GE Aerospace

Demonstration of a Gas Turbine-Scale RDC Integrated with Compressor and Turbine Components at 7FA Cycle Conditions

GE Team

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Agenda

- Overview and Status
- RDC Scaling along F-Class Cycle
- Steady-State Rig Status
- RDC-Turbine Interaction
- Summary and Next Steps

– Overview and Status

Program Overview

Demonstration of a Gas Turbine-Scale RDC Integrated with Compressor and Turbine Components at 7FA Cycle Conditions (2022 – 2026)

Project Team

GE Aerospace Research

Deep expertise:
- RDC and gas turbine design
- Gas turbine testing
- Compressor/diffuser aero
- Turbine aero
- Cooling design, heat transfer

Computational Combustion and Aero

University of Michigan

Prof. Raman

Measurements and Diagnostics

UCF

Prof. Vasu

Georgia Tech

Prof. Steinberg

NC State University

Prof. Narayanaswamy

Project Deliverables

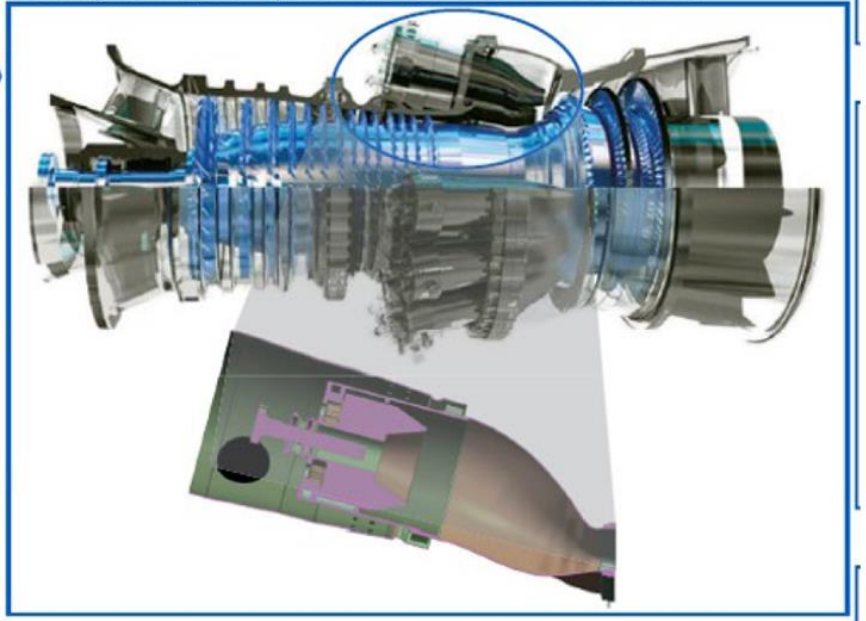
- Low-loss RDC design for turbine integration
- Experimental demos of compressor and turbine integration
- Turbine and compressor component performance estimates in integrated system from detailed test and measurement
- RDC-integrated GT performance estimates

Relevant Prior Work

- Air-cooled RDC demonstration
- RDC operation on natural gas at elevated T,P
- Preliminary gas turbine integration design
- RDC performance estimates
- USAF RDC Program

An 48-month, $8.75M project to develop and demonstrate rotating detonation combustion (RDC) technology in an integrated gas turbine system.

Project Objective(s): Develop low-loss rotating detonation combustor, integrate with upstream and downstream turbomachinery components and verify overall systems performance at F-class turbine conditions.



Technical Approach

- Design air-cooled RDC
- Test with Nat-gas H2 mixtures
- Integrate with compressor and turbine
- Test integrated system
- Verify performance based on high-fidelity data

Technical Challenges

- RDC operation over large P,T range
- Low-loss RDC inlet design
- Fuel flexible operation
- Unsteady flow effects on compressor and turbine performance

