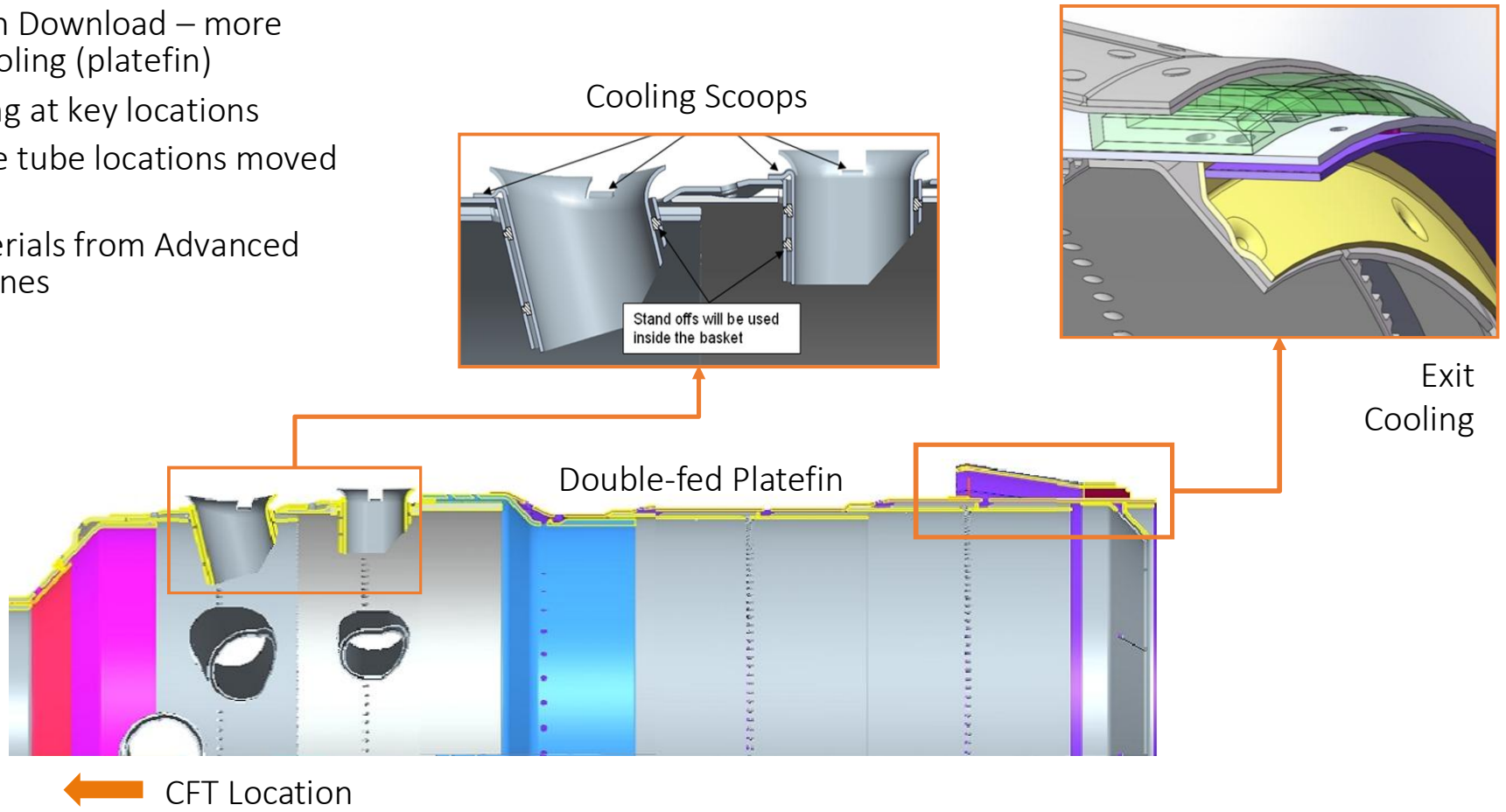
# IIEP 2.0 Combustor Basket Detail

- IGCC Design Download – more efficient cooling (platefin)
- Extra cooling at key locations
- Cross Flame tube locations moved upstream
- Latest materials from Advanced frame turbines



