SAND2024-16654C

Calibration Of Fiber Optic Rosette Sensors For Measuring Bending Moment On Tidal Turbine Blades

Budi Gunawan[a], Kim Haulenbeek[a], Mohammed Abdellatef[ab], Richard Streit[a], Eli Lynn[a], Michael Willis[a], Darren Pendley[a], Damian Gallegos-Patterson[a], Christopher Laursen[a], Vincent Neary[a], Martin Wosnik[c]

budi.gunawan@sandia.gov

[a]Sandia National Laboratories, NM

[b]Florida Atlantic University

[c]University of New Hampshire & Atlantic Marine Energy Center (AMEC)

International Conference on Ocean Energy

Melbourne, Australia, September 17-19, 2024

Background

US DOE Water Power Technology Office
Open Source Tidal Energy Converter (OSTEC):
Design, build and deploy an instrumented tidal energy converter – generate open-source R&D datasets

D=2.5 m rotor diameter MHKF1 turbine, blade span 1.05 m

University of New Hampshire / Atlantic Marine Energy Center Tidal Energy Test Site at Memorial Bridge in Portsmouth, NH (Piscataqua River – Great Bay Estuary)

Background

IEC -3 Measurement requirements & sensoring

- Blade root flapwise bending moment (**mandatory** on at least one blade; additional blade recommended, specified in table 12 of IEC TS62600-3), measured at the blade root using multiple fiber optic rosette strain sensors (using fiber Bragg-grating (FBG)).
- Blade root edgewise bending moment (**mandatory** on at least one blade; additional blade recommended, specified in table 12 of IEC TS 62600-3), measured at the blade root using multiple fiber optic rosette strain sensors.
- Load exerted in the prime movers, e.g., blades (**recommended**, specified in table 9 of the IEC TS 62600-3), measured along the blade using multiple fiber optic uniaxial strain sensors.

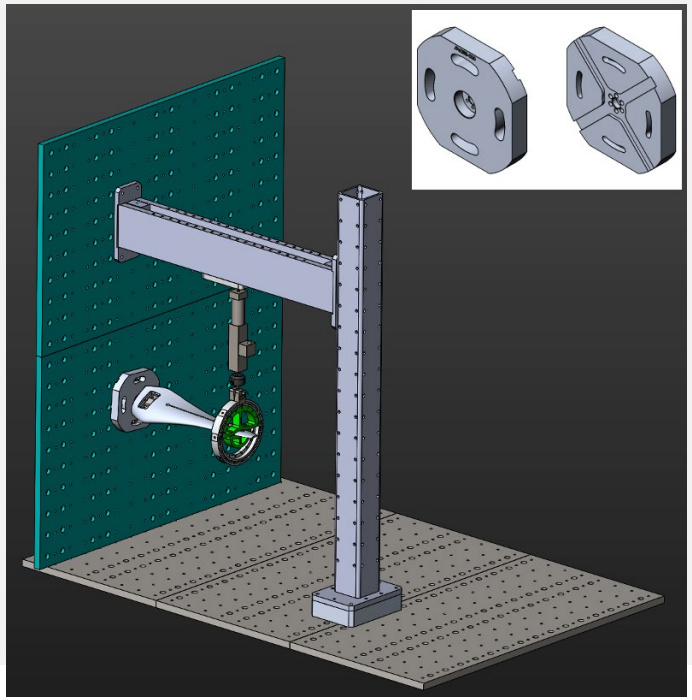
→ need to develop a calibration curve for that relates the strain measurements and bending moments

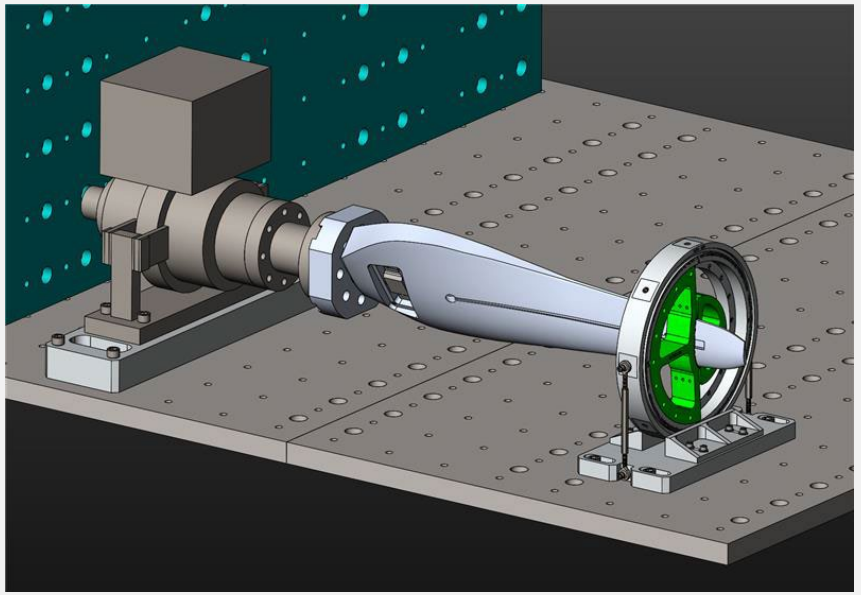
→ Sandia's Structural Mechanics lab

Structural Laboratory Test Objectives

Test objectives

- Calibrate the bending moment values derived from the blade root fiber optic rosette strain sensors against a set of known loads along the flapwise, edgewise and combined flap- and edge-wise directions.
- Calibrate the twist moment values derived from the rosettes.





