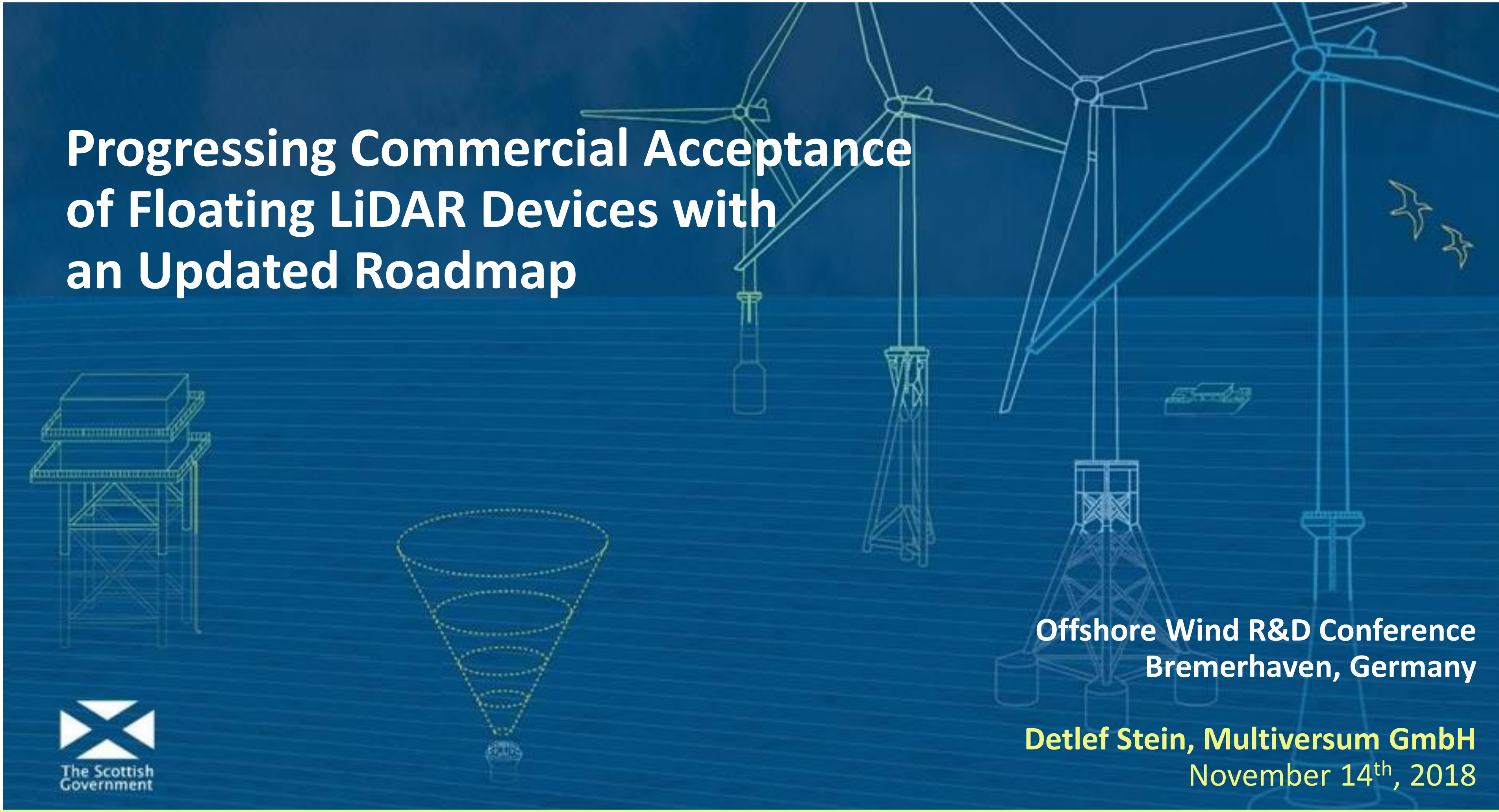
Progressing Commercial Acceptance of Floating LiDAR Devices with an Updated Roadmap



Offshore Wind R&D Conference
Bremerhaven, Germany

Detlef Stein, Multiversum GmbH
November 14th, 2018

Agenda and Floating LiDAR Roadmap Project Team

Why
- An update the OWA/CT Floating LiDAR Roadmap?

What
- has changed?

Who
- does it impact?

