NRG Systems
and
Spidar Direct Detect Lidar

NRG Seminar
Bangkok, March 21, 2019

NRG Systems™

Spidar

- Introduction to NRG Systems
- Why we purchased the Spidar technology
- Where does it fit in our product line
- Basic specifications and certifications
- Common uses of Spidar
- Images of Applications

About NRG Systems

- Founded in 1982
- Pioneer in Wind Energy Measurement
- Global HQ: Hinesburg, VT USA
- 100% Green
- Now part of ESCO Technologies (NYSE: ESE)

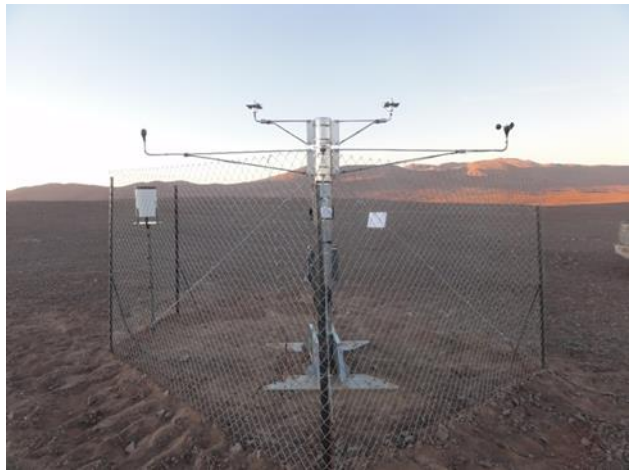
About NRG Systems

- 160+ Countries
- Over 4800 profitable wind farms globally have been constructed on data collected from NRG products for site assessment

Our Products: Resource Assessment

Wind and solar resource assessment

- Complete measurement systems
  - Lidar
  - Data loggers
  - Sensors
  - Towers
  - Communications



XinJiang Province

What we do

PRE - CONSTRUCTION

Wind / Solar Resource Assessment

- SymphoniePRO™ Data loggers
- Sensors
- Towers
- Complete systems
- Spidar Lidar

POST – CONSTRUCTION / WIND PLANT OPTIMIZATION

Power Performance Testing
Forecasting with Spidar
Bat Deterrence
Turbine Control Sensors

NRG Systems Acquires Pentalum Spidar Technology

NRG Systems Acquires Pentalum Spidar Technology

- NRG bought the Spidar technology only
- NRG did not buy the company Pentalum
- Pentalum no longer exists
- NRG will integrate the Spidar technology into our product portfolio as an effective remote sensing tool
- Towers will never go away

NRG Systems Acquires Pentalum Spidar Technology

- **Standardize**: Integrate technology into our global supply chain to keep cost low and standardize the units for reliability and performance.

- **Improve:** Integrate the technology into our engineering and innovation teams for future improvements to performance.

- **Support**: Include the Spidar product into our globally recognized technical support teams for fast and reliable local support (Primanex).

- **NRG Brand:** Incorporate the product into NRG Systems' recognized global trusted brand to keep NRG accountable for producing only the finest product in its class.

- **Local Partner:** Offer the product by carefully selected local partners responsible for complete solution including the Spidar, remote power supply, installation, maintenance and support.

NRG Systems Acquires Pentalum Spidar Technology

- NRG hired former Pentalum team to assists in complete knowledge transfer and product improvement
- First Spidar units made in original factory in Israel
- Then Spidar to be made in USA at NRG Systems factory

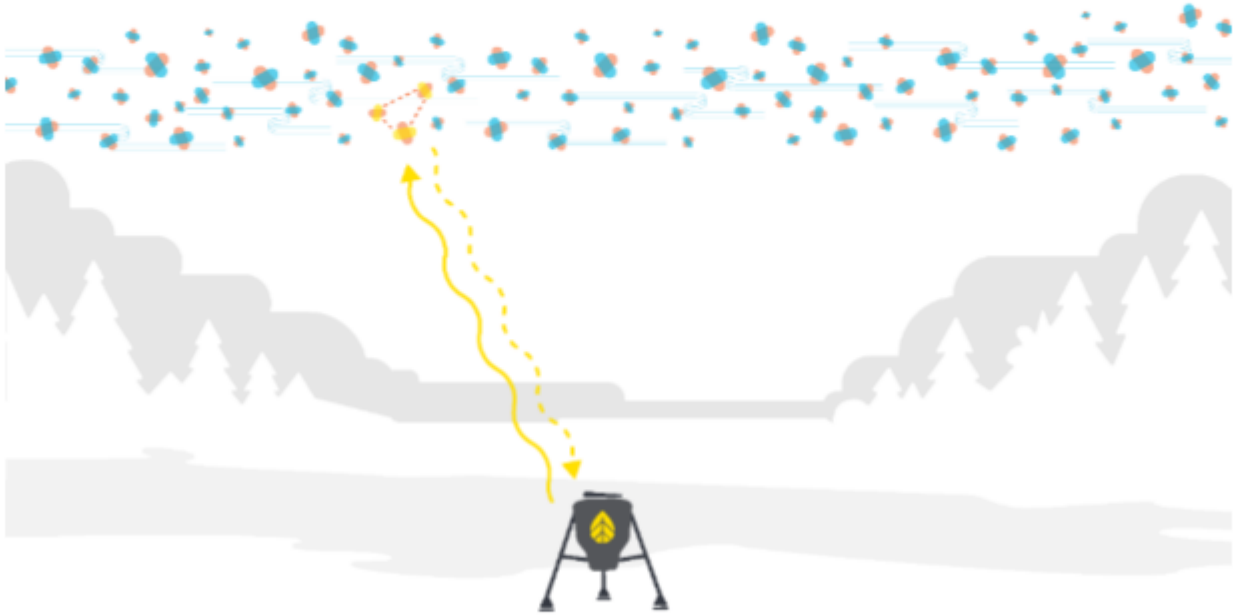
Why?

- Direct Detect Lidar (DDL) is an very effective and proven wind measurement tool
- DDL not specifically meant to compete directly against Doppler Lidar, but has beneficial advantages over Doppler
- DDL can be used effectively in wind measurement campaigns and other meteorological applications
- DDL is an important and critical tool for a wind developer’s toolkit

DDL - Direct Detect Lidar

Direct Detect Lidar and the Cross Correlation Method

Laser pulses from one Spidar beam sample the atmosphere. The reflected intensity of these pulses are received, analyzed and recorded. The resulting time series represents the aerosol density in the line of sight of the transmitted pulse over time at each range gate.



Spidar Pulsed Sampling

Aerosol density structures persist over time and travel with the wind.

DDL - Direct Detect Lidar

Laser pulses from the downwind Spidar beam sample the atmosphere. The same aerosol density signature is identified. This establishes the time of flight between the two beam locations. Combined with the known distance between the two locations, the Spidar is able to determine both wind speed and direction.