Testing was performed at Sandia National Laboratories' Structural Mechanics Laboratory, February – April 2024

Structural Laboratory Test Objectives

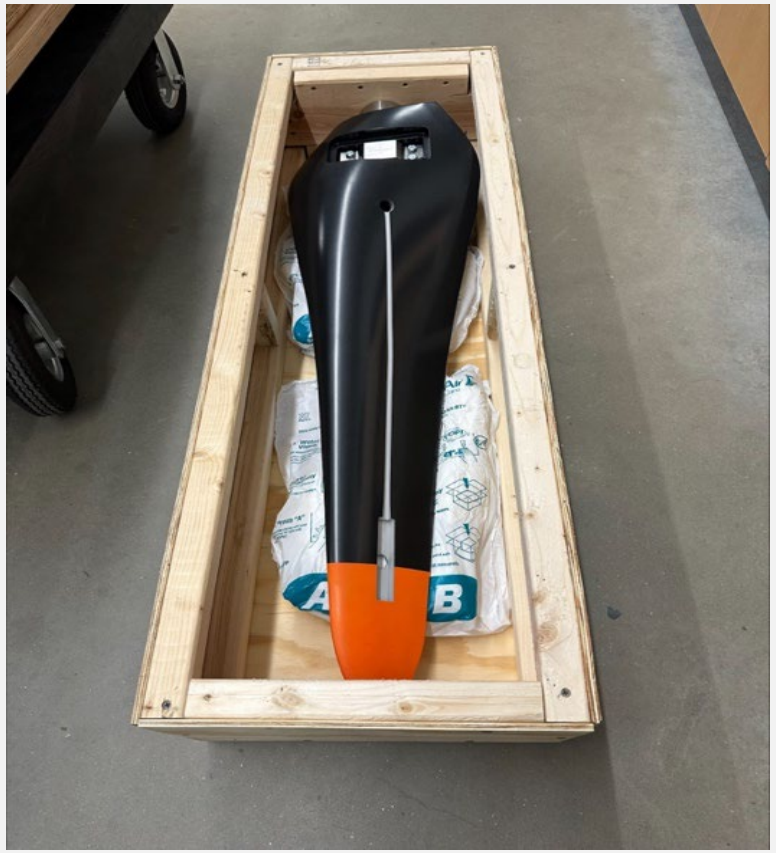
Test objectives

- Calibrate the bending moment values derived from the blade root fiber optic rosette strain sensors (referred as rosettes throughout this report) against a set of known loads along the flapwise, edgewise and combined flap- and edge- wise directions.
- Calibrate the twist moment values derived from the rosettes.

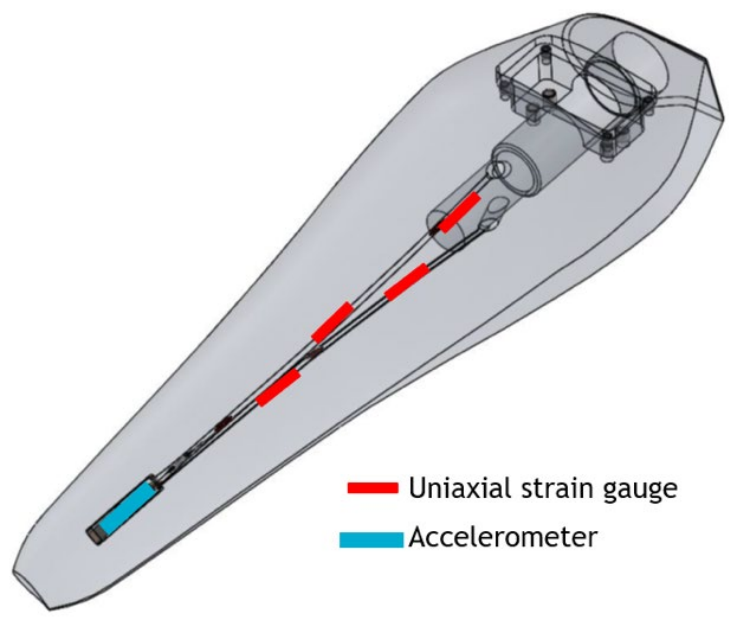
	Moment (ft-lb (Nm))	Equivalent point force applied (lb (kg))
Flapwise	3485 (4725)	1223 (555)
Edgewise	765 (1037)	268 (121)
Twist	116 (157)	

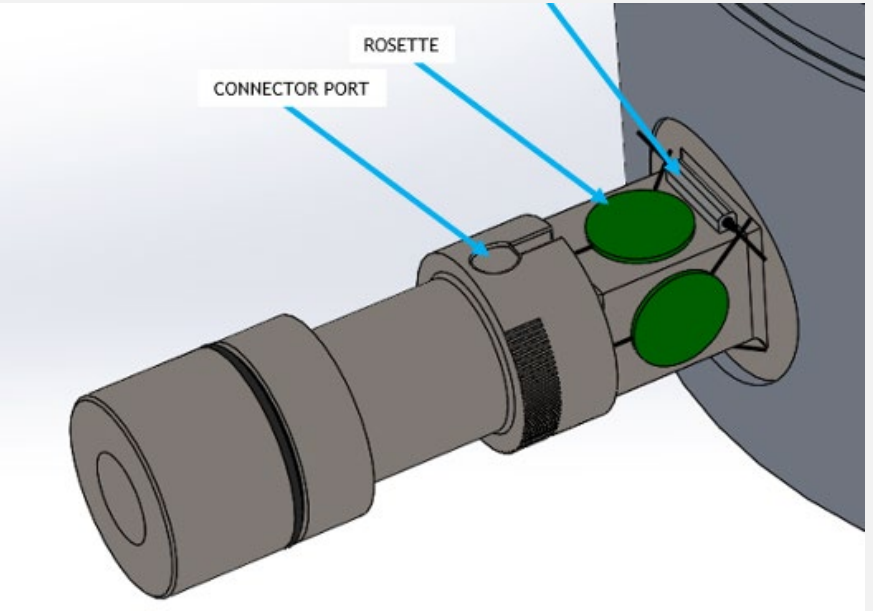
Maximum load, from various Design Load Cases (DLCs), simulated using OpenFAST

