Optimization of Fairing Geometry for ORPC Modular RivGen Power System

Cooperative Research and Development Final Report

CRADA Number: CRD-23-23451

NREL Technical Contact: Will Wiley

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5700-91320
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NOTICE

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Cover Photos by Dennis Schroeder: (clockwise, left to right) NREL 51934, NREL 45897, NREL 42160, NREL 45891, NREL 48097, NREL 46526.

Cooperative Research and Development Final Report

Report Date: September 17, 2024

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Ocean Renewable Power Company

CRADA Number: CRD-23-23451

CRADA Title: Optimization of Fairing Geometry for ORPC Modular RivGen Power System

Responsible Technical Contact at Alliance/National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s):

Office of Energy Efficiency and Renewable Energy (EERE), Water Power Technologies Office

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	$90,000.00
Year 2, Modification #1	$0.00
Year 3, Modification #2	$0.00
Year 4, Modification #3	$0.00
TOTALS	$90,000.00

Executive Summary of CRADA Work:

The work will optimize the hydrodynamic performance and flow augmentation of Ocean Renewable Power Company's (ORPC) modular fairing for their cross-flow marine hydrokinetic (MHK) turbine, using a computational fluid dynamics study. The influence of the fairing cross-sectional shape and rotor-fairing spacing will be assessed, to maximize power production and minimize structural loads.

CRADA benefit to DOE, Participant, and US Taxpayer:

- Assists laboratory in achieving programmatic scope
- Uses the laboratory's core competencies
- Enhances U.S. competitiveness by utilizing DOE developed intellectual property and/or capabilities

Summary of Research Results:

Task 1: NREL will develop the matrix of fairing geometries and spacings to test using computational fluid dynamics (CFD) simulations. This matrix will be informed by previous CFD work done by NREL for ORPC.

An initial fairing geometry matrix was used for 2D blade-resolved CFD analysis. This first matrix was based on the NACA foil sections and spacings defined in the test plan. The initial matrix was constrained by both the horizontal and vertical limits and the rotor area. Power comparisons of baseline geometries from the 2D blade-resolved CFD did not match previous 3D blade-resolved CFD. Work was done to identify which differences in the 3D domain drove the discrepancy. A limited matrix of 3D fairing geometries was tested with 3D blade-resolved CFD. One configuration with foil shaped vertical components, displayed in Figure 1, showed the potential benefits of design iterations only possible in a 3D domain. An actuator line model was put together for the ORPC turbine to more efficiently explore fairing geometries in a 3D domain.

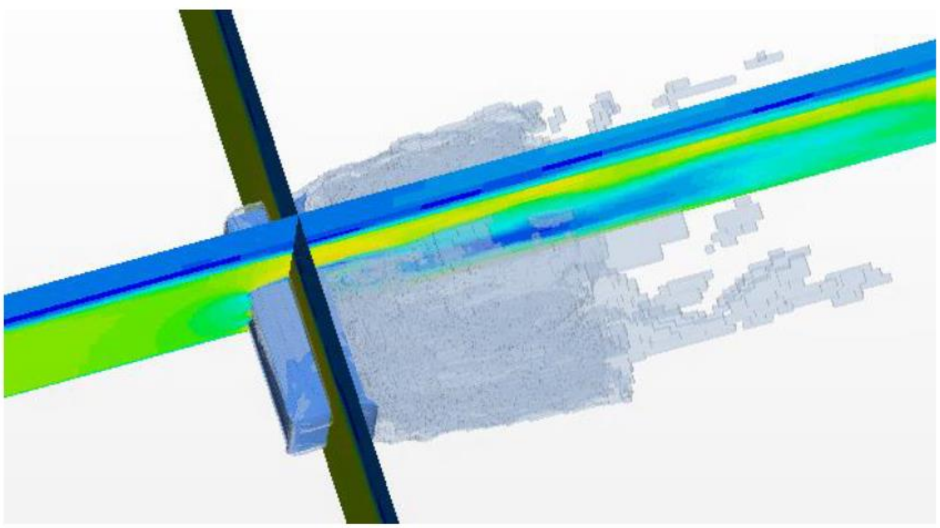

Figure 1. Velocity cross sections and vorticity threshold with support geometry variation with foil shaped vertical components in 3D blade-resolved CFD

Task 2: ORPC will review the test matrix to check for any practical limitations on operations or construction.

