30 YEARS OF EXPERIENCE
30 GW YEARS OF OPERATION

OUR EXPERIENCE YOUR ADVANTAGE

900+ Utility-Scale Projects Worldwide

Nearly 20 GW Awarded or Installed Globally

Installations in 25+ Countries

1989
Ron Corio develops first solar tracker for the Wattsun concentrator module.

1992
Ron Corio purchases the Wattsun Corporation and forms Array Technologies, Inc.

1996
Helium Balloon Tracker built for Steve Fossett's first Around the World attempt.

360 degree tracker purchased by the Canadian Government for use in the Arctic Circle.

2004
Array Technologies begins shipping trackers to utility-scale projects across Europe and Asia, including a 5.7 MW site in South Korea.

2006
DuraTrack® HZ installed in largest utility-scale solar project in the US, a 6 MW site located in Alamosa, CO.

2011
DuraTrack® HZ's terrain flexibility wins over fixed-tilt for 20 MW site located in Arizona, avoiding grading and maximizing land occupancy.

2012
Array partners with RWDI to study and solve how trackers should be designed for wind

1 GW Shipment Milestone surpassed

2013
Array Technologies ships DuraTrack® HZ tracker to a 265 MW in California, the largest tracked thin film project in the world, at the time.

2015
DuraTrack® HZ v3 is launched and ships to its first utility-scale site, Tranquility 256 MW.

2017
Array expands globally and opens offices in Europe, Central and South America, and Australia.

2018
Array introduces SmarTrack™ optimization software to boost power production.

2019
Array celebrates 30 years of solar innovation and surpasses 17+ GW awarded or installed milestone.

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RWDI

Principal wind consultant on ...

- 7 of the world's 10 tallest buildings
  - Nearly half of the top 100 (according to CTBUH)
- Some of the world's longest-span bridges

NAME	HEIGHT/SPAN (m)	LOCATION
Jeddah Tower	1,000	Jeddah, Saudi Arabia
Burj Khalifa	828	Dubai, United Arab Emirates
Shanghai Tower	632	Shanghai, China
Messina Strait Bridge (Suspension)	3,300	Sicily to Calabria, Italy
Golden Gate Bridge (Suspension)	1,280	San Francisco, CA, USA
Stonecutters Bridge (Cable-Stayed)	1,020	Hong Kong, China

RWDI will discuss

- Boundary Layer Wind Tunnel Testing
- Key Challenges of Single-Axis Trackers
- Components of Total Wind Load
- Aeroelastic Model Testing
- Aerodynamic Damping and Stiffness
- Stow Tilt Strategies: Low, Mid, High

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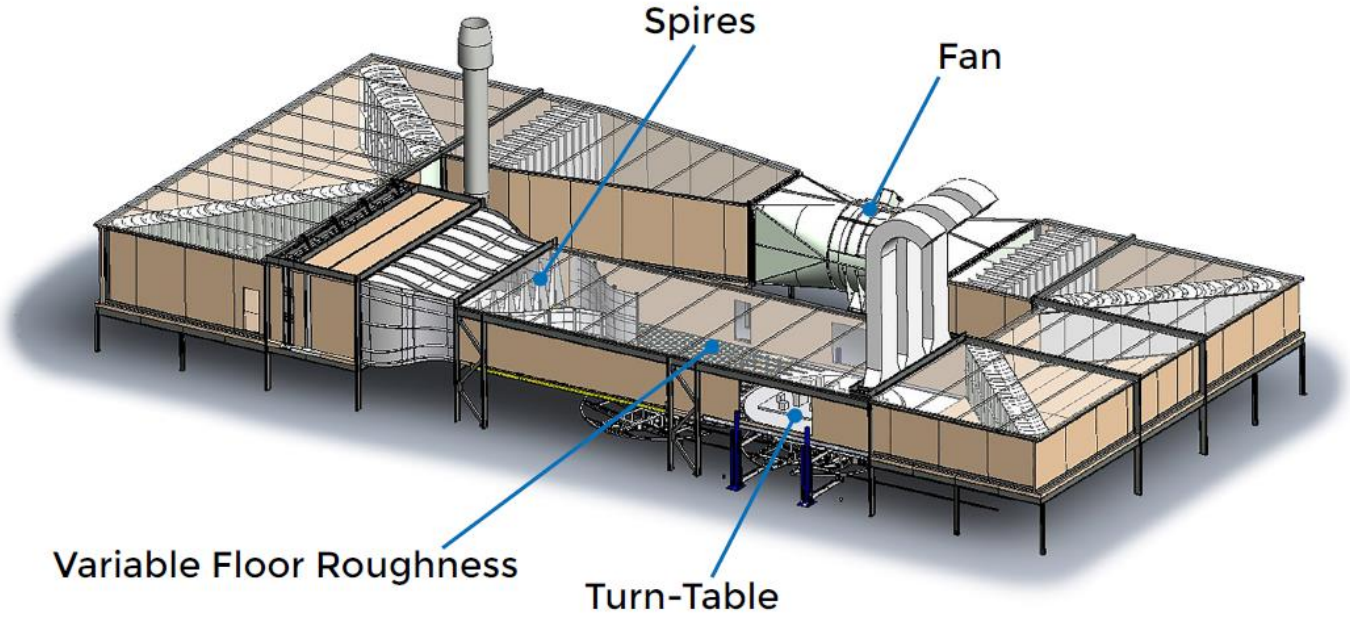
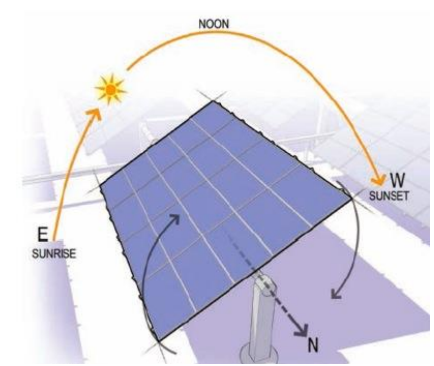
Boundary-Layer Wind Tunnel Testing



