Instrumenting the Gravity base foundations for the Blyth Offshore Demonstration wind farm

January 2018 | Jonathan Hughes and Paul McKeever

CATAPULT Offshore Renewable Energy

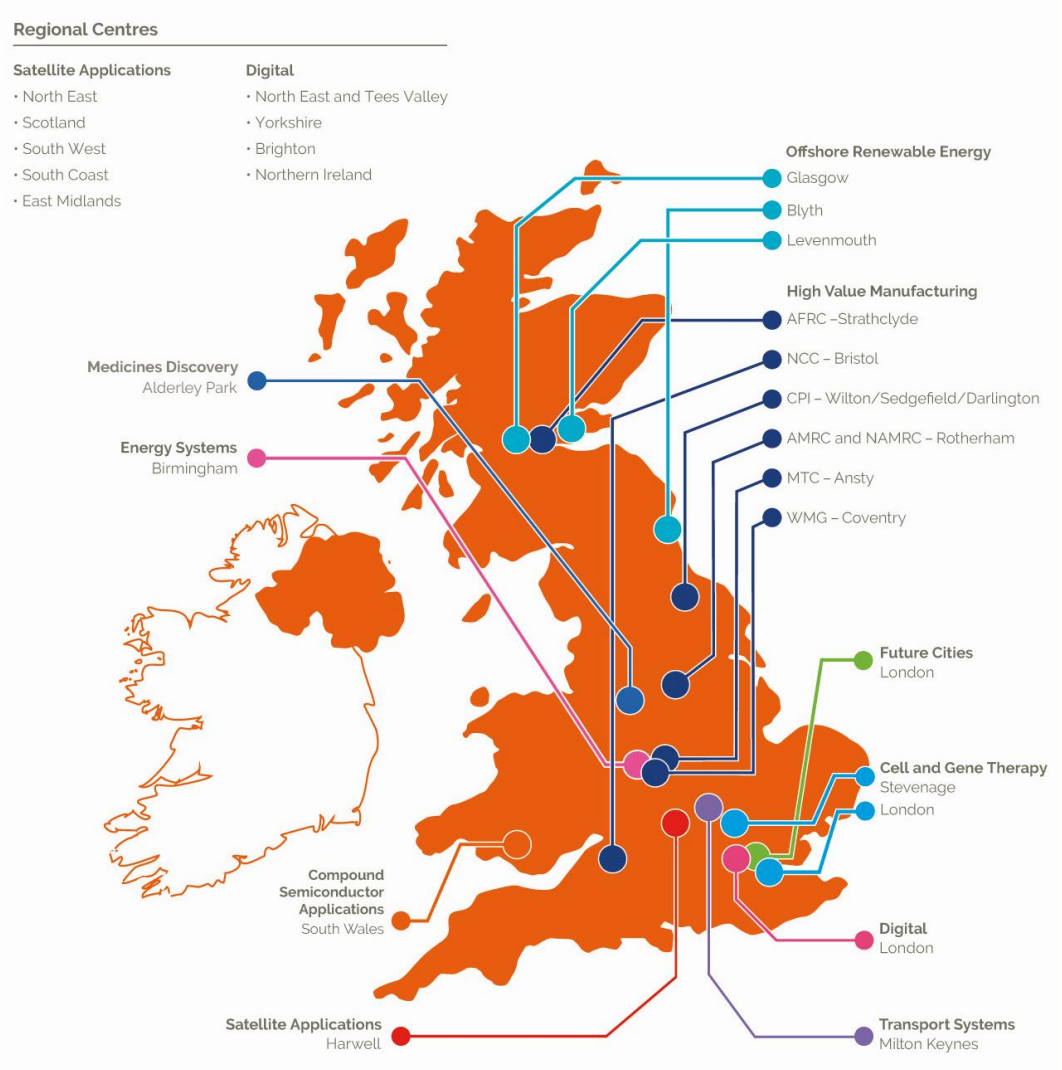
Agenda

- ORE Catapult
- Demowind and the FSFound Project
- The Blyth Offshore Demonstration Wind Farm
- The Project
- Instrumentation in the Marine Environment
- Future Work

The catapult network:
A long-term vision for innovation & growth

11 Catapults

- Established by InnovateUK
- Designed to transform the UK's capability for innovation
- Core grant leveraged with industry and other public funding



ore.catapult.org.uk
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Offshore Renewable Energy

