UFLORIDA NHERI
Powell Family Structures and Materials Laboratory

NHERI Experimental Facility at UF: Boundary Layer Wind Tunnel

Jennifer A. Bridge, Ph.D., Kurt Gurley, Ph.D., Forrest Masters, Ph.D., Brian Phillips, Ph.D.

SHORELINE21 Workshop

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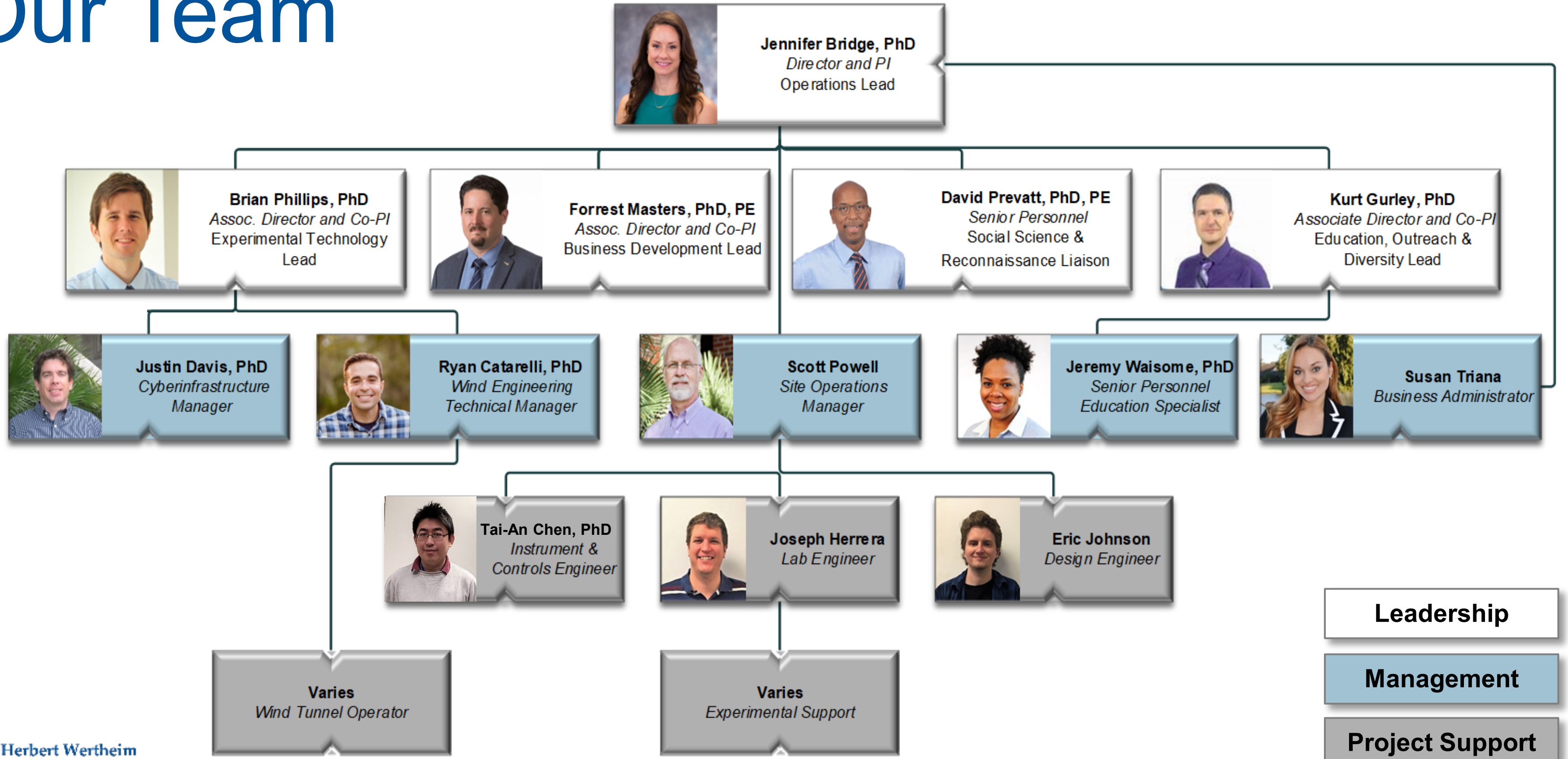
NSF Award# 2037725

UF NHERI Experimental Facility

- Provide users access to **advanced wind engineering experimental research infrastructure**
- Support **transformative wind hazard research** through state-of-the-art experimental resources, seamless integration of high-performance computing, skilled personnel, and a culture of safety and collegiality
- **Expand and diversify** the wind engineering community to develop a **workforce** that serves society to create the hazard resilient infrastructure of the future

NSF Award 2037725

Our Team


Jennifer Bridge, PhD
Director and PI
Operations Lead
Brian Phillips, PhD
Assoc. Director and Co-PI
Experimental Technology Lead
Forrest Masters, PhD, PE
Assoc. Director and Co-PI
Business Development Lead
David Prevatt, PhD, PE
Senior Personnel
Social Science & Reconnaissance Liaison
Kurt Gurley, PhD
Associate Director and Co-PI
Education, Outreach & Diversity Lead
Justin Davis, PhD
Cyberinfrastructure Manager
Ryan Catarelli, PhD
Wind Engineering Technical Manager
Scott Powell
Site Operations Manager
Jeremy Waisome, PhD
Senior Personnel
Education Specialist
Susan Triana
Business Administrator
Tai-An Chen, PhD
Instrument & Controls Engineer
Joseph Herrera
Lab Engineer
Eric Johnson
Design Engineer
Varies
Wind Tunnel Operator
Varies
Experimental Support
Leadership
Management
Project Support

Scientific Objectives: Grand Challenges

1. Reduce uncertainties in the wind loading chain

- Enable experimental rigor in boundary layer wind tunnel testing though advanced automation and control
- Provide flexibility and control to match desired flow characteristics to produce better composites of data

2. Advance physical modeling of complex flow fields to understand their impact

- Simulate nonstationary and non-neutral flow fields that are characteristic of thunderstorms and downbursts
- Quantify impacts of these flows on bluff body aerodynamics and building loads

3. Advance computational wind engineering to reduce reliance on physical testing

- Provide high-fidelity, repeatable datasets to inform computational modeling through advanced instrumentation and flow characterization

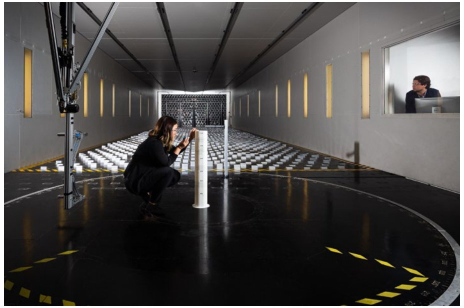
4. Advance automation and design of hazard resistant infrastructure

- Promote experiments to validate hazard resistance of emerging and automated design approaches
- Support cyberphysical wind tunnel testing, structural optimization, and machine learning to drive the future of engineering design


Powell Laboratory
University of Florida East Campus

UF Experimental Facility

Self-Configuring Boundary Layer Wind Tunnel (**BLWT**)
NSF Award 2037725



Multi-Axis Wind Load Simulator (**MAWLS**)

High Airflow Pressure Loading Actuator (**HAPLA**)

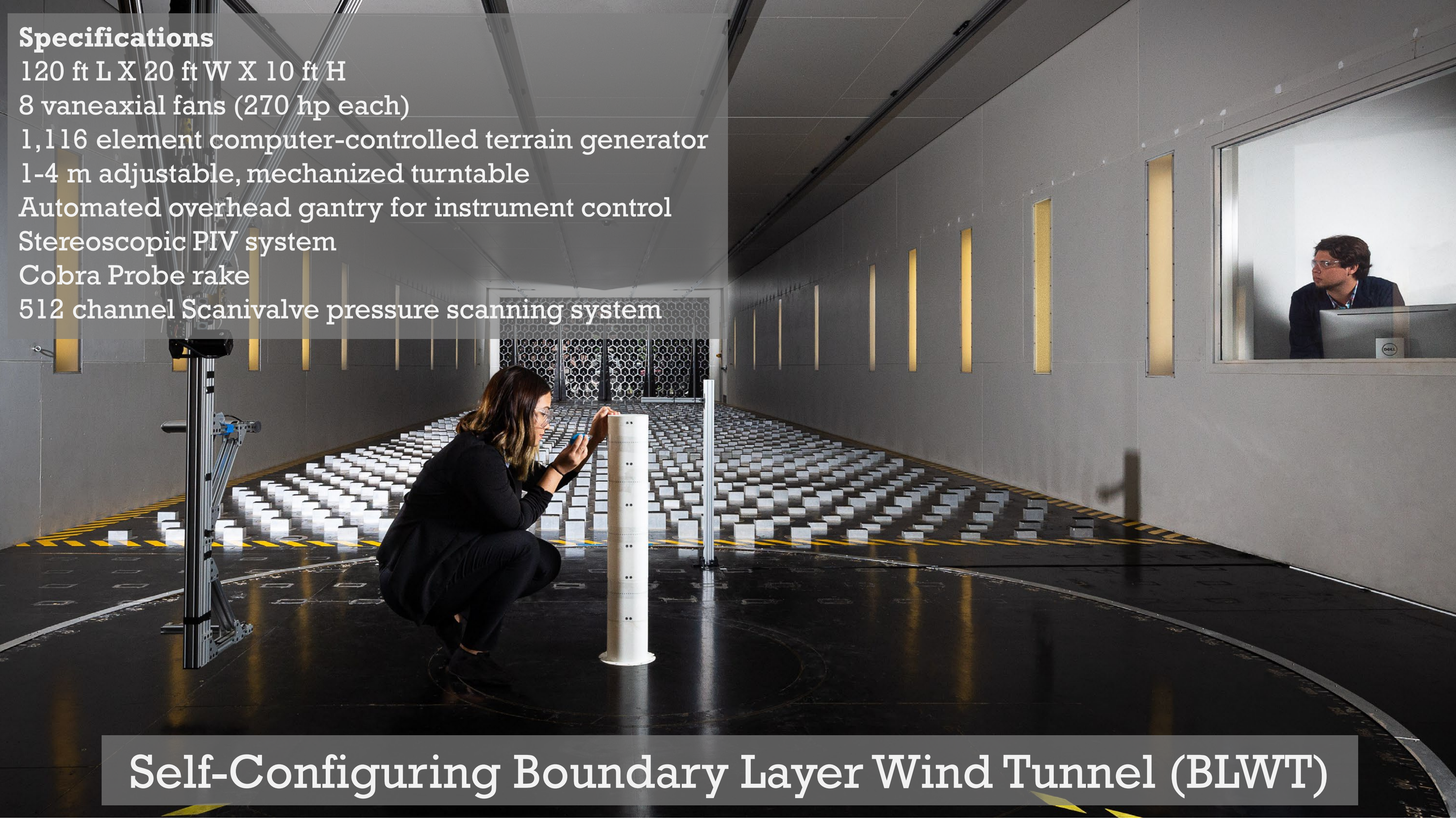
Dynamic Flow Simulator (**DFS**)

Spatiotemporal Pressure Loading Actuator (**SPLA**)

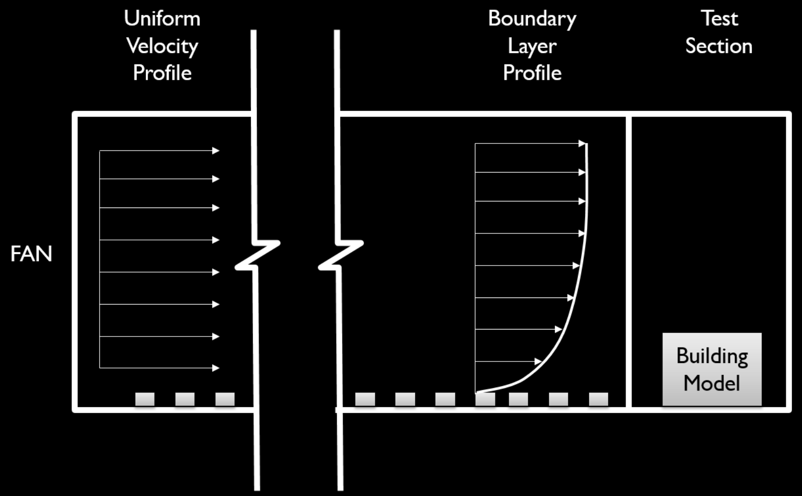
Self-Configuring Boundary Layer Wind Tunnel (BLWT)