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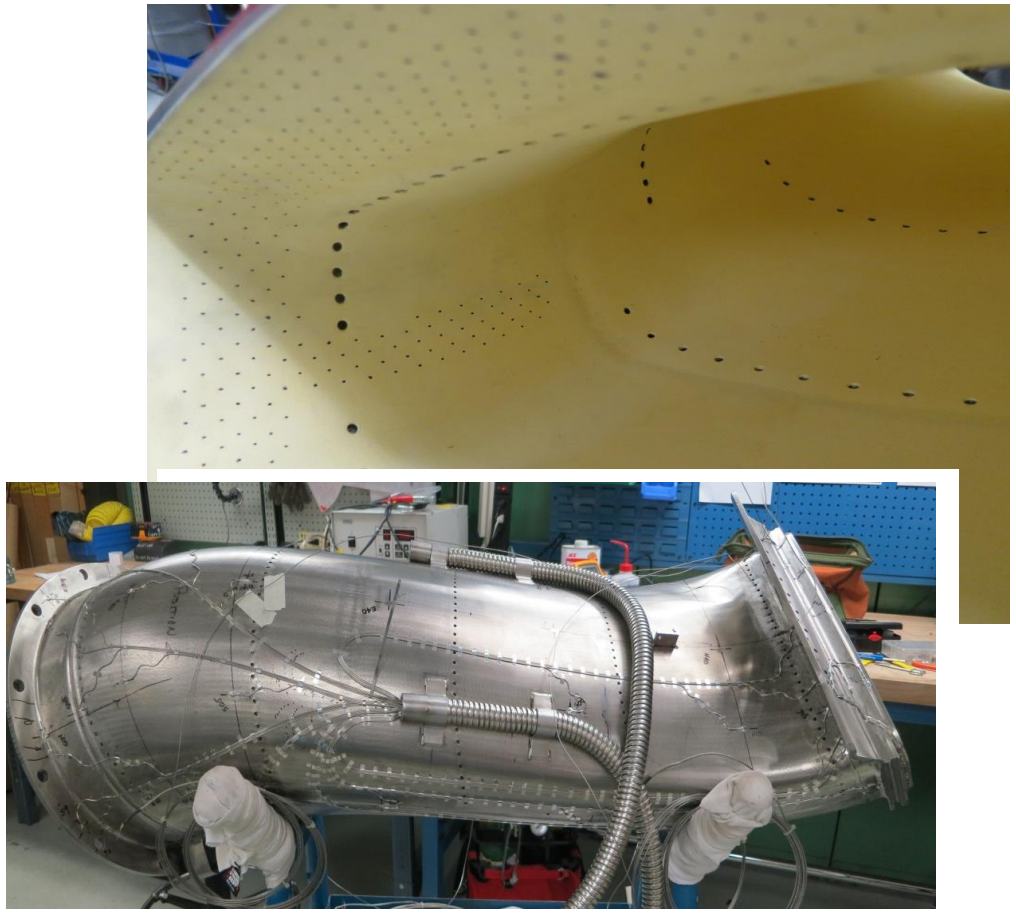
# IIEP 2.0 Combustor Transitions

- Enhanced design
- Smoother shape to reduce stagnation areas
- Flow turned sooner to spread flow
- Thicker panels to resist deformation
- Advanced cooling concept throughout panels
- Effusion cooling where needed
- Integrated Exit Piece (IEP), eliminates outer seal
- Latest materials from advanced frames





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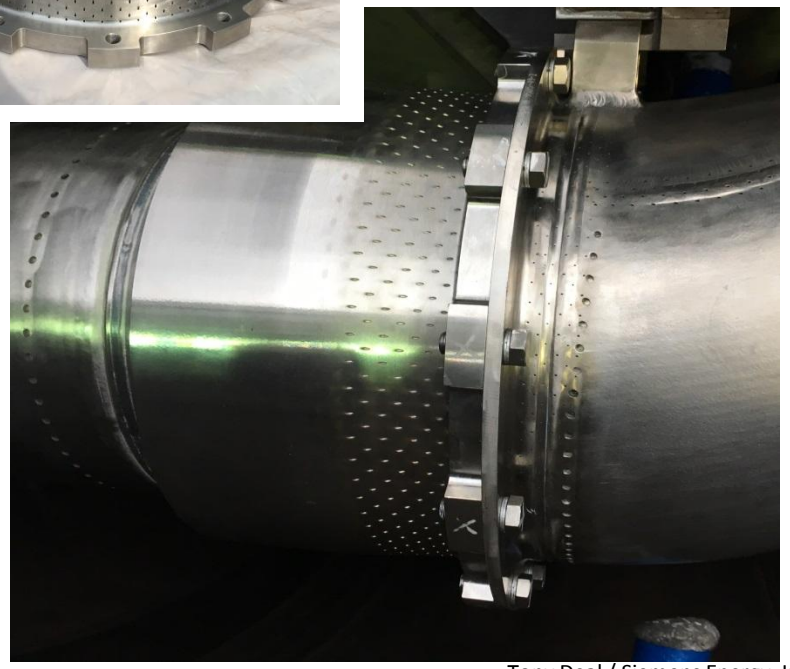
# IIEP 2.0 Bolted Combustor Coupling (BCC)