ORPC gave the goal practical constraints in the horizontal and vertical dimensions. Two matrices were tested, one with these limits and one without, to determine if significant power production benefits could be gained by exceeding the constraints.

Task 3: NREL will run the computational fluid dynamics (CFD) simulations for each fairing iteration in the matrix from Task 1. The runs will be performed on NREL's High Performance Computer, Eagle.

2D blade-resolved CFD simulations were run for the initial geometry matrix and the geometry matrix that exceeded the horizontal and vertical constraints. Unexpected relative performance between baseline fairing geometries compared to 3D blade-resolved CFD performance led to an expansion of simulations. This included a limited set of geometry iterations with 3D blade-resolved CFD simulations and the construction of a 3D actuator line CFD model. Verification was performed for the actuator line model using the baseline geometries, but there was insufficient time for an expansive geometry test matrix. Figure 2 shows the velocity field from two of the 2D blade-resolved CFD simulations. The two simulations use the same fairing, but different water depths, resulting in different blockages, and demonstrate the strong effect of the domain on the flow field.

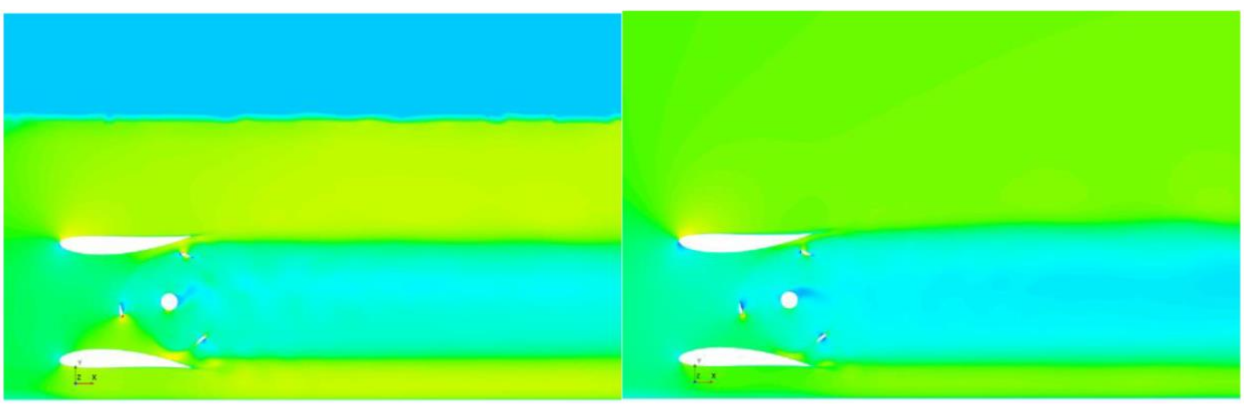

Figure 2. X-direction velocity field with foil fairing shape: c = 2.4 m, m = 4%, p = 50%, t = 14%, aoa = 3 deg, x = -2.0 m, spacing = 2.2 m, with matched depth (left) and matched blockage (right)

Task 4: NREL will post-process the data to quantify net power, ultimate loads, and fatigue loads for each iteration.

Post processing was performed for each completed simulation. This post-processing allowed each fairing geometry to be compared based on net power, net thrust, ultimate loads, and fatigue loads.

Figure 3 and Figure 4 show the normalized post-processed metrics for the full 2D blade-resolved test matrix at two different water depths and blockages.