Spidar Pulsed Sampling at a Second Beam Location

DDL - Direct Detect Lidar

SPIDAR WIND MEASUREMENT SPECIFICATIONS

Wind Speed + Direction	Default Measurement Height Range	30-150m
	Min + Max Measurement Heights	20m, 200m
	Number of Range Gates	10
	Data Sampling Rate	5s
	Default Data Averaging Interval	10 min
	Wind Speed Measurement Range	2.5 to 70 m/s (Height dependent)
	Range Gate Accuracy	1m
	Linear Regression Slope *(vs IEC class 1 anemometer)*	< ± 2% (0.98 to 1.02)
	Horizontal Wind Speed Accuracy *(2.5 to 10 m/s wind speed)*	< ± 0.207 m/s
	Wind Direction Accuracy	< ± 3°
	Full Cone Angle	10°

DDL - Direct Detect Lidar

Electrical Specifications

Power Consumption	35W (nominal) Up to 250W (w/ heaters, < 0°C)
Power Supply	24-32 VDC (Internal Voltage) 90-250 VAC (AC to DC converter)

Environmental Specifications

Operating Temperature Range (ETSI EN 300 019-2-4)	-40° to 50°C
Operating Humidity Range	0 to 100%
Ingress Classification	IP65
Eye Safety Classification	IEC Laser Class 1M
Maximum Slope	20°

Dimensions + Weights

Optimum Size (HxWxD)	1,092 mm x 1,259 mm x 1,425 mm
Minimum Size (HxWxD)	912 mm x 1,105 mm x 1,247 mm
Maximum Size (HxWxD)	1,305 mm x 1,444 mm x 1,640 mm
Spidar Weight	68.4 kg (150.8 lb)
Single Leg (3 legs included)	6.3 kg (13.9 lb)
Optical Assembly + Housing	49 kg (108 lb)
Met Sensors Assembly	0.5 kg (1.1 lb)

Data Specifications

Storage Format	ASCII
Internal Storage	Non removable Flash Disk, ~ 3 Years Capacity
Backup Storage	Non removable Flash Disk, ~ 3 Years Capacity
Output File Format	Time stamped measurement data by height: • Wind Speed (Average, Min, Max, STD) • Wind Direction (Average, Min, Max, STD) • Met Data (Average, Min, Max, STD) • Data Quality Indicator

DDL - Direct Detect Lidar

Schleswig-Flensburg, north Germany, March 2015

DNV Internal verification with 6 different units

DNV·GL

SPIDAR PERFORMANCE VERIFICATION

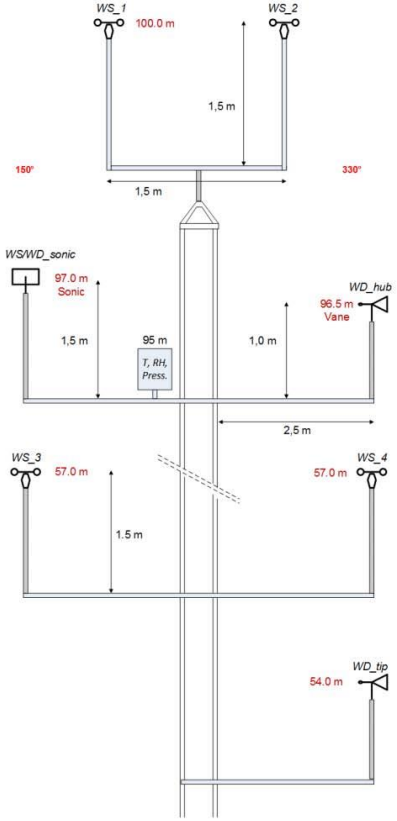
SPIDAR PERFORMANCE VERIFICATION OF UNIT 1304E00015 AT DNV GL TEST SITE IN JANNEBY, GERMANY

Pentalum Technologies

Report No.: GLGH-4257 14 11393 267-R-0005, Rev. A
Date: 2015-05-08

Spidar

“To conclude, the Janneby LPV campaign indicates that the Spidar with the serial number 1304E00015 is able to reproduce cup anemometer wind speeds and wind vane directions at a reasonably accurate level.”



Spidar

We expect to have the following:

6 Weeks: Position Paper form DNV GL Germany. Testing already complete. More in depth analysis.

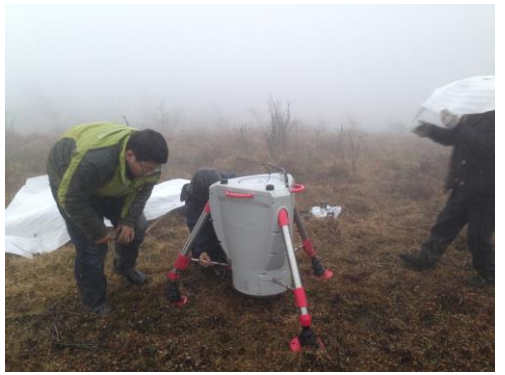
Several months after: DNV-GL Classification: “Stage 2 Device” is expected (not Stage 3).

“Just as verified and mature as Sodar, but with Lidar technology”

Spidar compared to Sodar

Spidar Benefits:

- No echo issues (i.e. forest)
- No noise disturbance (i.e. noise regulations, C&I, etc.)
- Superior performance in rain.
- Smaller cone angle (Co-locate closer to met tower and other structures)
- Excellent in complex terrain
- More mobile than sodar
- Highly ruggedized



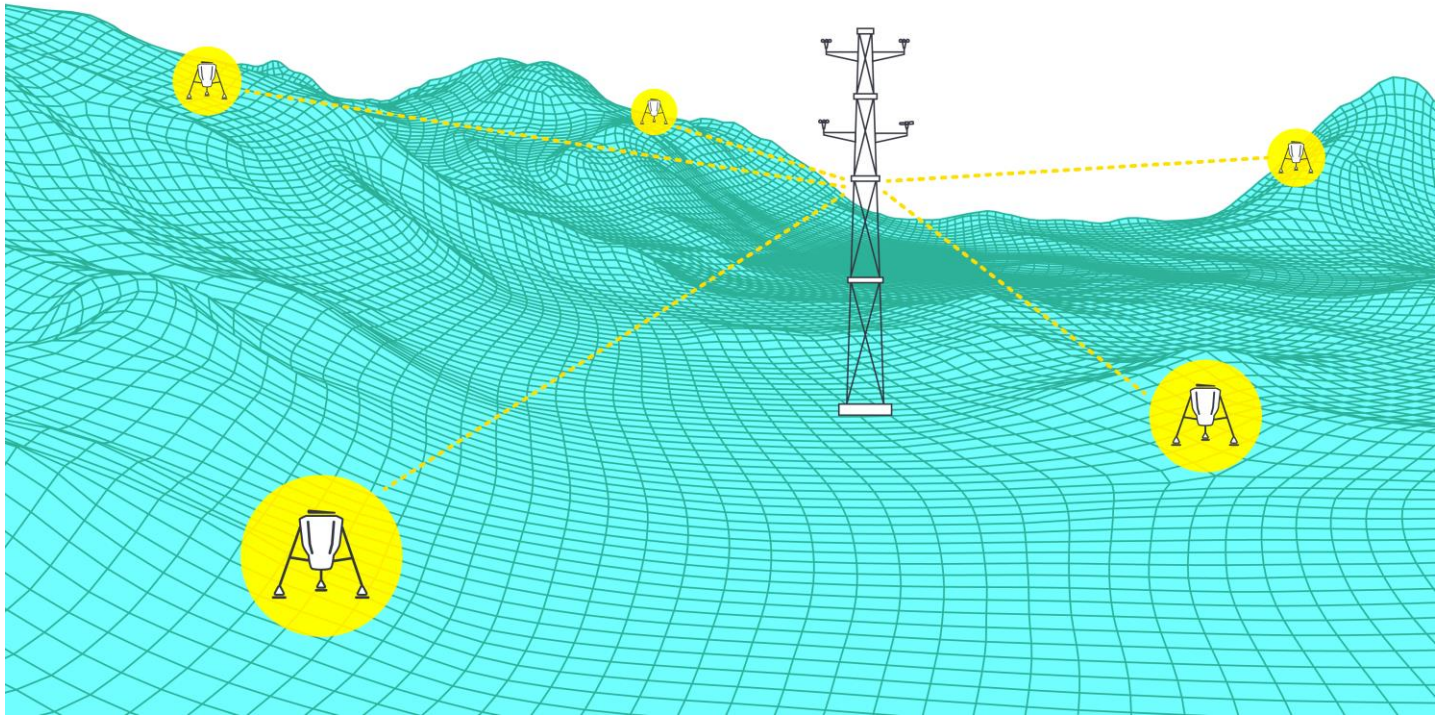
Installations:

- China
- Japan
- Australia
- Argentina
- USA
- Canada
- Belgium
- Thailand
- Indonesia
- Philippines
- Israel
- Mexico
- Bulgaria
- Sweden
- Finland
- Ukraine
- Latvia
- Brazil
- Chile
- South Africa
- Netherlands
- France
- Germany
- Honduras
- Curacao

150 Sites across China - cooperation with developers, turbine OEMs and 3rd party service providers

Spidar through the Wind Farm Lifecycle

Prospecting, Site Development, Construction, Operations & Maintenance and Repowering



Note: There are regional differences throughout the world!