Ground-Mounted Systems



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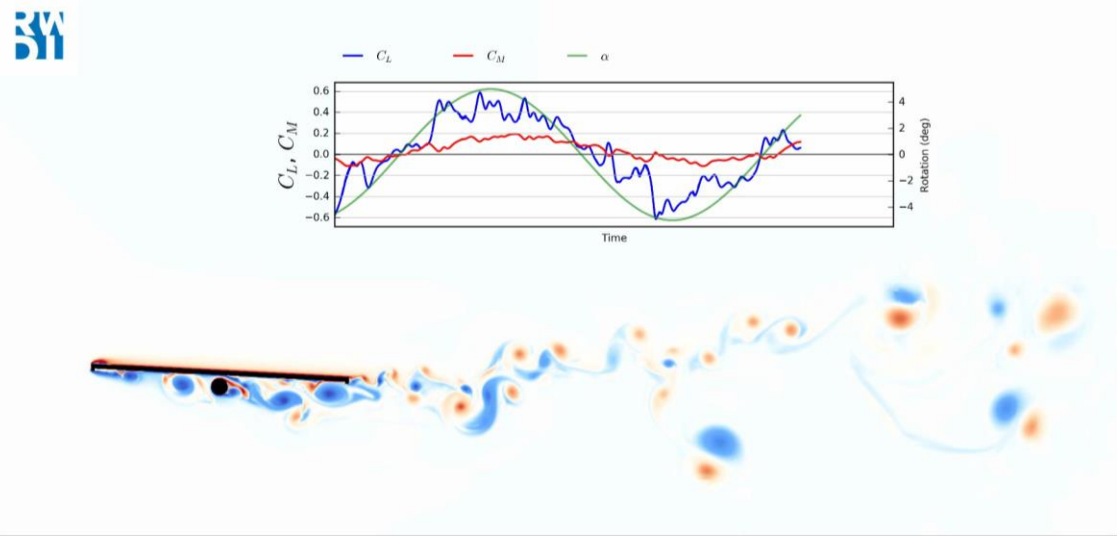
Key Challenges of Single-Axis Trackers

- **Prone to aerodynamic instabilities**
  - Torsional Galloping at Low Tilt Angles
  - Torsional Flutter at Mid Tilt Angles

- **Aeroelastic effects**
  - Self-Excited Forces
  - Design Wind Loads?