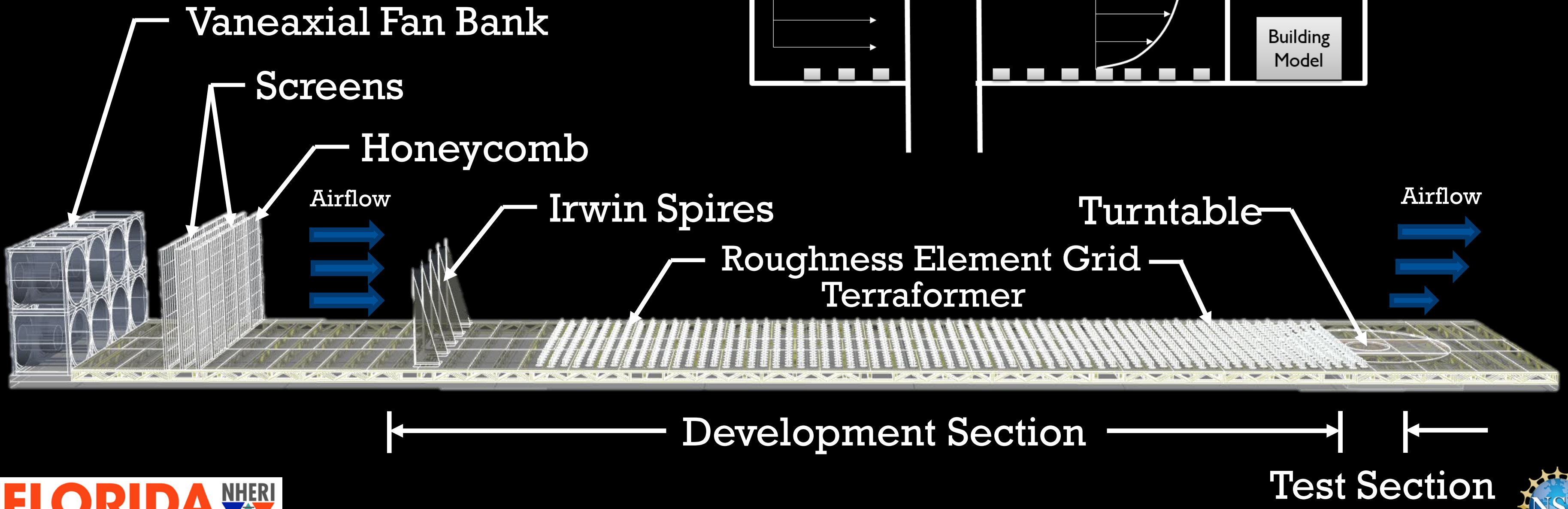
Specifications

120 ft L X 20 ft W X 10 ft H
8 vaneaxial fans (270 hp each)
1,116 element computer-controlled terrain generator
1-4 m adjustable, mechanized turntable
Automated overhead gantry for instrument control
Stereoscopic PIV system
Cobra Probe rake
512 channel Scanivalve pressure scanning system



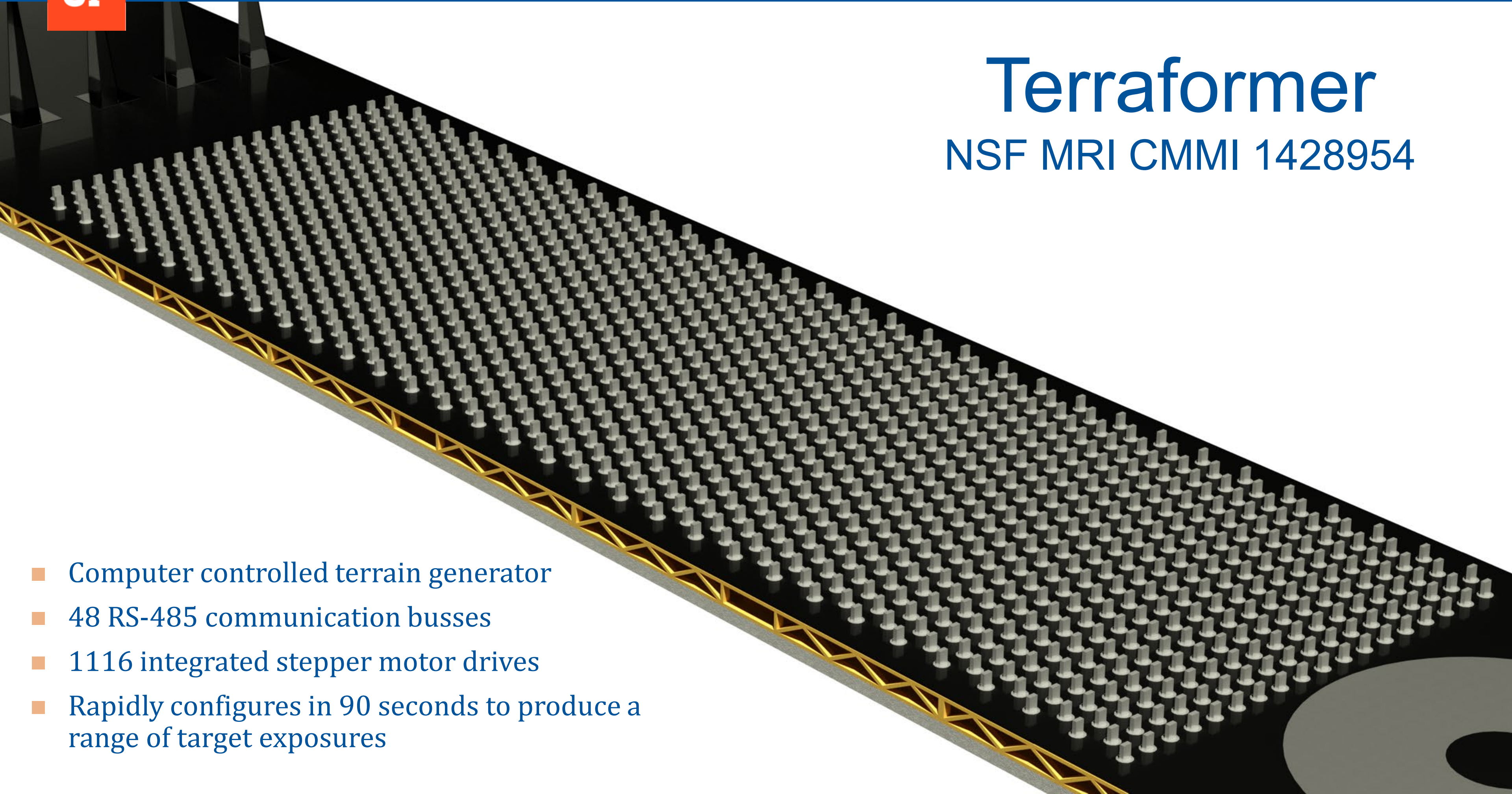
Principle of Operation



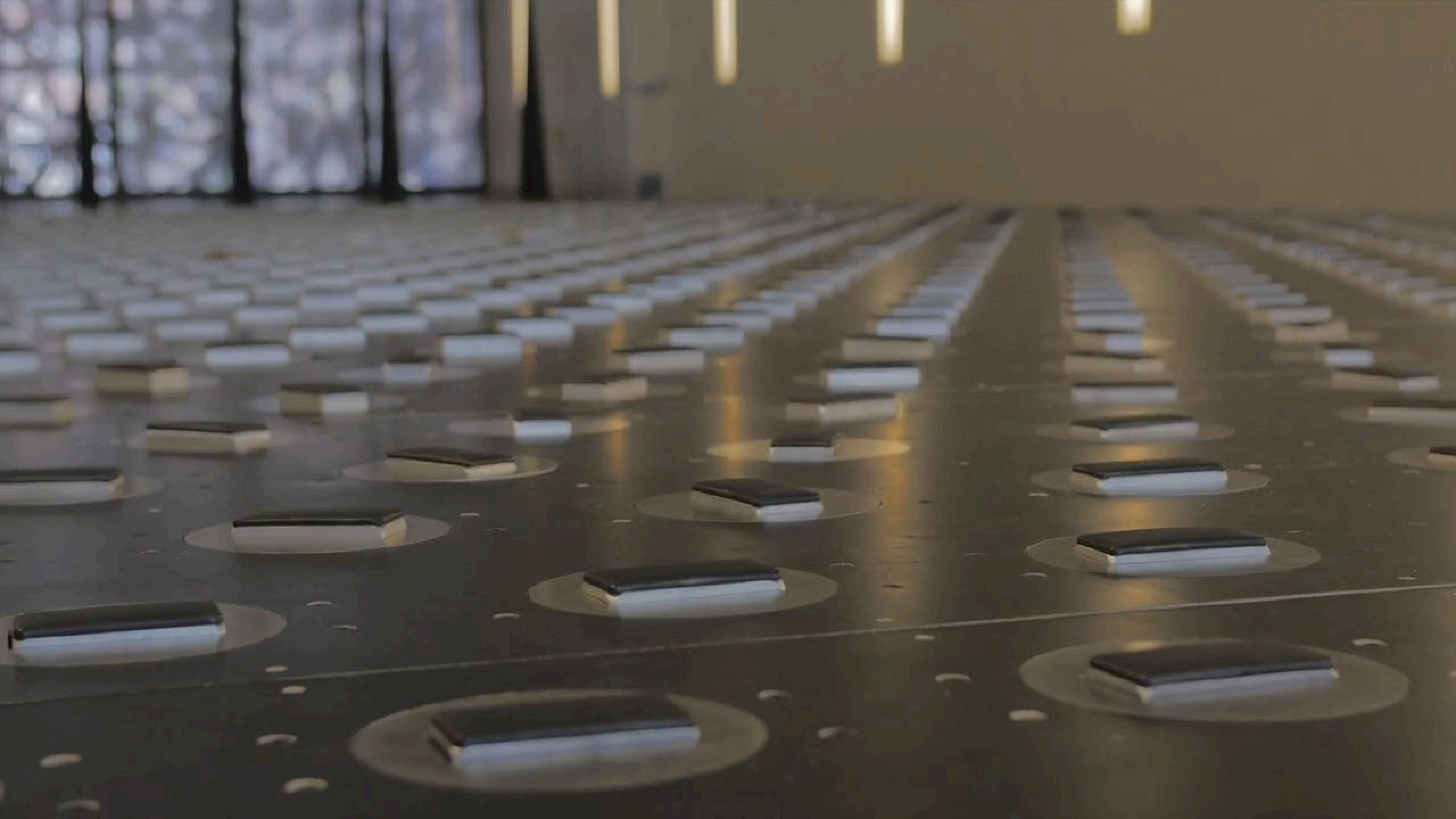


Terraformer

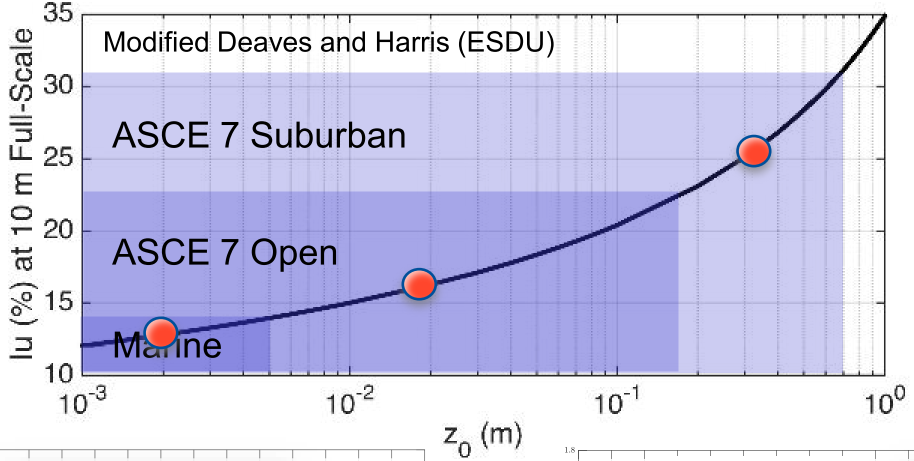
NSF MRI CMMI 1428954

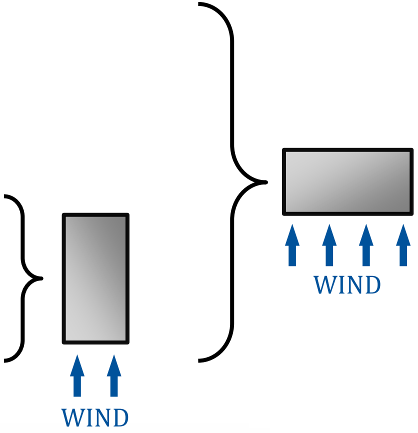


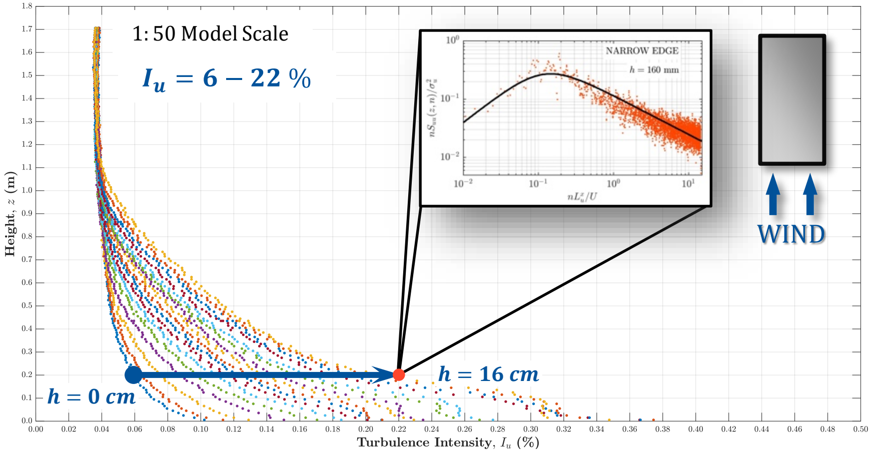
- Computer controlled terrain generator
- 48 RS-485 communication busses
- 1116 integrated stepper motor drives
- Rapidly configures in 90 seconds to produce a range of target exposures

