PARAMETRIC SOLUTIONS INC.
PRODUCT DEVELOPMENT SERVICES

NATIONAL ENERGY TECHNOLOGY LABORATORY

Zero-Emissions Supercritical Carbon Dioxide Syngas Oxy-Combustor Development & Testing Program

US D.O.E. Award DE-FE0031922

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University Turbine Systems Research and
Advanced Turbines Program Review

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Project Objectives

The objective of the project is to develop a syngas-fueled combustor for high-pressure, high-temperature, oxy-fuel, sCO_2 power cycles, with particular focus to the Allam-Fetvedt (AF) Cycle, in order to lower the cost of power with near-100% carbon capture.

- Raise the TRL level of AF Cycle combustors operating on Syngas from 3 to 6.
- Design a combustor for AF Cycle applications, operating on Syngas fuel, such that the technology can be readily applied to a combustor operated at a 200-300 MWe AF plant.
  - Syngas can be from gasified coal or gasified biomass for negative emissions
  - Combustor can also use natural gas or methane as fuel
- Manufacture the combustor and associated hardware to allow it to be installed and tested at the existing NET Power facility in La Porte, Texas.
- Modify the existing NET Power facility in La Porte, Texas to allow for installation and operation of the combustor running on Syngas (necessarily will include natural gas operation).
- Test the combustor to validate TRL 6 and readiness for commercialization.

Project Plan

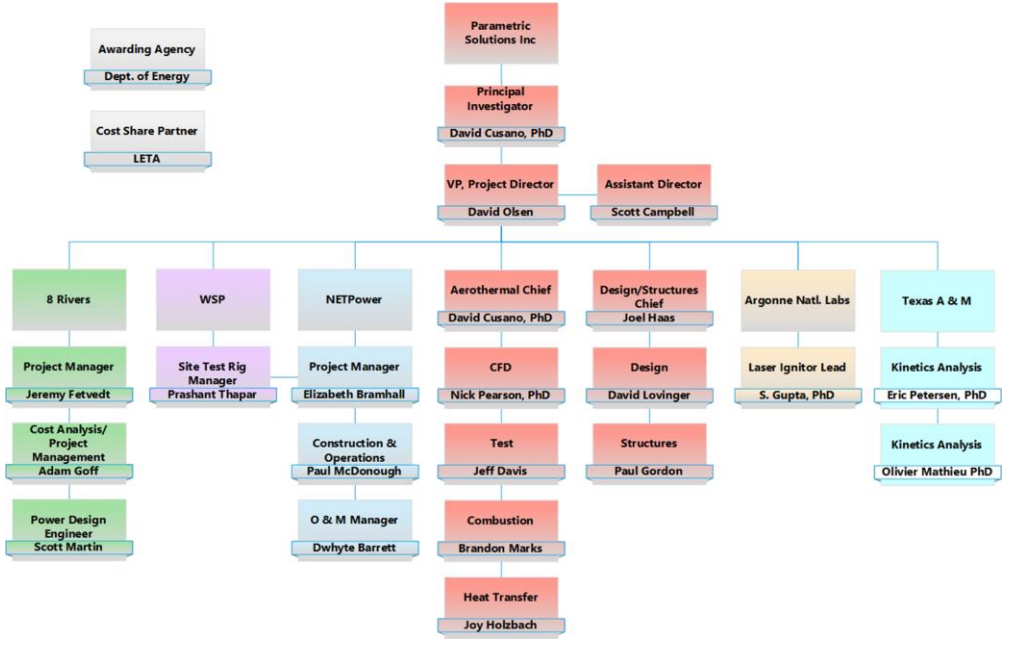
New Syngas Combustor and Test Rig Operated at A-F Cycle Demo Plant

- Development Combustor based on previous successful 300 bar sCO2 combustor testing
  - 20 MWth development combustor operated at full pressure.
  - Designed for three syngas compositions and natural gas.
- Production-like combustor, leveraging learning from development combustor testing.
- Modify existing demonstration plant for A-F Cycle
  - Replace sCO2 turbine with a multistage orifice and quill shaft
  - Syngas capability addressed through CO and H2 tube trailers, mixed to create syngas compositions.
  - Combustor operated at 12-20 MWth (limitation due to turbine removal)
  - CO2 capture and recycle provides commercial-like testing
- Successful testing of production-like combustor will allow for commercialization at the 200-300 MWe size