Test articles



Sensor locations

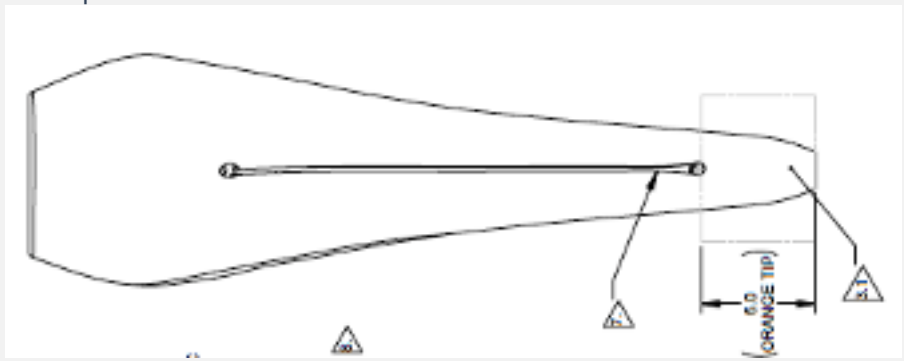


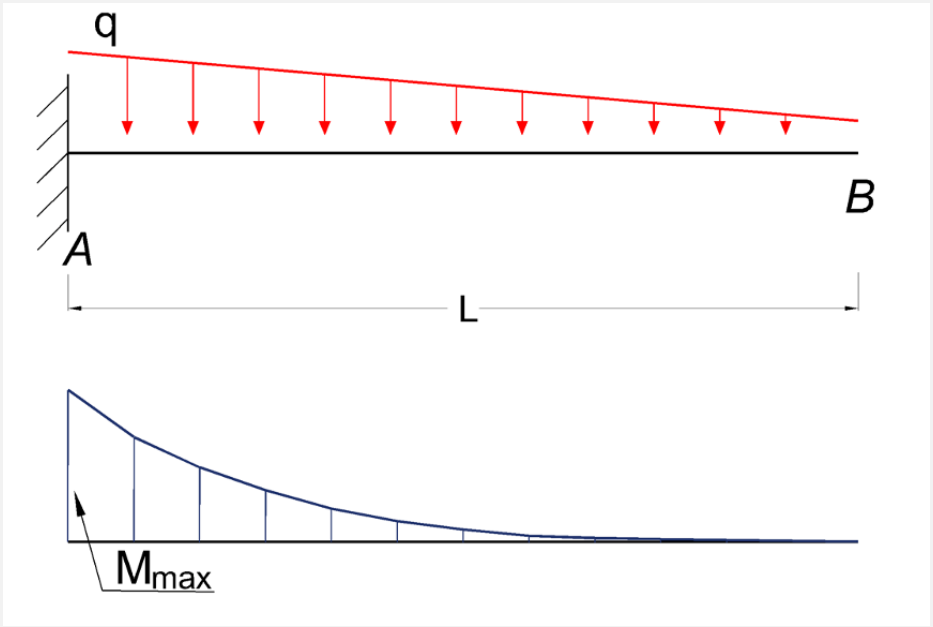


Simplification to point force

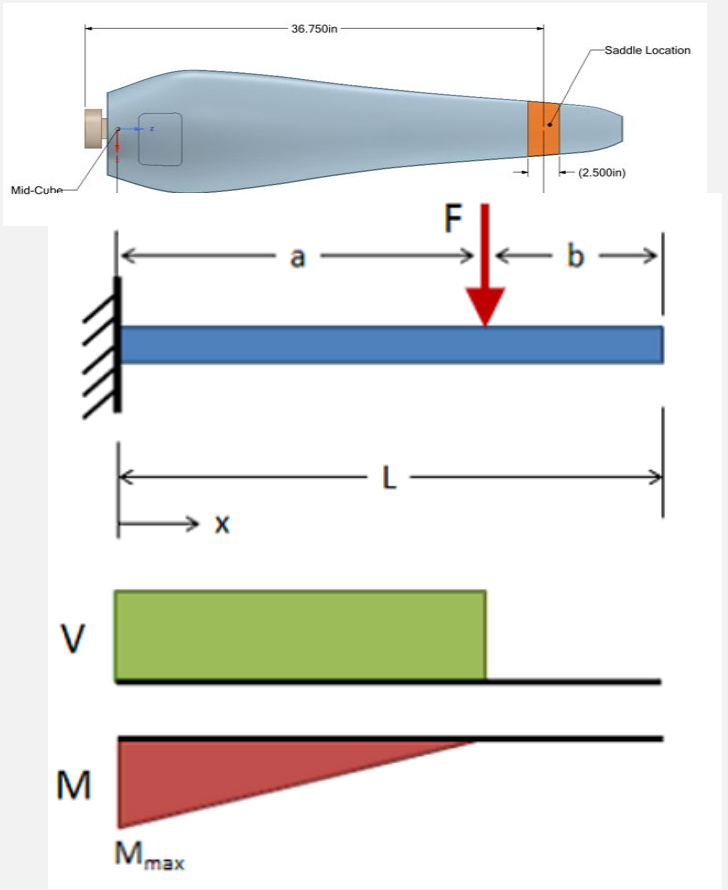
Figures are for illustration only

~Simplified load distribution on a rotor blade





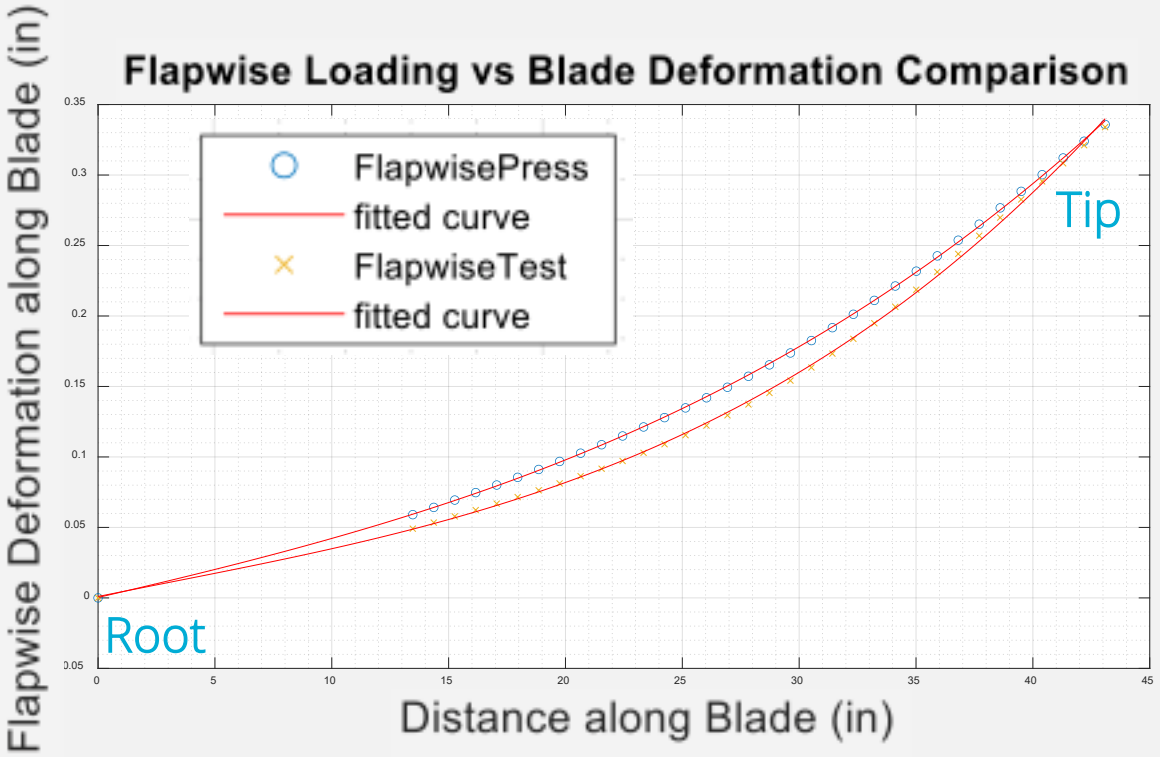