- **Stow strategy?**



Components of Total Wind Load

Conventional Pressure Model Test +
DAF Approximation

$$[K]\{Z\} = \{F\}_{SE} + \{F\}_{BUFF} - [M]\{\ddot{Z}\} - [C]\{\dot{Z}\}$$

Stiffness Force

Self-Excited Force

Buffeting Force

Inertial Force

Damping Force

Aeroelastic Model Test

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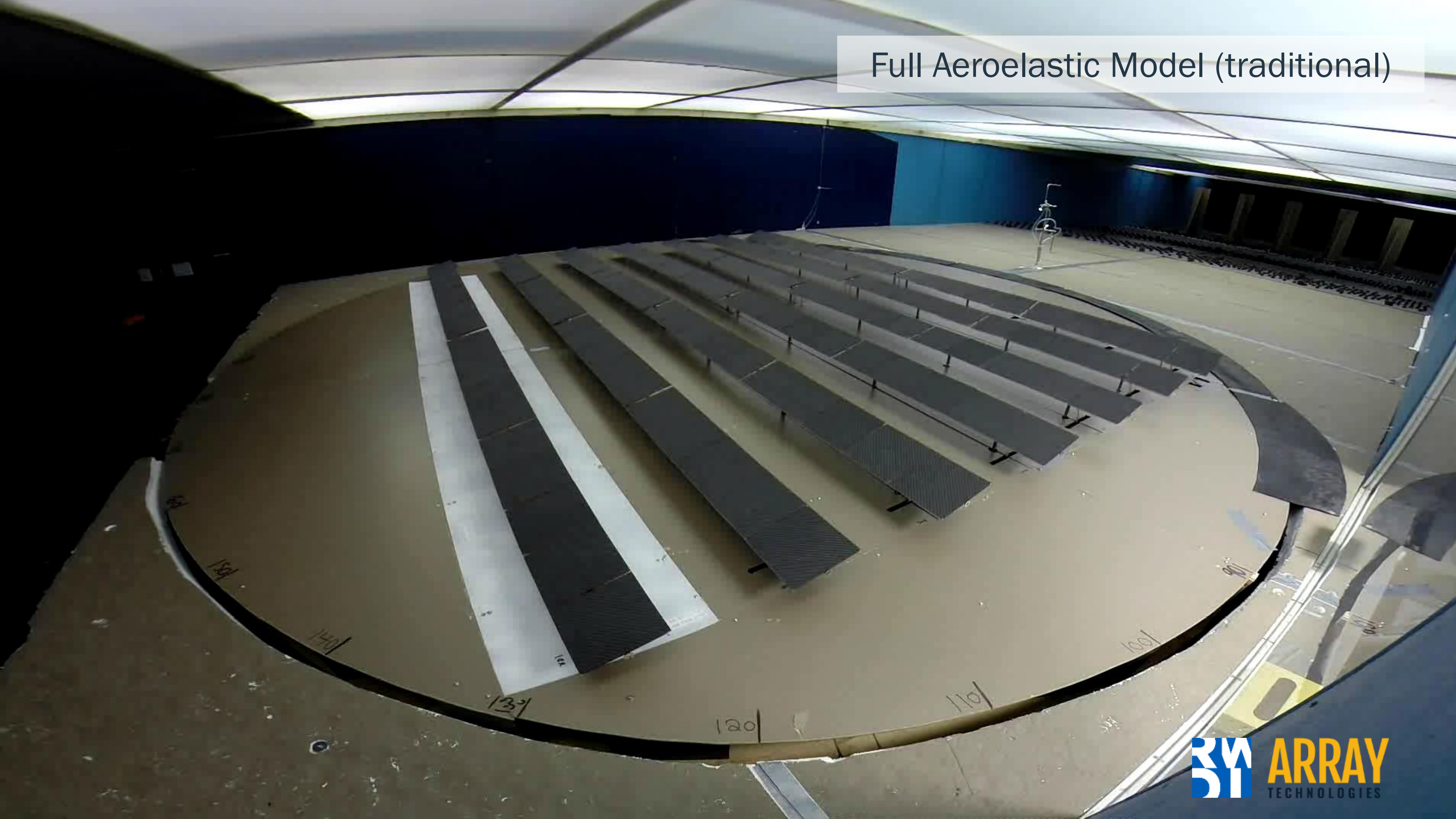
Full Aeroelastic Model (traditional)



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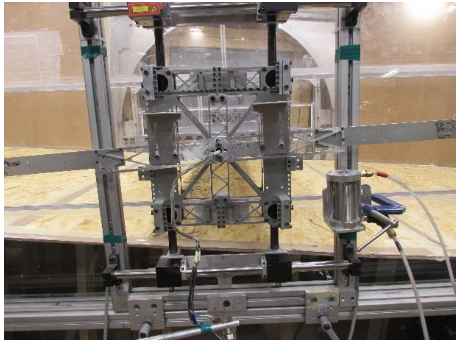
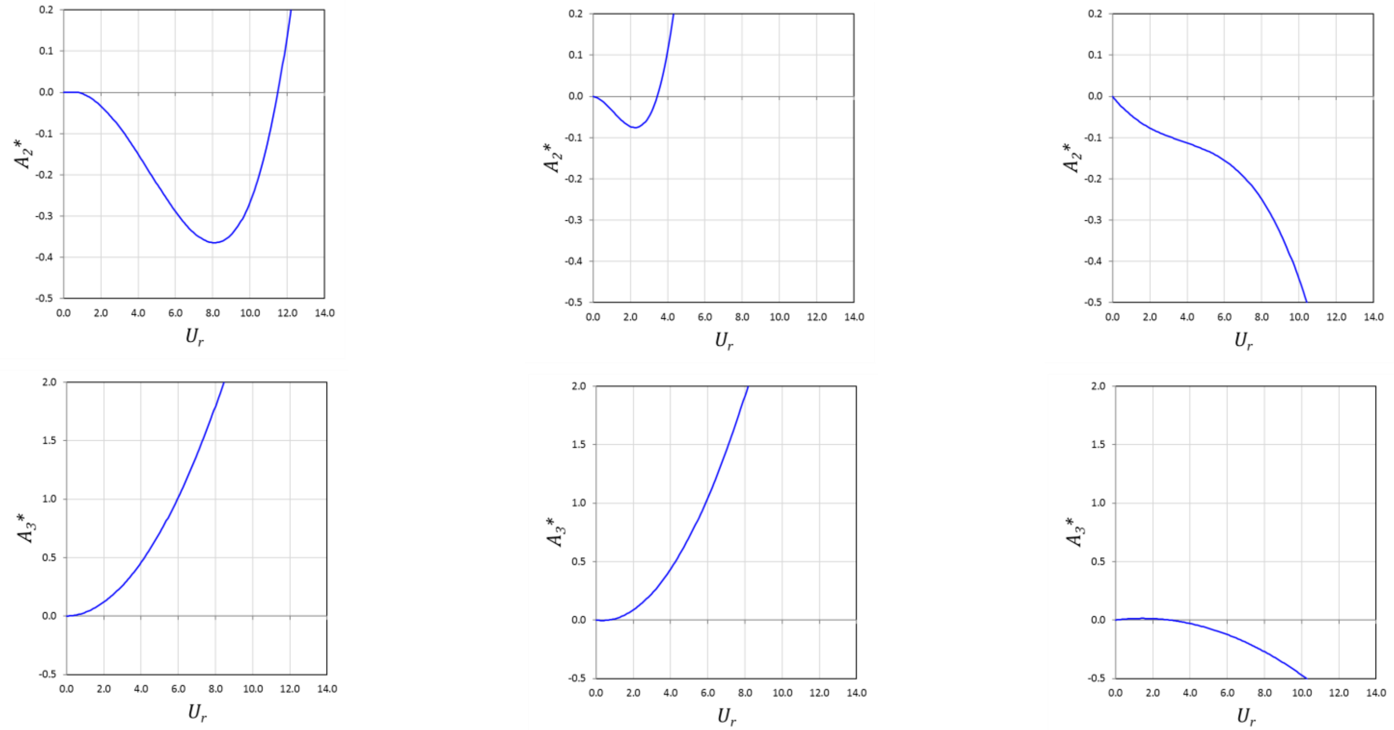
Aeroelastic Sectional Model Testing