- Summary

Carbon Trust OWA Floating LiDAR Roadmap Update Project Team

Carbon Trust
- Eloise Burnett

DNV GL (Project lead)
•- Marie-Anne Cowan

Frazer-Nash Consultancy
- Brian Gribben
- Jennifer Cocks

Multiversum
- Detlef Stein

Fraunhofer IWES
- Julia Gottschall

Carbon Trust has been working with government and industry to accelerate offshore wind for >10 years

The Offshore Wind Accelerator (OWA)

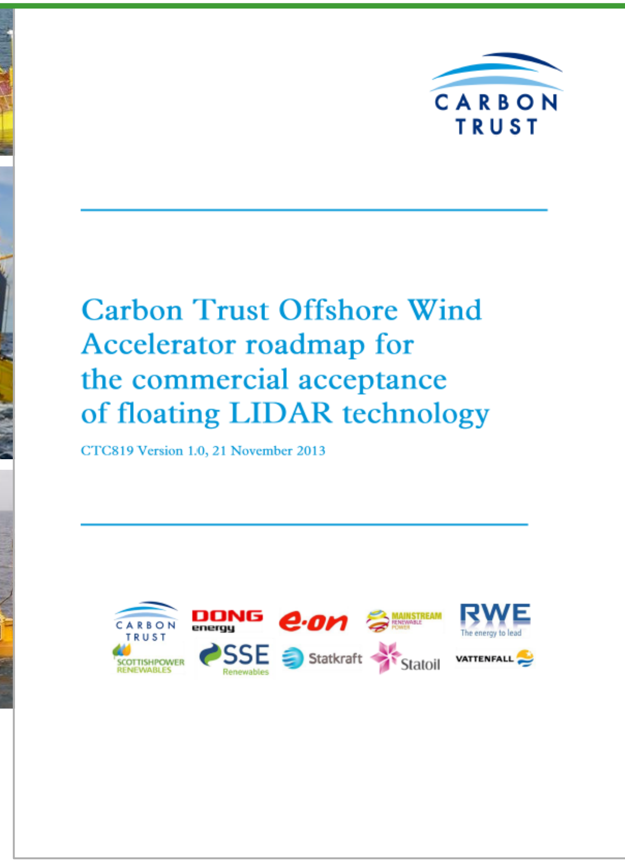
€100m+ Total programme spend	**60%** Industry funded
9 Leading developers	**10 yrs** Established 2008

The Scottish Government

Why

Progression in wind measurements and the OWA Floating LiDAR Roadmap

The OWA FL Roadmap seeks to provide industry consensus on and build industry confidence in the use of this technology in the offshore wind industry.



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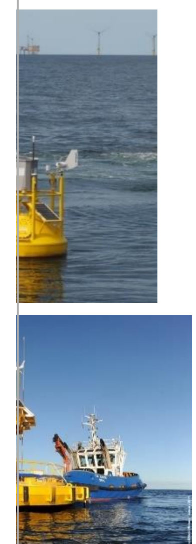
Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LIDAR technology

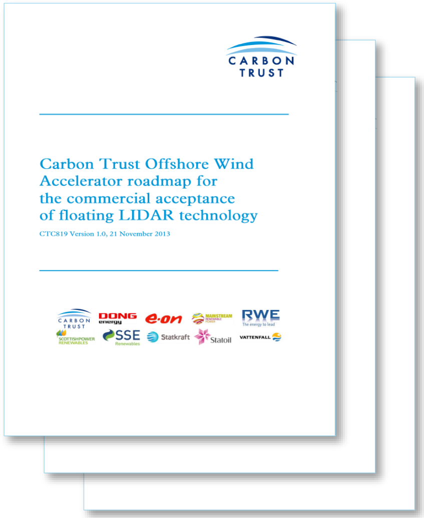
CTC819 Version 1.0, 21 November 2013



Why

The 3 maturity levels of the OWA FL Roadmap

The OWA CT-Roadmap provides guidance for floating LiDAR users, OEMs and other stakeholders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CTC819 Version 1.0, 21 November 2013

Baseline

Lidar type considered as proven technology in onshore industry. Complementary use with offshore met mast.

STAGE 1

Pre-Commercial

Pilot verification trial for FLS type completed successfully. Limited commercial use.

STAGE 2

Commercial

Commercial use in a range of conditions following further successful sea trial and pre-commercial deployments.