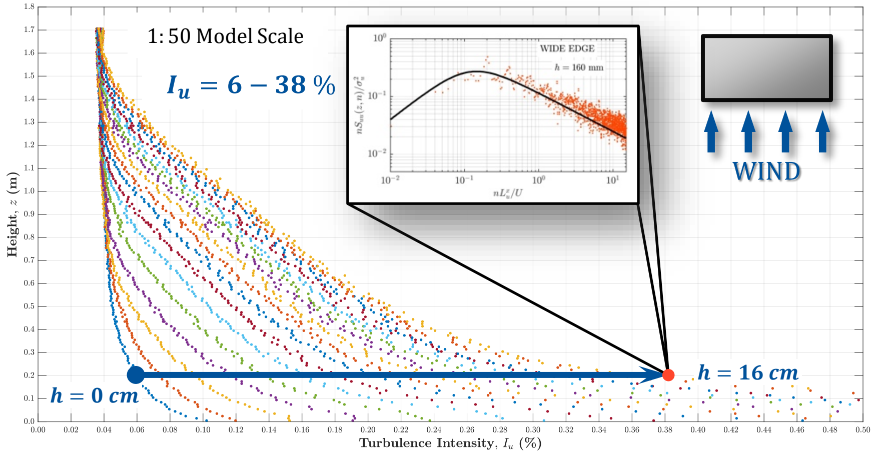


Continuum of Terrain Conditions









$I_v/I_u = 0.71 - 0.79$ $I_w/I_u = 0.59 - 0.63$

$I_v/I_u = 0.69 - 0.77$ $I_w/I_u = 0.56 - 0.62$

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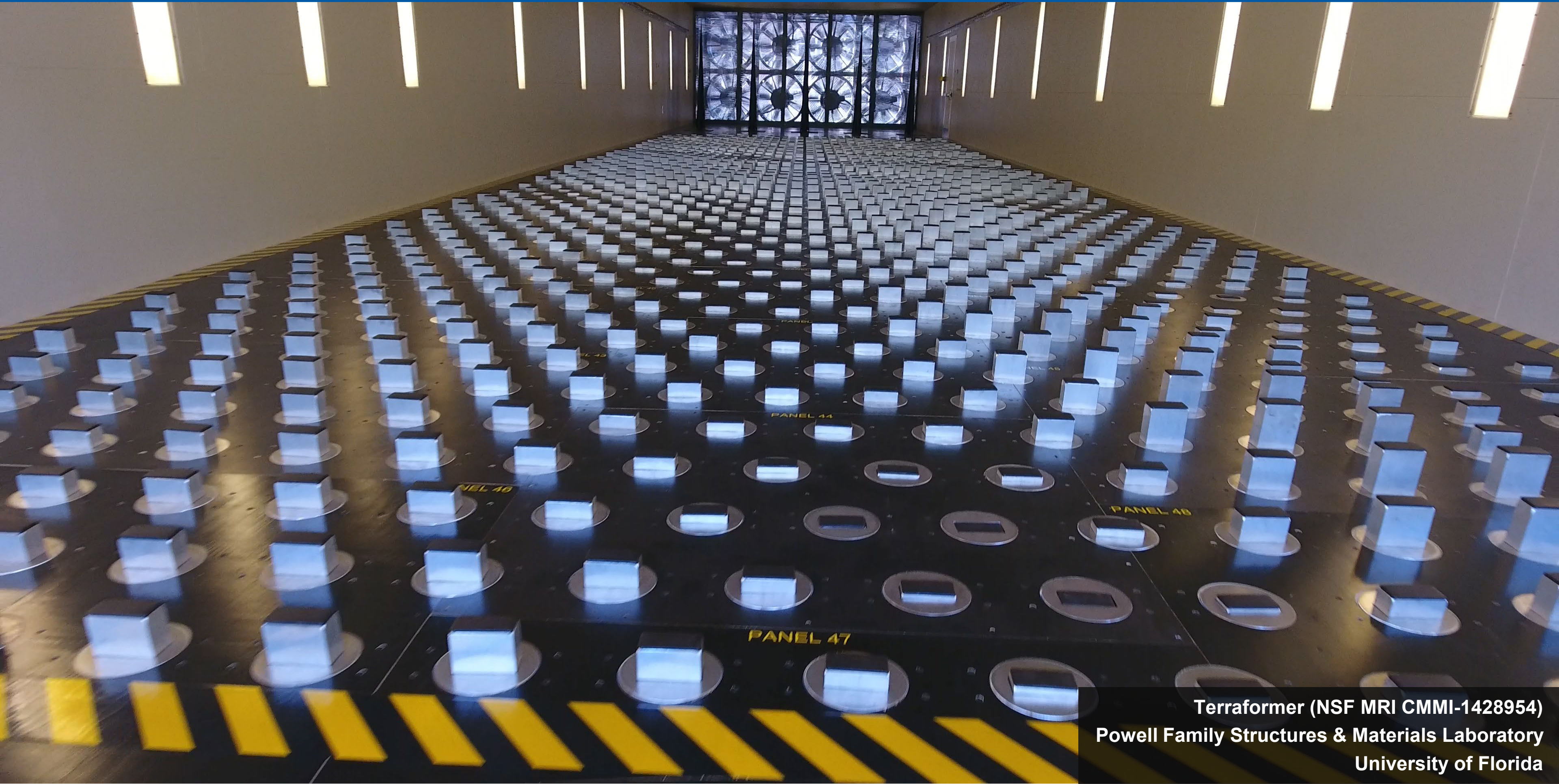

Terraformer (NSF MRI CMMI-1428954)
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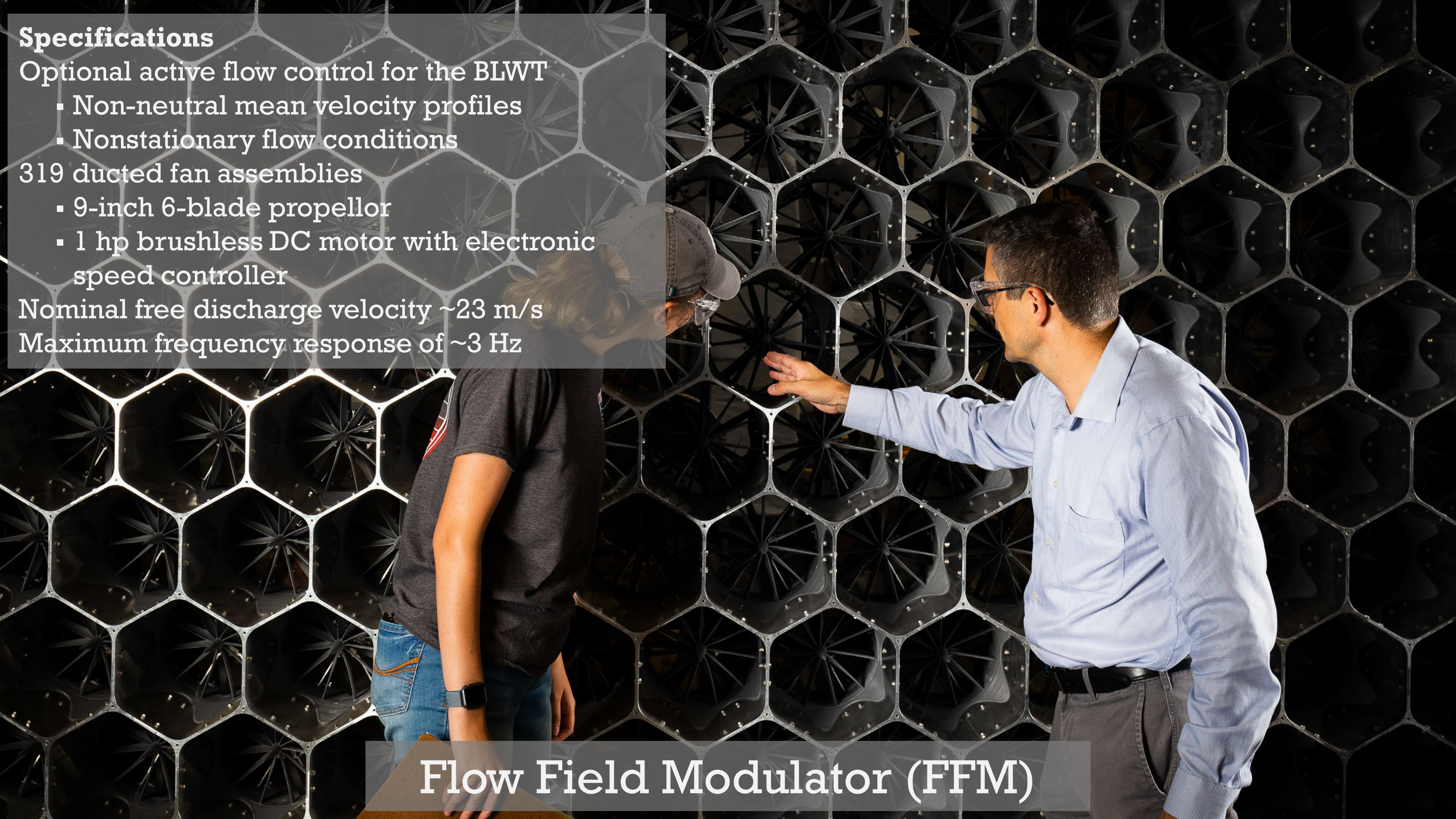


Specifications

Optional active flow control for the BLWT

- Non-neutral mean velocity profiles
- Nonstationary flow conditions

319 ducted fan assemblies

- 9-inch 6-blade propellor
- 1 hp brushless DC motor with electronic speed controller