Implementation in structural laboratory

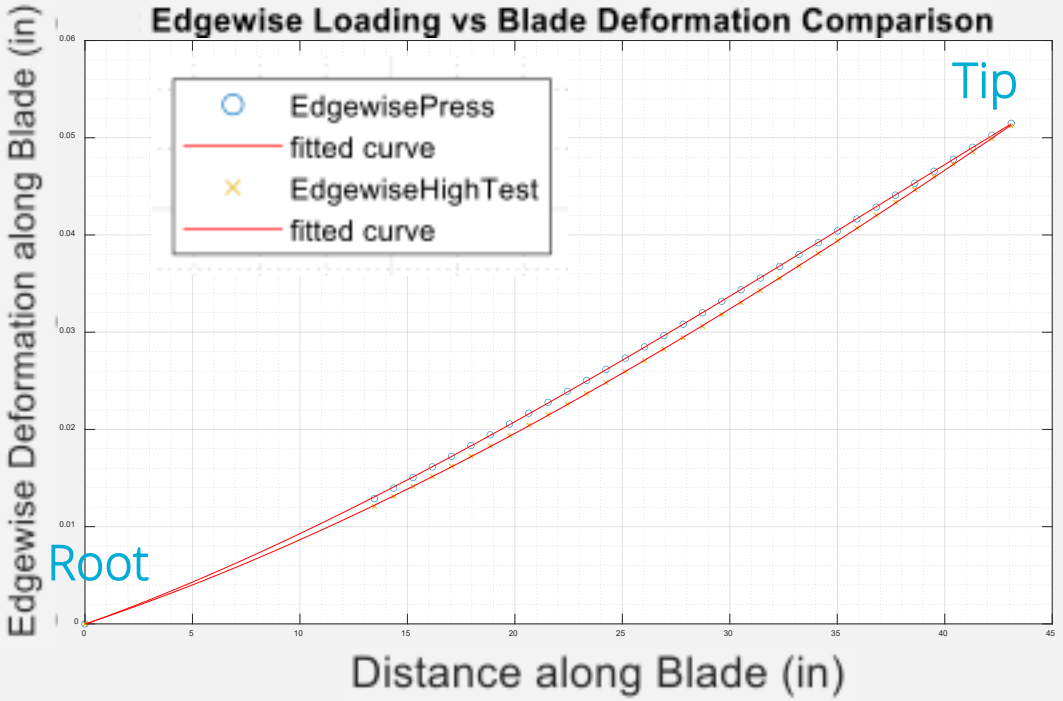


For a rigid body to be static, the net sum of forces and moments acting on it must be zero

Simplification to point force (continued)

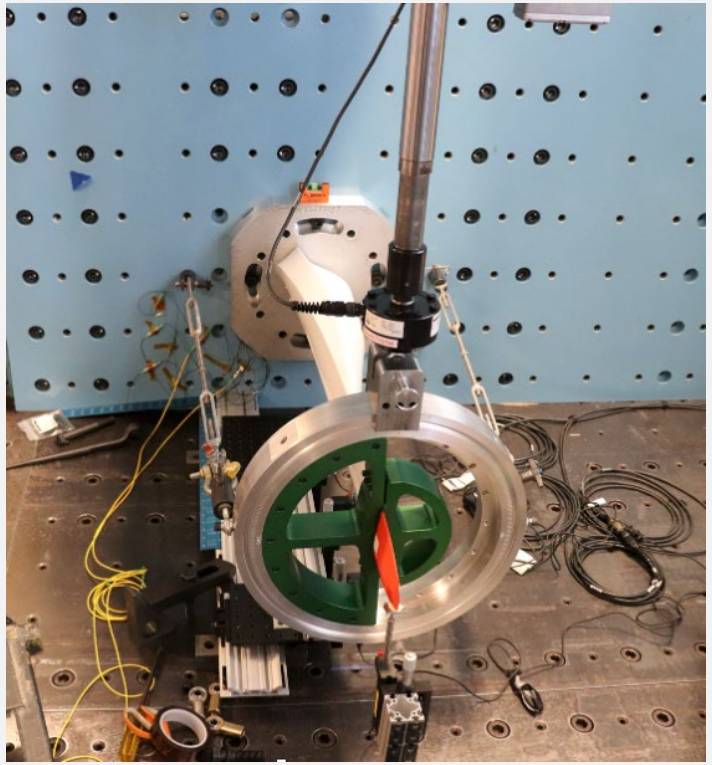
Blade deflection for distributed and point load cases, simulated using FEM