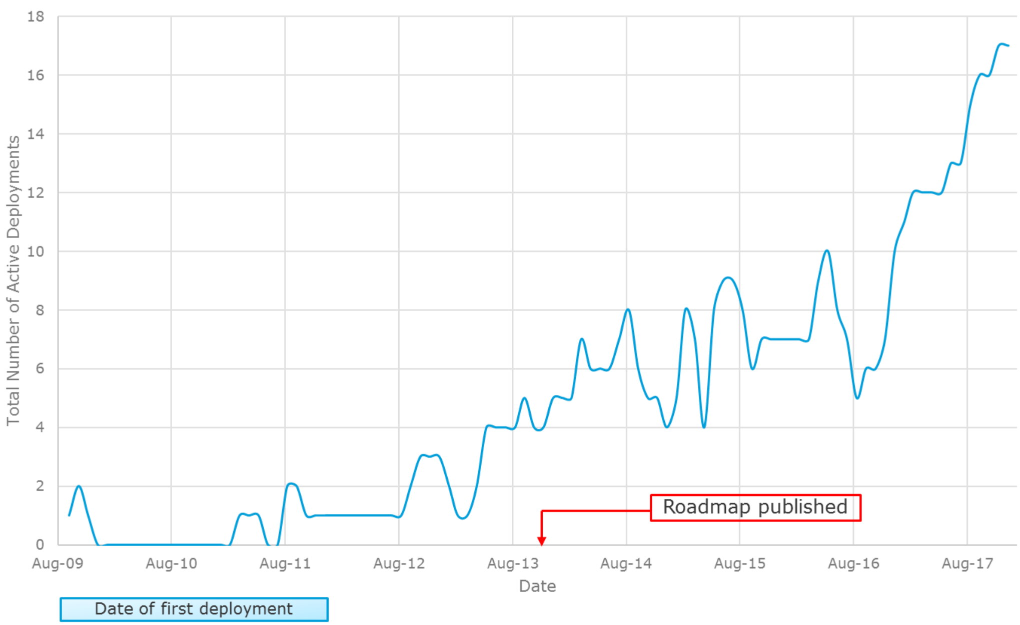
STAGE 3

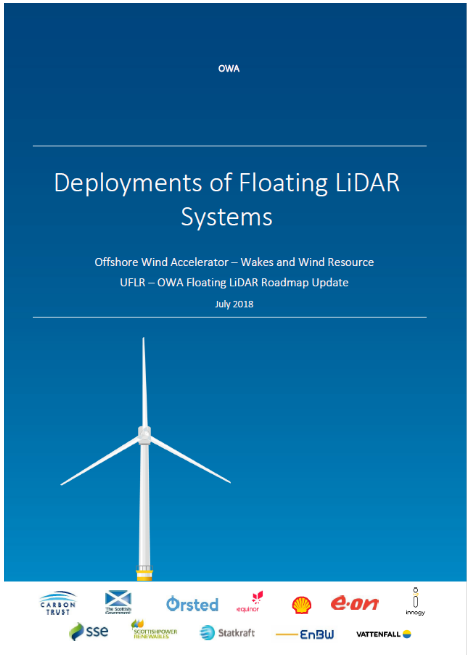
Why

Significant rise in Floating LiDAR System deployments

Floating LiDAR Repository

https://www.carbontrust.com/offshore-wind/owa/wakes/





- 84 FLS deployments
- 13 FLS types
- 40 locations
- Europe, North America, Taiwan
- 7 FLS types have reached Stage 2 maturity

Why — Ongoing OWA Floating LiDAR support → RM Update

Desk based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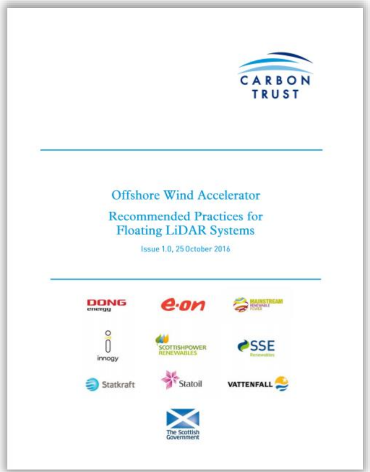
Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LIDAR technology

CTC819 Version 1.0, 21 November 2013

2013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Offshore Wind Accelerator