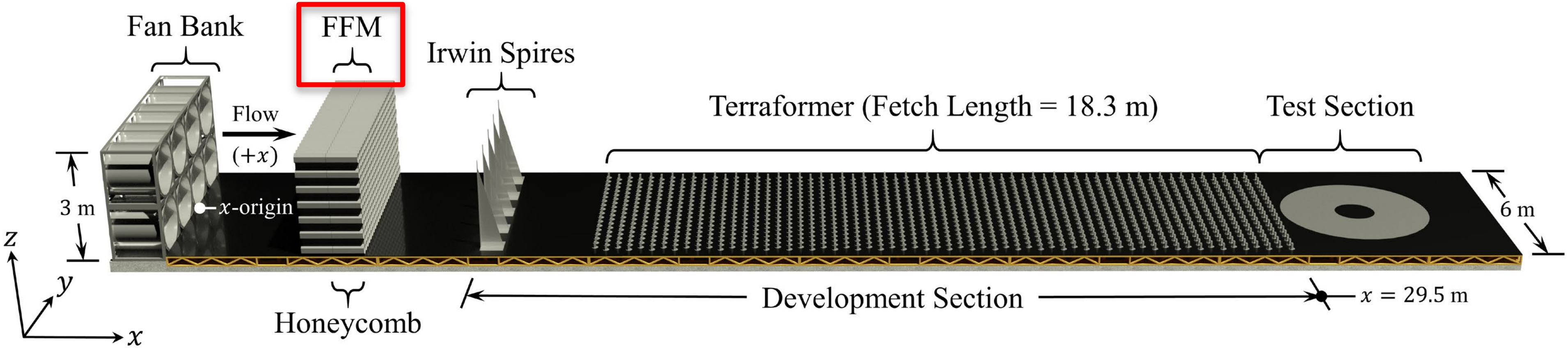
Nominal free discharge velocity ~23 m/s

Maximum frequency response of ~3 Hz

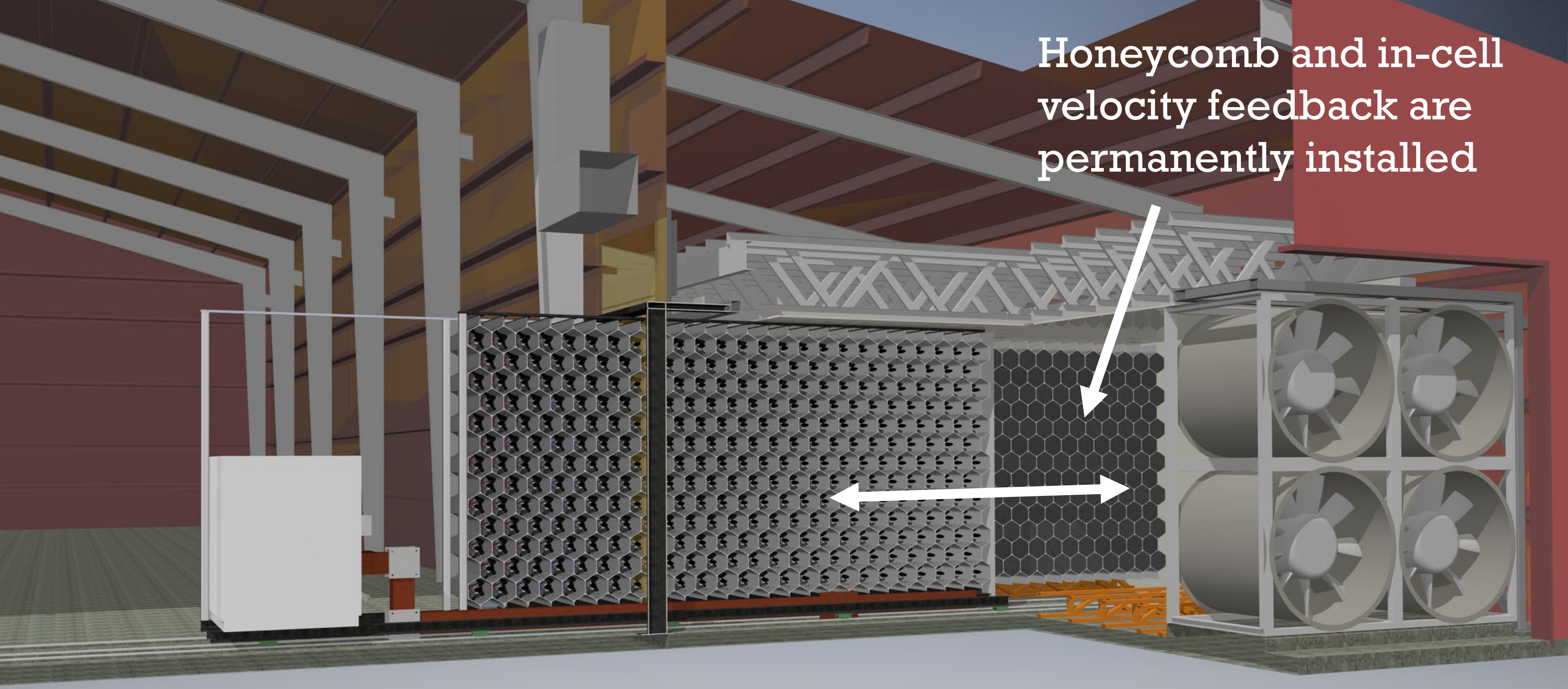
Flow Field Modulator (FFM)

Flow Field Modulator

Mean Velocity and Turbulence Generator



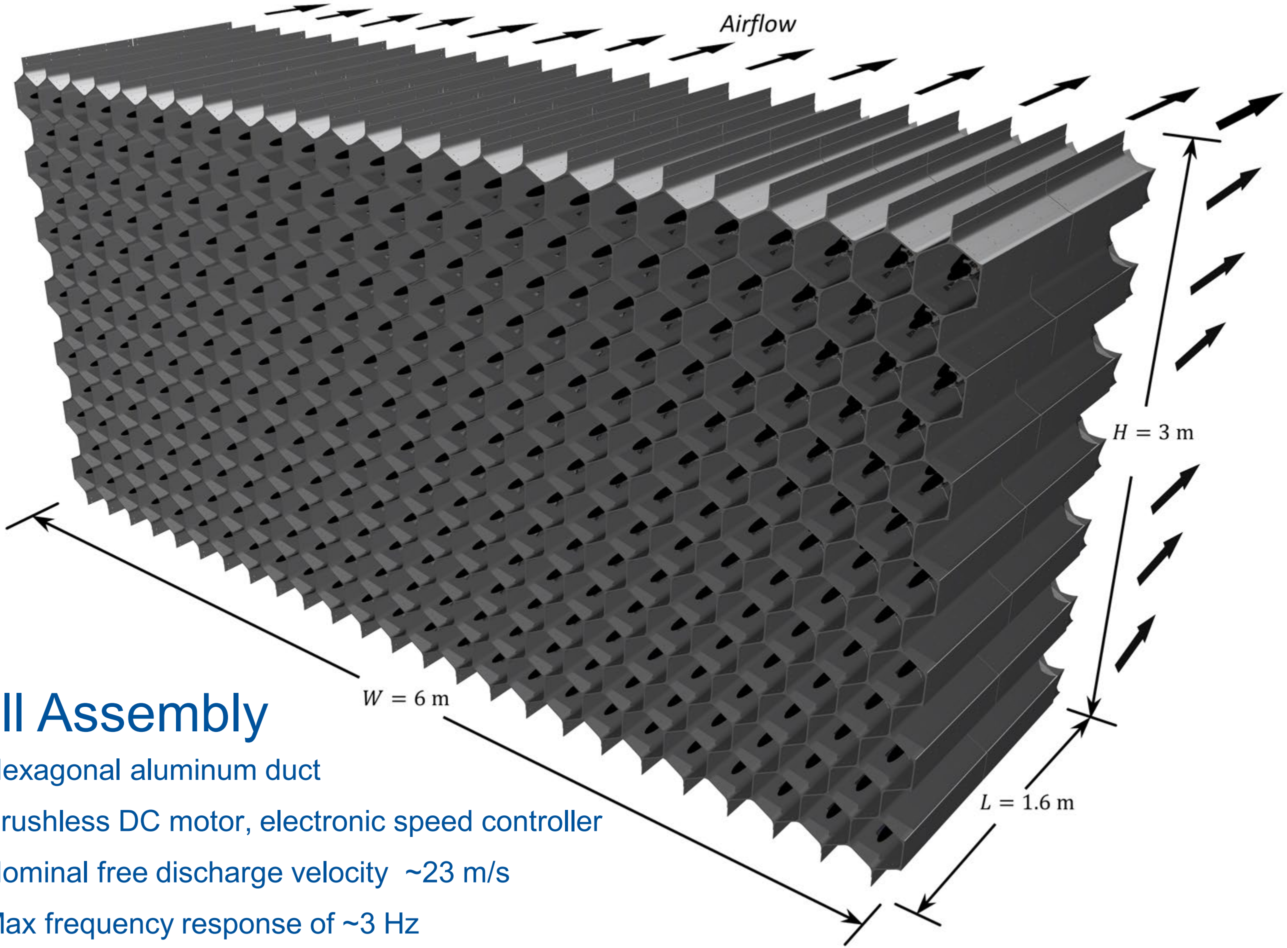
MRI (NSF Award 1428954)



The FFM **slides into** the wind tunnel to provide active flow control or **slides out** for conventional BLWT operation

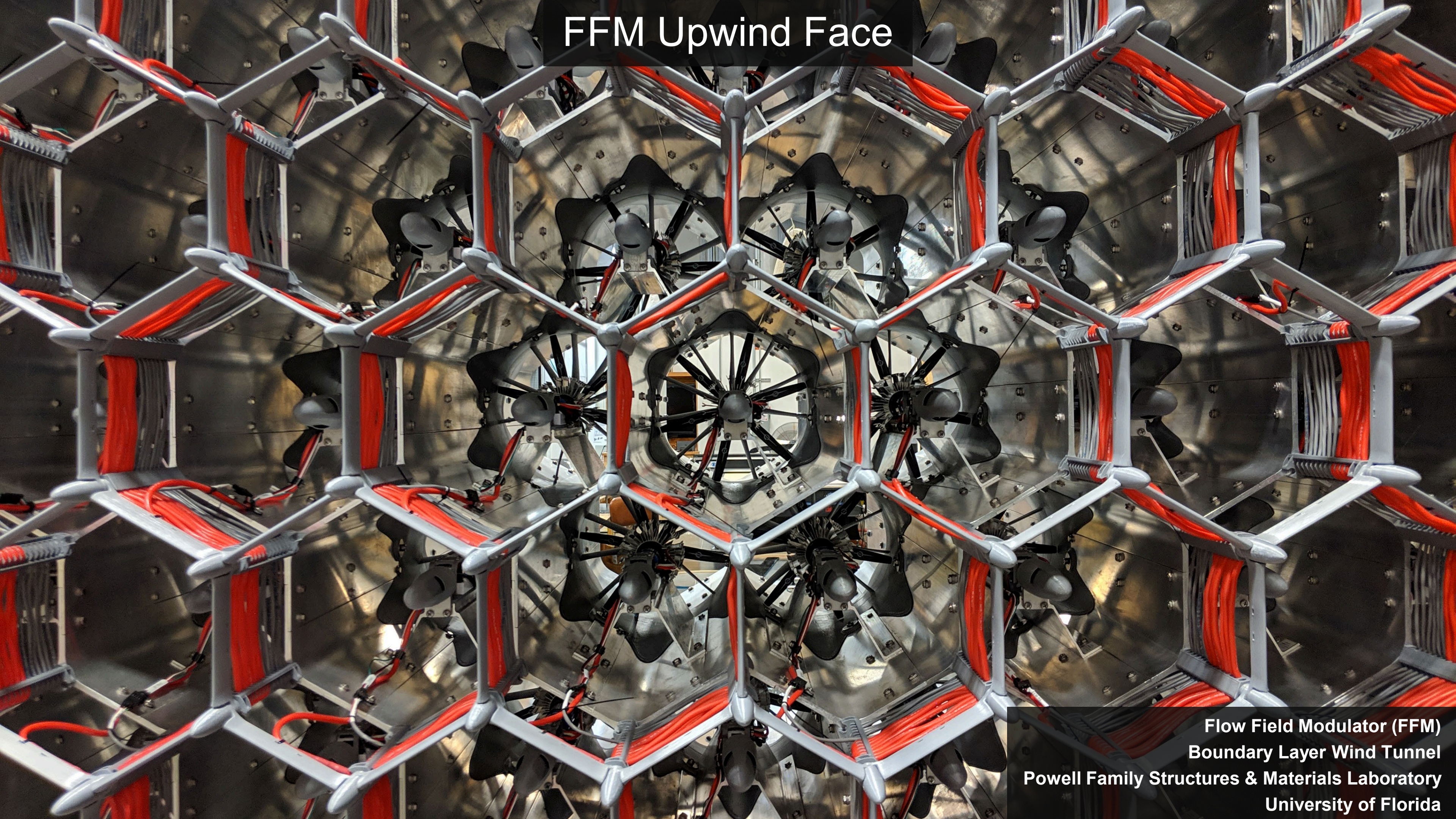
Flow Field Modulator

- 319 ducted fan assemblies
- Capable of reproducing user-specified non-monotonic and/or spatiotemporally nonstationary flows
- Velocity profiles produced along the height of the tunnel by varying row fan speeds
- Individual fan speeds fluctuate to achieve target turbulence properties



Cell Assembly

- Hexagonal aluminum duct
- Brushless DC motor, electronic speed controller
- Nominal free discharge velocity ~23 m/s
- Max frequency response of ~3 Hz