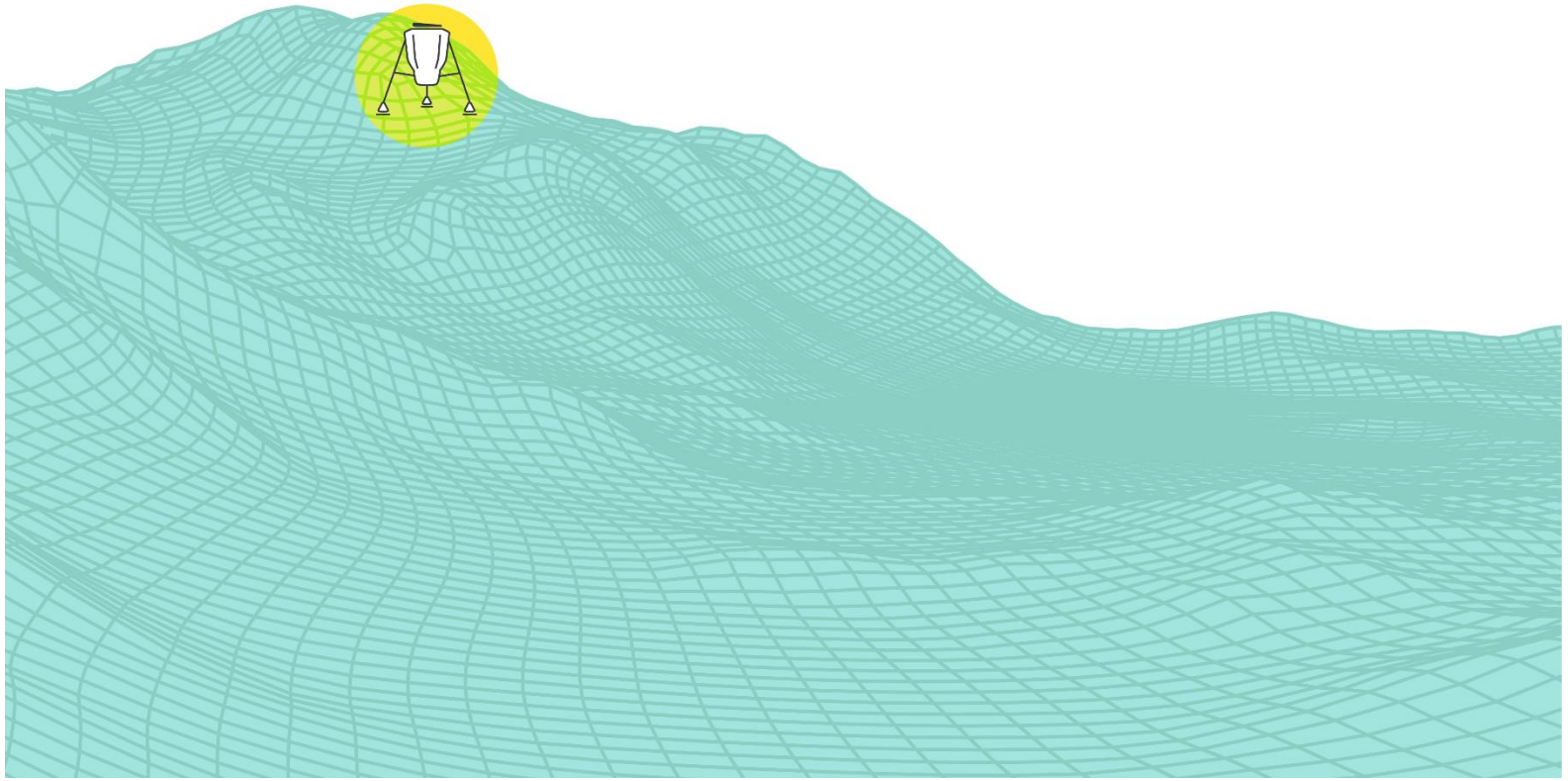
Prospecting Stage

Standalone Measurement (Solo Installation):

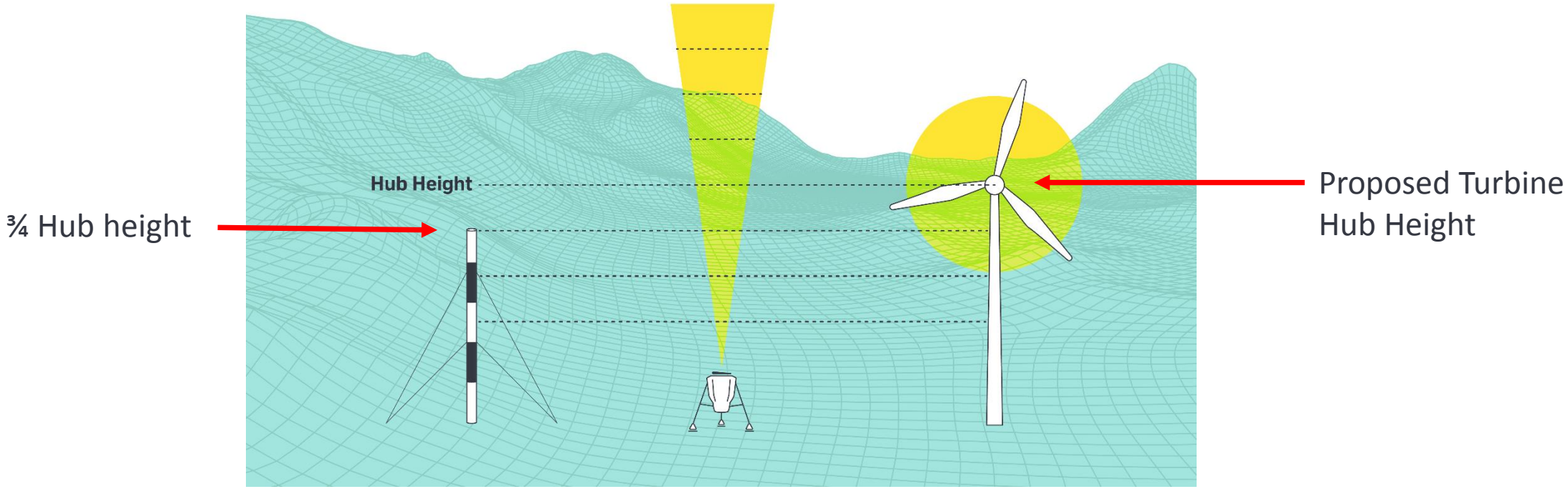
- “Pre-development” at locations where there are no other measurement towers present due to complex terrain and/economics for the duration of the measurement period.

- Validation campaign – Implement Spidar immediately upon site screening to confirm findings of Mesoscale maps or earlier collected Met Data. Key point to combine the Mesoscale/Reanalysis data and the initial campaign design to help in uncertainty reduction right from the beginning (i.e. creating an initial turbine layout and preliminary EPE (Energy Production Estimate).

Standalone Measurement



Further Site Prospecting



If Spidar is being used in the initial Mesoscale validation phase, a tall met tower of at least "3/4th" height of proposed WTG Hub Height can be implemented. For example, if the proposed WTG Hub Height for the site is 120 meters then 90 meter tall met tower can be used onsite along with Spidar.