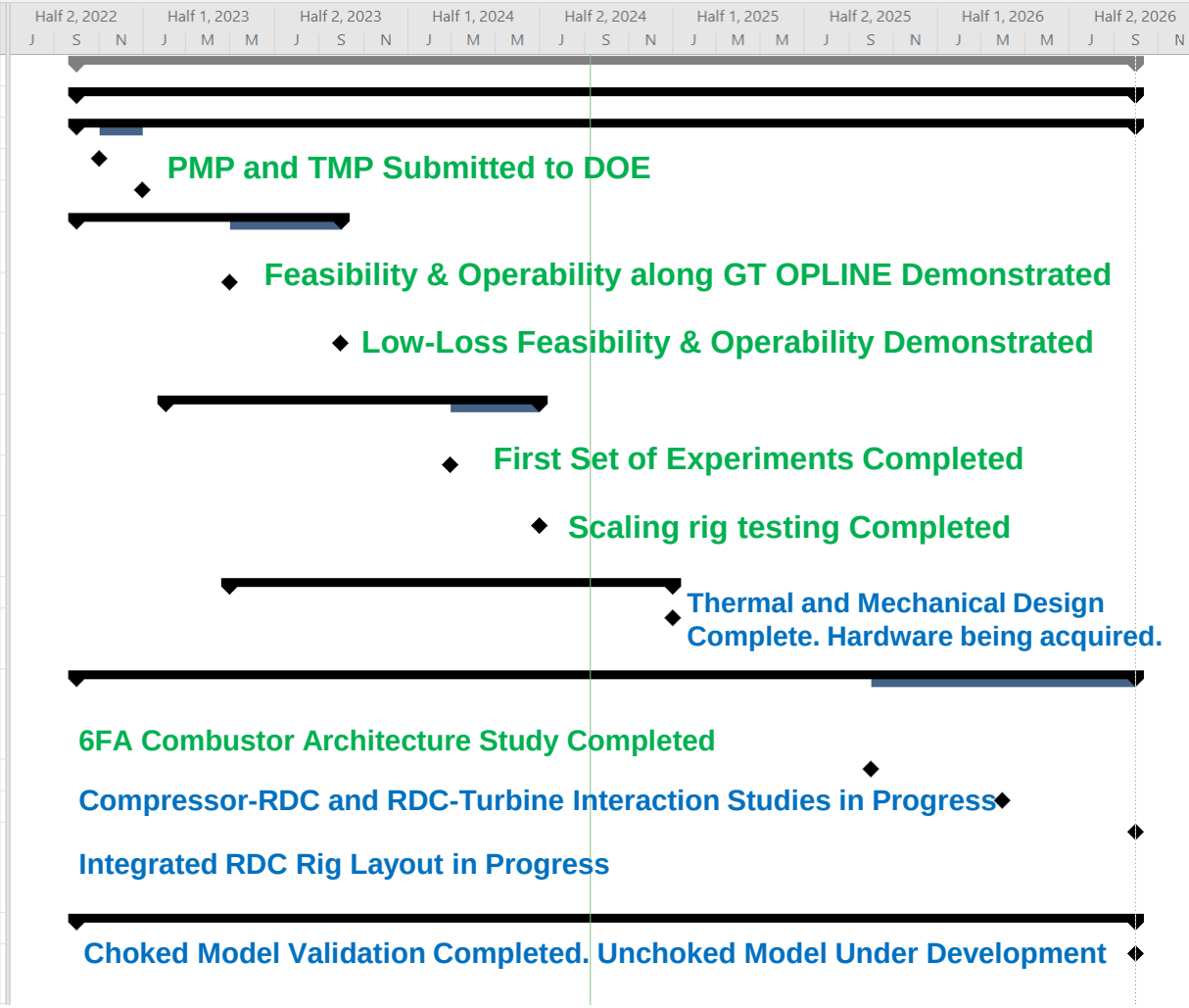
Program Schedule, Status, and Milestone

Complete

In Progress

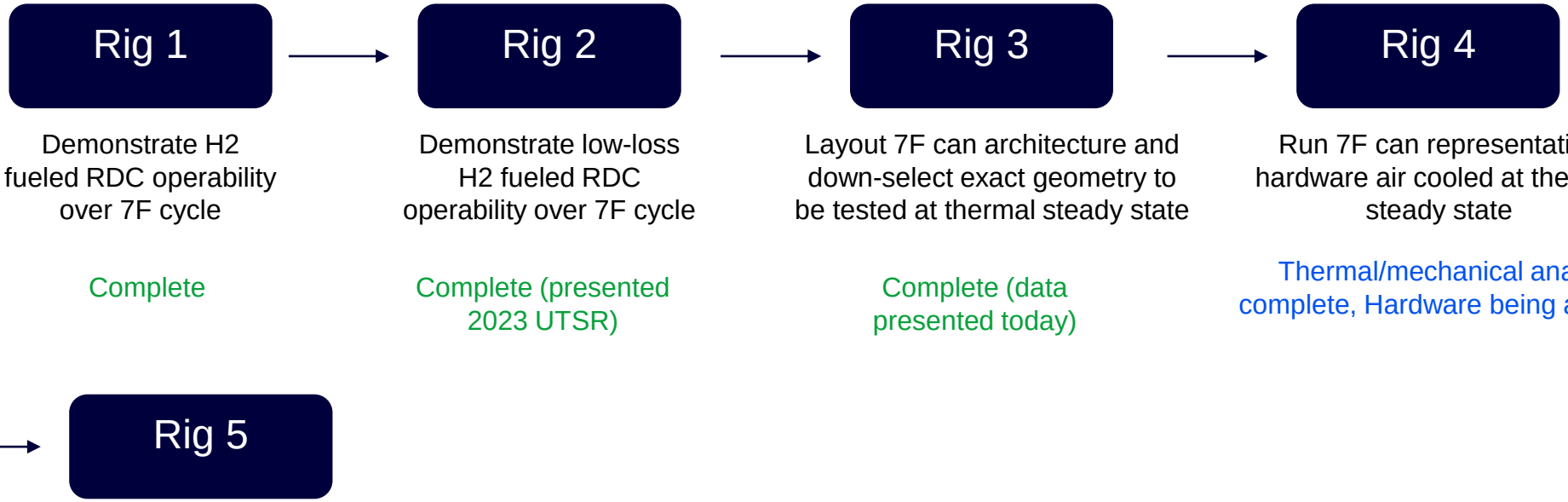
	Text	% Complete	Task Name	Duration	Start	Finish
0	Task	0%	**GRC-DOE_RDC**	**1044 days**	**Sat 10/1/22**	**Wed 9/30/26**
		0%	**Appendix L : AOI 12**	**1044 days**	**Sat 10/1/22**	**Wed 9/30/26**
1		100%	**Task 1 : Project Management and Planning**	**1044 days**	**Sat 10/1/22**	**Wed 9/30/26**
3		100%	Submission of Project Management Plan to DOE	0 days	Mon 10/31/22	Mon 10/31/22
4		100%	Submission of Technology Maturation Plan to DOE	0 days	Fri 12/30/22	Fri 12/30/22
2		100%	**Task 2 : Low-Loss RDC Feasibility and Operability along 7FA Op Line**	**262 days**	**Sat 10/1/22**	**Sat 9/30/23**
6		100%	Feasibility and Operability along GT OPLINE Demonstrated	0 days	Sun 4/30/23	Sun 4/30/23
7		100%	Demonstration of Low-Loss RDC Feasibility and Operability along 7FA Op Line	0 days	Sat 9/30/23	Sat 9/30/23
3		100%	**Task 3 : Development of Design Rules, Scaling Laws, and Validated Tools for RDC**	**369 days**	**Wed 2/1/23**	**Sun 6/30/24**
9		100%	First Set of Experiments for Design Rules and Scaling Laws Complete	0 days	Wed 2/28/24	Wed 2/28/24
10		100%	Development of Design Rules, Scaling Laws, and Validated Tools for RDC Complete	0 days	Sun 6/30/24	Sun 6/30/24
4		0%	**Task 4 : Demonstration of Thermal Steady State RDC**	**438 days**	**Mon 5/1/23**	**Tue 12/31/24**
12		65%	Demonstration of Thermal SS RDC Operation along 7FA Op Line	0 days	Tue 12/31/24	Tue 12/31/24
5		0%	**Task 5 : Demonstration of Upstream and Downstream Turbomachinery Boundary Conditions Integrated RDC along 7FA Op Line**	**1045 days**	**Sat 10/1/22**	**Wed 9/30/26**
14		50%	Preliminary Assessment of BC Intergrated RDC Complete	0 days	Tue 9/30/25	Tue 9/30/25
15		0%	Performance Evaluation of BC Integrated RDC Complete	0 days	Tue 3/31/26	Tue 3/31/26
16		0%	Demonstration of Upstream and Downstream Turbomachinery Boundary Conditions Integrated RDC along 7FA Op Line	0 days	Wed 9/30/26	Wed 9/30/26
6		0%	**Task 6 : System Integration and Component Performance**	**1045 days**	**Sat 10/1/22**	**Wed 9/30/26**
18		10%	Report on System Integration and Component Performance	0 days	Wed 9/30/26	Wed 9/30/26