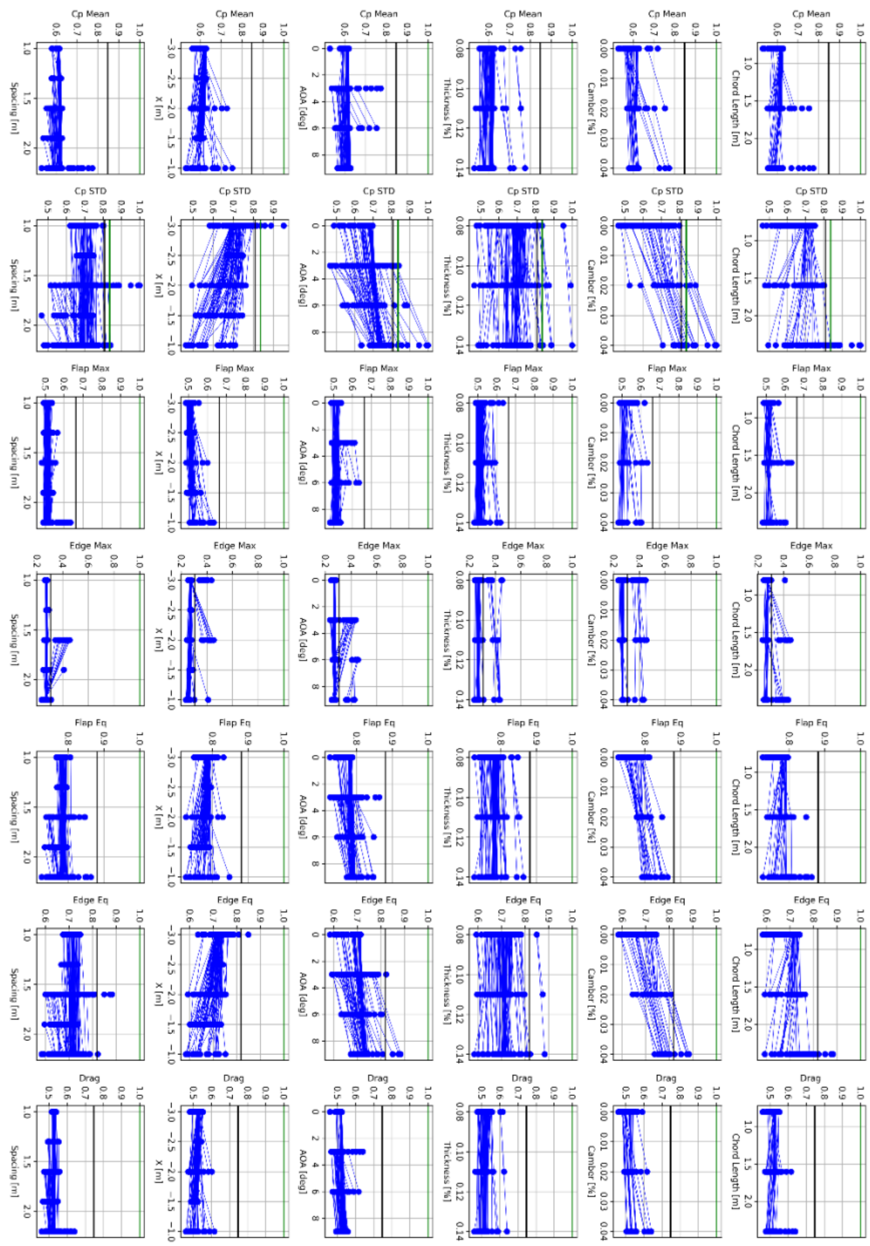

Figure 3. 2D blade-resolved CFD in 5.1 m water depth (same depth as 3D domain) normalized metrics as a function of individual support fairing foil parameters. Connected points share all parameters except x-axis parameter.