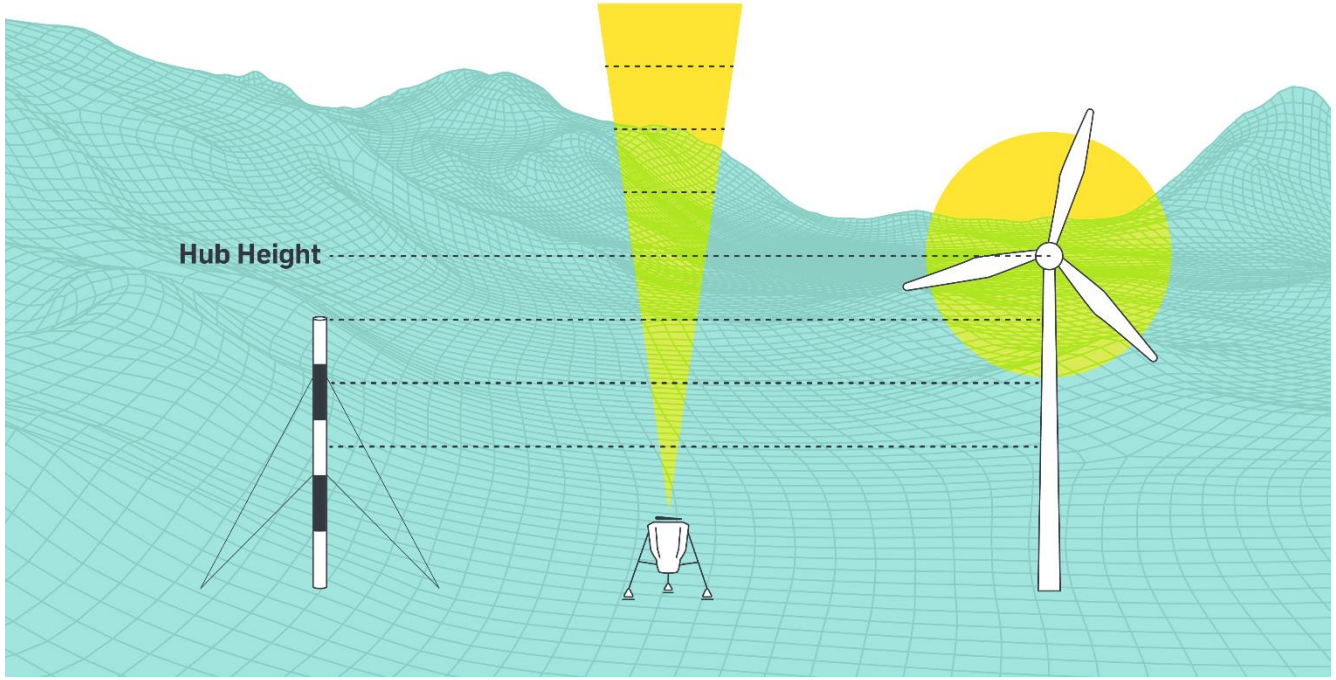
Site Development Stage – WRA Campaign

Vertical Extrapolation:

“Wind Shear Validation” is a process of combining a 60-80m tower with lidar and extrapolating wind at heights above the tower with lidar reference. An optimal application for Spidar.

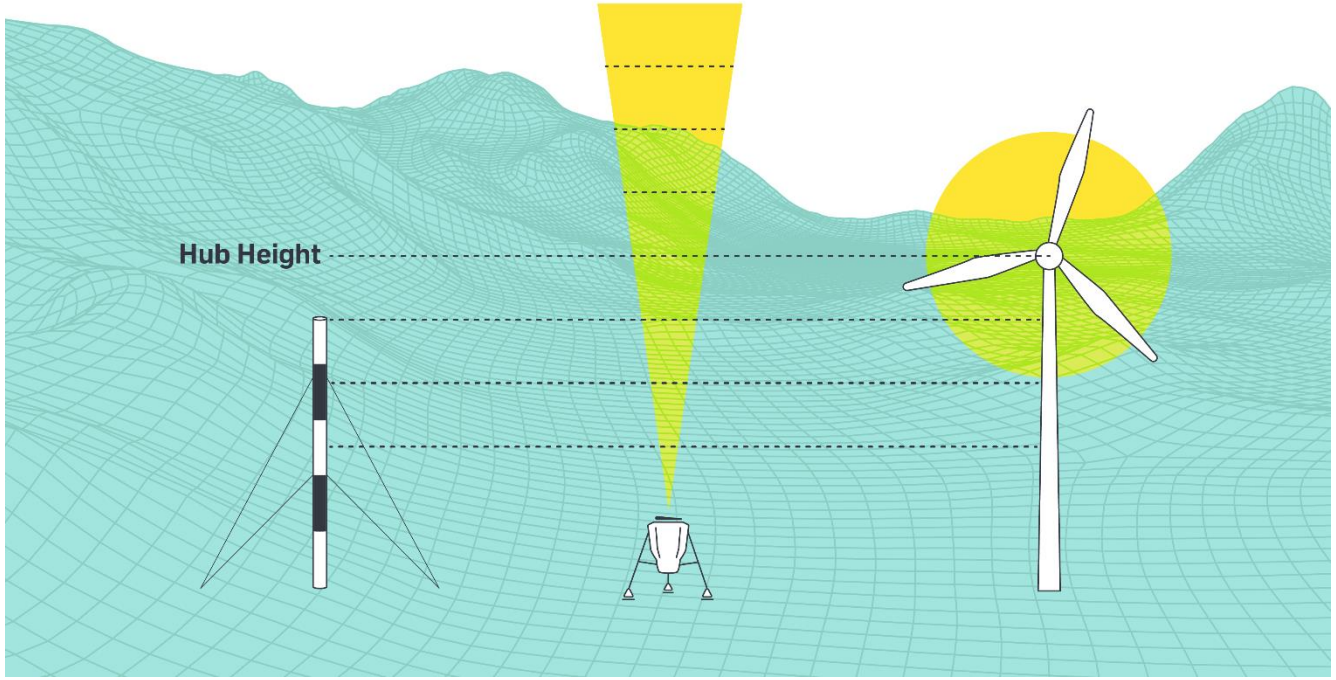
Looking for “Hotspots of Uncertainty”