GANTT CHART



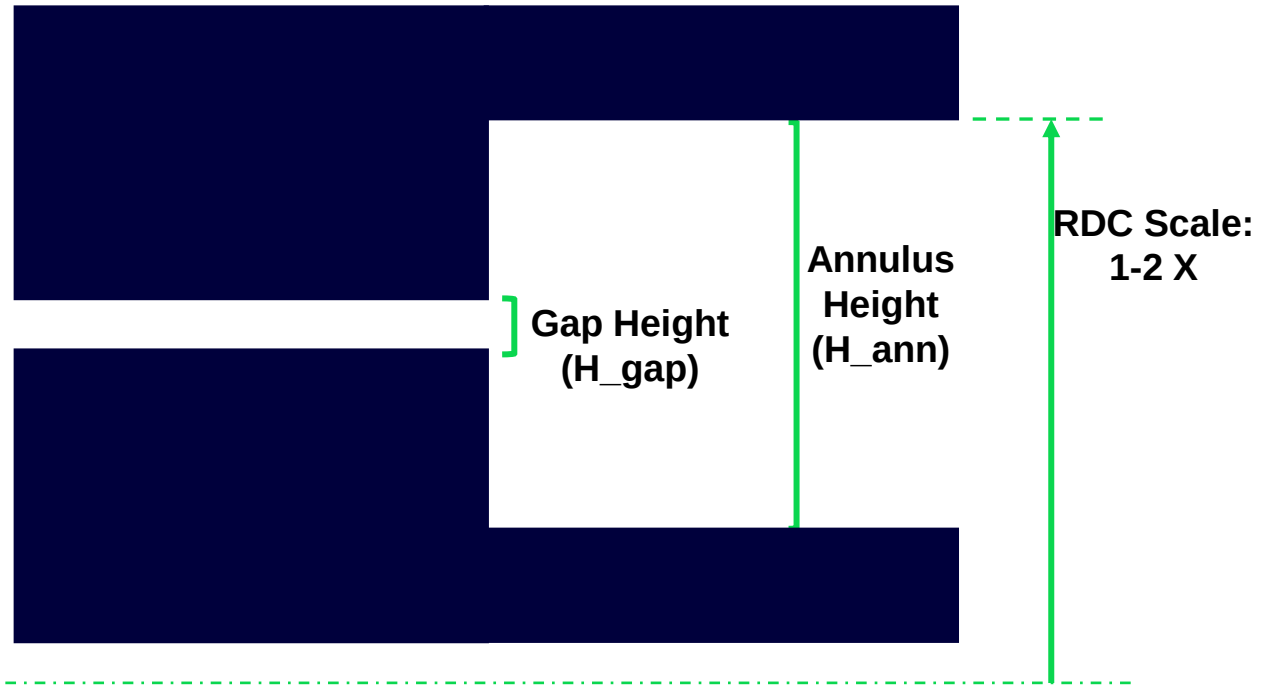
Experimental Approach

Experimental Rig Progression

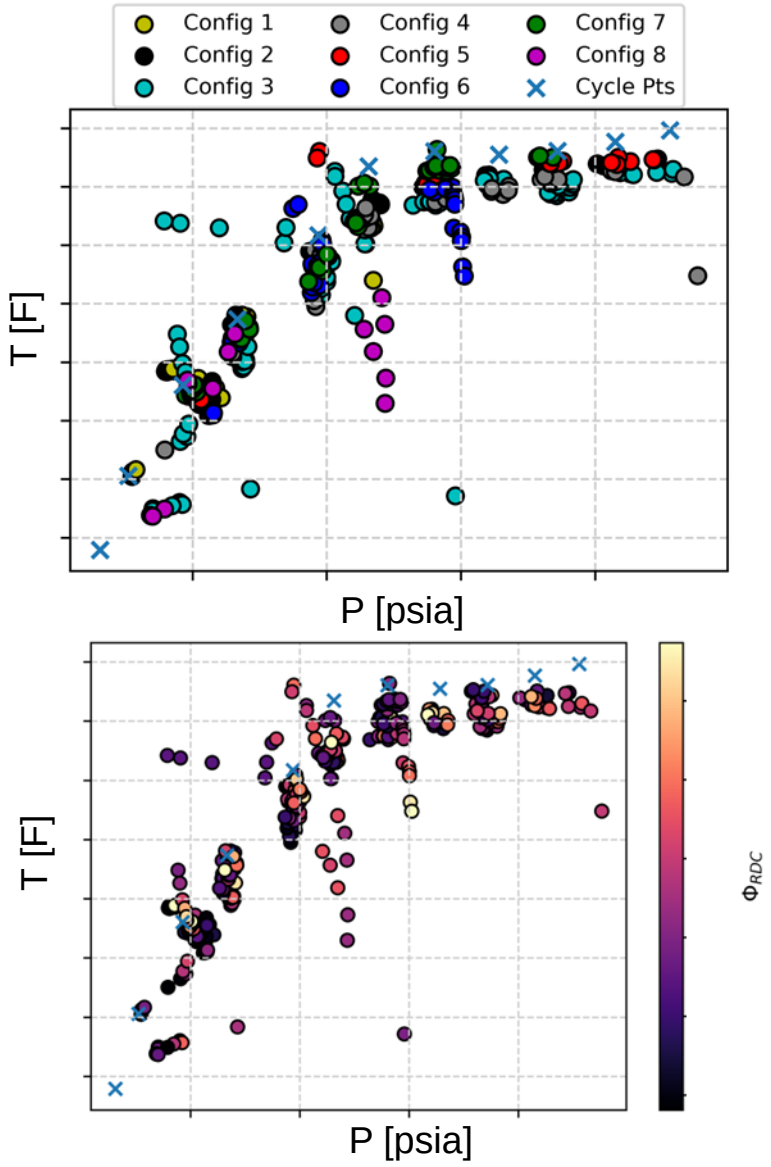


Configurations Tested

H_gap	H_ann	H_gap/H_ann	A_gap/A_ann	Fuel Inj. Distance
0.88-1.33x TSS	0.75-2.08x TSS	0.48-1.33x TSS	0.73-1.30x TSS	0.66-1.33x TSS



