



# Support of the Massachusetts — NREL Wind Technology Testing Center

## Cooperative Research and Development Final Report

**CRADA Number: CRD-07-00240**

NREL Technical Contact: Scott Hughes

**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-5000-92235  
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## Cooperative Research and Development Final Report

**Report Date:** November 13, 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:** Massachusetts Technology Park Corporation (d/b/a Massachusetts Technology Collaborative)

**CRADA Number:** CRD-07-00240

**CRADA Title:** Support of the Massachusetts — NREL Wind Technology Testing Center

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

Scott Hughes (Mod 4) | [Scott.Hughes@nrel.gov](mailto:Scott.Hughes@nrel.gov) -- For Nathan Post (Mods 1-3) and Jason Cotrell (PI from original CRADA, Mod 0) No longer at NREL

Derek Berry | [Derek.Berry@nrel.gov](mailto:Derek.Berry@nrel.gov) (Co-Author)

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Rahul Yarala | [RYarala@MassCEC.com](mailto:RYarala@MassCEC.com)

**Sponsoring DOE Program Office(s):**

Office of Energy Efficiency and Renewable Energy (EERE), Wind Energy Technologies Office

**Joint Work Statement Funding Table showing DOE commitment:**

<b>Estimated Costs</b>	<b>NREL Shared Resources a/k/a Government In-Kind</b>
Original Agreement	\$13,511,833.00
Modification #1	\$0.00
Modification #2	\$0.00
Modification #3	\$0.00
Modification #4	\$0.00
<b>TOTALS</b>	<b>\$13,511,833.00</b>

### **Executive Summary of CRADA Work:**

Under the shared-resources CRADA agreement, NREL will collaborate with the Massachusetts Technology Park Corporation, d/b/a Massachusetts Technology Collaborative (MTC), in its efforts to design, construct, and operate the Massachusetts-NREL Wind Technology Testing Center (WTTC), which is an advanced blade testing facility capable of testing blades up to at least 70 meters in length. The WTTC building will be owned and the facility operated by the MTC.

In the CRADA, NREL agrees to provide certain capital equipment and certain NREL employees at the WTTC facility for training, commissioning, and continued technical assistance. In addition, NREL will provide one or more Laboratory staff to serve on any WTTC advisory committee, a no-cost license of the NREL blade-resonance fatigue testing technology (NREL Testing IP) and training to MA staff at the NREL blade test facilities in Colorado. MTC will provide all other resources necessary to design, construct, and operate the WTTC.

### **CRADA benefit to DOE, Participant, and US Taxpayer:**

- Uses the laboratory's core competencies, and/or
- Enhances U.S. competitiveness by utilizing DOE developed intellectual property and/or capabilities.

### **Summary of Research Results:**

#### **Task 1: NEPA environmental assessment**

**Task 1 Description:** The WTTC site was used in the past as a coal terminal and for scrap metal exporting. Possible contaminants of concern include PCBs in groundwater, and soil contaminants including pervasive (throughout the site) PCBs, PAHs, Extractable and Volatile Petroleum Hydrocarbons, lead, zinc, and VOCs (sporadic). DOE requires that an Environmental Assessment be performed. A subcontractor will be hired by NREL to complete an environmental assessment of the site. MTC shall not commence and shall not authorize any contractor to commence, any final design and construction work under this CRADA without written notification from NREL authorizing commencement of final design and construction work determined by the U.S. Department of Energy to be compliant with National Environmental Policy Act requirements. An Environmental Impact Statement (EIS) is not expected to be required; however, if required, the funding for the EIS will be negotiated between the CRADA partners and the schedule for this CRADA shall be extended as appropriate.

**Task 1 Results:** The U.S. Department of Energy (DOE), in coordination with the Massachusetts Technology Collaborative (MTC), and support from NREL, conducted an Environmental Assessment (EA) that analyzed the potential impacts associated with the construction and operation of the Wind Technology Center. DOE determined that providing funding and technical support to construct and operate the WTTC would not constitute a major Federal Action significantly affecting the quality of the human or natural environment, as defined by the National Environmental Policy Act (NEPA). DOE determined the preparation of an Environmental Impact Statement was not required and issued a Finding of No Significant Impact. The Final Environmental Assessment is available at:

<https://www.energy.gov/nepa/downloads/ea-1652-final-environmental-assessment>

## **Task 2: WTTC preliminary and detailed design**

**Task 2 Description:** MTC will be responsible for the program definition, preliminary and detailed design, and construction of the facility. NREL will offer comments and recommendations in the program definition, preliminary design and detailed design of the WTTC and will make reasonably available to MTC all technical data pertaining to the design and construction of the existing facility at NWTC, and other facilities it may have access or rights to information from. This support will include advice and review of the facility specifications including items such as test stand construction, building size and layout, equipment design, and hydraulic systems. NREL will provide written concurrence with the preliminary and detailed designs for purposes of the CRADA and related agreements.