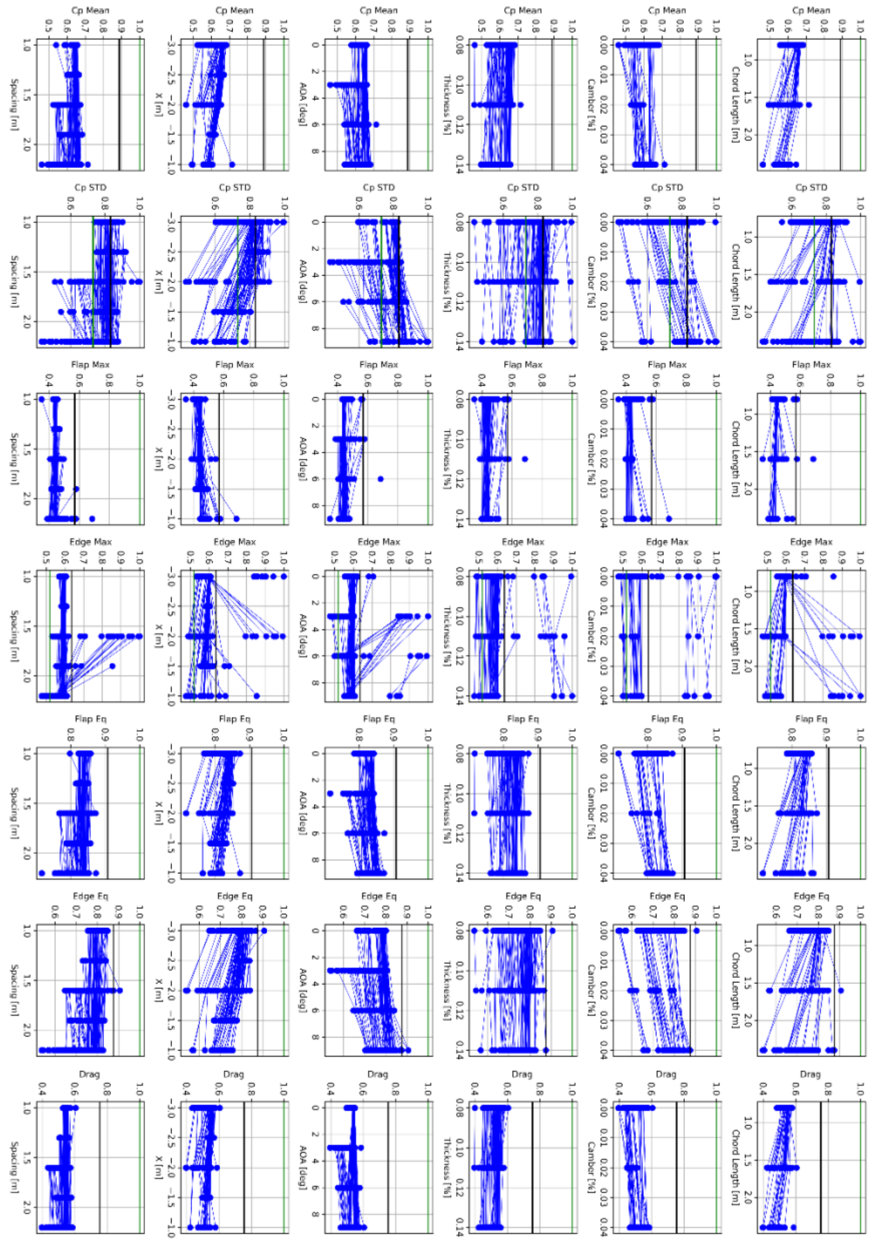

Figure 4. 2D blade-resolved CFD in 12.96 m water depth (same rotor blockage as 3D domain) normalized metrics as a function of individual support fairing foil parameters. Connected points share all parameters except x-axis parameter.

Task 5: NREL and ORPC will look at the results across the matrix and determine if further iterations should be considered. If it appears that performance (high power and low loads) is trending better at the extents of the test matrix, additional designs can be tested in this region.

Additional fairing geometries were studied outside of the original horizontal and vertical constraints.

Task 6: Continued other work at the direction of ORPC, consistent with the scope and subject to the availability of funding.

The actuator line model was constructed to allow ORPC to more efficiently explore the 3D effects of the fairing geometry. Given time and budget constraints this model was not used for an expansive geometry test matrix. The model will be transferred to ORPC to use for future design improvement efforts.

Figure 5 shows the momentum source and velocity field from a verification case of the actuator line simulation.