Aerodynamic (Flutter) Derivatives



Low Tilts (0°-5°)　　Mid Tilts (20°-30°)　　High Tilts (45°-55°)

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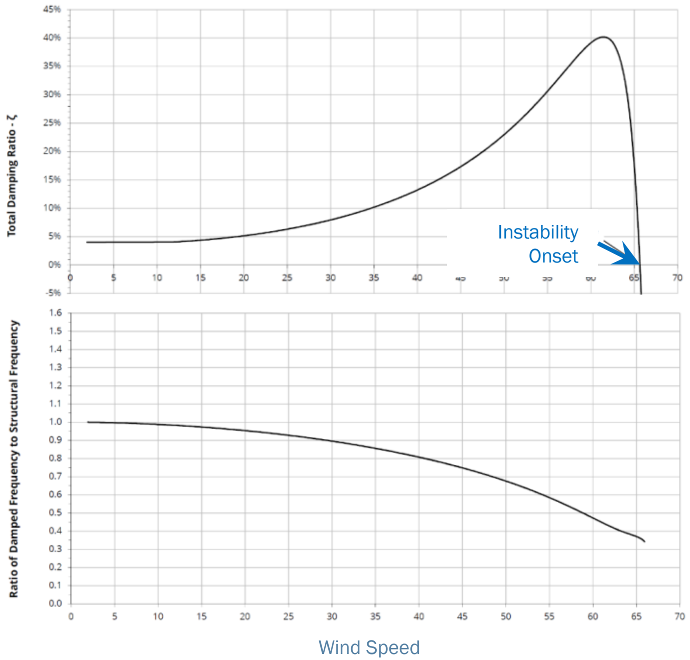
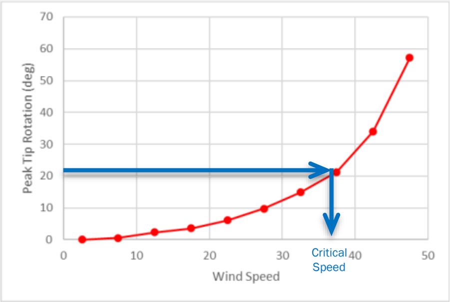
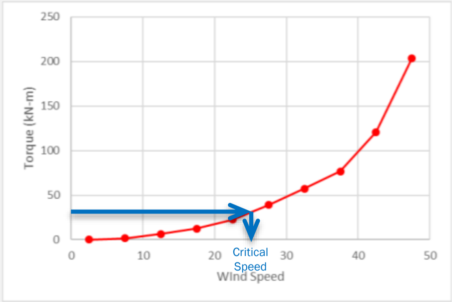
3D numeric simulations in the time domain