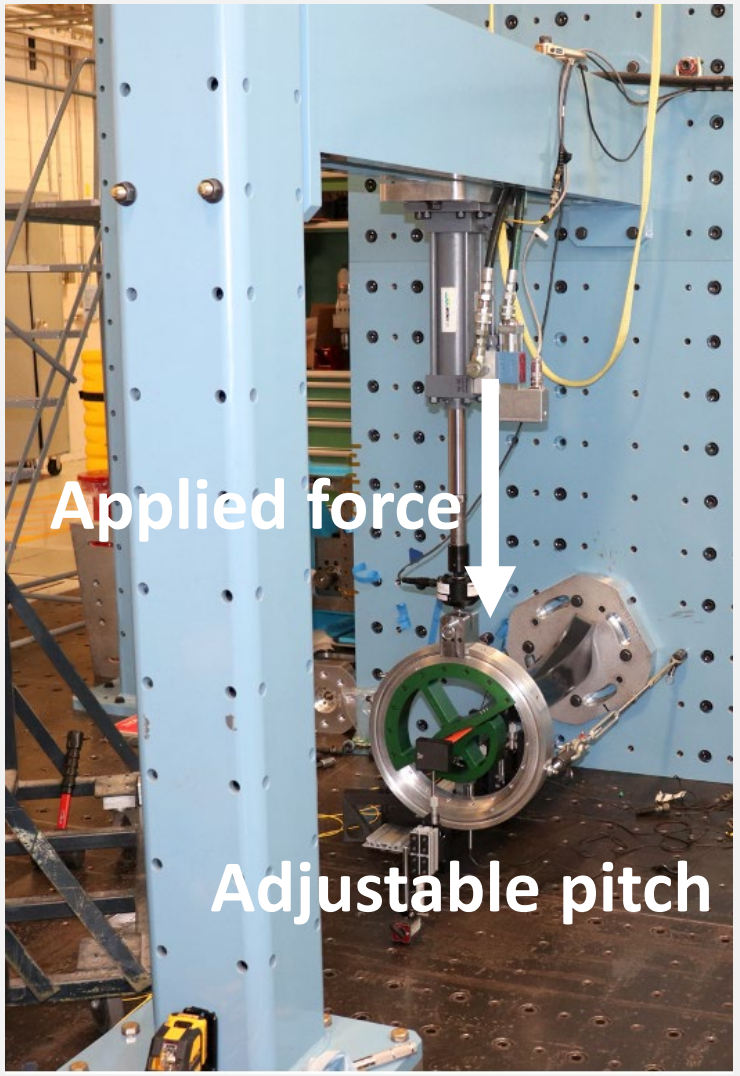


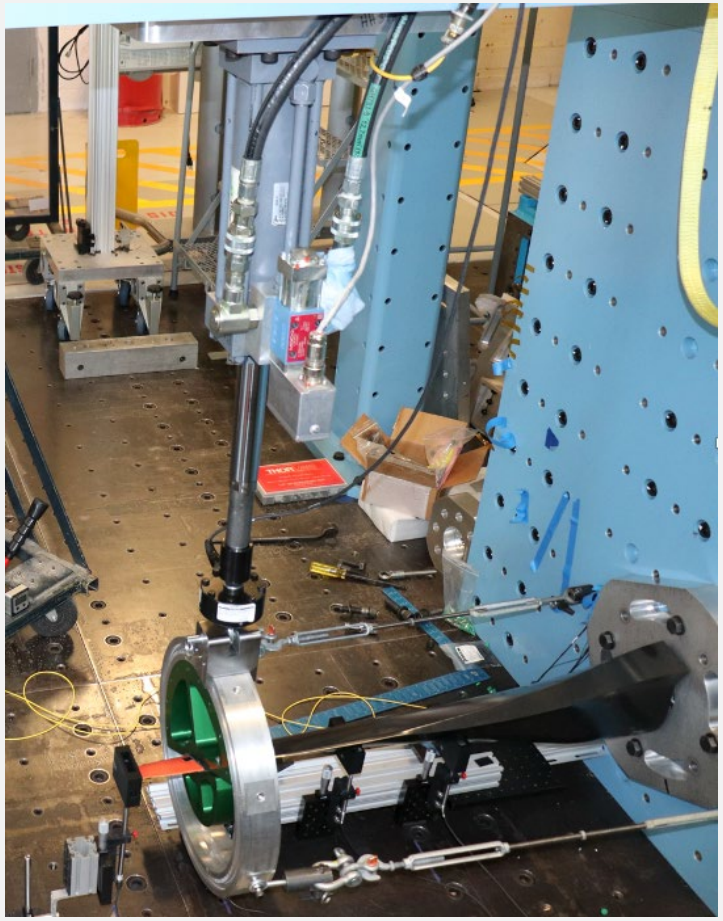


Point-force application location is selected from location with good deflection profile agreement