**Task 2 Results:** NREL provided comments and recommendations leading to the detailed design of the WTTC. NREL analyzed specific use cases that were used to recommend sizing and functional specifications of facilities and equipment. [do we have a written concurrence?]

The following photographs provide information on the construction of the WTTC.





**Figure 1 - Pile driving at construction site for the MassCEC WTTC (25 March 2010)**



**Figure 2 - Rebar placement for the test stand support structure (13 April 2010)**



**Figure 3 - WTTC wall trusses and test stand (20 August 2010)**



**Figure 4 – Application of siding to WTTC (22 February 2011)**





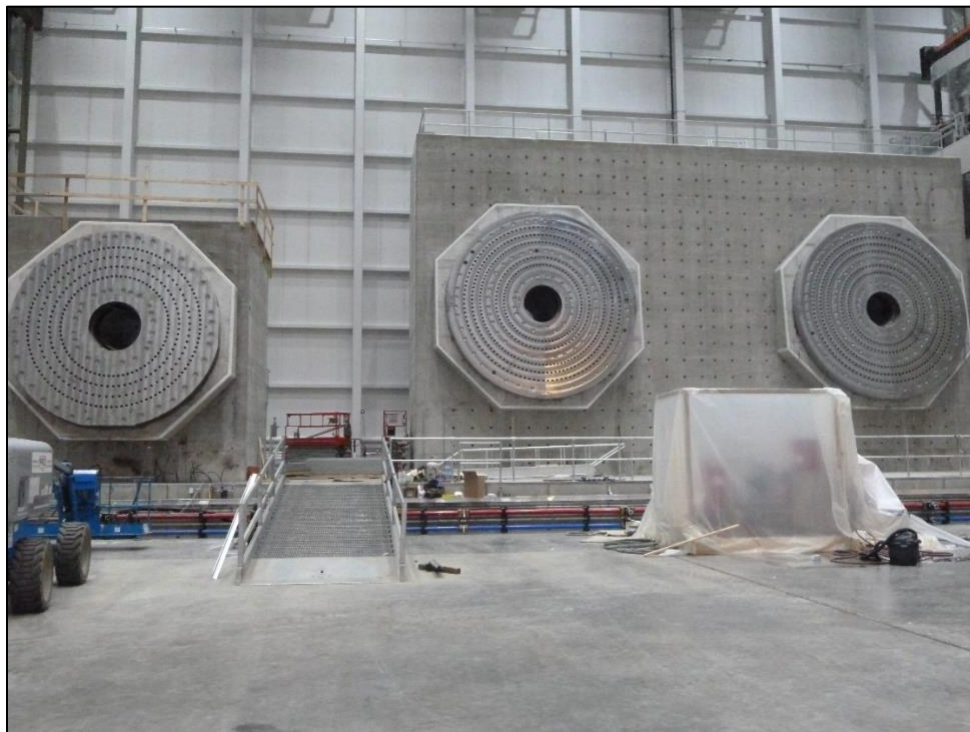
**Figure 5 – Massachusetts Governor Deval Patrick visit to WTTC (15 March 2011)**



**Figure 6 – WTTC Completed Exterior (06 April 2011)**



**Figure 7 – Side pull towers at WTTC (12 May 2011)**



**Figure 8 – Completed test stands at WTTC (12 May 2011)**

**Task 3: Identification, design, and procurement of capital equipment, and identification of costs associated with the WTTC building and other associated costs.**