Data range relative to final down-selected hardware



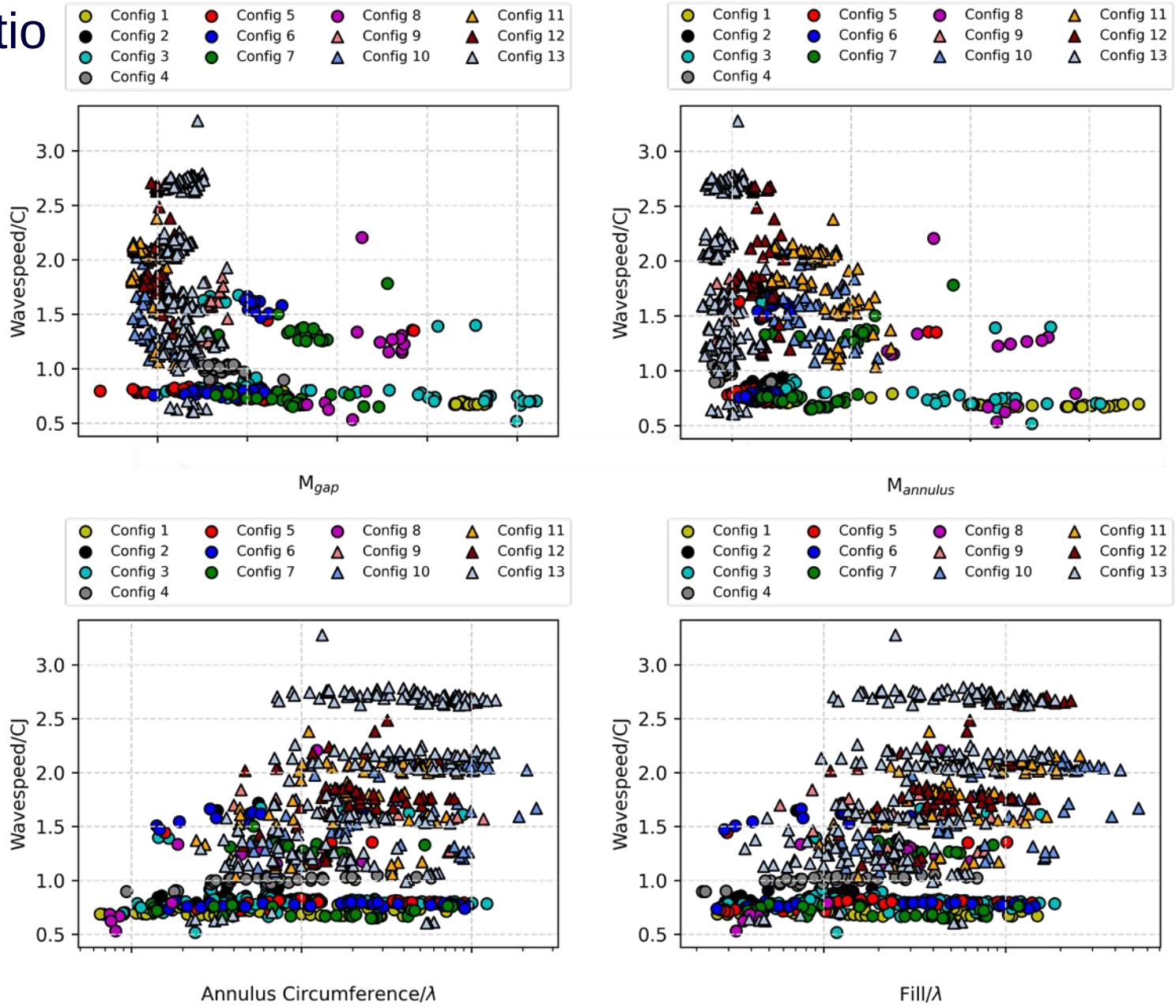
- Operability demonstrated over the 7F cycle
- All cases are sustained detonations

Wave Speed: CJ Velocity Ratio

- Wave speed calculated based on peak FFT frequency
- Most cases ~0.75 indicating single wave operation