Vertical Extrapolation: Wind Shear Validation



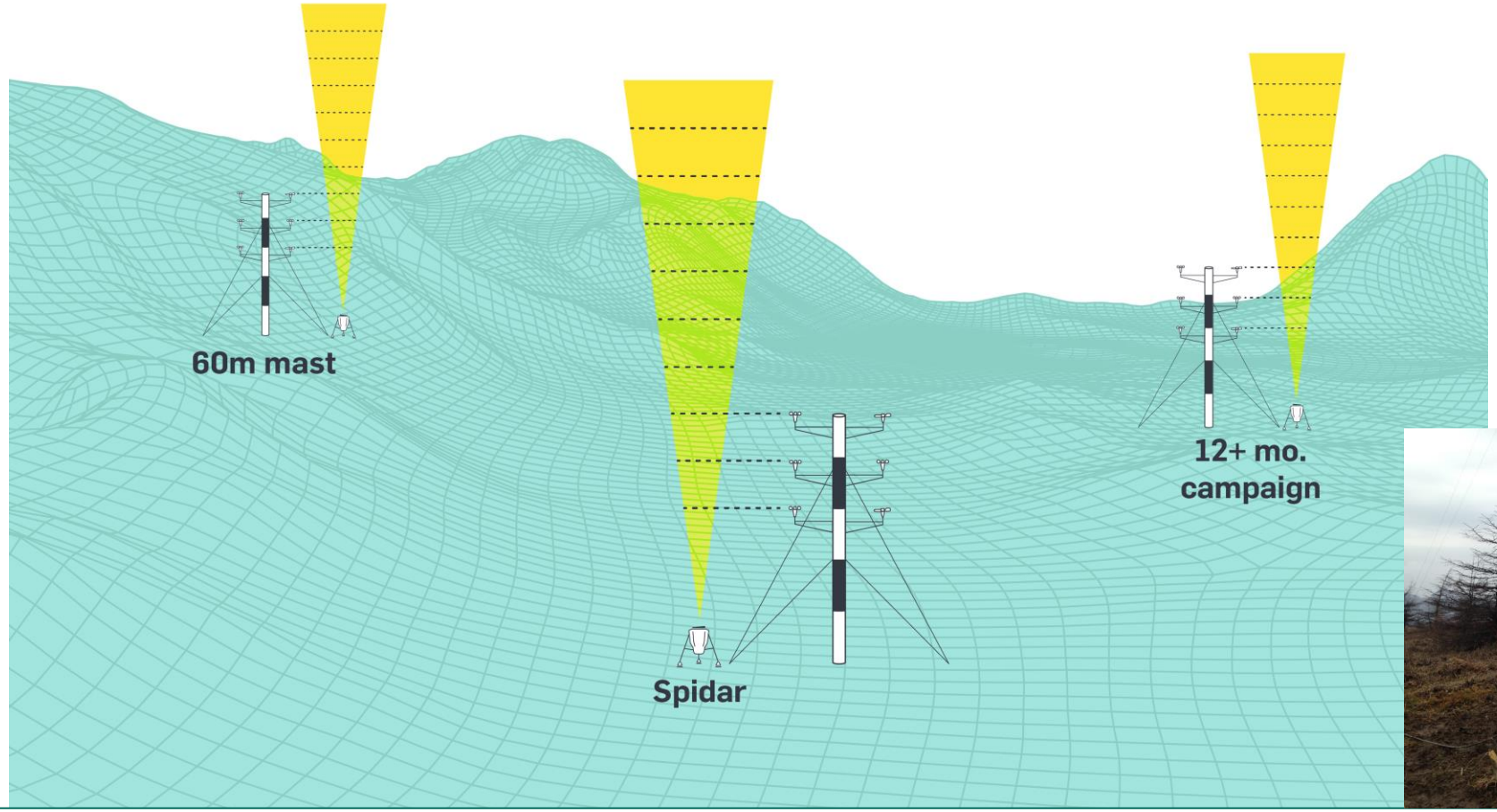
- Expensive lattice towers are required to measure at the hub height of modern turbines using conventional methods.
- Data from shorter, economical met masts must be extrapolated vertically to predict hub height wind speeds.
- These calculated hub height values have high uncertainty, and require validation by other data sources.

Vertical Extrapolation: Wind Shear Validation



- Complementing an economical met mast with a Lidar will allow you to measure up to 120m to validate the wind shear profile at your potential turbine location.
- The Lidar and met mast should have at least 2 common measurement heights, and the top met mast height should be at least 60m.
- Data should be collected for a full year for best results, but shorter 3-6 month campaigns can provide reasonable estimates of annual shear conditions.

Vertical Extrapolation: Wind Shear Validation

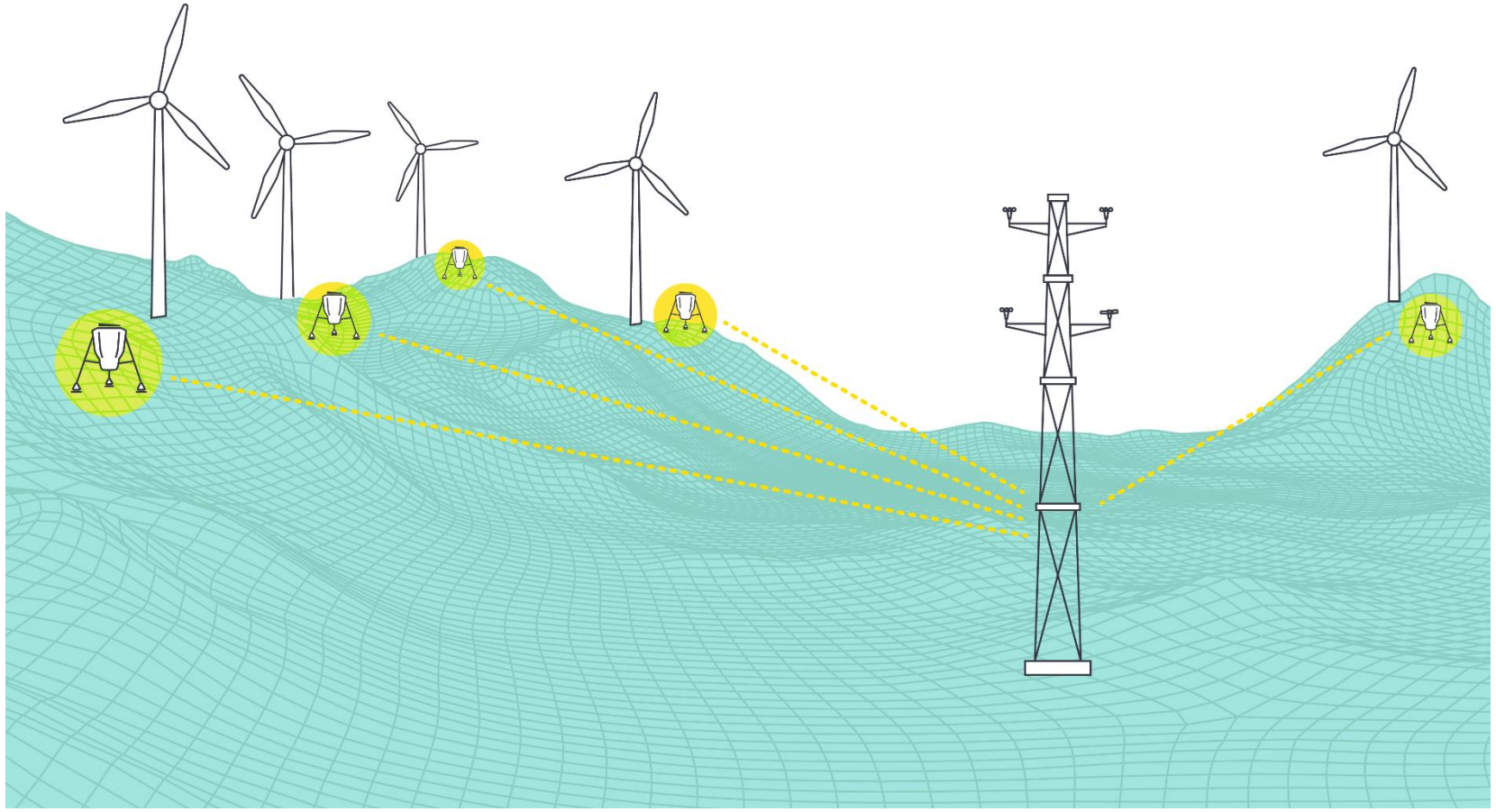


- By moving your Lidar every 3-12 months you can validate the calculated shear profiles across a fleet of shorter met towers.
- Following this methodology, multiple expensive, permanent lattice towers can be replaced with more economical, temporary masts paired with a roving lidar for wind shear validation.