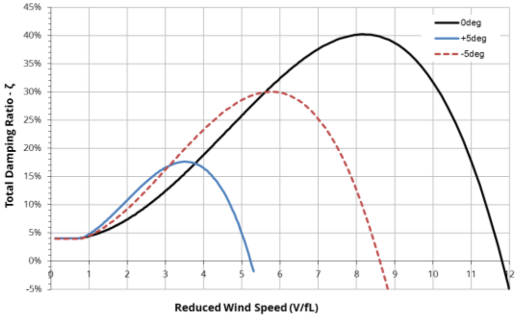
3D Flutter Analysis

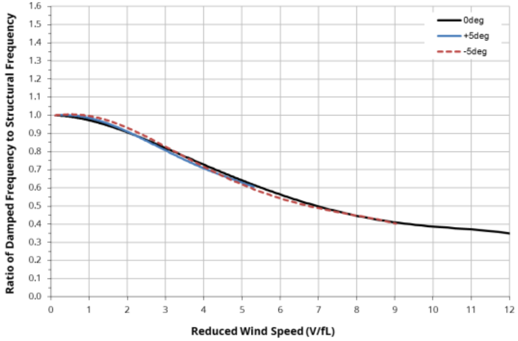




3D Buffeting Response Analysis

Stow Tilt Strategies

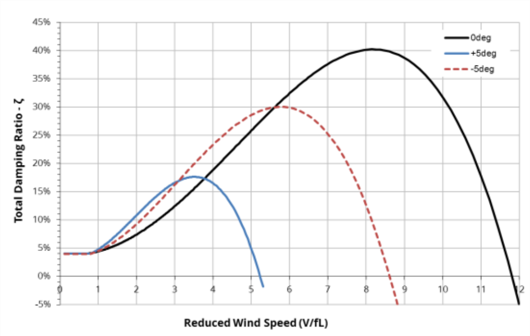


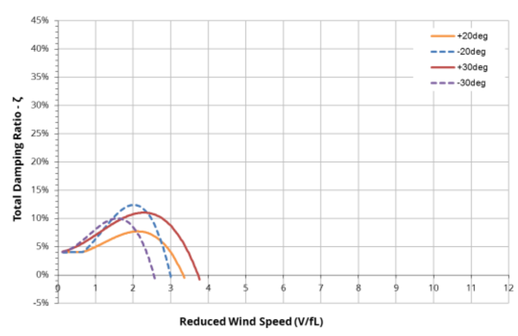


Aerodynamic Stiffness

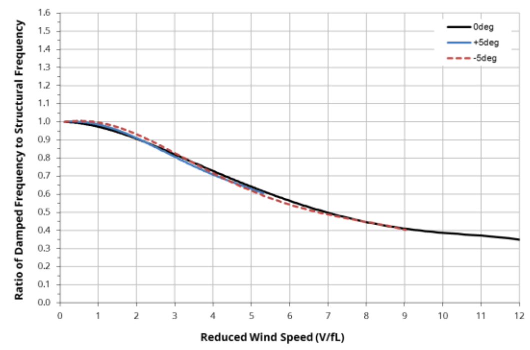
Low Tilts (0°-5°)

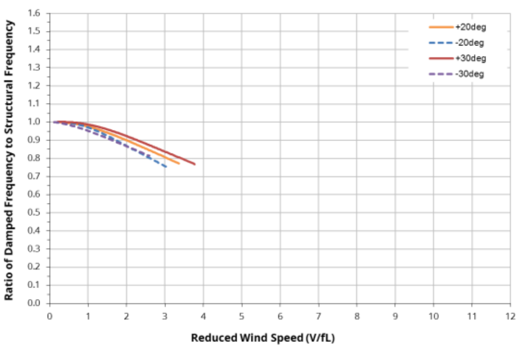
Stow Tilt Strategies





Aerodynamic Damping

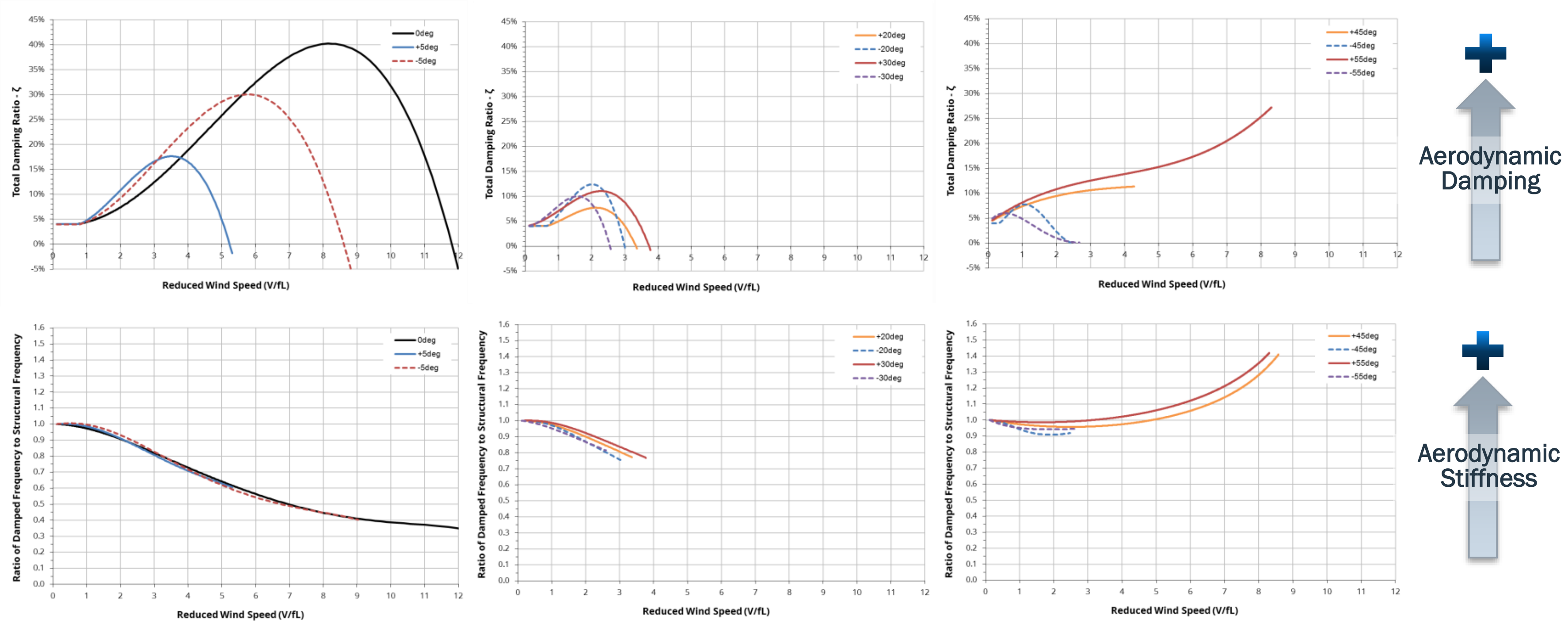




Low Tilts (0°-5°)