Recommended Practices for Floating LiDAR Systems

Issue 1.0, 25 October 2016

2016


Deployments of Floating LiDAR Systems

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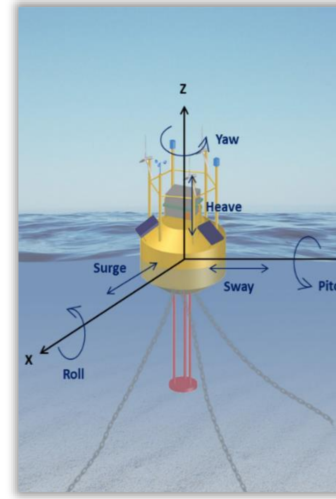
Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LiDAR technology

Version 2.0, 2018

2018



Available to download:
https://www.carbontrust.com/offshore-wind/owa/wakes/

What | # Key changes to the OWA FL Roadmap

Extensive industry stakeholder engagement to inform key focus areas for the OWA Roadmap update

A Extended definition for Stage 3.

B Clarifying requirements for pre and post deployments.

C FLS uncertainty calculation framework

D Impact of design changes to the FLS type maturity validity.

E Allowing for fixed LiDAR as trusted reference source in trials.

F Clarity on who confirms a stage maturity milestone has been met.

Accompanying Guidance Note provides further background on these area. Key topics **A**, B and C to be presented today.

What | **Clear definition for Stage 3 maturity (commercial)**

Best Practice accuracy criteria

- Higher acceptance criteria thresholds

More demanding reliability performance

- Higher KPI thresholds
- Demonstrated over a number of long and short campaigns

Subject to 3 Classification Trials

- Route to uncertainty

What

Stage 3 system and data reliability requirements

A More stringent Acceptance Criteria for system and data availability.

KPI		Definition / Rationale	Acceptance Criteria	
			Stage 3	Stage 2
System Availability	MSA_{1M}	Monthly System Availability – 1 Month Average	≥ 95%	≥ 90%
	OSA_{CA}	Overall System Availability – Campaign Average	≥ 97%	≥ 95%
Data Availability	$MPDA_{1M}$	Monthly Post-processed Data Availability – 1 Month Average	≥ 85%	≥ 80%
	$OPDA_{CA}$	Overall Post-processed Data Availability	≥ 90%	≥ 85%

For Stage 3, more demanding acceptance criteria for system and data availability are defined

What

Stage 3 wind data accuracy requirements

A Stringent Acceptance Criteria for wind data regression KPIs

KPI		Definition / Rationale		Acceptance Criteria: Best Practice	Acceptance Criteria: Minimum
Mean Wind Speed	X_{wms}	**Slope**	Slope returned from single variant regression with the regression analysis constrained to pass through the origin. A tolerance is imposed on the Slope value. Analysis shall be applied to wind speed ranges a) all above 2 m/s; b) 4 to 16 m/s	0.98 – 1.02	0.97 – 1.03
	R^2_{wms}	**Coefficient of Determination**	Correlation Co-efficient returned from single variant regression. A threshold is imposed on the Correlation Co-efficient value. Analysis shall be applied to wind speed ranges a) all above 2 m/s; b) 4 to 16 m/s	> 0.98	> 0.97
Mean Wind Direction	X_{mwd}	**Slope**	Slope returned from a two-variant regression. A tolerance is imposed on the Slope value. Analysis shall be applied to a) all wind speeds above 3 m/s	0.97 – 1.03	0.95 – 1.05
	OFF_{mwd}	**Offset**	In terms of mean deviation (absolute value) (same as for M_{mwd})	< 5°	< 10°
	R^2_{wmd}	**Coefficient of Determination**	In terms of mean deviation (absolute value) (same as for M_{mwd})	> 0.97	> 0.95

For wind data accuracy, exclusively Best Practice criteria are to be applied for Stage 3

What

Expanded pre-requisites for Stage 3

A Extended requirements for size of trial and operational evidence base

- At least **6 verification trials** (3 short, 3 long > 3 monthts) meeting:
  → Data accuracy Criteria – Stage 2 best practice specification
  → System & data availability – increased Acceptance Criteria
- **3 Classification Trials** → long 3 months trials
- **5 Early Commercial Project Deployments** → independently verified

Consequences

- **Stage 2 is mandatory** for "bankable" FLS Wind Resource Assessment
- A **"recipe" for 3rd party to verify Stage 3** maturity to be applied
- Stage 3 **benefits**
  - FLS provides an **increased operational reliability** level
  - FLS is ready for a **concise wind data uncertainty assessment** including **verification and classification** components

What

Risk based approach to pre-deployment verifications (Stage 3)

Current practice:

- All FL Systems require pre-deployment verification → traceable uncertainty

Stage 3 maturity results in:

- Significant body of evidence across range of deployment conditions.