Team Overview

Uniquely Qualified and Global Team Focused on DOE Project

- Parametric Solutions, Inc. (US) – Project Prime
  - 30 years of propulsion engineering, manufacturing and development
  - First company to test sCO2 at 300 bar - 2012
- 8 Rivers, LLC (US) - Subrecipient
  - Patented sCO2 cycle – Allam-Fetvedt cycle
- NET Power, LLC (US) - Subrecipient
  - Owns/operates a sCO2 power plant in Texas capable of 20MWt output
- WSP (UK) – Subrecipient
  - Plant construction engineering
- Texas A&M (TEES) (US) – Subrecipient
  - sCO2 Combustion kinetics
- Argon National Laboratory (ANL) (US) – Direct to DOE
  - Laser ignitor development
- Low Emissions Technology Australia (AUS) – Funding Partner & Cost Share Provider
  - Invests in technologies that reduce and remove carbon emissions from energy / heavy industry



Schedule Status

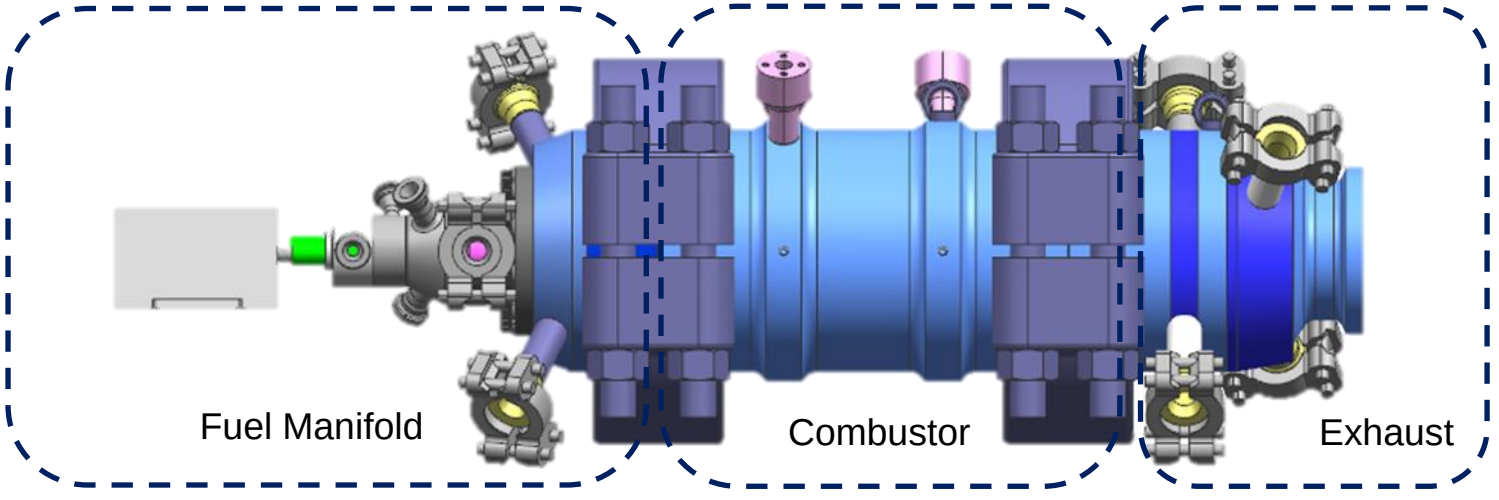
Project on Schedule with Low Risk of Issues

✓ ATP	10/1/2020
✓ Project Management Plan	10/29/2020
✓ Project Kickoff Meeting	11/3/2020
✓ Combustor Concept Design Review (CDR)	2/11/2021
✓ Technical Interchange Meeting #1 - Facility CDR	2/24/2021
✓ Technical Interchange Meeting #2 - Risk Review	4/14/2021
✓ Combustor & Test Facility Preliminary Design Reviews (PDR)	5/13/2021
○ Combustor & Test Facility Detailed Design Reviews (DDR)	5/15/2022
○ Test Facility Commissioning Complete	12/15/2022
○ Development Combustor Hardware Available	3/1/2023
○ Development Combustor Testing	3/15 - 4/15/2023
○ Production-Like Combustor Design Complete	6/30/2023
○ Testing of Production-Like Combustor	8/15 - 9/15/2023
○ Analysis of Test Data Complete	11/15/2023
○ Final Program Report	12/15/2023