**Task 3 Description:** NREL will assist MTC in compiling a list (Schedule A) based on experience at the NWTC of the required testing equipment to be provided under the CRADA or otherwise necessary to operate the WTTC. NREL will select, design, fabricate or procure, in cooperation with MTC, equipment valued at \$2 million from Schedule A to use at the WTTC for the duration of the CRADA, and assure its safe arrival at the WTTC in Boston, Massachusetts. NREL will also assist MTC in identifying the WTTC building costs and other associated facility costs. MTC will be responsible for payment of such building and other facility costs. NREL shall arrange all aspects of the transport and delivery from the manufacturer, and/or from NREL, to the WTTC facility of all loaned capital equipment. The equipment loan term and the responsibilities for possession of the capital equipment shall commence upon MTC's documented receipt and acceptance of the capital equipment at the WTTC in Boston, Massachusetts. NREL shall seek approval from DOE to insure the equipment in an amount not less than its replacement costs while it is at NREL and until it is received by MTC. Subject to such approval, NREL shall be responsible for insuring the capital equipment while it is on-site at NREL, and during transport, and for replacement or repair of such capital equipment from available insurance proceeds in the event it is damaged or lost prior to MTC's documented receipt and acceptance at the WTTC. The Parties understand that actual costs incurred by NREL for transporting and insuring the capital equipment until delivery and acceptance by MTC at the WTTC and actual costs incurred for any replacement or repair other than from available insurance proceeds of any capital equipment that is not delivered to the WTTC shall reduce the \$2 million value of the capital equipment to be loaned and accepted by MTC under the CRADA and this JWS.

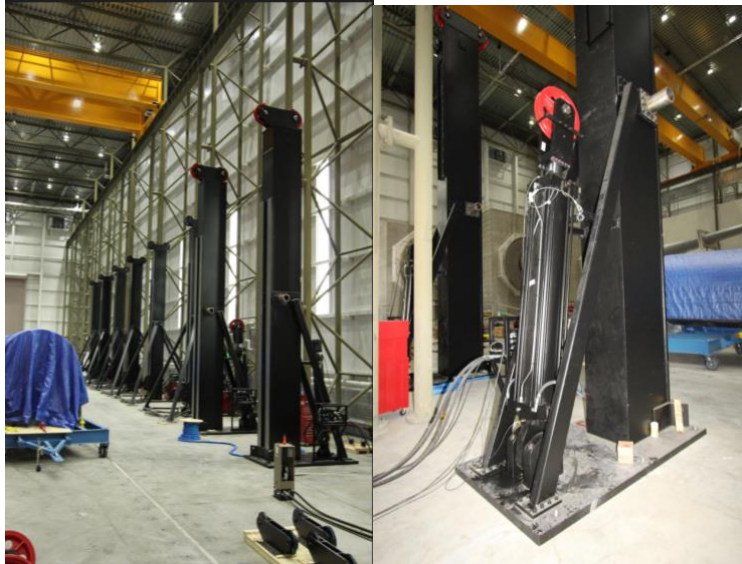
**Task 3 Results:** NREL supported the development of necessary equipment to commission and operate the WTTC. Funding was used to purchase data acquisition system equipment, and mechanical and hydraulic test equipment. National Instruments data acquisition equipment included PXI chassis, and acquisition computers. This hardware was used with existing NREL data acquisition software. NREL collaborated with hydraulic test system supplier MTS to develop commercial test equipment for fatigue testing including Universal Resonant Excitation (UREX) systems. Mechanical and hydraulic equipment procured included UREX's, actuators and winches for static testing, hydraulic pumps and controllers, and supporting equipment including hydraulic hoses. Table 1 provides a listing of the equipment procured using DOE funding.

**Table 1. DOE funding equipment procured and commissioned at the WTTC.**

<b>Description</b>	<b>Manufacturer</b>	<b>Model</b>	<b>Serial</b>
DATA ACQUISITION SYSTEM	NATIONAL INSTRUMENTS	PXI 8110	18513D4
CHASSIS 4 SLOT	NATIONAL INSTRUMENTS	PXI1031	1579C3A
8 SLOT CHASSIS	NATIONAL INSTRUMENTS	PXI1042Q	V08X07876
WINCH	THERN WINCH PRODUCTS	4HPF25M S24	401264142
WINCH	THERN WINCH PRODUCTS	4HPF40M S15	401265071
ACTUATOR HYDRAULIC	MTS	201.70T	10326272
ACTUATOR HYDRAULIC	MTS	201.45S	10326512
CONTROLLER	MTS	FT200	02068643F
HYDRAULIC PUMP	MTS	505.15	10329329
HYDRAULIC PUMP	MTS	505.15	10329336
ACTUATOR	MTS	244.21S	10326363A
ACTUATOR	MTS	244.21S	10326363E
ACTUATOR	MTS	244.21S	10326363F
ACTUATOR	MTS	244.21S	10326363G
ACTUATOR	MTS	244.21S	10326363C
ACTUATOR	MTS	244.21S	10326363D
ACTUATOR	MTS	244.40S	10388662
COMPUTER	HEWLETT PACKARD	COMPAQ 6000 PRO MICROTOWER	2UA0380ZPC
COMPUTER	DELL	OPTIPLEX 960	HHMTFQ1
WINCH	THERN WINCH PRODUCTS	4HPF40M S16	401265072
WINCH	THERN WINCH PRODUCTS	4HPF40M S16	401264289
WINCH	THERN WINCH PRODUCTS	4HPF40M S16	401264252
WINCH	THERN WINCH PRODUCTS	4HPF25M S24	401265073



The following photographs show the DOE furnished equipment as installed and commissioned at the WTTC.