Proposed risk based approach:

- Offers a route to reducing the requirements for full sea trials under certain conditions.
- Acknowledge residual risk that a 'tested' FLS unit does not perform in the same way as other units of same type.

What | ## Wind measurement uncertainty

- **Version 1.0:** Indicative measurement uncertainty ranges expected for each maturity stage.

Weak evidence base

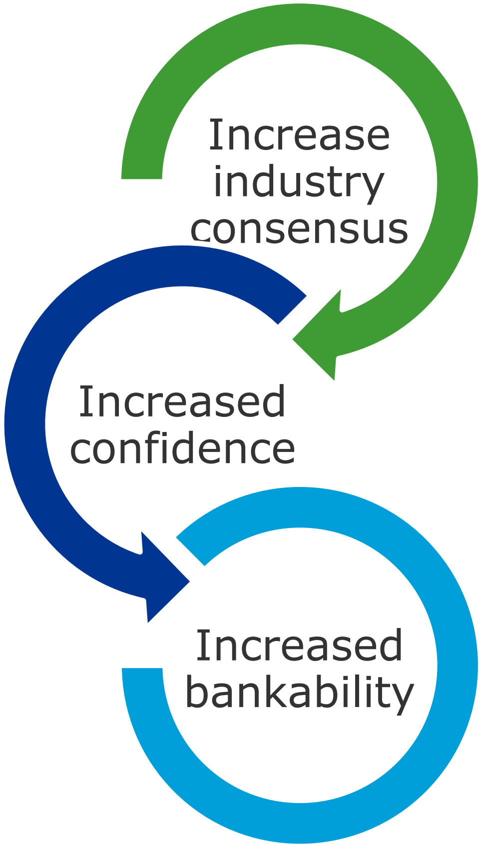
- Industry evidence suggests: measurement **uncertainty is not a driver of maturity**
  → focus on technical reliability

- **Version 2.0: Case specific uncertainty calculations** should be performed for each deployment, (including verification AND **classification components**)

Who — Is impacted by the OWA FL Roadmap update?

- Floating LiDAR System manufacturers
- Wind farm developers
- Technical advisors / consultants
- Investors

EVERYONE!