Combustor Rig Configuration

Combustor Design Leveraged from Previous Successful sCO2 Demonstration

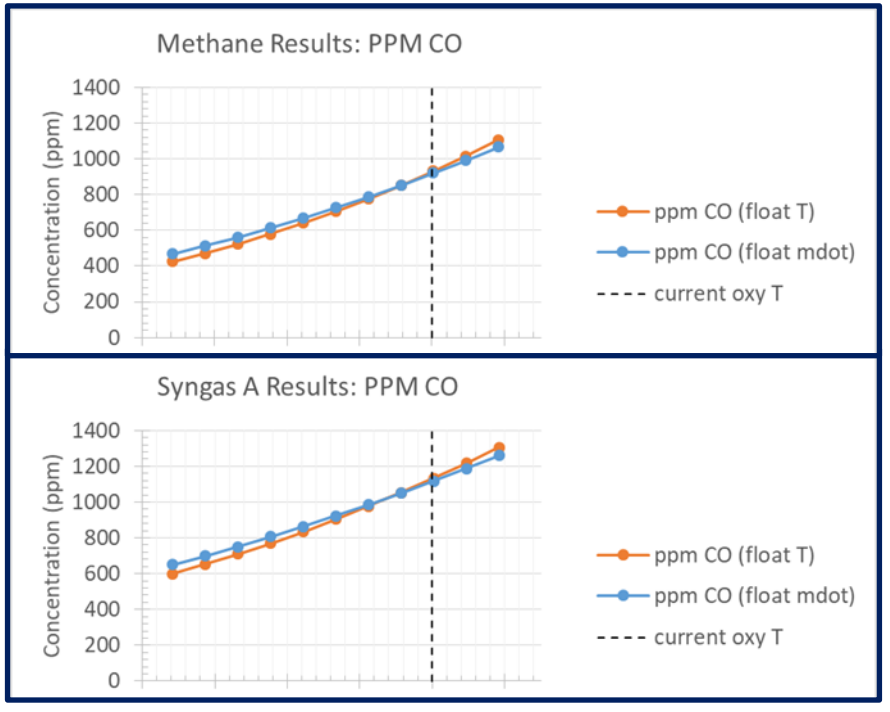
- Syngas sCO2 Combustor Challenges Design & Integration Capabilities
  - Proven natural gas sCO2 combustor architecture used for Syngas system design
  - Common fuel manifold and nozzle for all fuels
  - Common combustor liner for all tests conditions and fuel types
  - Robust instrumentation suite for operational fine-tuning and to support future commercialization
- Modular Design Provides Ease of Assembly, Installation and Access
- Interface Coordination Ongoing with All Project Team Organizations
  - Combustor to test site – physical, functional, instrumentation and installation interfaces baselined.
  - Test site modifications – syngas compressor, MSO, CO & H2 trailers



Kinetics Analysis

Kinetics Models Used to Evaluate all Conditions and Fuel Types

- Kinetics analyses have yielded improvements in emissions throughout the Preliminary Design Phase
- Mixing and volume trade studies performed to determine the influence of different injector, dilution, and cooling configurations on emissions profile.
- Matching kinetics models and combustion CFD validation in process
- Syngas provides the most challenging combustion performance
  - Heat capacity
  - Emissions



Combustor Rig Analysis

Evaluating All Fuel Types, Rig Configurations and Operating Ranges

- Combustion and CFD Analysis
  - Mixing and dilution analysis are prime path to success
  - Part power conditions are limiting operating points
- Thermal and Structural Analysis
  - Thermal environment unique for combustors with reduced transient time/temp
  - Component temperatures to meet full life components using high temperature metals
  - Operating pressures and temperatures drive casing configuration and materials

Syngas Testing Overview

- Leveraging experienced team which has previously completed similar test for NG fired combustor.
- Unique facility allows for:
  - Multiple types of syngas, mixed on demand
  - Learnings applicable to gasified coal, gasified biomass, and natural gas to support zero-to negative-carbon power from a variety of fuel sources to accelerate global decarbonization
  - Operation in representative environment and conditions
  - Commercially relevant size

Plant Site – NET Power

Existing Test Facility Being Readied for Testing in 2022

- NET Power is a clean energy technology company that develops and licenses a proprietary process that generates electricity from natural gas with zero emissions
- This process – called the Allam-Fetvedt Cycle – uses a semi-closed loop, CO2-powered cycle to create cheap electricity while capturing all emissions and producing no air pollutants
- NET Power's test facility in La Porte, Texas achieved first fire in 2018, validating the core technology and becoming the world's first large-scale supercritical carbon dioxide power plant
- NET Power partners with developers and other stakeholders to develop power plants that help the world reach its climate goals. Recently, 8 Rivers announced the development of two commercial-scale Allam-Fetvedt Cycle plants, one in Illinois and one in Colorado

Project Final Report

Following successful design, fabrication and test of development and production-like combustors, a final report will be submitted summarizing the following:

- Development project summary
  - Development and production-like combustor designs
  - Test facility modifications
  - Combustor test results
  - Overall combustor and plant operation findings
- Techno-economic analysis of proposed 200-300 MWe AF-Cycle coal power system
  - Commercial-scale AF-Cycle plant description
  - Capital cost estimates
  - Maintenance requirements
  - Consumables cost estimates
  - Detailed sizing for all critical equipment
  - Commercial implementation feasibility assessment