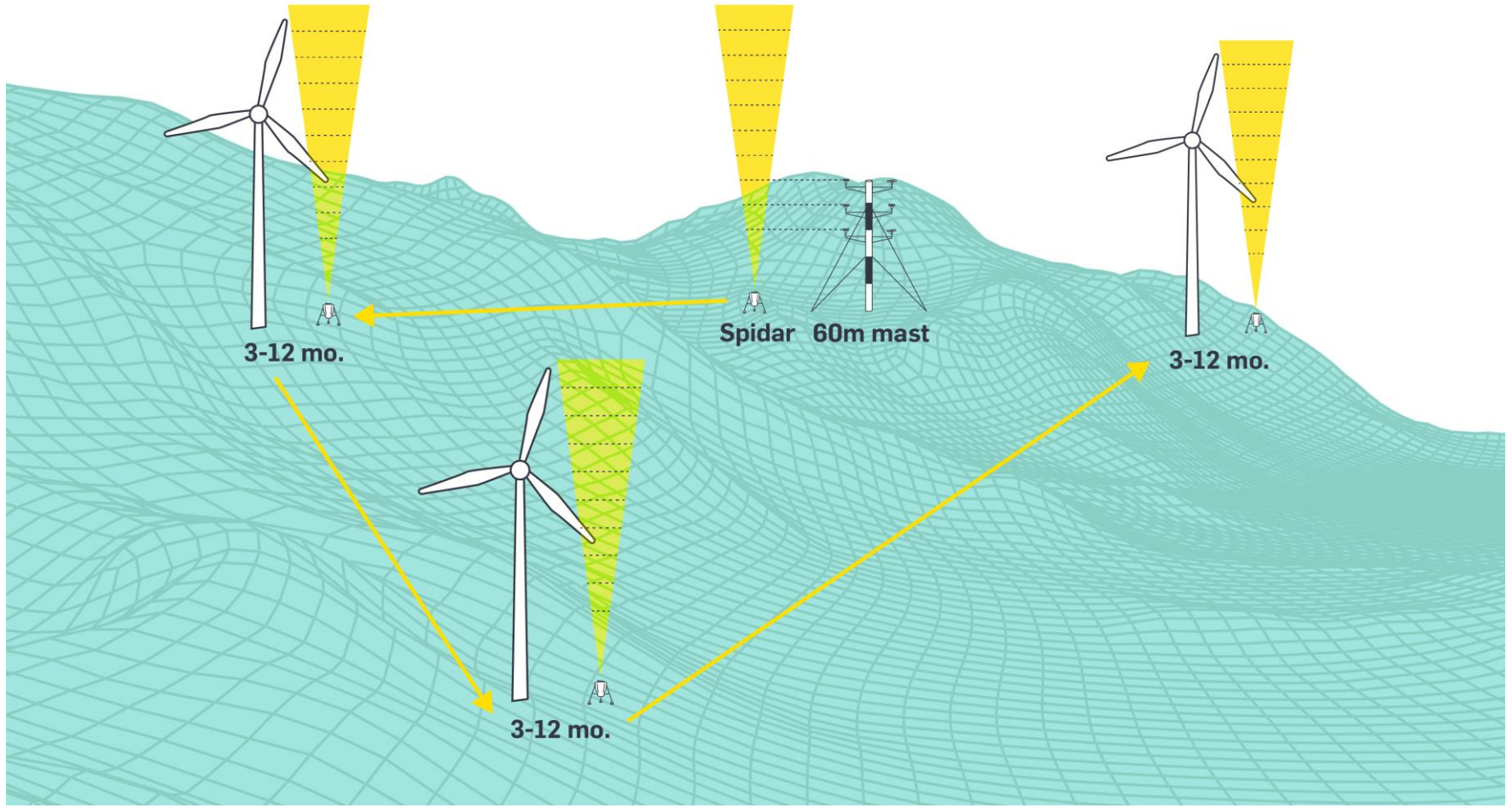
Horizontal Extrapolation

A valid deployment strategy, but it involves long term solo installations following an initial site calibration, which may not be acceptable for all customers

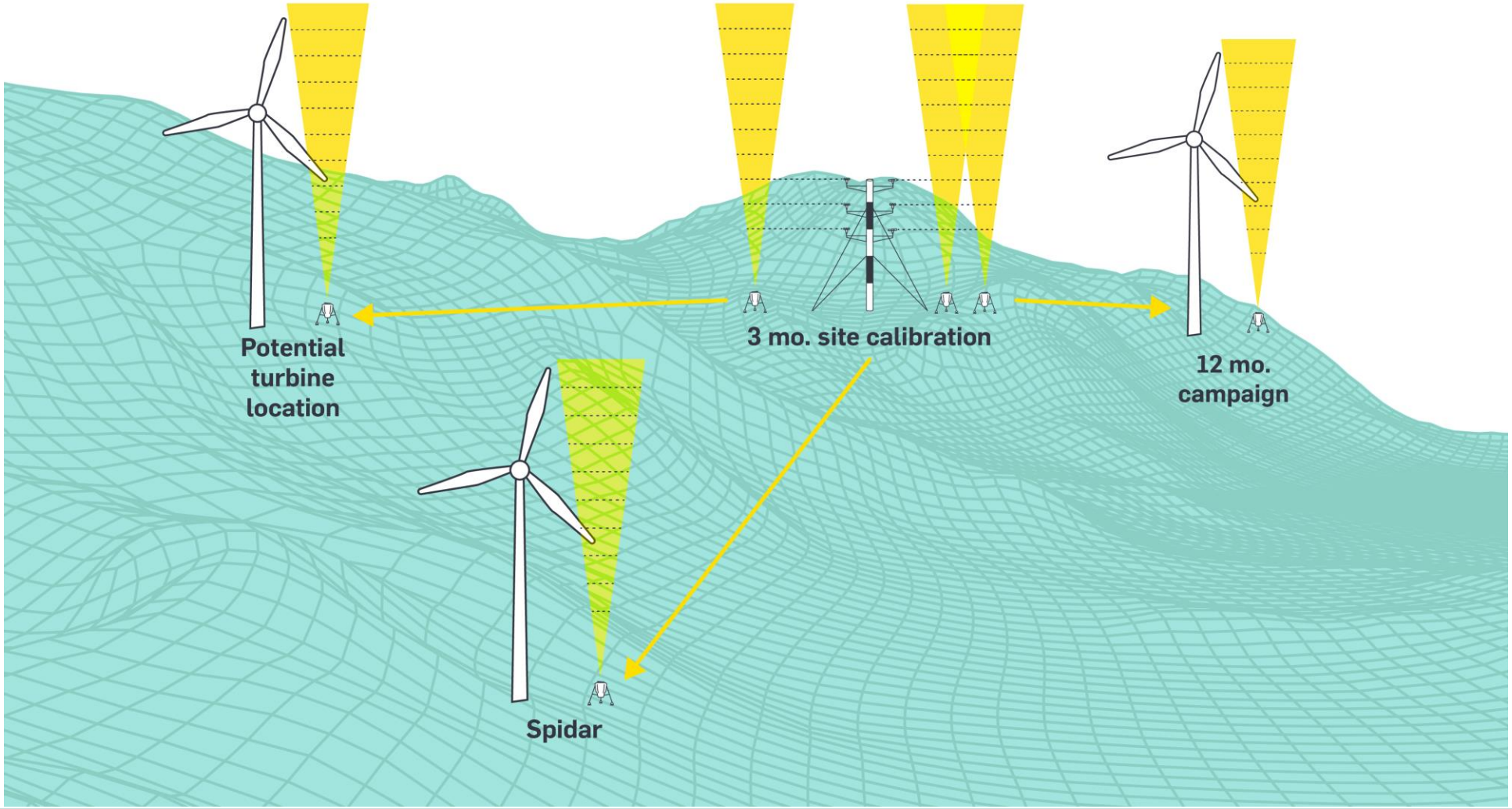
Horizontal Extrapolation



- Sometimes it is not technically or economically feasible to install a tower at every potential turbine location.
- Instead of direct measurements, met tower data are extrapolated horizontally based on the site's terrain.
- These calculated wind speed values at locations without local measurements have high uncertainty, and require validation by other data sources.