Mid Tilts (20°-30°)

Stow Tilt Strategies



Low Tilts (0°-5°) Mid Tilts (20°-30°) High Tilts (45°-55°)

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Understanding tilt angles and key stability drivers

Low Tilts:

- Torsional Galloping: stiffness-driven instability
- Potentially large aeroelastic forces/rotations
- Damping mitigation is less effective

Mid Tilts:

- Torsional Flutter: damping-driven instability
- Aeroelastic forces/rotations are still possible; higher static lateral loads
- Damping mitigation is more effective

High Tilts:

- Positive tilt angles are aerodynamically stable
- Negative tilt angles can be unstable at low damping
- Generally small aeroelastic forces/rotations; highest static lateral loads

All Tilts:

- What are the appropriate design wind loads?

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Overview of the Problem

Dynamic wind forces can amplify the load on single axis trackers, which can lead to damage, downtime, and higher cost of ownership.

Ensuring the stability of solar tracking systems and modules during wind events is one of the top concerns of solar site owners, project developers and EPC contractors.

Array has over 30 years and 30GW-years of field experience with trackers and wind. For the better part of a decade, Array and RWDI together have been studying and solving this complex problem.

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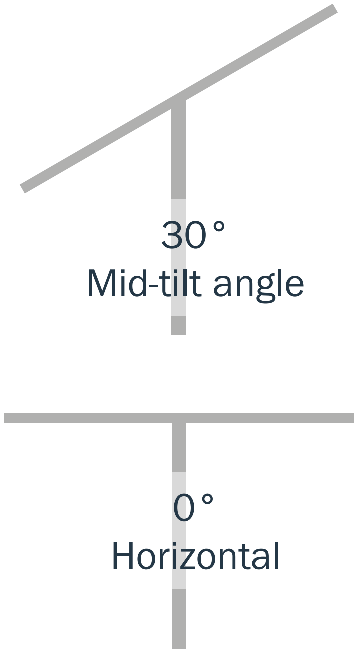
Conventional Tracker Wind Mitigation Methods

Many conventional tracker wind mitigation methods actively stow the entire solar field between 0° and 30° during a wind event

- Why? Static wind loads are lower on horizontal modules than on modules at higher tilts.
- Lower static wind loads mean that structures theoretically can be made less robust with thinner or weaker materials.
- Capital costs decisions drive many tracker manufactures to design for lower and lower wind loads.



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Issues may arise with the conventional approach

- A system is only as strong as its weakest link
- Slow response time / offline
- Structural inadequacies
- Module or tracker damage
- Torsional galloping can still occur
- Lost energy production due to frequent wind events

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High and low tilt angles for single-axis trackers in extreme winds, a different approach…

Throughout our partnership with RWDI and with our understanding of the complex challenges of wind design, we set out to create a system that answers the following questions:

- Is it safe at any tracker angle?
- Is it safe at any designed wind speed and direction?
- Is it possible to take a no-stow approach?
- Is it dependent on on a power source, batteries, sensors, or communications to react?
- Is it stable both during construction and in operation?
- Does it maximize the value of the solar asset?

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How did Array Solve the Problem?

- Partnered with industry leading firms to study the effects of wind on single axis trackers
- Validated our extensive simulations and physical testing, and tracker experience with the wind tunnel studies.
- Focused on eliminating failure points – even in worst case scenario, the system is safe at any angle.
- Ensure each row can act independently – only rows affected by wind respond: Better Performance
- Created a ground-up design that can resist maximum wind speed, from any direction.
- Customer Focused Solution: Protect the asset for the long haul.

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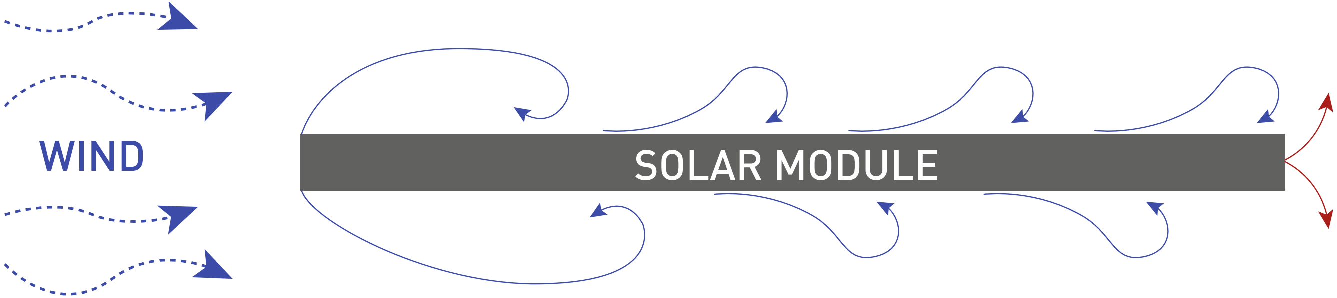
Understanding the Wind