## Bolted Combustor Coupling (BCC)

- Bolted flange design
- Reduced distortion
- Retrofittable to existing transitions
- No relative motion between mating parts expected
- Scallops between bolts for life extension
- Cooling holes at transition junction
- Hard face mating surface with basket



## Design Experience:

- Installed in Siemens W701DA units since 2000
- Based on validation data – reparability is a goal
- No reported operational issues

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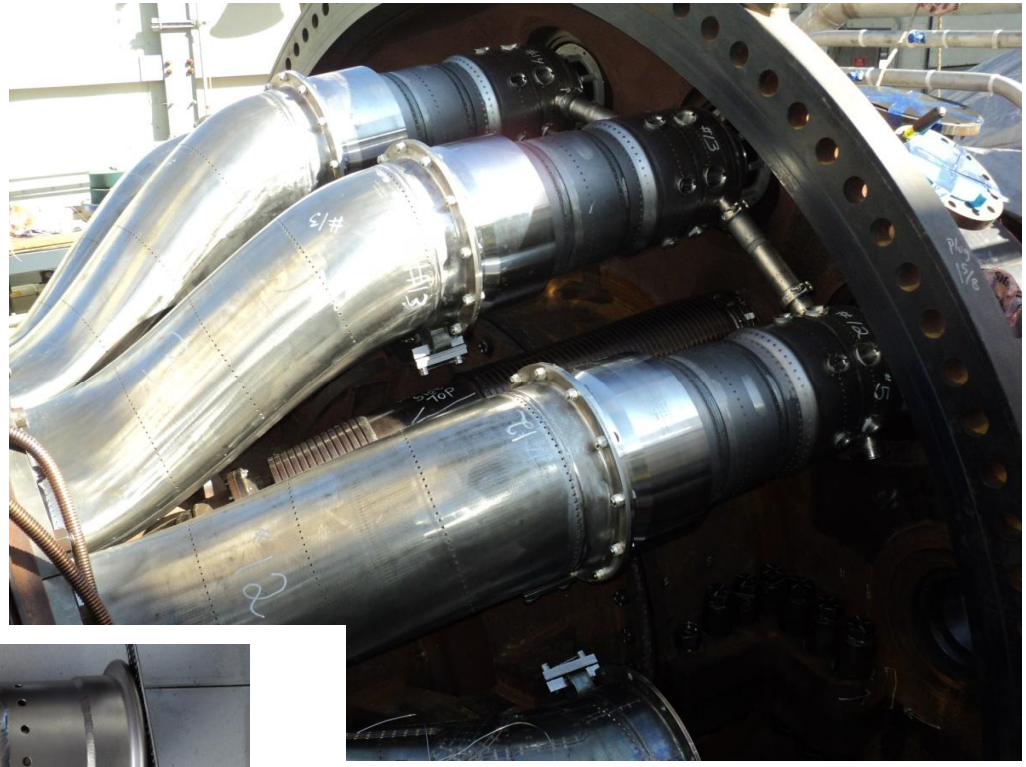
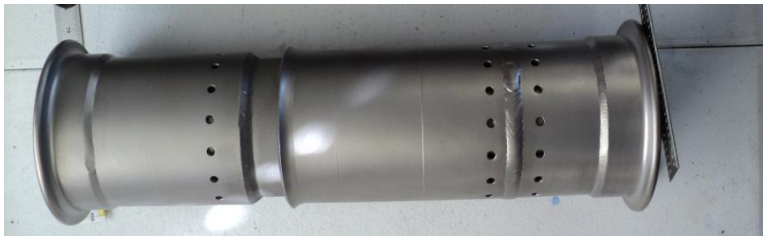
# IIEP 2.0 Combustor System Installed