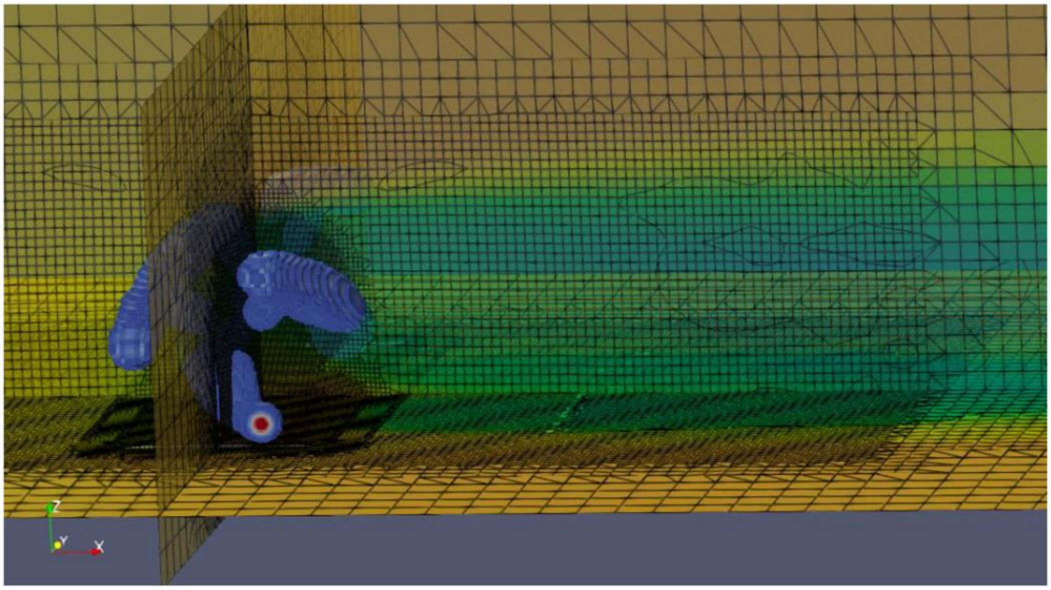

Figure 5. Actuator line (turbinesFoam) source representation and velocity field (OpenFOAM) with reference support structure at a tip speed ratio of 3.0

Figure 6 shows power and thrust verification comparisons of the actuator line model and previously computed 3D blade-resolved results. A strong dependence on the dynamic stall model was demonstrated. The tested dynamic stall model configurations did not accurately capture the effect for this turbine compared to the blade-resolved loads. Figure 7 shows the spanwise torque distribution using additional variations of the time parameters for the dynamic stall model.

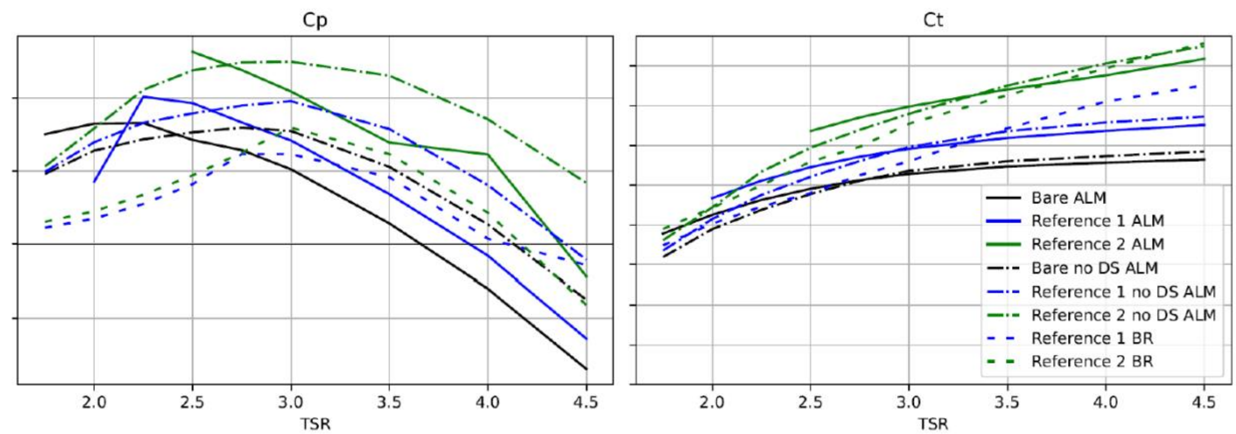

Figure 6. Net power and thrust comparison for actuator line model (ALM) with and without an active dynamic stall model (DS) and blade-resolved (BR) CFD simulations with two reference supports and a bare rotor