- To better understand the horizontal distribution of wind resource across a site, a Lidar can be moved between points of interest while the primary measurement device remains fixed.
- It is important to first calibrate your Spidar against the fixed data source, and then measure elsewhere in minimum periods of 3-6 months to ensure an adequate sample is taken at each location.
- 12 months is best in order to fully capture seasonal differences.

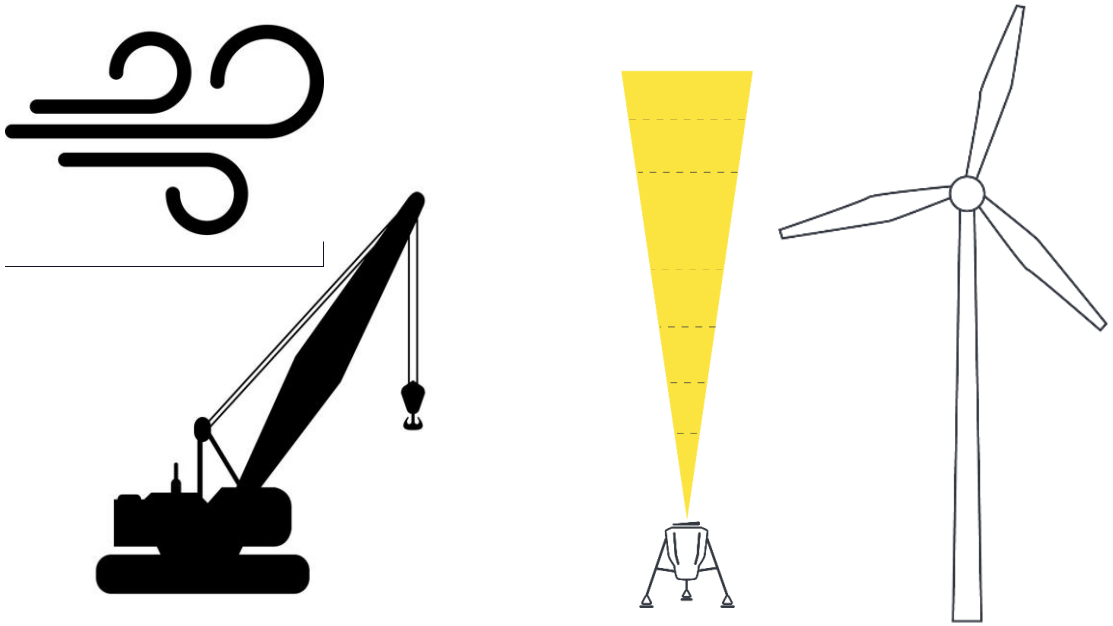


To achieve longer measurement periods at a potential turbine site, multiple Spidar units can undergo site calibration simultaneously before being moved to their final measurement location. This method ensures that you get 12 months of data up to 120m at each potential turbine location that is directly traceable to traditional cup anemometry on your met mast, without having to install a met tower at each potential turbine location.

Construction Stage

- Non-contractual power curve validation before wind farm is constructed. Developers can move Spidar around to potential turbine locations to determine to validate and correct windiness at turbine locations.

- Crane lift monitoring for installing turbines to keep installation within safety regulations



Operations and Maintenance Stage

- Non-contractual “Pre-power performance test” concept gaining interest. Use low-cost Spidar to screen individual turbines for potential issues. Suspect turbines can then go through contractual IEC power curve testing.

- Permanent on-site met mast
  - Apply curtailment strategies
  - Mobile measurements for turbine failures or power loss to support insurance claims
  - Forecasting
  - Craning

Upgrades and Repowering

Validate each turbine in repowering campaign

Other markets

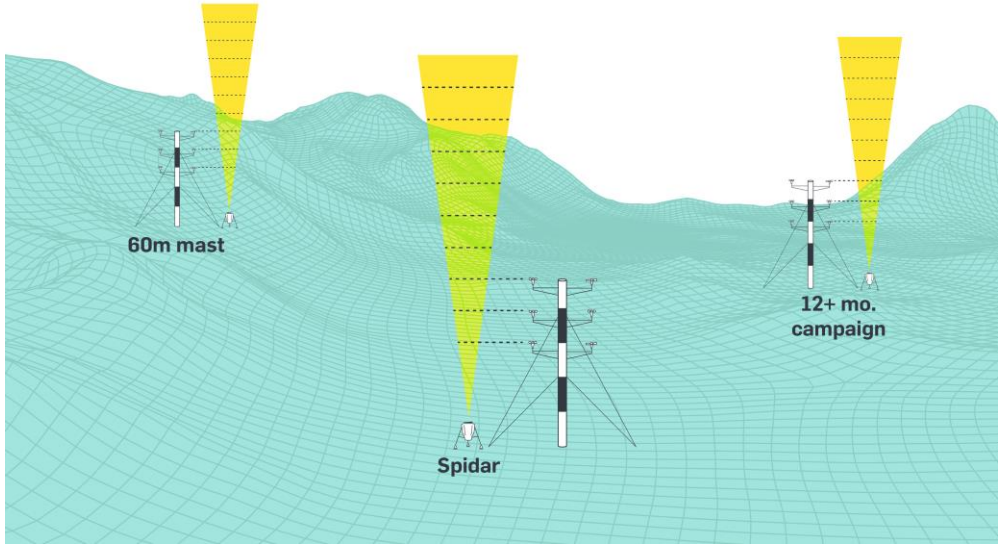
- Meteorology – Research and Operations
- Aviation
- Military
- Fire warning
- Air quality
- Etc.

Use your imagination!