ORE Catapult

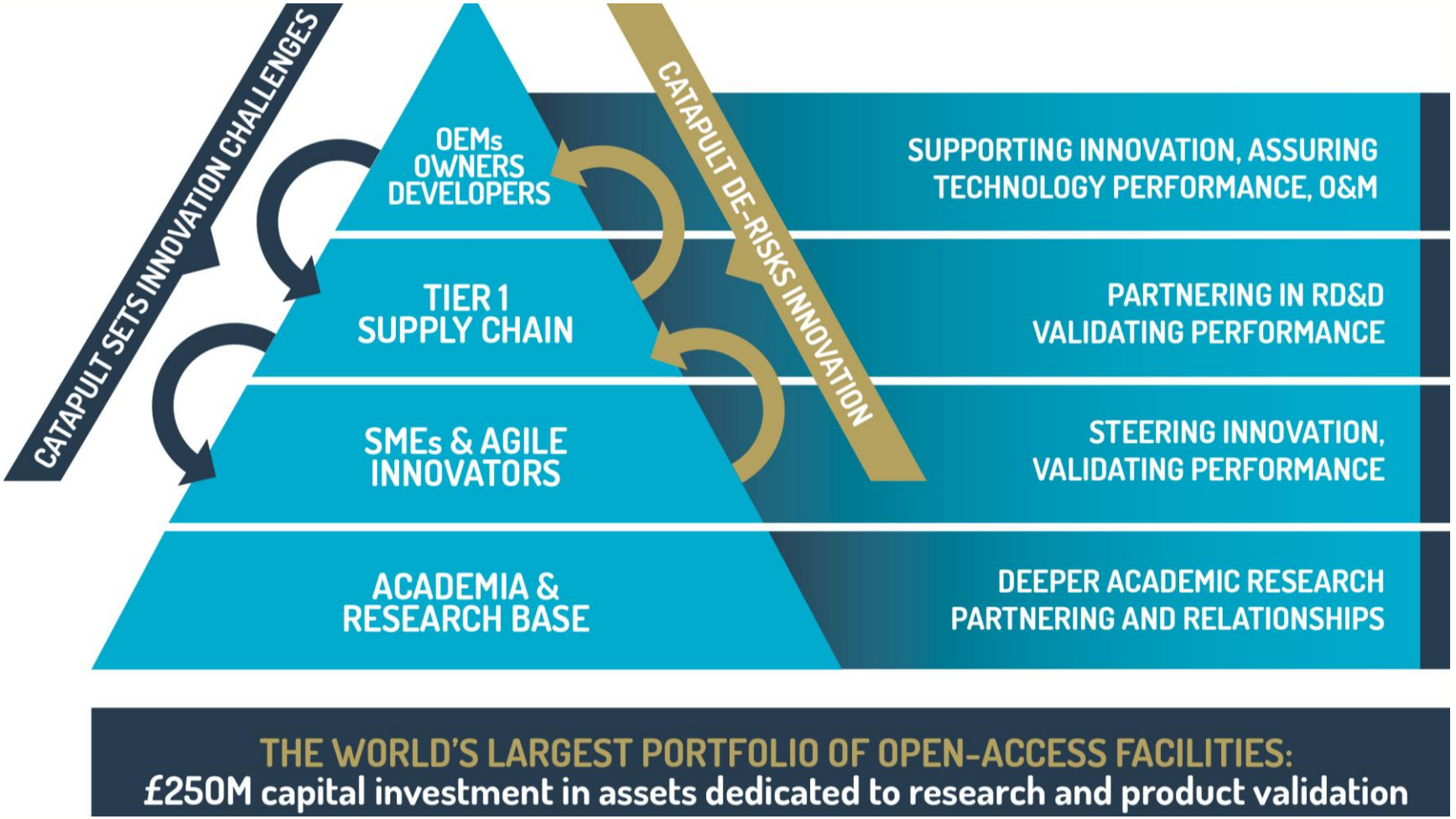
Our Vision:

Abundant, affordable energy from offshore wind, wave and tide

- Reduce the cost of offshore renewable energy
- Deliver UK economic benefit
- Engineering and research experts with deep sector knowledge
- Independent and trusted partner
- Work with industry and academia to commercialise new technologies