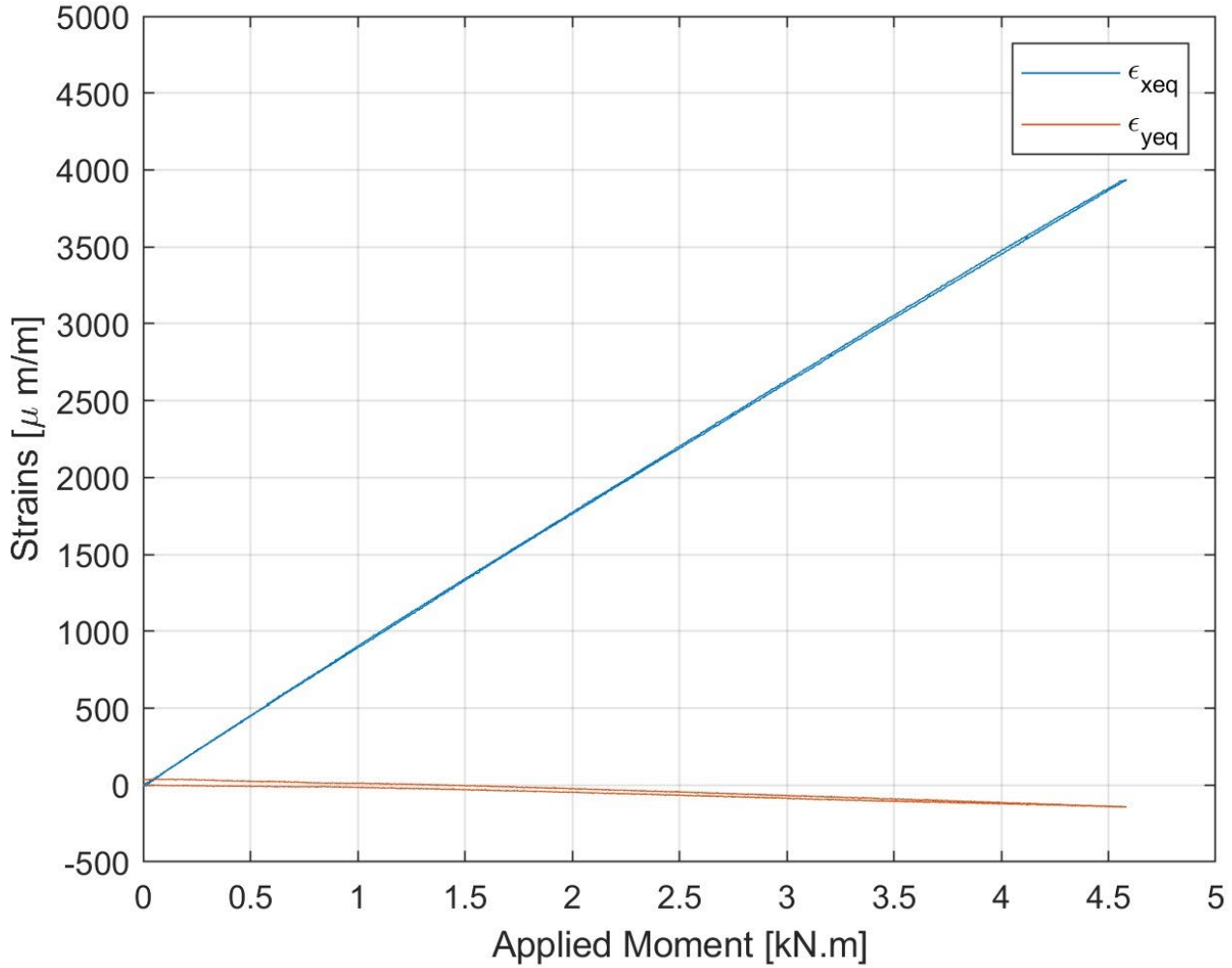
Bending moment testing





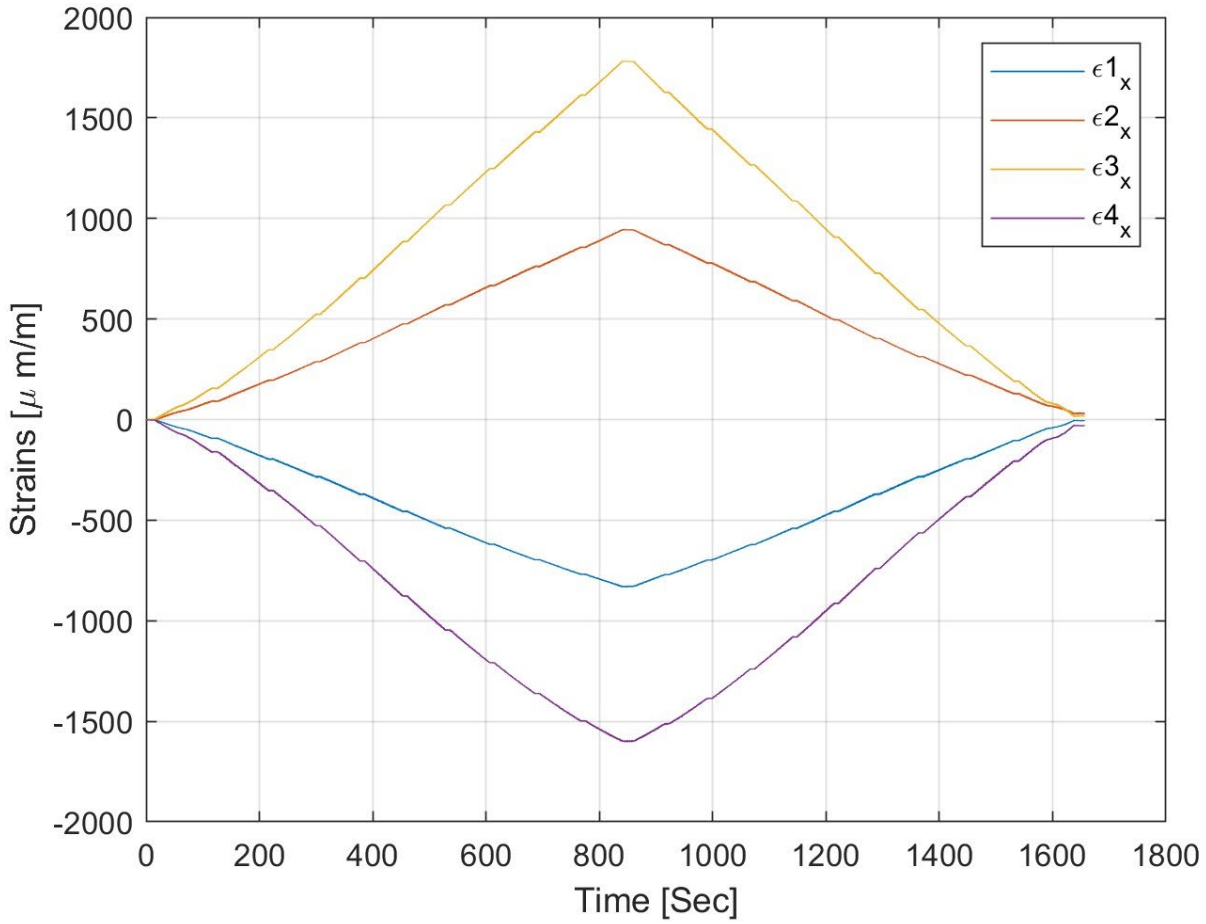


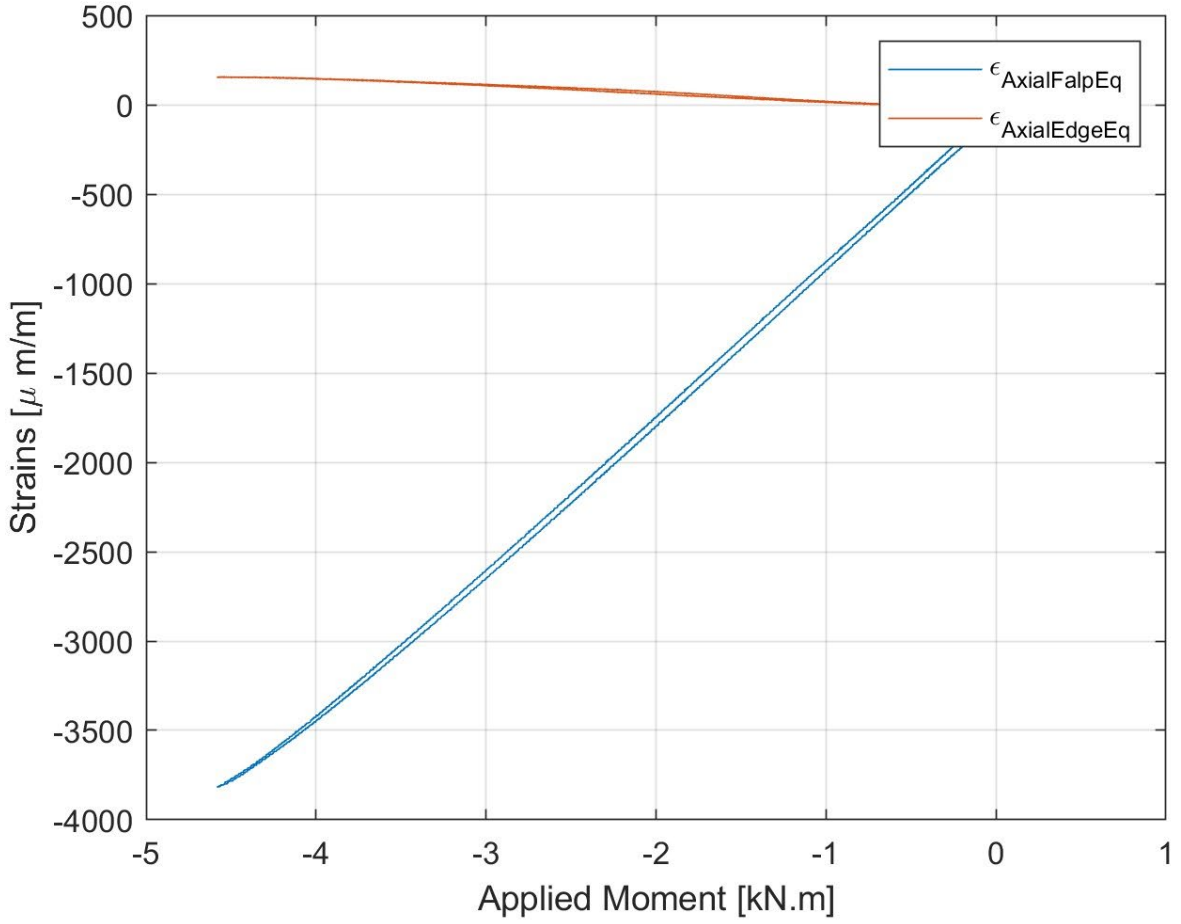
Example result:
Blade 3 - Run 21 (1,185 (524 N) lbf flapwise ; 4,575 Nm)



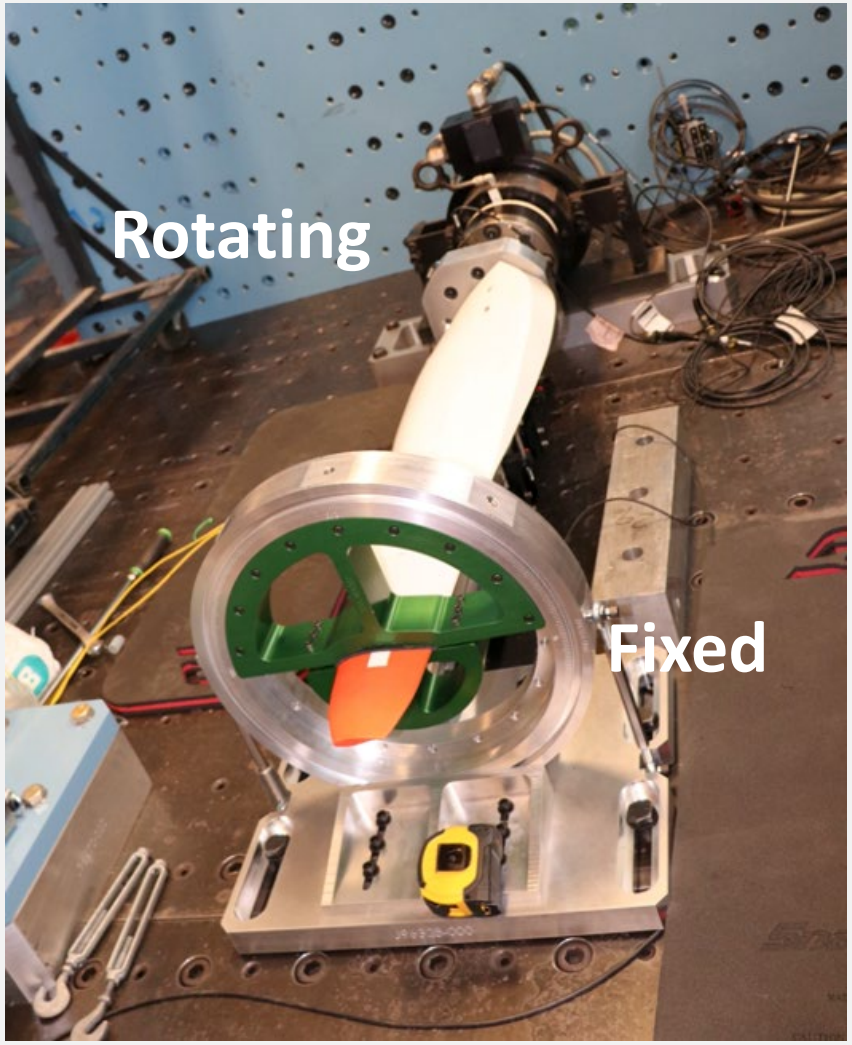
Applied moment (by actuator) Vs Equivalent strain epsilon x : - ~linear relationship