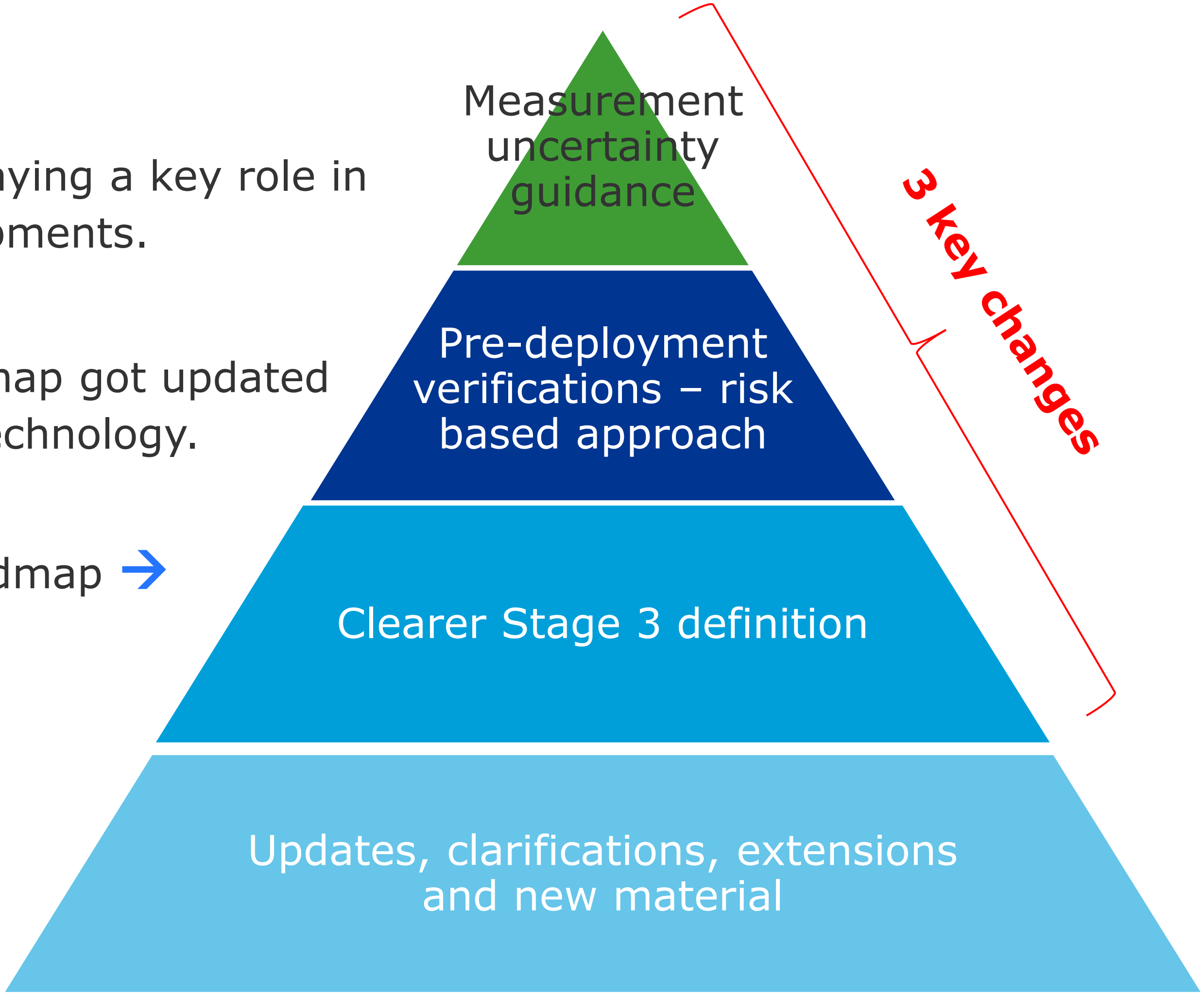


Webinar: "What does the OWA FL Roadmap Update mean for the industry?"

- Already given on 11th October 2018
- Slides available here

Summary

- Floating LiDAR Systems playing a key role in offshore wind farm developments.
- OWA Floating LiDAR Roadmap got updated to reflect latest status of technology.
- Several changes to FL Roadmap →



➢ Supplementary guidance provided on CT website

https://www.carbontrust.com/media/676663/owa-floating-lidar-roadmap-update-webinar-october2018.pdf

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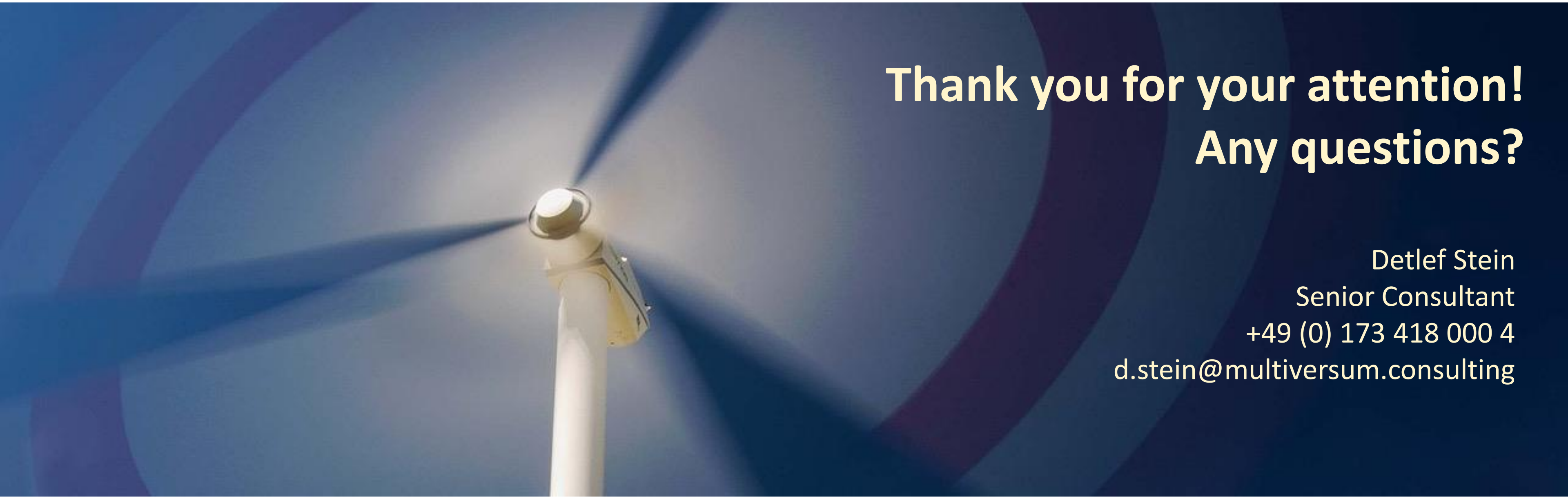