**Figure 9 - Static loading equipment including uprights, actuators and winches**



**Figure 10 - Hydraulic winch and pulley systems**





**Figure 11 - UREX units including hydraulic actuators**



**Figure 12 - Hydraulic Power Units**

#### Task 4: MTC staff training

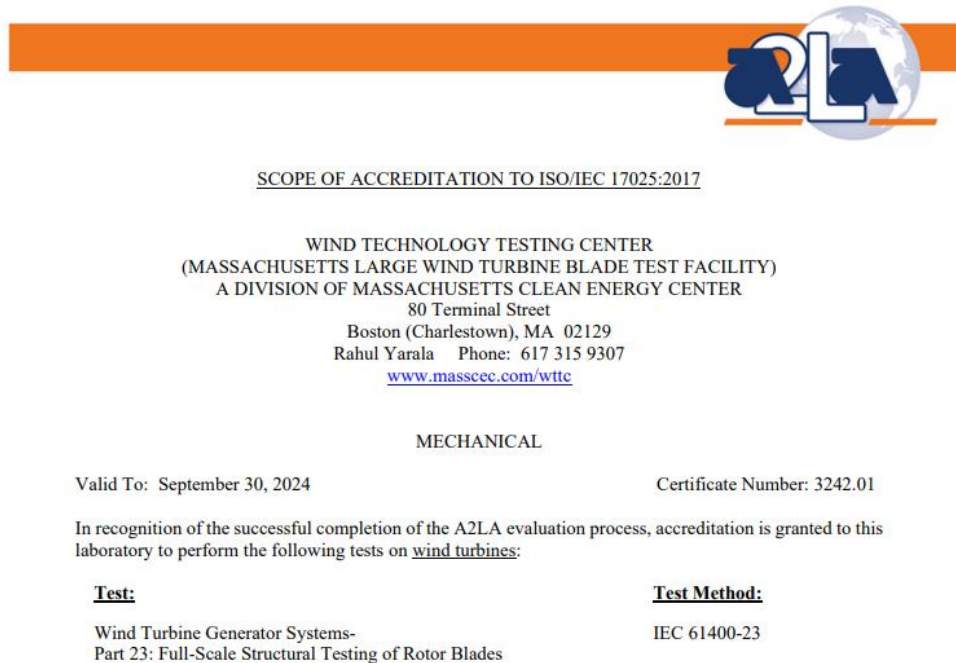
**Task 4 Description:** Training to MTC staff will be provided at NREL and the WTTC. Such training will include but not be limited to observation and instruction of testing and operating procedures at the NREL blade test facilities and the WTTC. Office workspace will be made available to visiting professionals during this training.

**Task 4 Results:** Over the course of development, Three NREL full time employees were located at the WTTC to support the training of WTTC employees. WTTC staff also trained on location at NREL, participating in the performance of wind turbine blade testing at NREL’s Flatirons Campus. Training including use of data acquisition systems, mechanical and instrumentation setup, and documentation of test plans and test reports.

#### Task 5: Facility accreditation

**Task 5 Description:** NREL will provide technical assistance and advice to MTC in setting up laboratory accreditation procedures for the WTTC. This may include process and procedures for extending the accreditation of the NWTC testing facilities to the WTTC.

**Task 5 Results:** NREL supported the development of the quality management system at the WTTC. NREL provided the framework of the existing NREL ISO 17025 quality management system and assisted in developing the WTTC quality management system. The WTTC achieved, and continues to maintain, accreditation to ISO/IEC 17025:2017 for testing wind turbine blades according to the IEC 61400-23 standard. Accreditation is through A2LA (American Association of Laboratory Accreditors). The WTTC A2LA certificate number is 3242.01, an image of the accreditation is shown in Figure ##, as well as a link to the A2LA site.