- Wind is unpredictable and can come from any angle
- Both high and low speed wind events can induce damaging behavior on a single axis tracker
- The exterior areas of a solar farm can be the primary areas affected by wind



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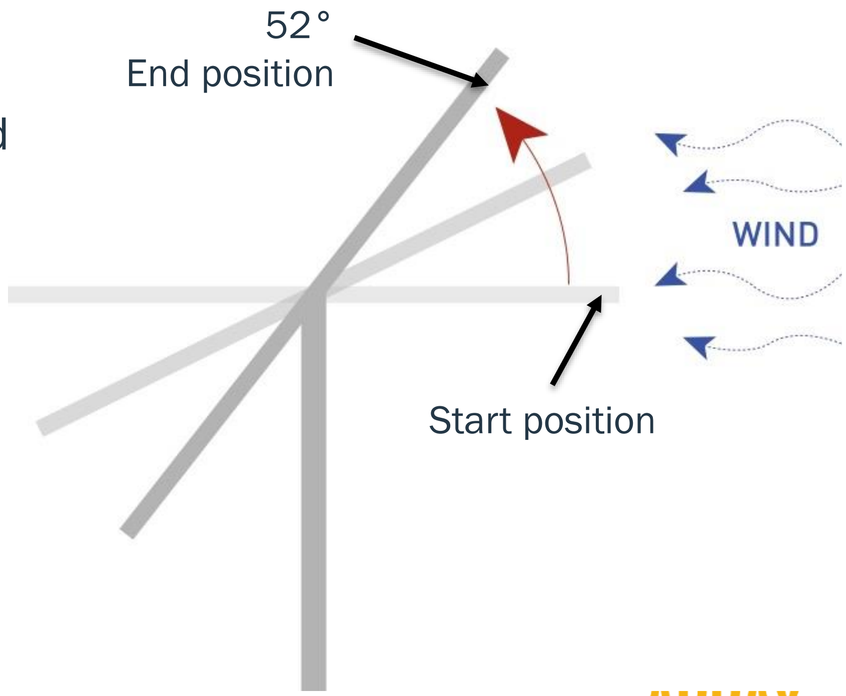
A unique approach to wind mitigation

- Patented, passively controlled, mechanical release
- Single row actuation – not all rows effected
- Functions during construction periods
- Designed to handle site wind speed requirements, regardless of tracker position
- Ultimately channels wind forces to the foundation
- Includes damping components to handle portions of the wind inputs of the system