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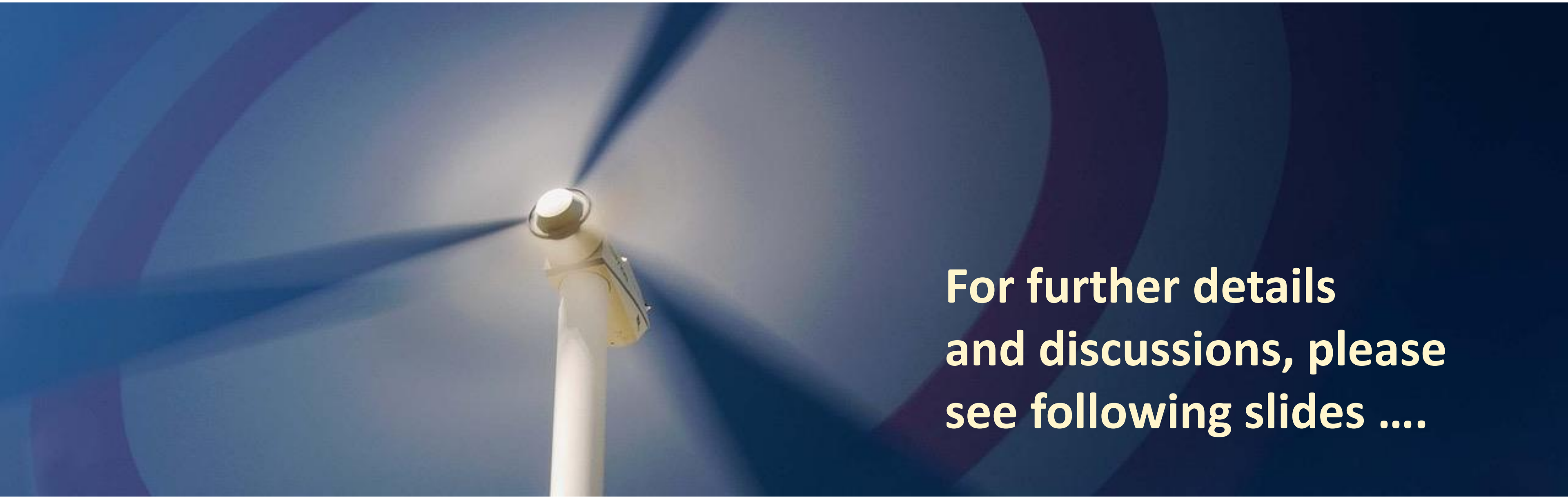


For further details and discussions, please see following slides ….

2 Details on Stage 1, 2, 3: pre-requisites and durations

Maturity Level	FL <u>type</u> verification (1 long trial)	FL <u>unit</u> verification (3 long and 3 short trials)	FL Offshore Classification (3 long trials)	Early commercial project deployments
Stage 1	Not required	Not required	Not required	Not required
Stage 2	❑ # >= 1 ❑ D >= 6 months **Uninterrupted single campaign** **Stage 2** Availability KPIs → meet at **Stage 2 ACs** **Stage 2** Data Accuracy KPIs → meet at **minimum AC**	Not required	Not required	Not required
Stage 3	✓ **Stage 2 type verification** May count as 1 of 3 long trials if **Availability KPIs** → meet **Stage 3 AC** **Data accuracy KPIs** → meet **Stage 2 <u>Best Practice AC</u>** *(may count to classification trials)*	❑ **# >= 6 (min. 3 short + 3 long)** ❑ **D >= 3 months for long trials** **Uninterrupted single campaign** **Availability KPIs** → meet **Stage 3 AC** **Data accuracy KPIs** → meet **Stage 2 <u>Best Practice AC</u>** *(may count to classification trials)*	❑ **# >= 3** ❑ **D >= 3 months** **2 individual units of same FLS type are trialled at same test site** **One unit trialled at two different sites** **Uninterrupted single campaign** *(may count to long trials if all KPIs meet Stage 3 AC)*	❑ **# >= 5** ❑ **D >= 12 months** **Uninterrupted single campaign** Availability KPIs → meet at **Stage 3 AC**