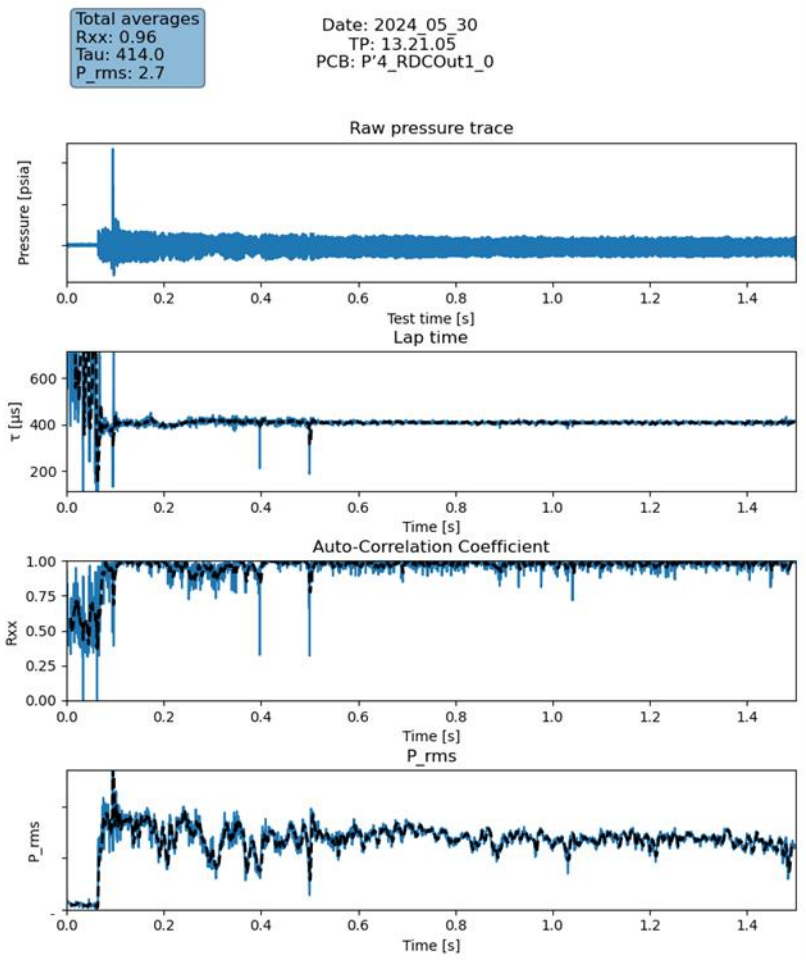
● 1x scale RDC

▲ 2x scale RDC

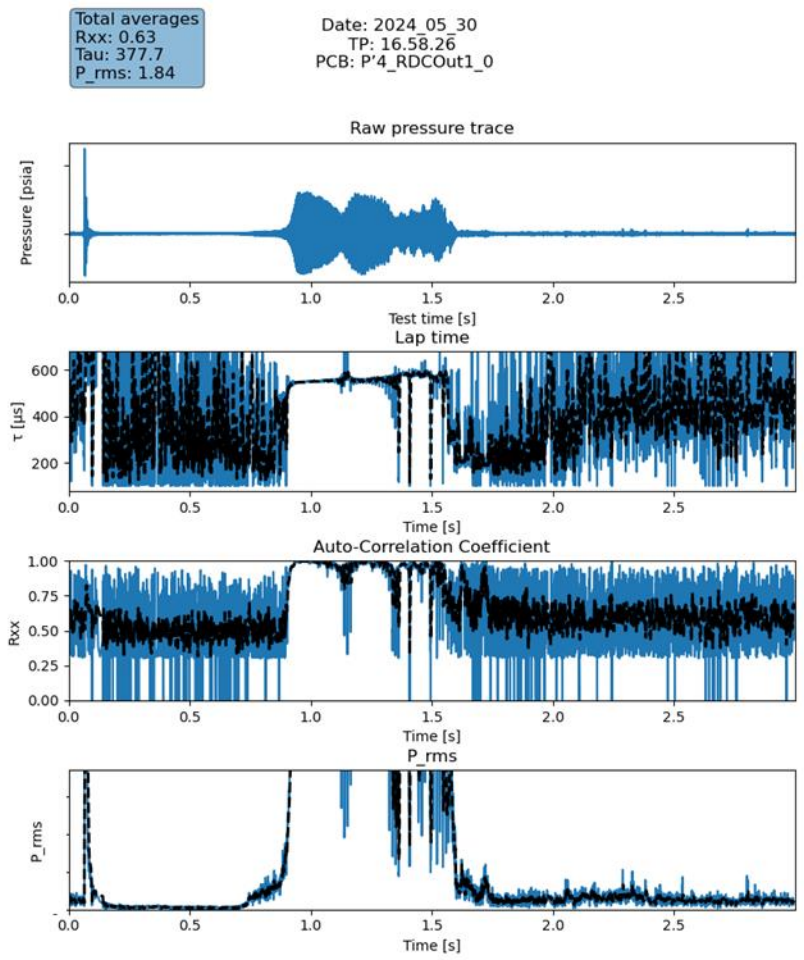


Autocorrelation

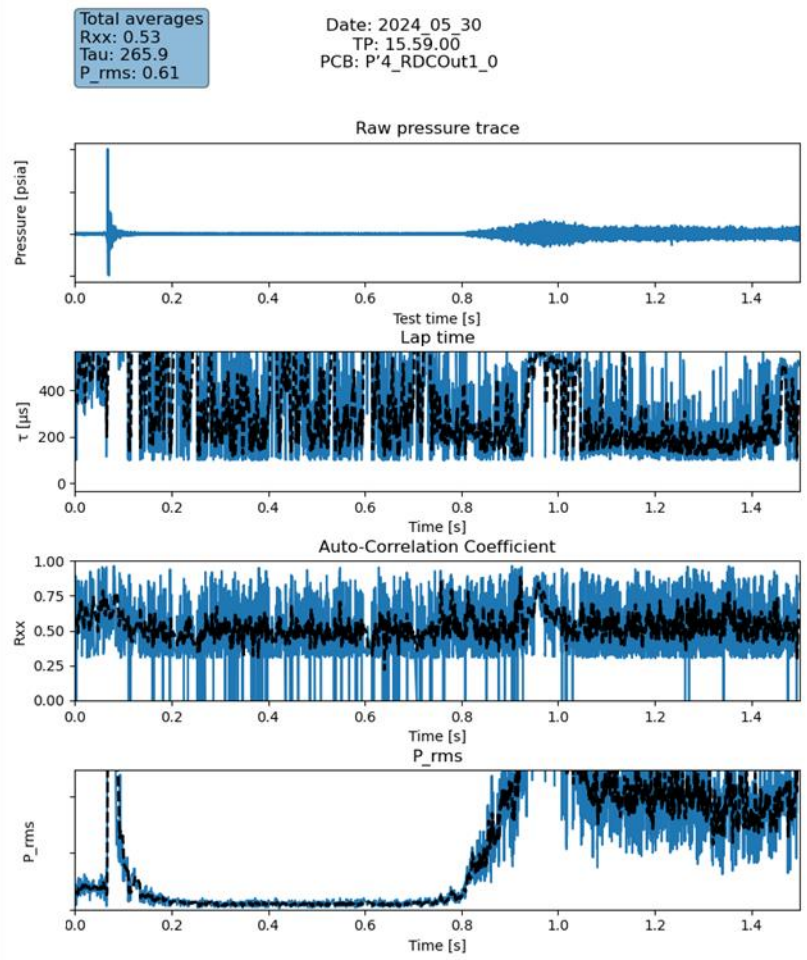
Sustained detonation



Intermittent detonation

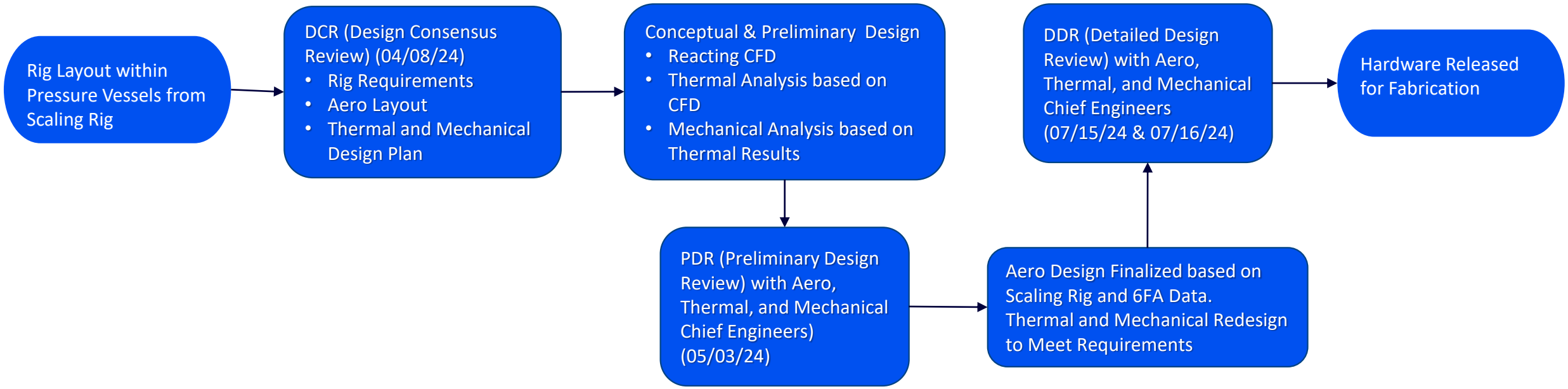


Deflagration

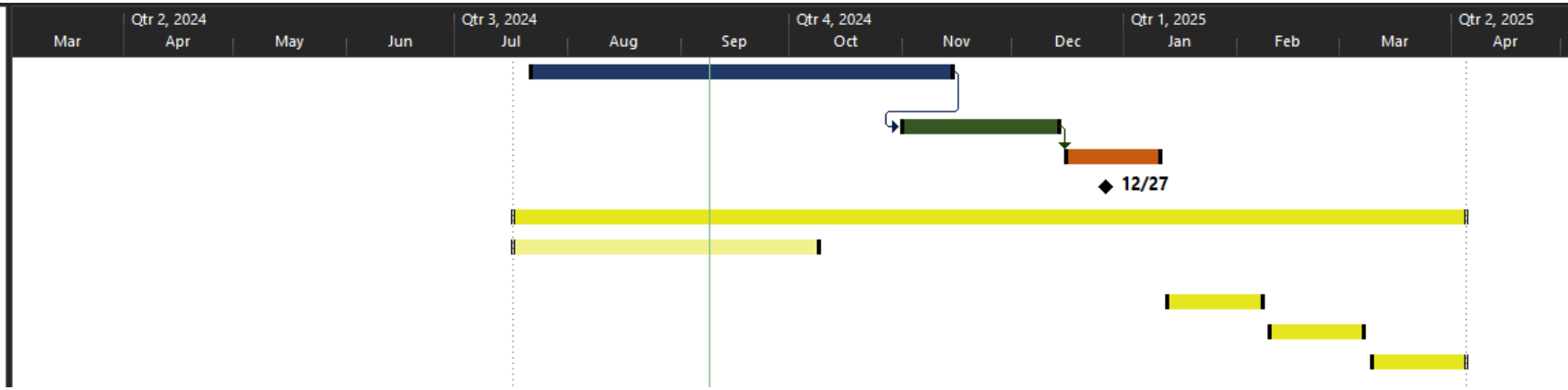


– Steady State Rig Status

Steady State Rig Design Approach



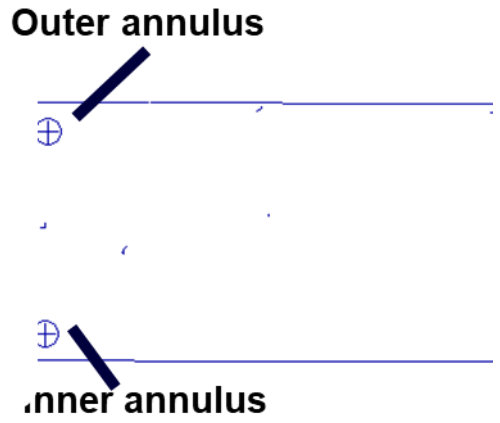
Task Mode	Task Name	Duration	Start	Finish	Predecessors
	Hardware Acquisition	84 days	Mon 7/22/24	Thu 11/14/24	
	Buildup	31 days	Fri 11/1/24	Fri 12/13/24	1FS-5 days