FFM Upwind Face
Flow Field Modulator (FFM)
Boundary Layer Wind Tunnel
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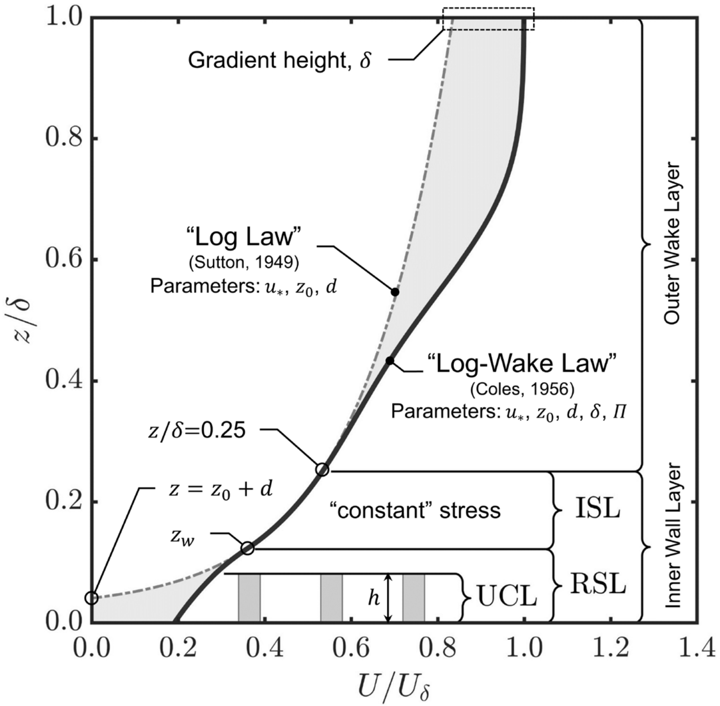
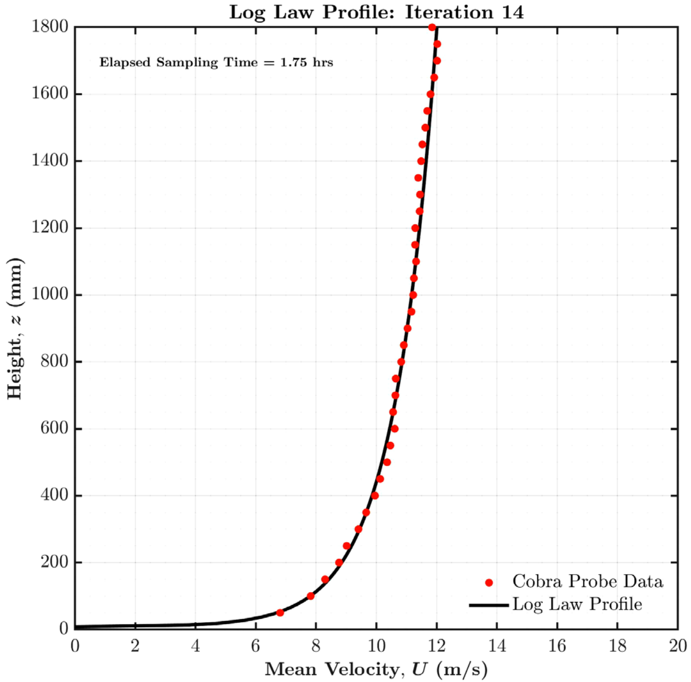
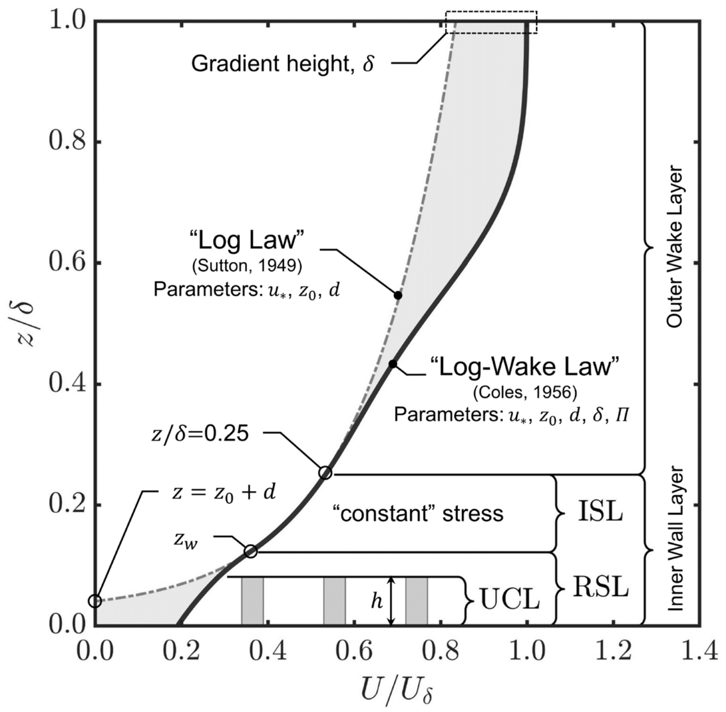
University of Florida

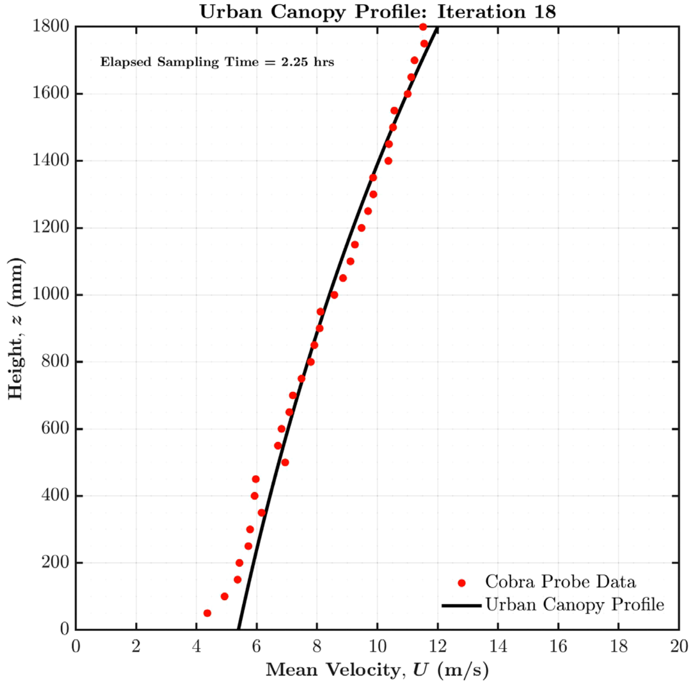
Example Target Profiles – Log Law





Example Target Profiles – Urban Canopy





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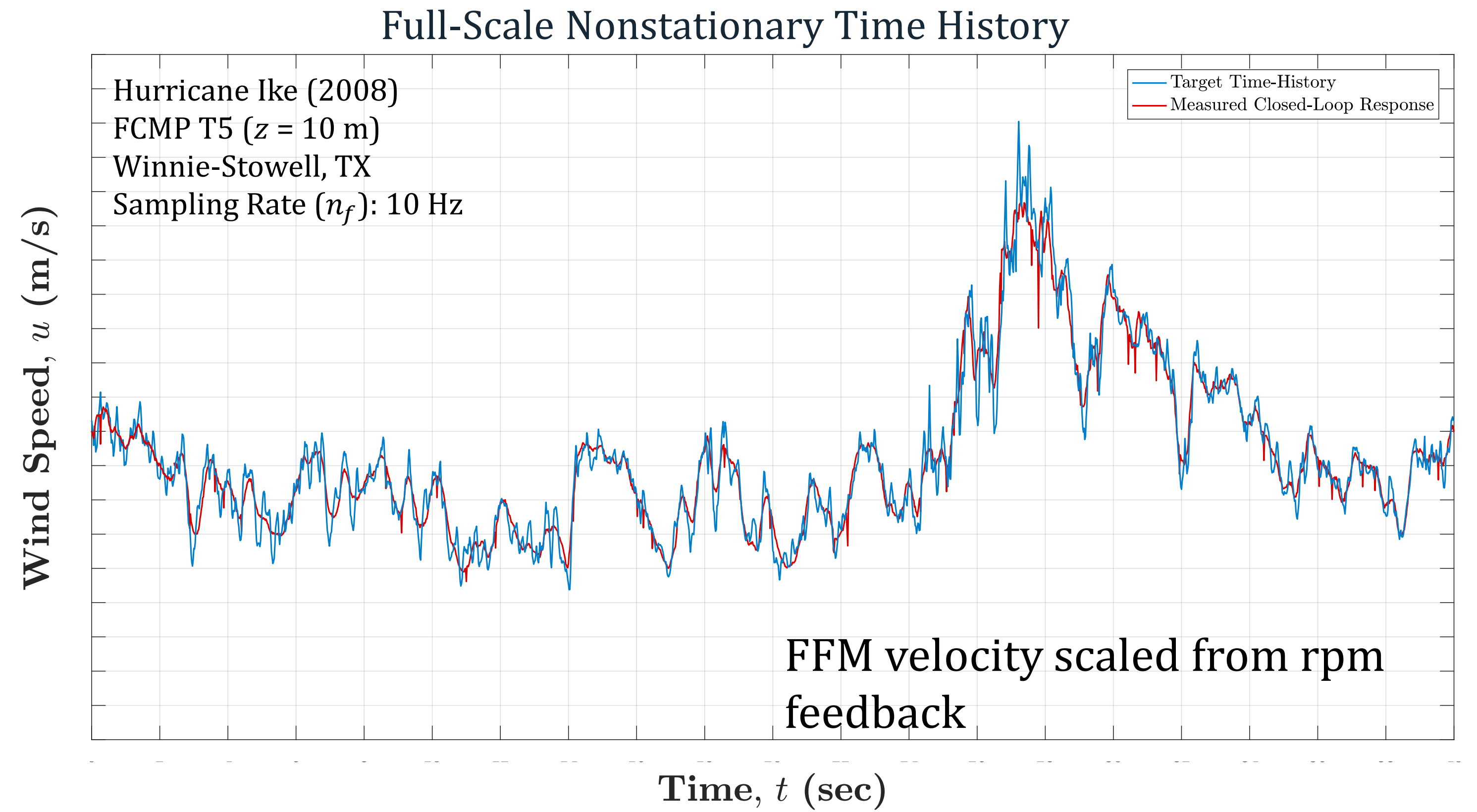
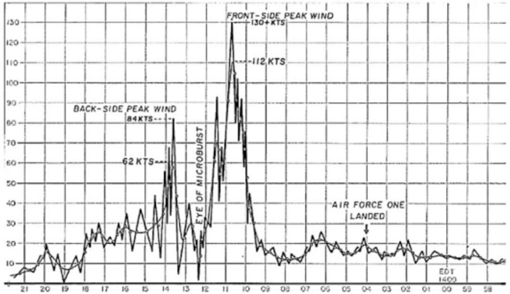
Time History

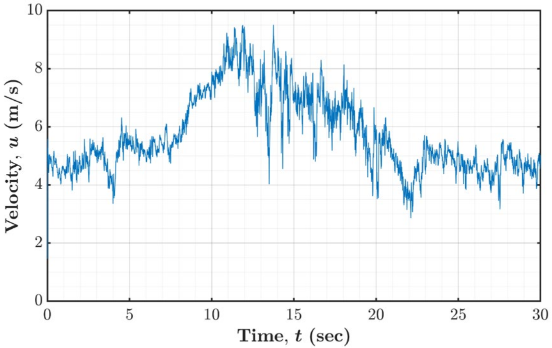


Next evolution of simulation

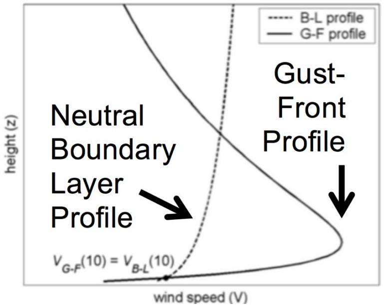
- Non-stationary events



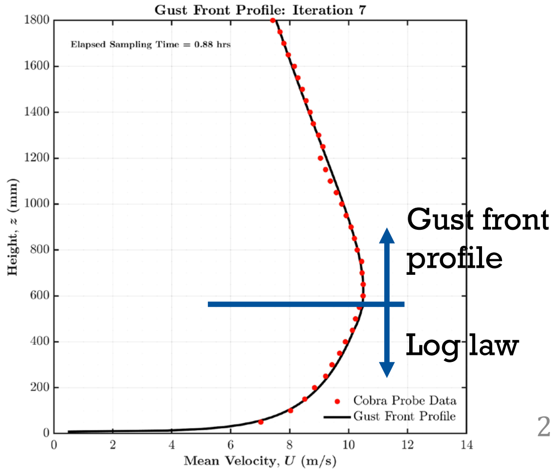
Example of nonstationary velocity record measured during downburst at Andrews Airforce Base (Fujita 1985)



- Non-neutral flows



Mean velocity profiles (Kwon and Kareem, 2009)

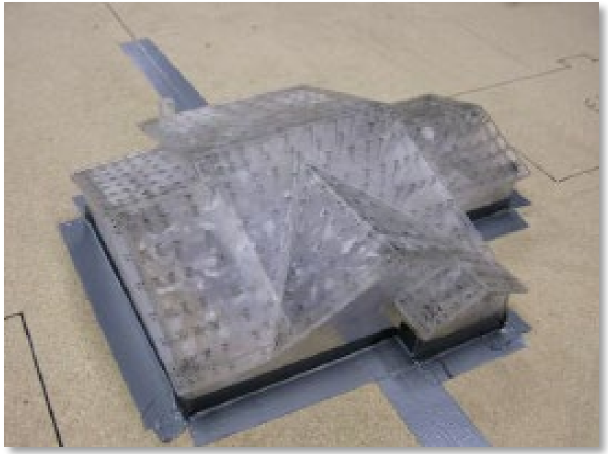


Kwon, D. K., & Kareem, A. (2009). Gust-front factor: New framework for wind load effects on structures. *Journal of structural engineering*, *135*(6), 717-732.