Note 1: Assumes trial is undertaken against a trusted reference source as defined in IEA FL Recommended Practices (e.g. met mast or fixed LiDAR)

2 Risk based approach to pre-deployment verifications and risk based approach (Stage 3)

B Clarifying requirements for pre and post deployments.

Current practice:

- All FL Systems require pre-deployment unit verifications (traceable uncertainty).
- Further guidance given in IEA Recommended Practices[1].

Challenge:

- Pressure to reduce cost and time burden on WRAs using FLS as maturity increases whilst maintaining accuracy of measurements.

Stage 3 maturity results in:

- Significant body of evidence across range of deployment conditions.

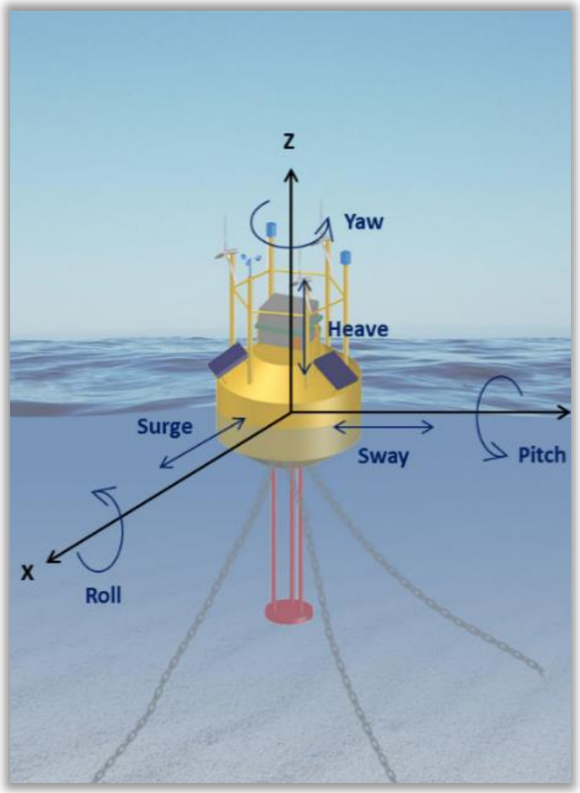
Proposed risk based approach:

- Offers a route to reducing the requirements for full sea trials in certain conditions **for Stage 3 maturity systems only**.
- Acknowledge residual risk that a 'trialled' unit does not perform in the same way as another unit.

2 Process proposed to assess impact of design change on Type maturity

C Impact of design changes to the FLS type maturity validity.

- An FLS design change is identified.
- Arguments made for why the design change does not affect overall performance (both accuracy and reliability of the FLS).
- Suitably qualified and experience 3rd party confirms this assertion.



In principle, it does not matter which stakeholders action this process, although in practice it is more likely to be practicable for the FLS OEMs to do so, as it is considered they will own the FLS configuration control process.

2 Proposed framework to undertake FLS uncertainty calculation

C FLS uncertainty calculation framework

Version 1.0

- Provided indicative measurement uncertainty ranges.

Industry evidence to date

- Gained an improved understanding of FLD wind data uncertainty.
- Lacking evidence base to support the **indicative** ranges in Version 1.0.

Version 2.0

- Includes proposed framework to perform case specific uncertainty calculations (as per IEA FL Recommended Practices and IEC 61400-12-1 Ed2).
- Case specific uncertainty calculations should also be performed.

Other observations

- Results from the OWA LiDAR Uncertainty project indicate that uncertainty is not a driver of maturity – supporting a decoupling

2 Assessment of onsite wind measurement uncertainty of FLS

C FLS uncertainty calculation framework