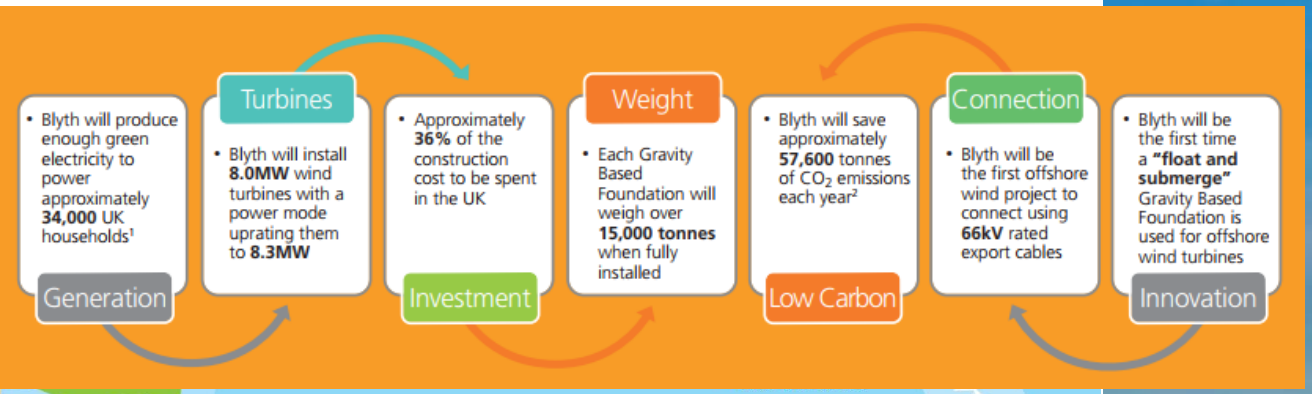
80+ technical experts

ORE Catapult Business Model



Blyth Offshore Demonstrator Wind farm

- 5x 8.3MW turbines
- 6.5km off the coast of Blyth
- 191.5m Tip Height (AOD)
- Approx 40m Water Depth



Installation of GBFs at Blyth – Satellite Imagery

Image from Aeronet-OC Project

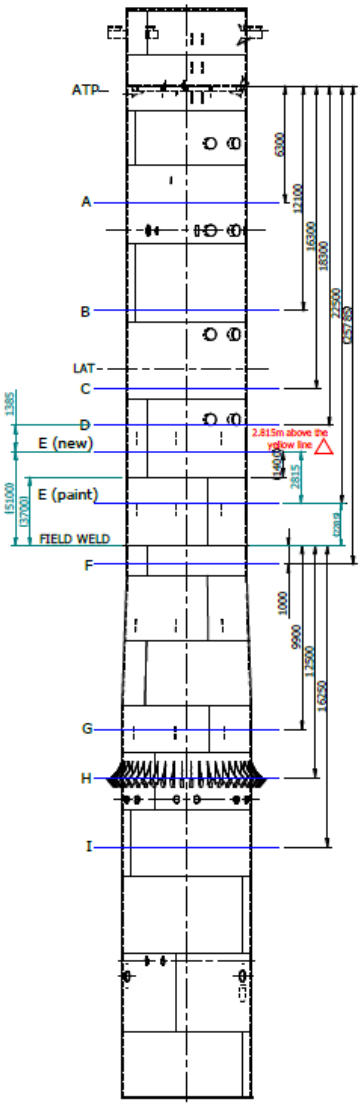
FSFound Project Aims

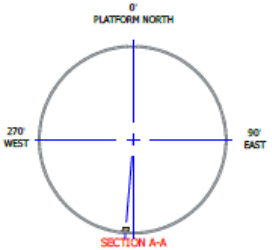
To validate the FS GBF solution as an alternative solution to energy provision by proving that FS GBF performs as intended and can be installed cost-effectively;

- *To conduct a range of simulation and modelling studies to minimise the uncertainties and inefficiencies in the deployment process and in various weather windows;*
- *To compare the actual costs and performance with the cost-benefit analysis performed;*
- *To assess structural response to extreme and fatigue loads on the FS GBF and compare theoretical loads with real ones;*
- *To establish the effect of cyclic loadings on the seabed through monitoring and measurement and verify/calibrate models for differential settlements in the soil;*
- *To establish the optimal seabed preparation requirements (i.e. minimum preparation depth).*

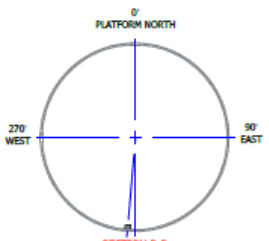
Aims of the measurement campaign?