Instrumentation

Model Instrumentation

- Scanivalve pressure scanning system
  - 512 pressure taps can be measured simultaneously from eight ZOC33 modules
  - Max sampling rate = 625 Hz
- 6-axis force balance sensors
- Displacement sensors
- Accelerometers



Flexible tubes inside model connects pressure ‘taps’ to pressure scanning modules

Slide Courtesy of Pedro Fernandez

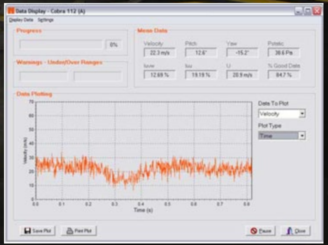
Wind Profile Measurements

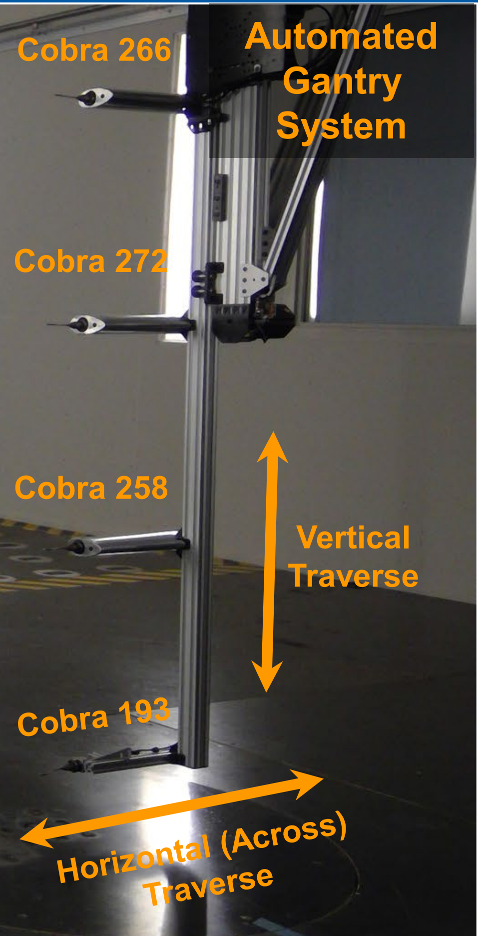
Series 100 Cobra Velocity Probes

Turbulent Flow Instrumentation

TurbulentFlow Instrumentation

- Measure u, v, and w velocity components and static pressure
- Acceptance cone: ±45°
- Maximum frequency response: 2 kHz
- Sensing range: 2-65 m/s






Data Collection Time-Lapse*
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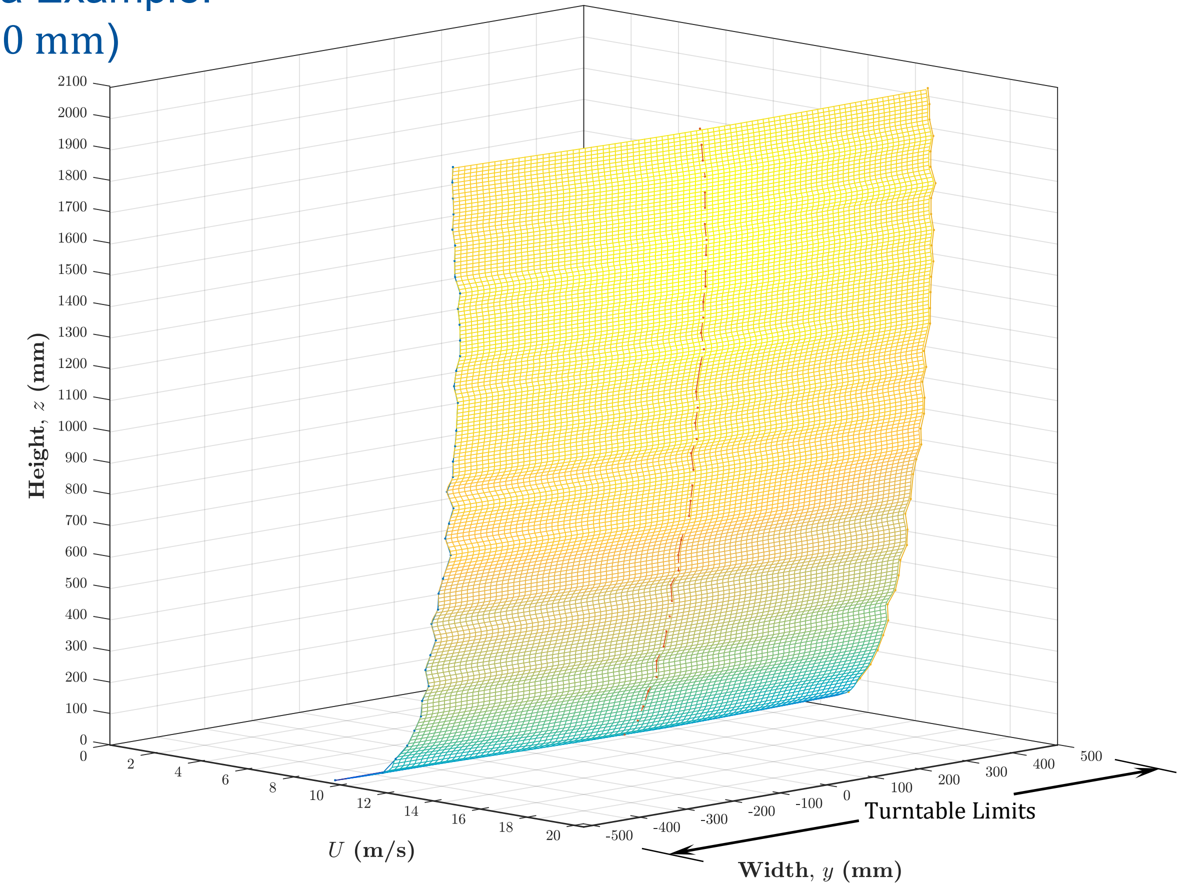
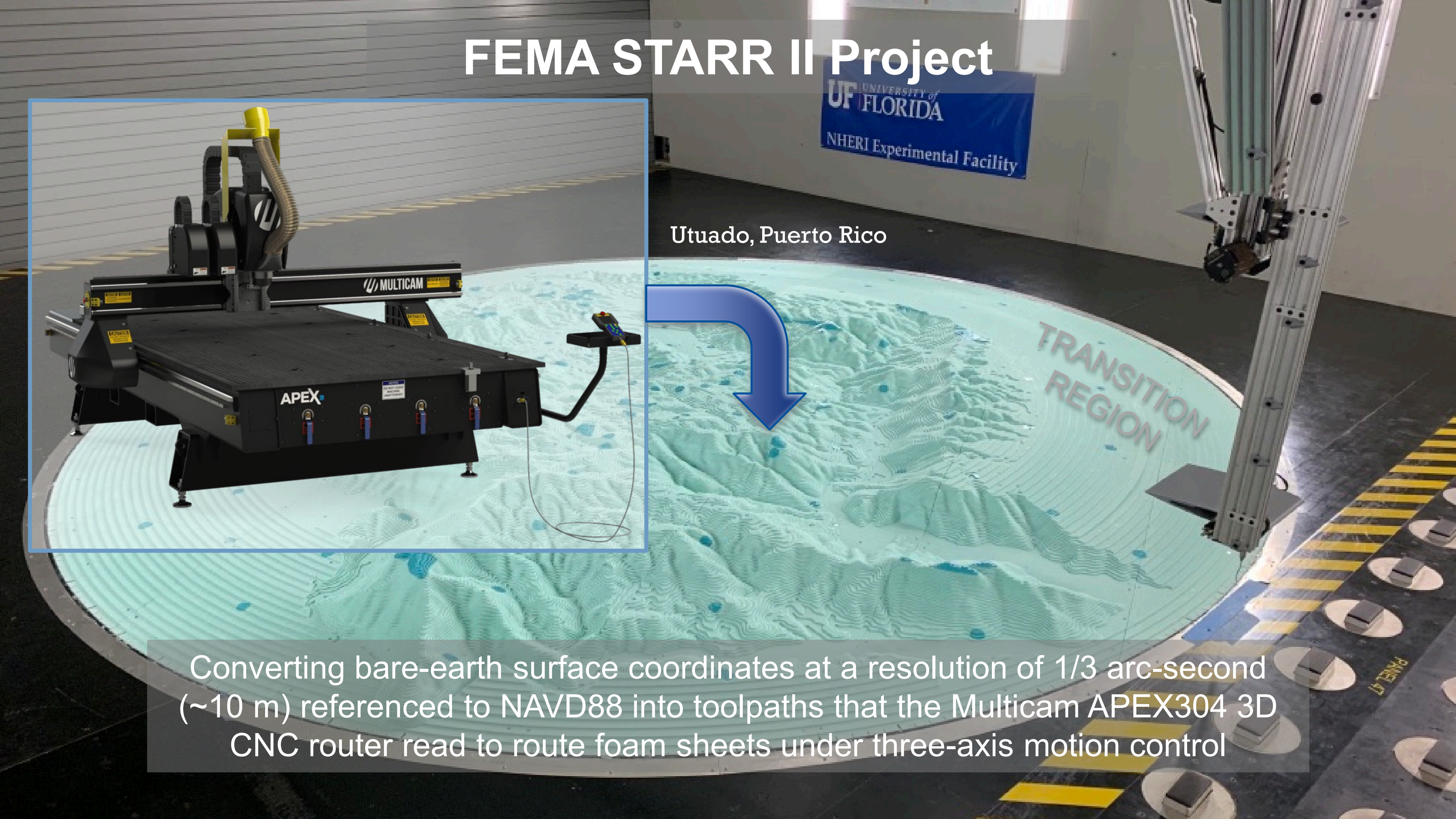
*Not recorded during actual testing

Cobra Probe Data Example: Flush Case ($h = 0$ mm)



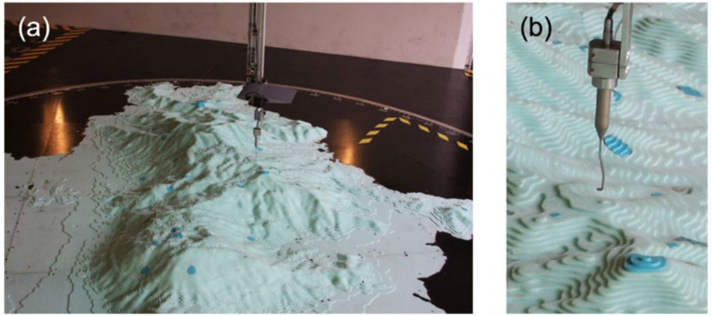
FEMA STARR II Project



Converting bare-earth surface coordinates at a resolution of 1/3 arc-second (~10 m) referenced to NAVD88 into toolpaths that the Multicam APEX304 3D CNC router read to route foam sheets under three-axis motion control

FEMA STARR II Project

3D instrument control of the Cobra Probe Rake for precision measurement of surface flows