Example result: Run 24 (Flapwise (1180 lbs) 5.25 kN.m)

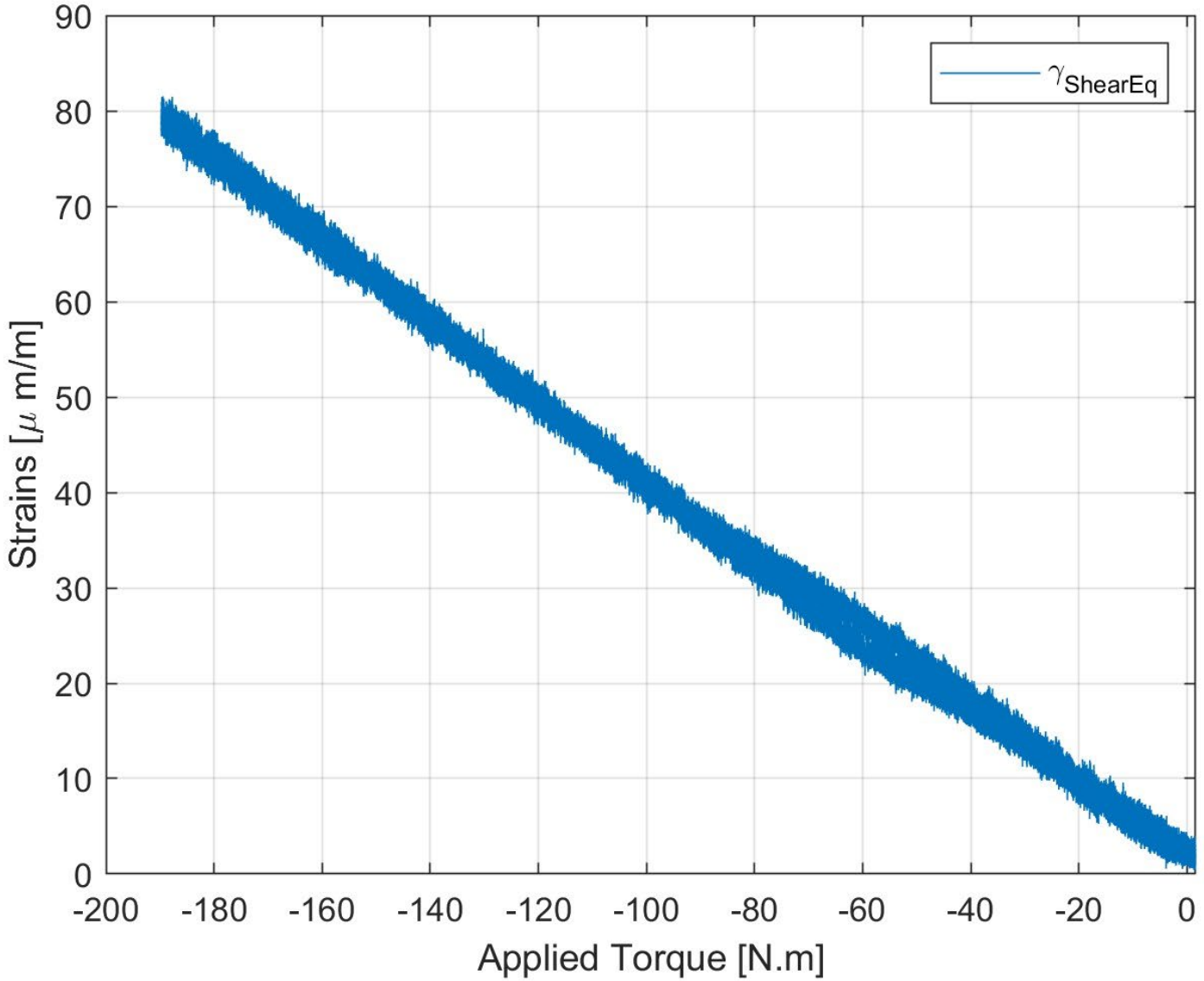




Torsion testing



Example result: Run 47 (Torque (139 ft -lbs) 188.5 N.m)



Preliminary conclusions

- Virtually linear relationship is observed on strain vs the various quantities of interests (flapwise bending moment, edgewise bending moment, torsion)
- ready for system integration, dry system testing, then open-water testing
- Bending moment can be derived from the strain measurements using theoretical equations (~10% difference from the prescribed value)

Acknowledgements

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) under contract DE-NA0003525. This written work is authored by an employee of NTESS. The employee, not NTESS, owns the right, title and interest in and to the written work and is responsible for its contents. Any subjective views or opinions that might be expressed in the written work do not necessarily represent the views of the U.S. Government. The publisher acknowledges that the U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this written work or allow others to do so, for U.S. Government purposes. The DOE will provide public access to results of federally sponsored research in accordance with the DOE Public Access Plan.