	Testing	20 days	Mon 12/16/24	Fri 1/10/25	10
	Thermal SS first fire	0 days	Fri 12/27/24	Fri 12/27/24	
	Subs	188 days	Wed 7/17/24	Fri 4/4/25	
	Modified Hardware	60 days	Wed 7/17/24	Tue 10/8/24	
	UCF	20 days	Mon 1/13/25	Fri 2/7/25	17
	GT	20 days	Mon 2/10/25	Fri 3/7/25	
	NCSU	20 days	Mon 3/10/25	Fri 4/4/25	

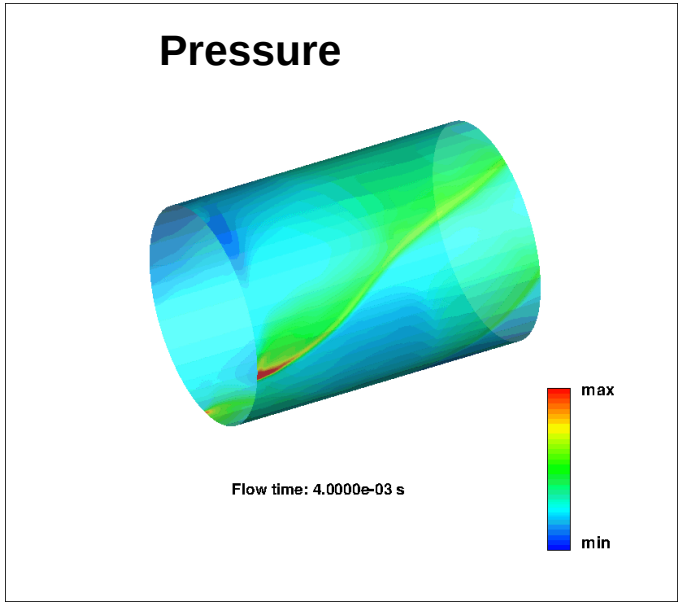


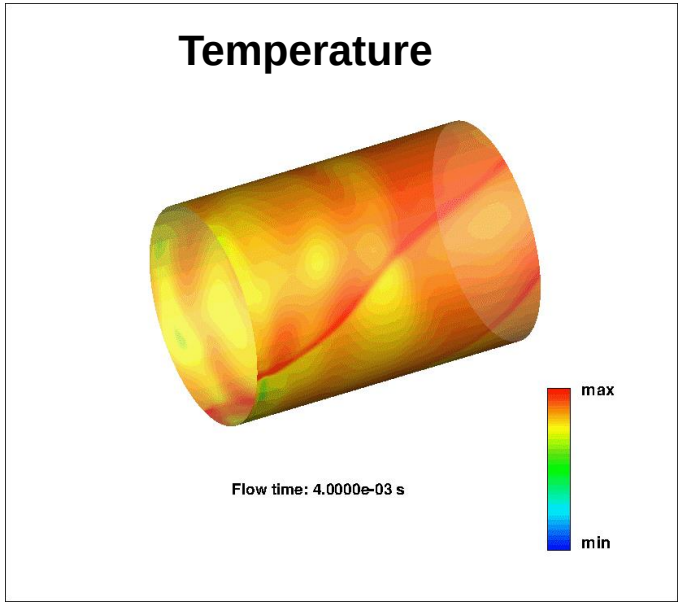
SS Rig : CFD

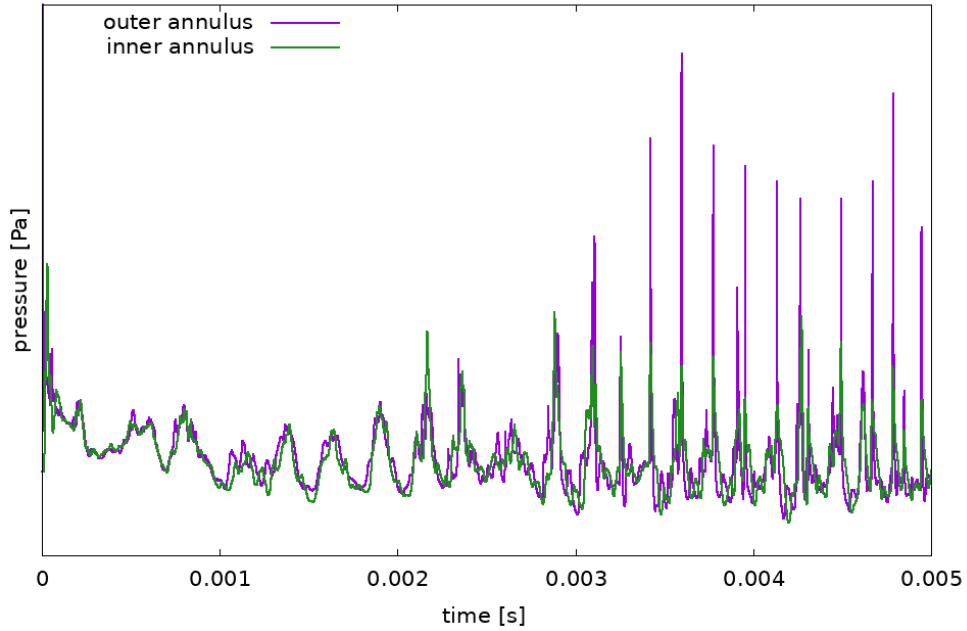
Example Reacting Flow Case for Axial Rig:

- Configuration 3 geometry
- CP3 at dP/P ~ 0.2 and eq. ratio = 1
- Detonation wave establishes after 3 ms