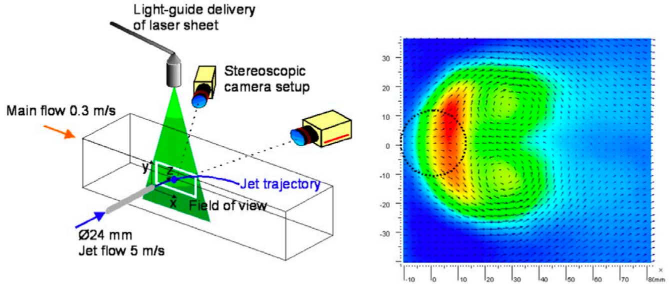


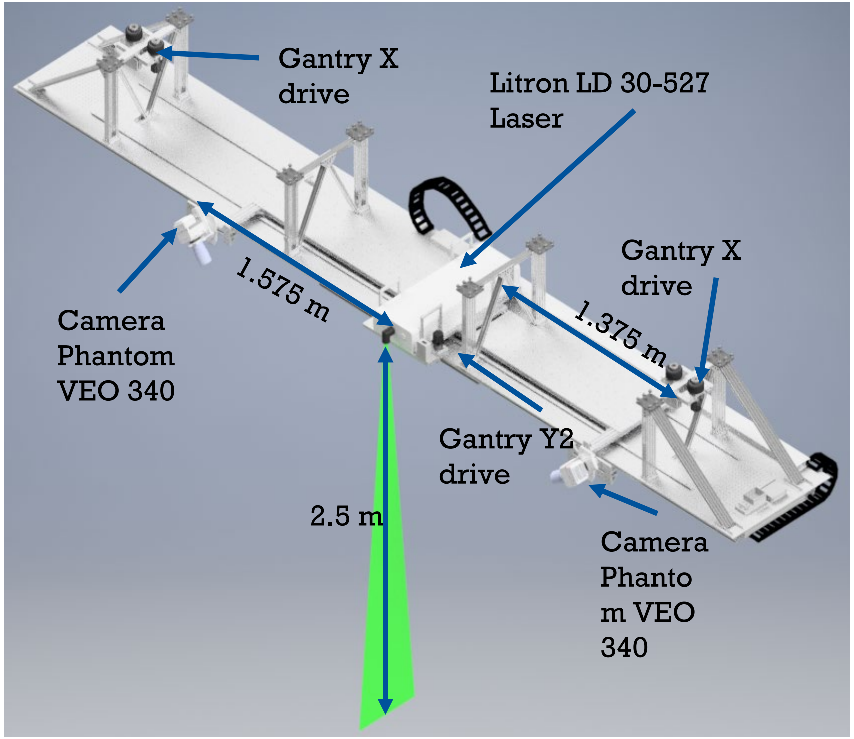
(a) Cobra Probe installed in instrument traverse

(b) Zoomed in view of the Cobra Probe over the topographic model surface

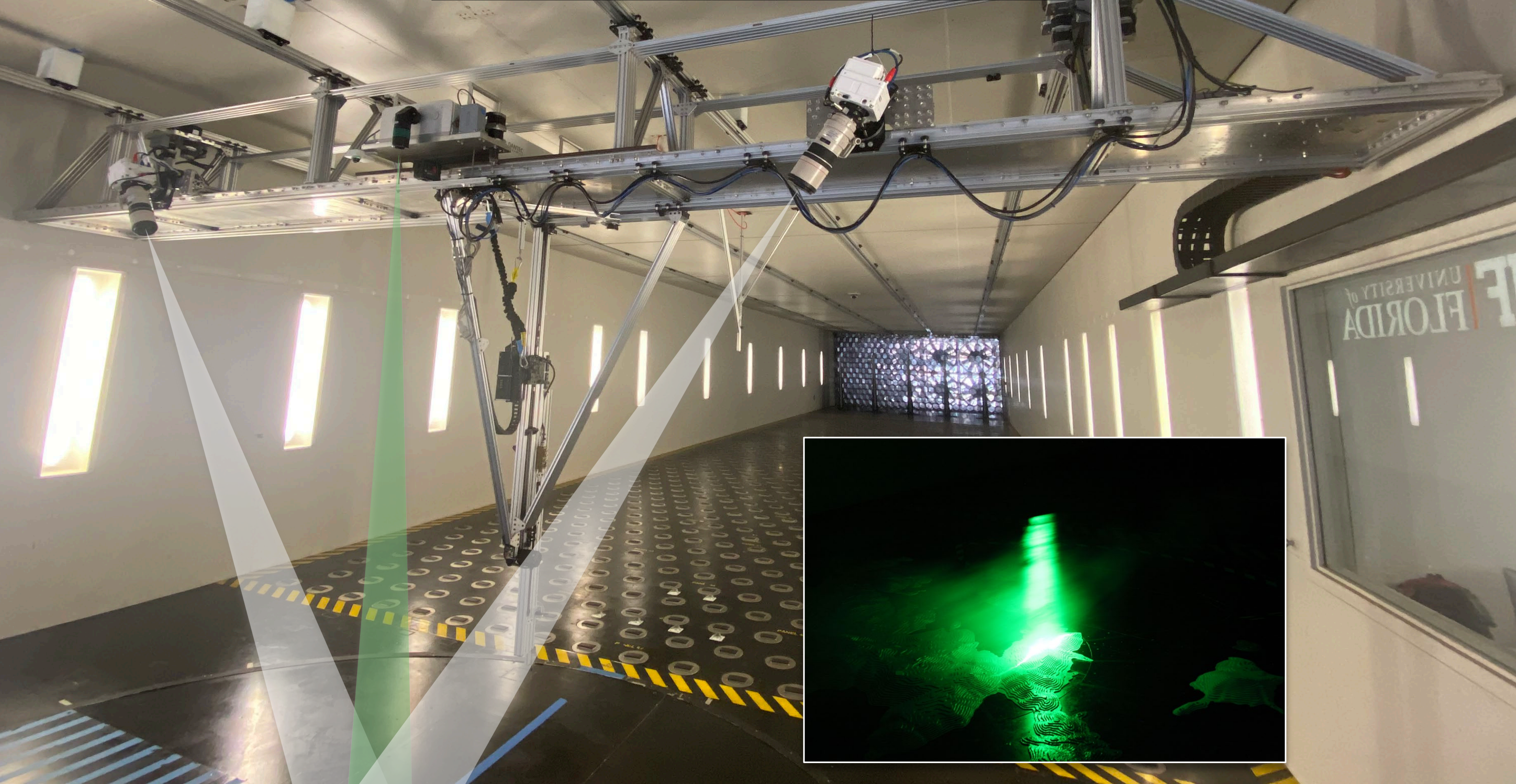
Particle Image Velocimetry (PIV)

- Dantec Dynamics PIV system
  - DualPower 30-1000 laser (2 X 30 mJ at 1000 Hz; 527 nm)
  - SpeedSense VEO 340 camera that can record up to 72 GB of data at 4MP and 800 fps
  - Camera is equipped with a 10 Gb interface to enable rapid transfer of data





Particle Image Velocimetry (PIV)



PIV Setup

- Designed and built seeders in house
  - Produce particles of the correct size (1-2 micron)
  - Evenly and sufficiently distribute particles in PIV window
  - Use safe and inexpensive fluid

Seed Particle Distribution and Mixing

Boundary Layer Wind Tunnel
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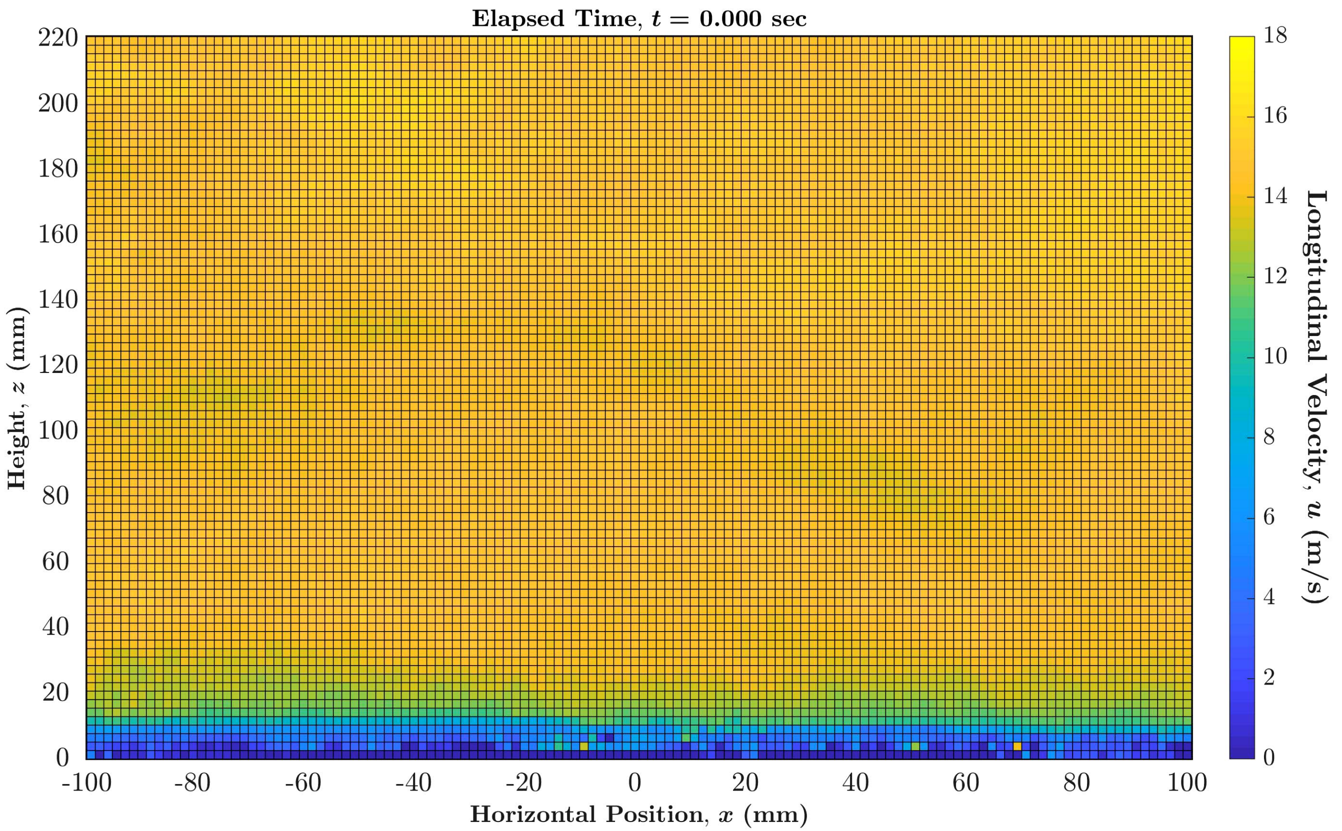
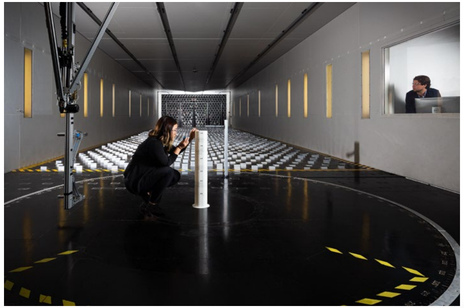
Time-resolved Longitudinal Velocity from PIV



UF Experimental Facility

Self-Configuring Hybrid Boundary Layer Wind Tunnel (**BLWT**)



Multi-Axis Wind Load Simulator (**MAWLS**)

High Airflow Pressure Loading Actuator (**HAPLA**)

Dynamic Flow Simulator (**DFS**)

Spatiotemporal Pressure Loading Actuator (**SPLA**)

Full-scale performance testing:

- Walls/windows
- Cladding
- Doors

Uniform dynamic pressure loads

Multi-Axis Wind Load Simulator (MAWLS)

High Airflow Pressure Loading Actuator (HAPLA)
Time Varying, Spatially Uniform Loads, Wetting

Simultaneous dynamic pressure and wind driven rain

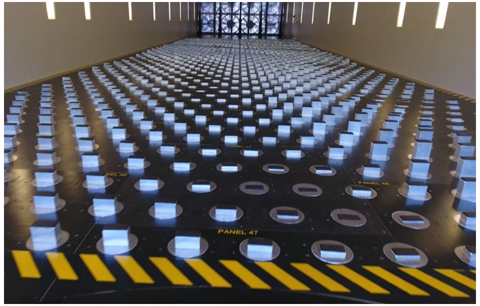
Bridging ASTM and other test protocols to expected performance and failure thresholds under realistic dynamic extreme wind loading

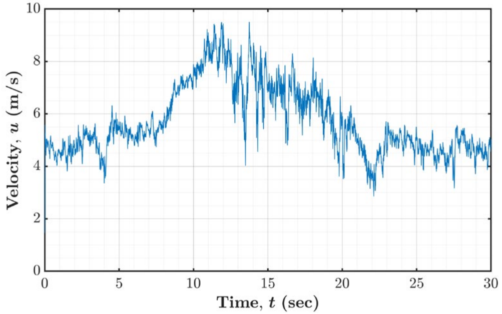
Pressure Valve with Connection to Pressure Box