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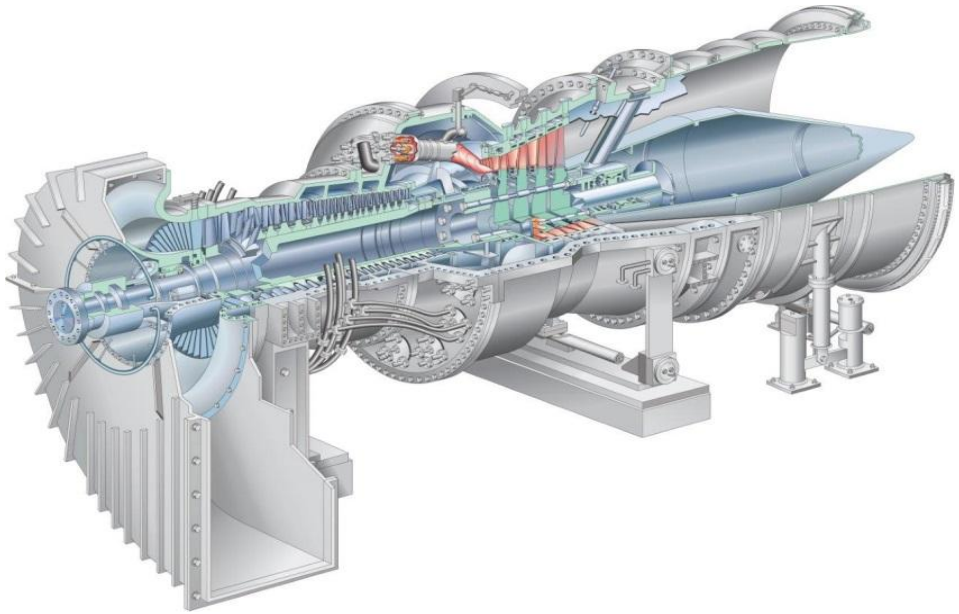

# Termoflores Reference D5A JRSP2
# Project Results – Flores I

| Item | Improvement | Commercial Benefit |
|---|---|---|
| Capacity of 1X1 CC Plant | 6 MW Increase | • More MWh available for sale annually<br>• Displaces duct firing |
| Heat Rate of 2X1 CC Plant | ~376 BTU/kWh decrease | • Reduction in fuel gas costs due to increased GT efficiency |
| Recommended Inspection Interval | JRSP3 2 x current recommended inspection Interval | • Increased plant availability<br>• Reduction in O&M costs |



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## Slide 23

**JRSP2** New slide inserted for Flores 1 (CC 1x1)
Jose Rafael Serje Polo, 10/1/2018

**JRSP3** It should be same as before
Jose Rafael Serje Polo, 10/1/2018

# Termoflores Reference D5A
# Project Results – Flores IV

| Item | Improvement | Commercial Benefit |
|---|---|---|
| Capacity of 2X1 CC Plant | JRSP4 ~10 MW Increase | • More MWh available for sale annually<br>• Displaces duct firing |
| Heat Rate of 2X1 CC Plant | JRSP5 ~287 BTU/kWh decrease | • Reduction in fuel gas costs due to increased GT efficiency |
| Recommended Inspection Interval | JRSP6 2 x current recommended inspection Interval | • Increased plant availability<br>• Reduction in O&M costs |

**JRSP4** 10 MW  in the CC (8,5 Mw from the CT2)
Jose Rafael Serje Polo, 10/1/2018

**JRSP5** -286.93 BTU/kWh with the CT2 upgrade
Jose Rafael Serje Polo, 10/1/2018

**JRSP6** We pass from 10,600 to 16,000 EBH (combustor inspection interval).
Jose Rafael Serje Polo, 10/1/2018

# Key Takeaways
# (from all M&U Product Presentations)

- Advanced ULN combustion system can help achieve < 9 ppm NOx, while supporting advanced thermal performance upgrade products
- Wide array of performance upgrade products; e.g., FD2, per GT, up to 36 MW / - 620 BTU HR
- FD6 rotor technology (pre-swirler) can eliminate air separator and can significantly help improve performance
- Advanced Exhaust Solutions (SPEX and ATP) continue to perform very well
- Products for operating flexibility (LLTD, ALLTD, OTC+, GT-ACO, Inlet Heating) to support changing market demands
- Environmental Permitting and BoP equipment require necessary due diligence for proper implementation of M&U products




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## Thank You!!

Question and Answer



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