**Figure 13 - WTTC Scope Accreditation to ISO/IEC 17025:2017**

Link to WTTC scope of accreditation:

<https://customer.a2la.org/index.cfm?event=directory.getDocument&accreditationPID=5516E4A6-60CE-4332-82CE-4DAEA0137117&documentPID=616E93B2-7BE9-420C-A472-80D33A29CBF4>

### **Task 6: WTTC commissioning**

**Task 6 Description:** NREL will assist MTC in the development of a generic test plan for commissioning the WTTC facility. The tests will be designed to exercise all the test hardware and identify start-up problems. NREL staff will travel to the MTC facilities for the commissioning activities. Commissioning will be considered complete after the first fatigue, static, and modal blade tests are executed whether the tests are intended solely for training or accreditation purposes or are on behalf of a facility customer. NREL labor and travel expenses for this task will be paid for by NREL. In addition, NREL staff will be available for telephone and email consulting throughout commissioning. MTC will be responsible for training costs of outside vendors not associated with NREL and be responsible for implementing procedures for safe operation at the WTTC site.

**Task 6 Results:** Reporting on WTTC commissioning has been documented and summarized in DOE publications including the DOE 2012 Wind Power Peer Review Report and the DOE 2014 Wind Energy Program Peer Review Report:

[https://www1.eere.energy.gov/wind/pdfs/2012\\_wind\\_power\\_peer\\_review\\_report.pdf](https://www1.eere.energy.gov/wind/pdfs/2012_wind_power_peer_review_report.pdf)

<https://www.energy.gov/sites/default/files/2014/10/f18/2014%20Wind%20Energy%20Peer%20Review%20Report.pdf>

The WTTC was commissioned in May of 2011. NREL staff supported the completion of commissioning through completion of reporting on fatigue, static, and modal tests. NREL staff were responsible for writing final reports for these tests. Reports were provided to blade test customers and are confidential documents. The document numbers for these test reports are:

- Static and modal testing – Document number: T004-030502-05
- Fatigue testing – Document number: T004-030702-05

Figures 14 through 16 provides photographs of the WTTC commissioning ceremony attended by the mayor of Boston and the governor of Massachusetts.



Figure 14 - WTTC Commissioning (18 May 2011)



Figure 15 – Boston Mayor Thomas Menino speaks at WTTC Commissioning (18 May 2011)





**Figure 16 – Massachusetts Governor Deval Patrick speaks at WTTC Commissioning (18 May 2011)**

Articles promoting the opening of the WTTC include:

<https://www.energy.gov/eere/wind/articles/doe-s-new-large-blade-test-facility-massachusetts-completes-first-commercial>

### **Task 7: Facility management and advisory support**

**Task 7 Description:** One or more follow-on agreements will be entered into between NREL and MTC as necessary to address matters such as:

1. Define the WTTC staffing organization, roles and responsibilities, and other managerial and advisory functions for NREL and MTC staff.
2. Estimate on a best effort basis (subject to DOE funding) the schedule and number of NREL employees to be temporarily or permanently located at the WTTC facility for training, commissioning, technical, administration, and operational assistance. The parties agree to the equivalent of three full time persons as the number of NREL employees to be provided.
3. Provide NREL a first right-of-refusal for purchasing the WTTC facility and assuming MTC's lease obligations if MTC elects to terminate the CRADA and cease operating the WTTC facility.
4. Ensure acknowledgment of NREL's support in the name of the facility and in marketing and promotional materials
5. Address other issues, concerns, and rights that may arise.



**Task 7 Results:** Appendix E of the CRD-07-240 CRADA provided the WTTC Facility Access and Use Agreement between NREL and MTC. The terms and conditions established in Appendix E were incorporated and made collateral to the CRADA work. Upon completion of design, construction, and commissioning, MTC become the owner and operator of the WTTC. Upon completion of design, construction, and commissioning the WTTC was equipped with MTC owned or leased equipment and Government owned and leased equipment.

#### **Task 8: Facility Use by Third Parties and NREL**

**Task 8 Description:** MTC will draft a User Agreement containing terms established by MTC in its discretion that will provide, among other things, protocols, pricing and intellectual property ownership and use provisions for tests performed on behalf of third parties at the WTTC facility. MTC and NREL shall also enter into the Use Agreement attached to the CRADA as Appendix E to govern NREL's rights to utilize the WTTC facility.