Sliding Door Installation on HAPLA Face with Protective Viewing Panel

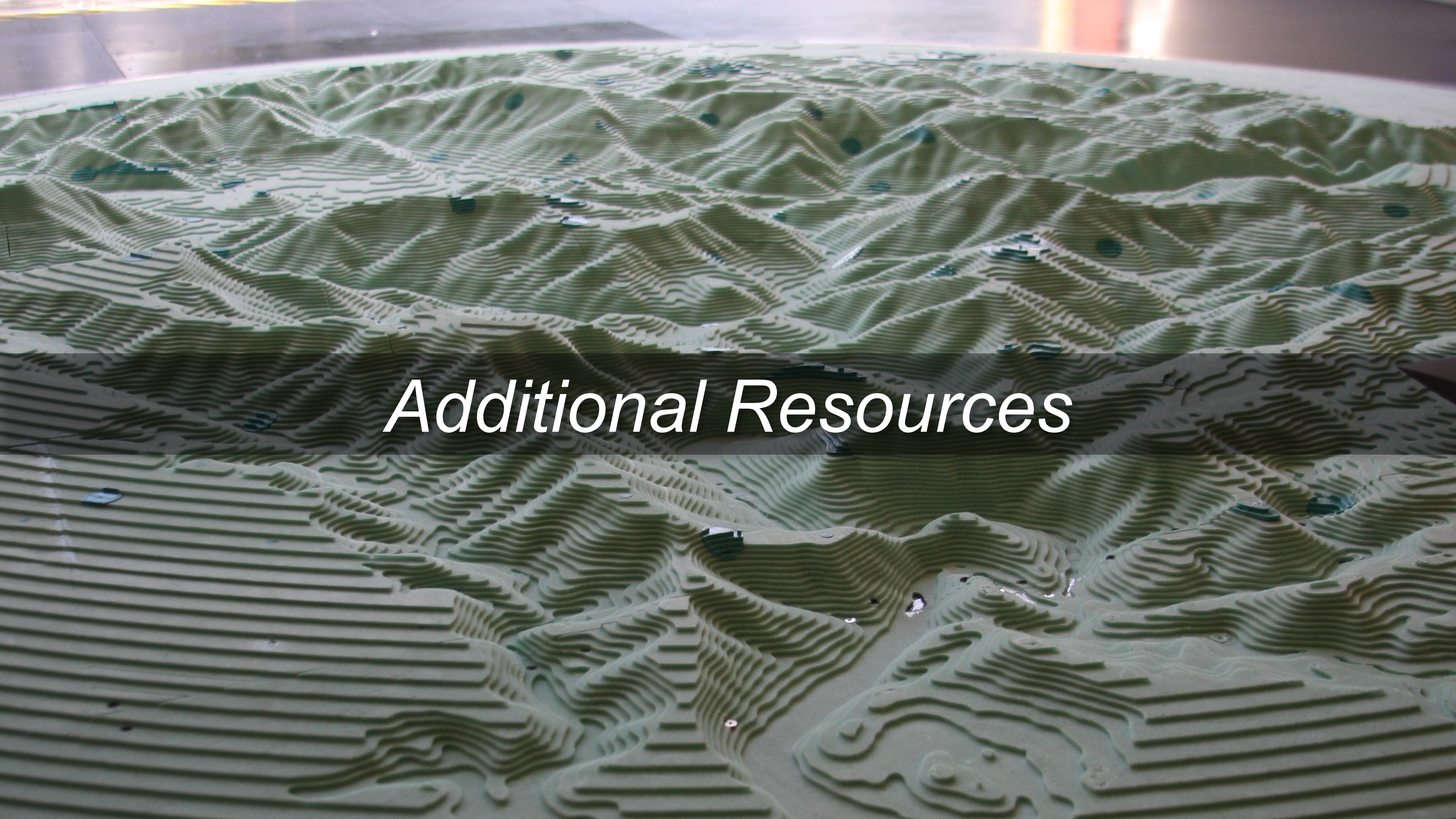
Field Data + Laboratory Resources

- Site-specific impacts on building loads
  - High resolution site imaging + Damage assessment + Terraformer heterogenous terrain in BLWT
- Effects of transient and non-synoptic flow
  - Ground-based measurements + Flow Field Modulator/BLWT
- Wind and rain effects on wall systems, components, and cladding
  - Tower measurements/pressure traces + Damage assessment + Pressure loading actuators (HAPLA - non-NHERI)

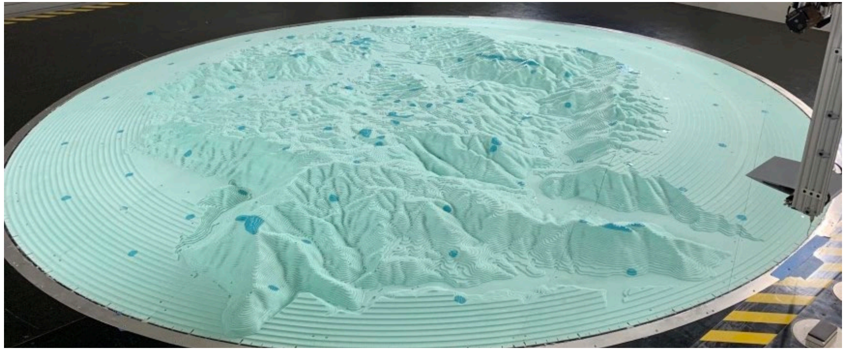




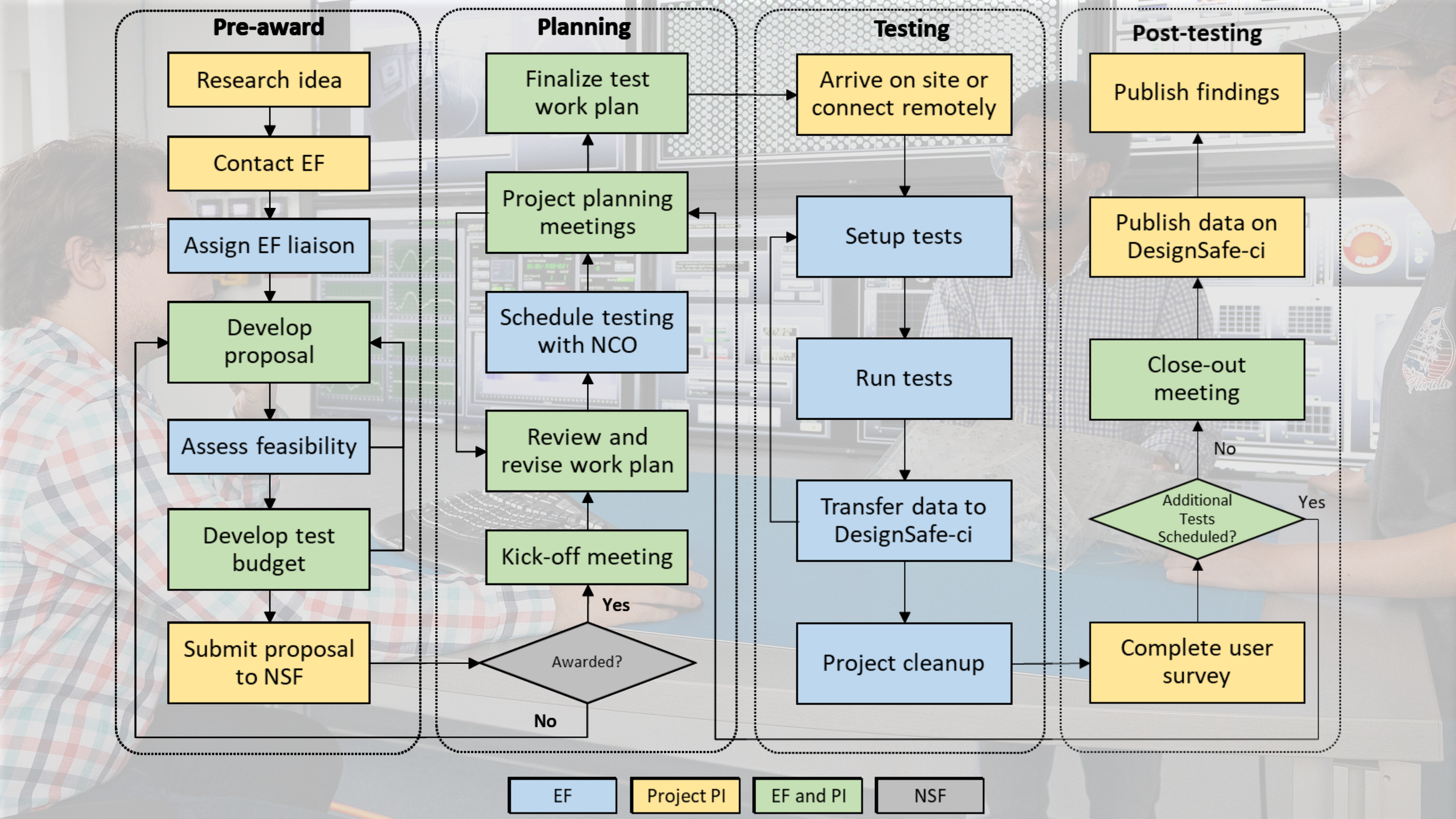
Additional Resources



In-House Fabrication

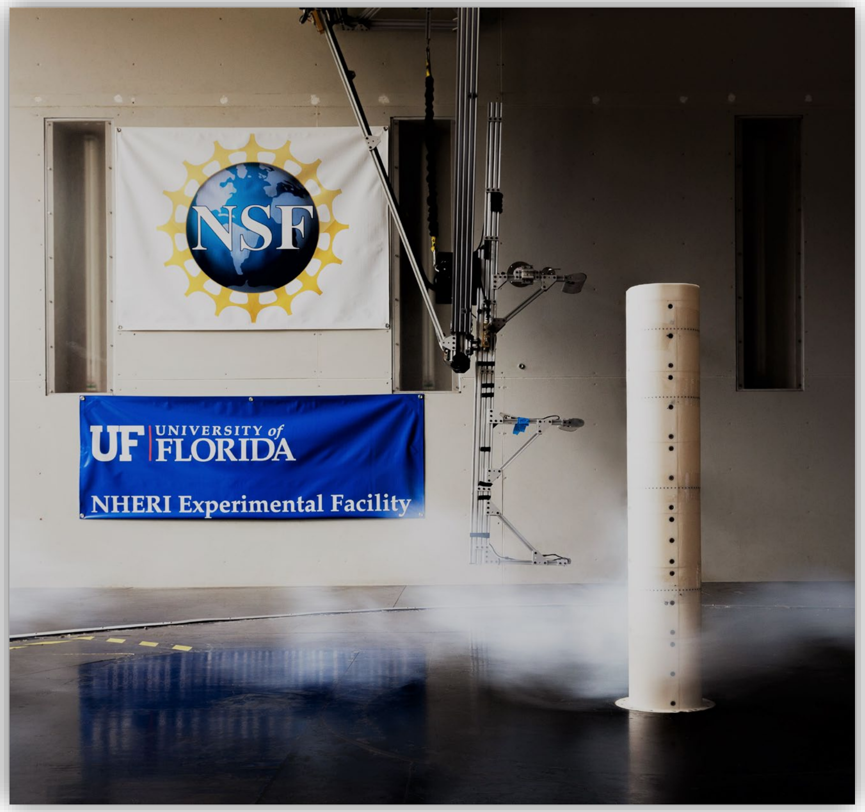


- 3-axis CNC router
  - Fully programmable MultiCam APEX3R CNC Router for routing foam, wood, plastics, and aluminum model components
  - 1.5m x 3m
- 3D printers
  - Three Formlabs Form 2 stereolithography 3D printers for high-resolution rigid pressure-tapped models
  - Five LulzBot TAZ 6 Fused Filament Fabrication 3D printers for production of larger lower resolution model components
- Machine shop and skilled design/fabrication staff


Pre-award
Research idea
Contact EF
Assign EF liaison
Develop proposal
Assess feasibility
Develop test budget
Submit proposal to NSF
Planning
Finalize test work plan
Project planning meetings
Schedule testing with NCO
Review and revise work plan
Kick-off meeting
Yes
Awarded?
No
Testing
Arrive on site or connect remotely
Setup tests
Run tests
Transfer data to DesignSafe-ci
Project cleanup
Post-testing
Publish findings
Publish data on DesignSafe-ci
Close-out meeting
No
Additional Tests Scheduled?
Yes
Complete user survey
EF
Project PI
EF and PI
NSF

How do I learn more?

- https://ufl.designsafe-ci.org
- **Contact one of the PI team**
  - Jennifer Bridge, jennifer.bridge@essie.ufl.edu
  - Forrest Masters, masters@ce.ufl.edu
  - Kurt Gurley, kgurl@ce.ufl.edu
  - Brian Phillips, brian.phillips@essie.ufl.edu
- **Upcoming workshop – May 19**
  - BLWT Simulation of Transient and Non-synoptic Wind Events



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