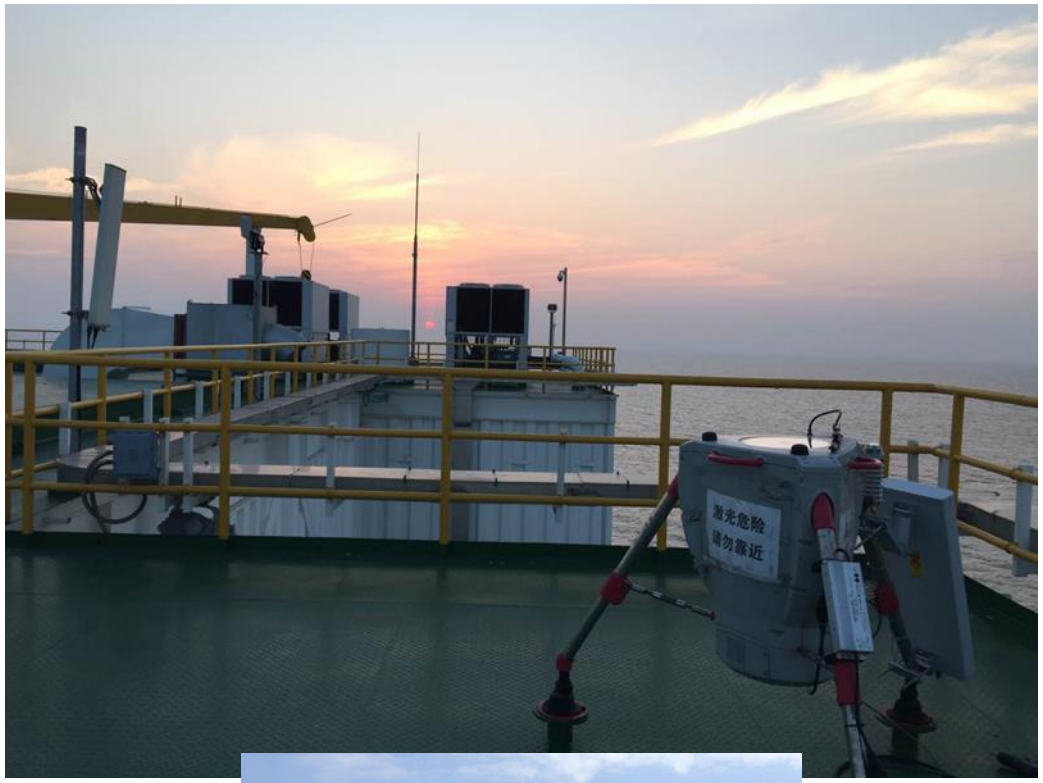
Spidar and Tower Bundles

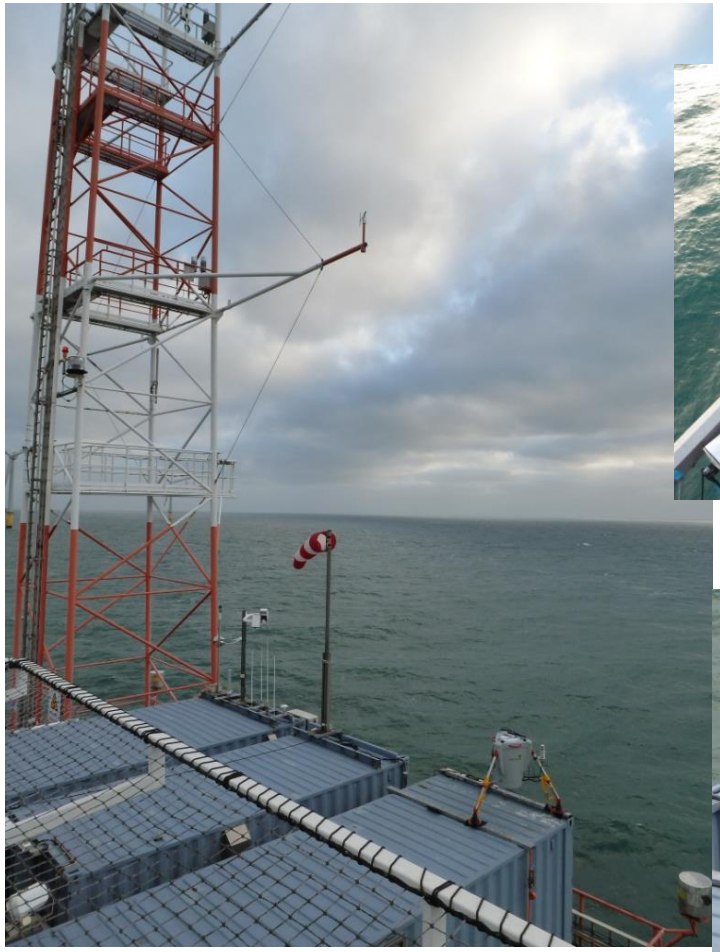
- NRG will be providing lidar / tower bundles
- 60 Meter and 80 Meter tilt-up
  - All towers arrive on site as complete kit (Loggers, sensors, towers, anchors, etc.)
  - Temporary towers need no concrete foundation in most locations
- Discounts given on entire package

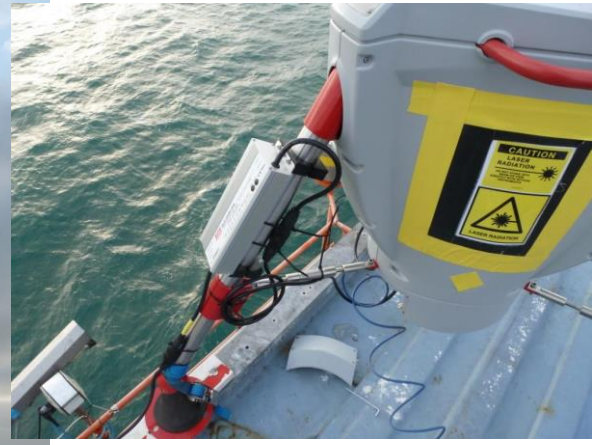




Spidar Applications: Wind Energy Offshore







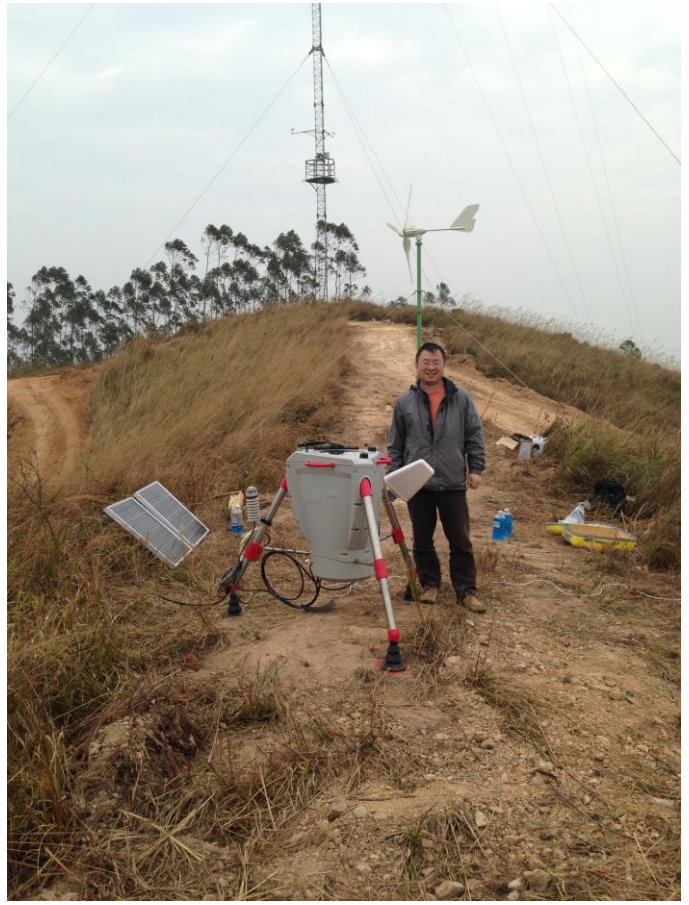
Spidar Applications: Wind Energy

Power Curve Testing

Ex. Re-Powering assessment and
Non-contractual studies

Spidar Applications: Wind Energy

Remote Site Installation for Wind Resource Assessment



Spidar Applications: Wind Energy

Remote Site Installation for Wind Resource Assessment

Spidar Applications: Wind Energy

Remote Site Installation for Wind Resource Assessment

Spidar Applications: Wind Energy

Remote Site Installation for Wind Resource Assessment

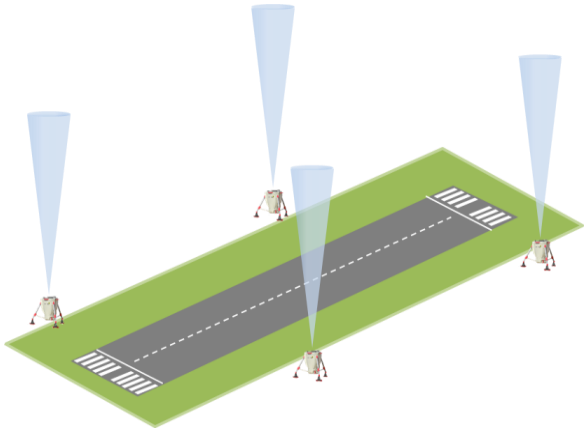
Spidar Applications

Meteorology

Air Quality

Shanghai Meteorological Service

Spidar Applications: Aviation



Remote Power Supply

Fujian Province

Guangxi Province

Timelines and Prices

- First units available May, 2019 with NRG Power Controller
- All Value Added Resellers (VAR) must be approved and sign Agreements
- All VARs must complete in-person product training
- We are now taking orders with deposits

Conclusion

- NRG is the global trusted wind energy brand for quality, reliability and ease of use

- We selected to purchase Pentalum's Direct Detect Lidar Technology for quality, reliability and ease of use

- We are providing a proven Stage 2 lidar with an economic advantage

Gregory Erdmann, VP Global Sales
NRG Systems
Hinesburg, VT USA
gse@nrgsystems.com T: (802)-482-2255