**Task 8 Results:** NREL entered into the Use Agreement as Appendix E.

#### **Task 9: Long-Term Operational Support**

**Task 9 Description:** NREL staff will provide operational support at the WTTC facility for the duration of the CRADA. The operational support will (subject to appropriation) take the form of three (3) full time permanent or contract employees, as more fully set forth in Task 7. The scope and focus of such operational support shall be determined over time.

**Task 9 Results:** Three NREL staff provided dedicated support to the WTTC during commissioning of the facility. Two NREL engineers and one NREL technician provided on-site support at the WTTC. Over time, NREL staffing support was reduced to two engineers.



**Figure 17 – GREX Commissioning at WTTC (12 May 2013)**



**Figure 18 – Wind blade unloading at WTTC (19 February 2014)**

## **Task 10: Long Term Technical and Warranty Support**

**Task 10 Description:** NREL will provide the following technical and warranty support for the duration of the CRADA as follows:

- (a) comprehensive support for the RTS technology during the term of the license of such technology, as more fully set forth in Appendix B of this CRADA;
- (b) responsibility for resolution of all issues concerning Original Equipment Manufacturers' warranties for the duration of the loan of the capital equipment to MTC , as more fully set forth in Appendix C of this CRADA; and
- (c) subject to the availability of DOE funding under the Contractor's M&O contract, technical, engineering, modification, and non-routine maintenance services (collectively "services") to support sustained performance and operation of capital equipment custom designed by Contractor for the duration of the loan of the capital equipment to MTC , as set forth in Appendix C of this CRADA.

**Task 10 Results:** NREL assisted with the maintenance and upkeep of test equipment.

### **Modification #1**

Modification #1 updated the Participant's (Massachusetts Clean Energy Center) contact information, CRADA terms, and task descriptions (no scope or dollar increase).

### **Modification #2: Task 11**

**Task 11 Description:** Under this agreement, NREL will provide consulting services to MassCEC in support of full-scale blade testing and related activities at the Wind Technology Testing Center (WTTC). These services will be provided by Nathan Post who will maintain his primary office location at the WTTC during the period of performance in order to be able to interact directly with the MassCEC employees at the WTTC and work directly on active blade testing programs.

The scope of work to be conducted under this agreement can include:

- Leading test programs – lead one test program at any given time, typically collaborating with another engineer to support test activities. Provide support and technical advice to other ongoing test programs and interface with customers on specific technical issues as needed and as time as time allows.
- Provide technical support in identifying and solving testing issues as they arise including problems with equipment, instrumentation, and test articles. This effort can include the specification and design of new equipment to address these issues.
- Provide continued support for the NREL developed data acquisition software including installing new software versions at the WTTC as they become available, training WTTC to use this software, and providing feedback of to NREL to influence the software development and ensure that it meets WTTC testing needs.
- Develop specialized algorithms and software tools to assist in designing blade tests, analyzing data and reporting results.

- Provide guidance on quality management system improvement including drafting procedures and forms to address quality concerns and provide continuous improvement of the WTTC Quality Management System.
- Work with blade test customers to address specific blade handling and rotation requirements or other testing concerns for certain blades.
- Address safety related items within the scope of blade testing including reviewing and recommending safety procedures for various aspects of the operation.
- Work on special projects geared toward introducing new testing technology and capabilities to the WTTC such as:
  - Dual Axis testing
  - New generation instrumentation (fiber-based sensors or other developments)
  - Non-destructive testing and other inspection techniques to improve early-stage failure detection.

**Task 11 Results:** NREL staff provided support for facility operations and performing test engineer functions. Support was provided by NREL staff on-site at the WTTC, and supporting efforts by NREL staff in Colorado. NREL staff supported development of dual axis test methods and improvements to static test methods. Technical publications on the development dual axis test methods and improvements to static test methods can be found in the following locations:

<https://www.nrel.gov/docs/fy16osti/65227.pdf>

<https://www.nrel.gov/docs/fy16osti/65996.pdf>

### **Modification #3: Task 12**

**Task 12 Description:** Task 12 extended the period of performance for NREL staff supporting operations at the WTTC.

**Task 12 Results:** WTTC provided funding for NREL staff supporting work.

### **Modification #4:**

Modification #4 was a no cost time extension, adding 12 months to the period of performance.

### **Subject Inventions Listing:**

ROI-16-64 – method for Conducting a Biaxial Resonance Fatigue Test on a Wind Turbine Blade with a 2:1 Lead-Lag to Flap Frequency Ratio. Post, Nathan, Desmond, Michael, Hughes, Scott

### **ROIs:**

None.