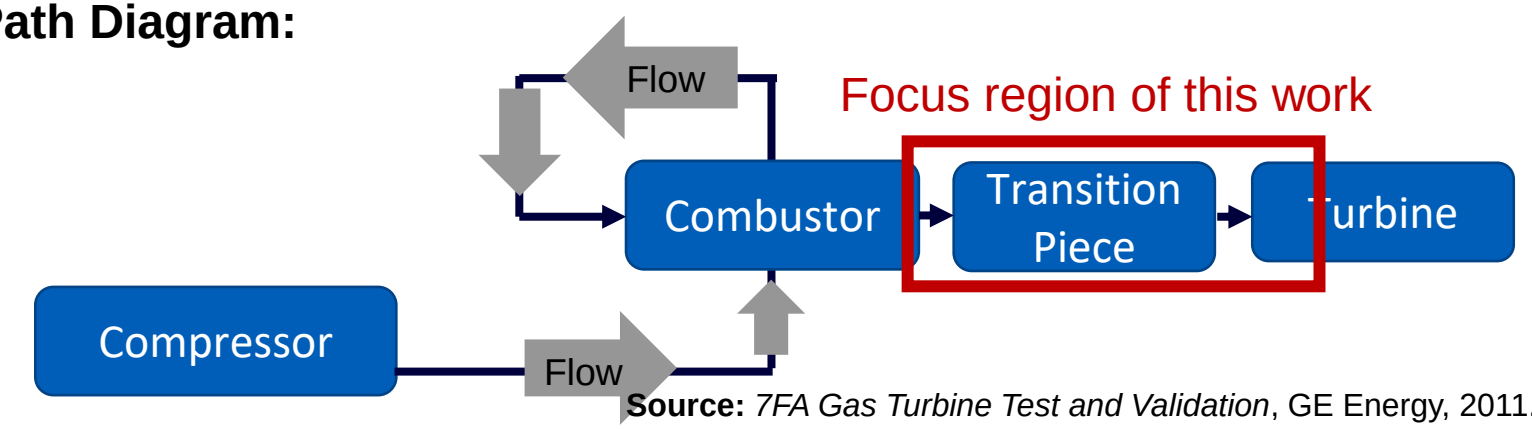
- One strong detonation wave (τ_{cycle} ~ 1.7E-04 sec) and one weaker wave predicted
- Time-averaged temperature & pressure data provided to thermal & mechanical teams to develop steady-state rig capabilities

RDC-Turbine Integration

RDC Integration into Engine System

- Drop-in reverse-flow combustor for gas turbine application

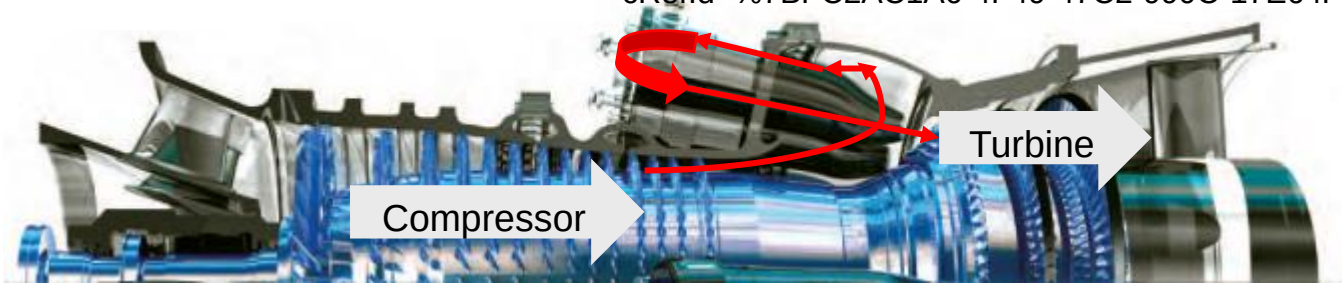
Flow Path Diagram:



Source: *7FA Gas Turbine Test and Validation*, GE Energy, 2011.

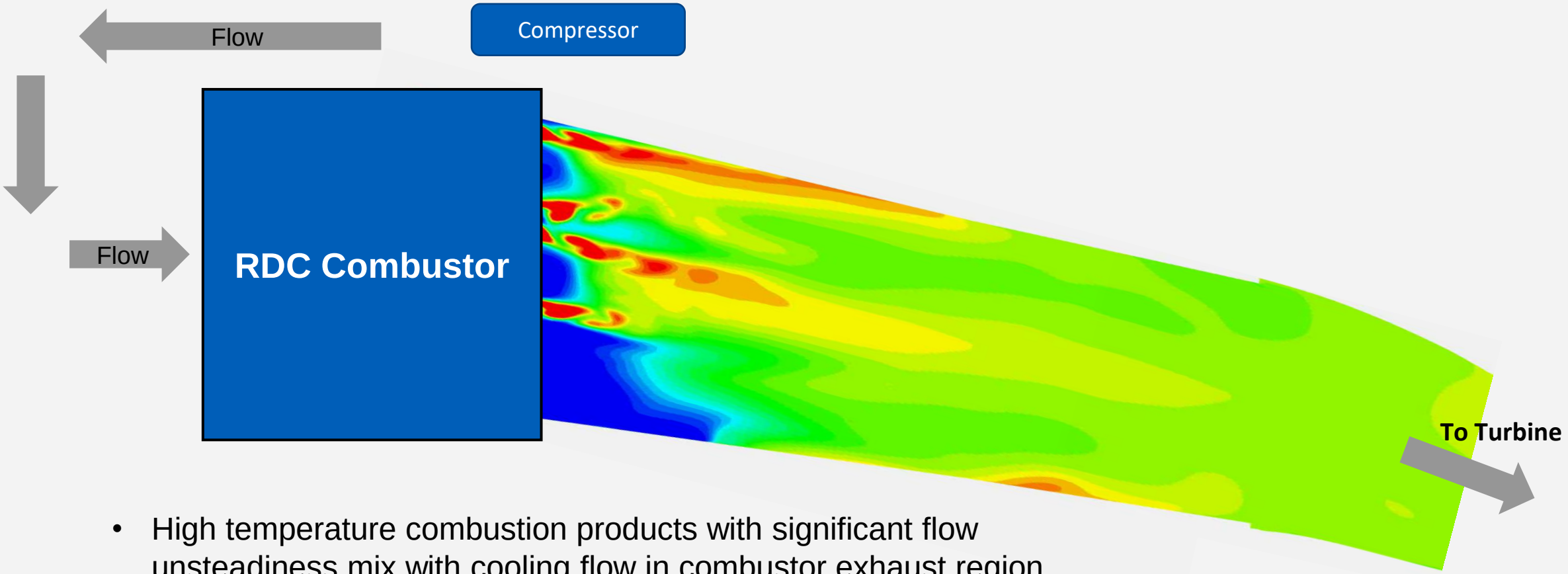
Engine X-Section:

https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BFC2AC1A6-4F49-47C2-990C-17E64F9B0E82%7D



RDC combustor adds significant unsteadiness to flowfield that is not accounted for in current turbomachinery designs.