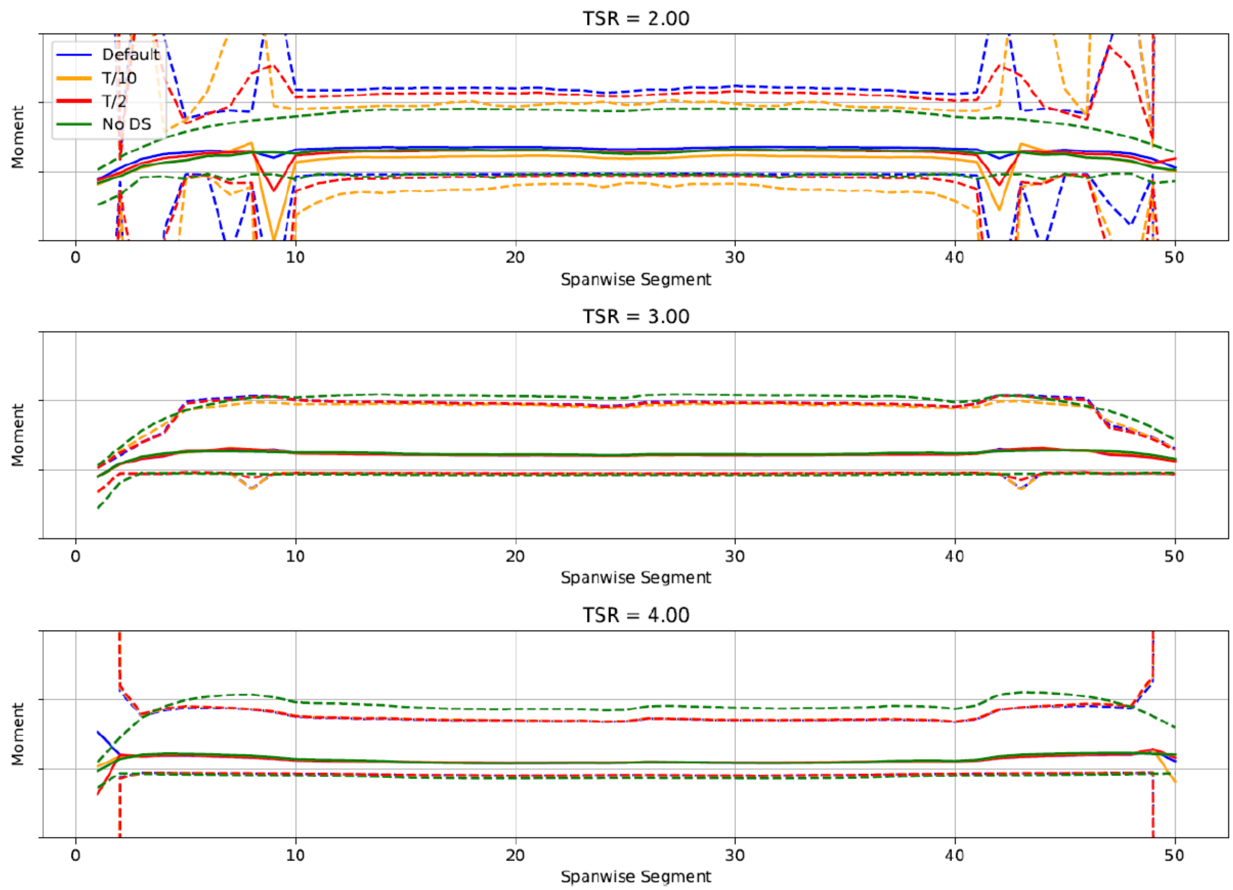

Figure 7. Comparison of varying SGC Leishman-Beddoes dynamic stall parameters on the mean (solid line), minimum, and maximum (dashed lines) moments within a rotation along the span of the blade for the bare rotor at different TSR's

Task 7: CRADA Final Report: Preparation and submission in accordance with Article X will be written by NREL with feedback from ORPC

This report serves to meet the requirement for the CRADA Final Report with preparation and submission in accordance with the agreement's Article X.

References: N/A

Subject Inventions Listing: N/A

ROI#: N/A