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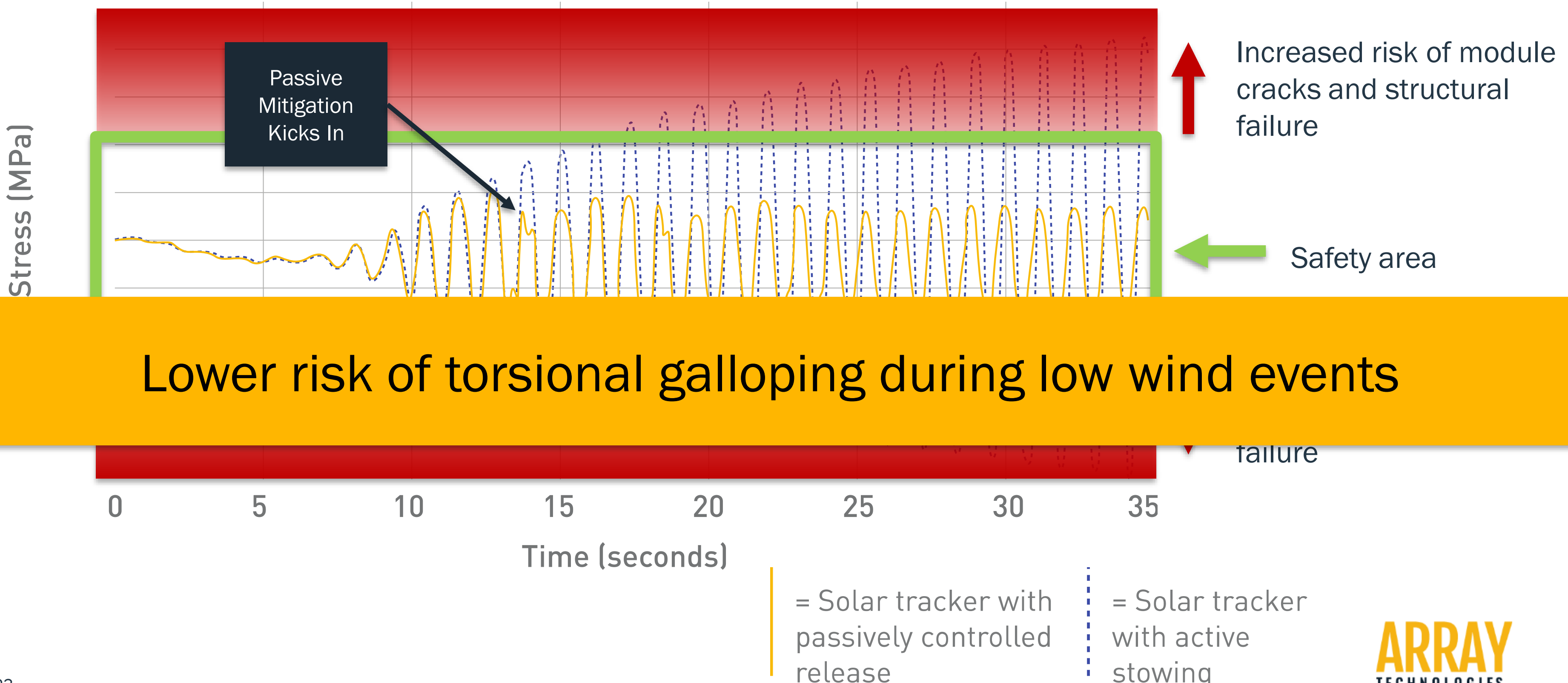
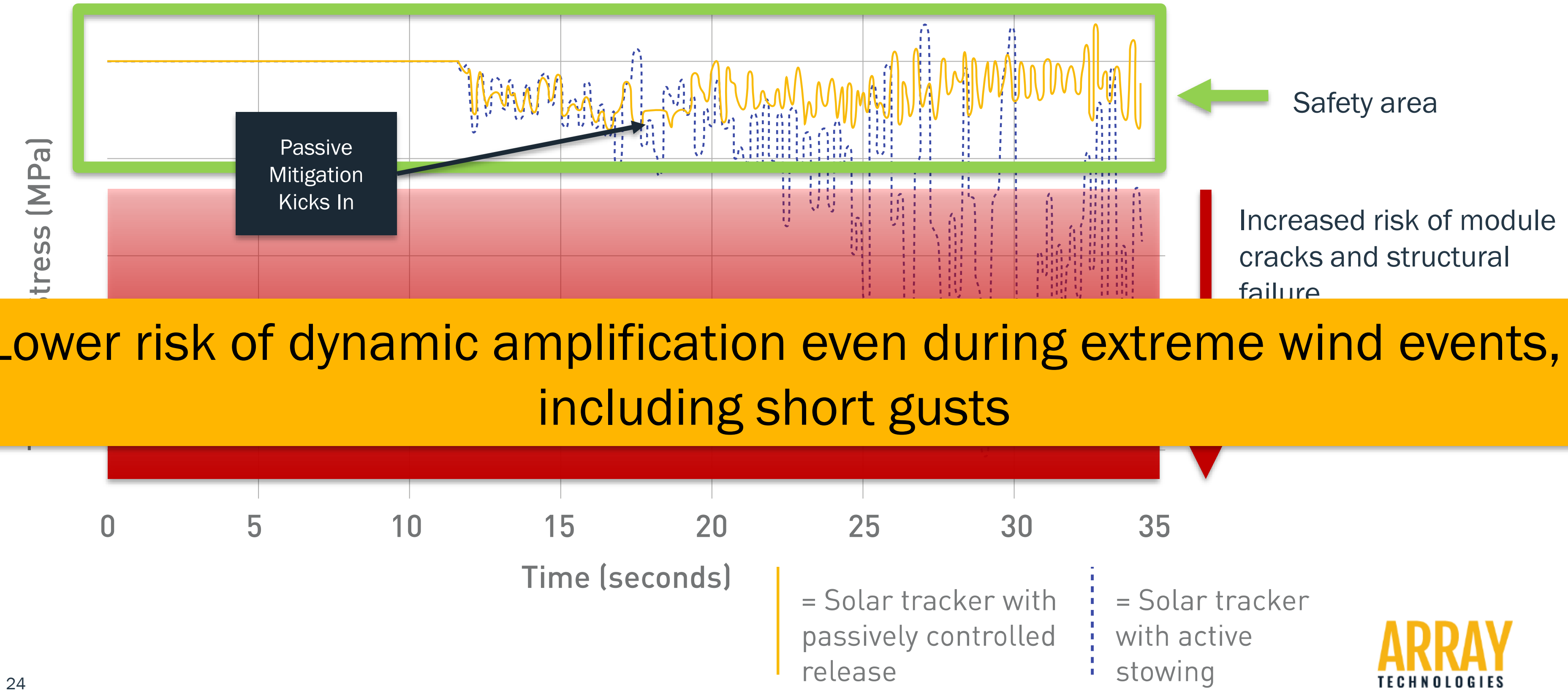
Active Stow vs Passive Mitigation



Lower risk of torsional galloping during low wind events

Active Stow vs Passive Mitigation



Lower risk of dynamic amplification even during extreme wind events, including short gusts

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Problem Solved

Passive Wind Mitigation System that:

- Ensures safety at any angle – reduces potential for failure and expensive downtime
- Based on 30GW year of experience and industry leading partner research
- Fewer mechanical components to fail, wear out, require maintenance
- Single Row actuation – Better Site performance
- Doesn’t require power, complex systems to actuate – works during construction
- **Continuously protects the customer’s assets for the design life of the tracker**

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Thank you.