Domain Inlet – Temperature Animation



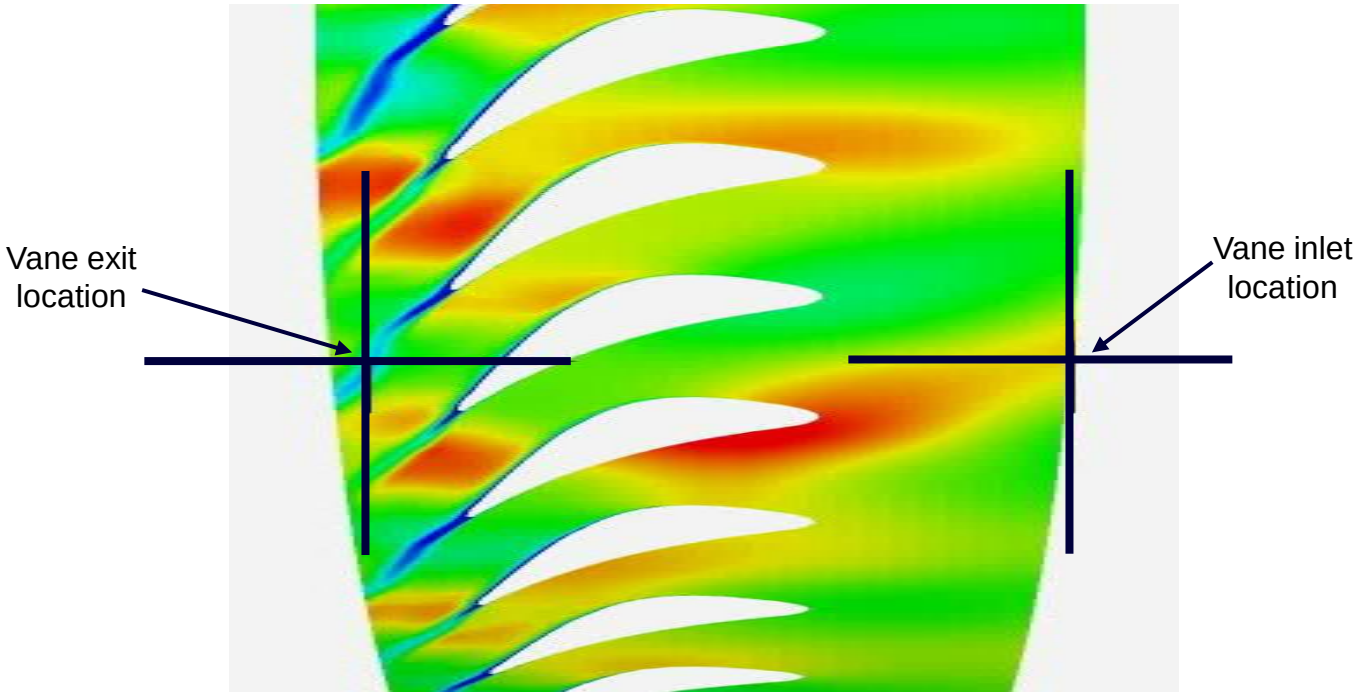
- High temperature combustion products with significant flow unsteadiness mix with cooling flow in combustor exhaust region

Hot gases mix effectively with cooling flow prior to reaching turbine section.

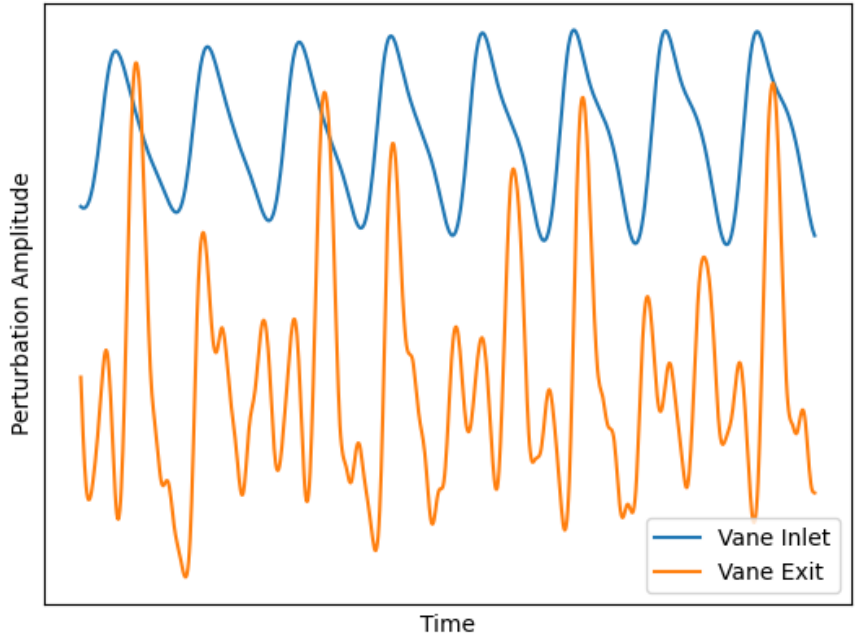
Pressure Waves in Vanes

- RDC unsteadiness breaks down into large-scale nonuniform flow disturbances before reaching the turbine vane
- Clear unsteady content aligned with RDC frequency upstream and downstream of vane

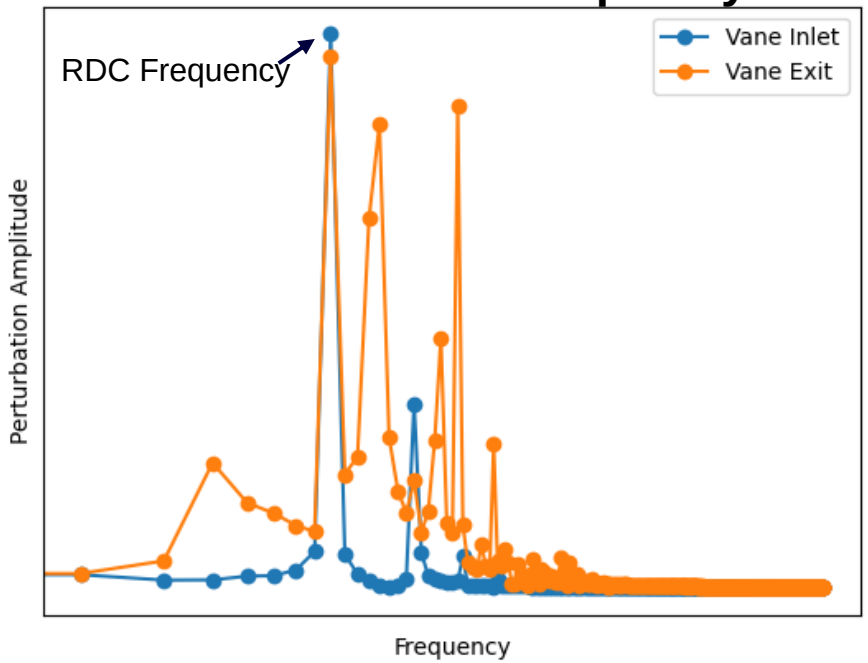
Contours of Total Pressure



Pressure Probe Data -- Time Domain



Pressure Probe Data -- Frequency Domain



– Summary and Next Steps

Summary And Next Steps

- Task 3 : Scaling rig testing completed.
- Task 4 : Thermal steady state design finalized. Hardware being acquired.
- Task 5 : Preliminary RDC-Turbine interaction study completed. Laying out Integrated-RDC rig.
- Task 6 : Choked model validated. Unchoked in progress.

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