1. Validation of the design, including input to verifying simulation models
2. Providing feedback to the design limits of the structure, such that an updated life expectancy can be calculated (if required)
3. Understanding the interaction between:
    - GBF and Seabed (e.g. settlement)
    - GBF and WTG (e.g. modal interaction, load transfer)
    - GBF/WTG combination and the Environment (e.g. wind/wave misalignment loads)
    - Effect of internal divisions on the displacement of the caisson outer walls
4. Provide inputs to the design of a Structural Health Monitoring system for GBF system
5. Provide inputs to the cost model, in the form of estimated O&M OPEX costs
6. Provide a platform for the development of a prognostic methodology for NDT of GBFs

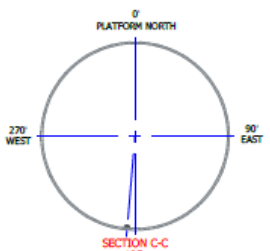




SECTION A-A
185°
INCLINOMETER PROTECTION ASSEMBLY
NX 00021532
CABLE - JB/AS/INC/A
SCALE 1:80



SECTION B-B
185°
INCLINOMETER PROTECTION ASSEMBLY
NX 00021532
CABLE - JB/SS/INC/A
SCALE 1:80



SECTION C-C
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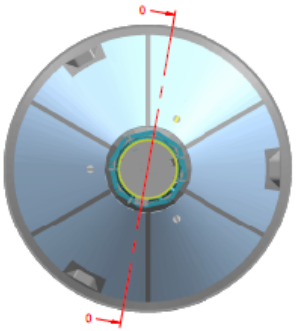
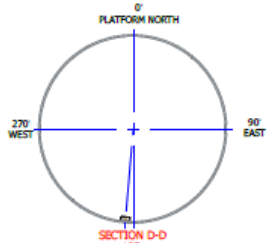
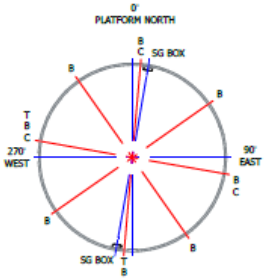
PRESSURE SENSOR PROTECTION ASSEMBLY
NX 00021546
CABLE - PSR/Upper 2
SCALE 1:80

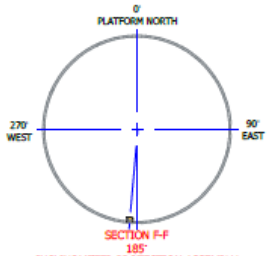




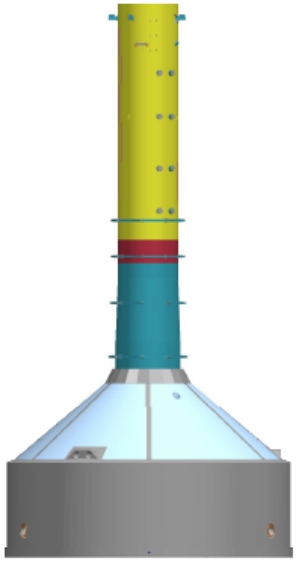
SECTION D-D
185°
IDP & DO PROTECTION ASSEMBLY
NX 00024430 & NX 00024434
CABLE - JB/US/IDP/A
SCALE 1:80

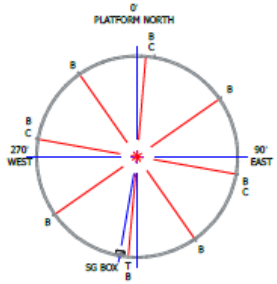


SECTION E-E
10° AND 190°
STRAIN GAUGE PROTECTION ASSEMBLY
NX 00024437
CABLE - JB/AFW/SG/A + STRAIN GAUGES
(5°, 50°, 95°, 140°, 185°, 230°, 275°, 320°)
SCALE 1:80

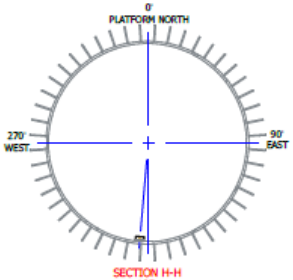


SECTION F-F
185°
INCLINOMETER PROTECTION ASSEMBLY
NX 00021532
CABLE - JB/ST/INC/A
SCALE 1:80

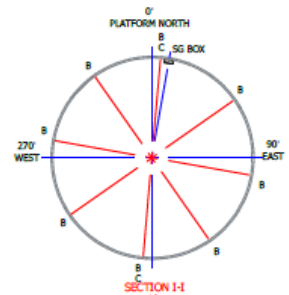




SECTION G-G
190°
STRAIN GAUGE PROTECTION ASSEMBLY
NX 00024437
CABLE - JB/BWJ/SG/A + STRAIN GAUGES
(5°, 50°, 95°, 140°, 185°, 230°, 275°, 320°)
SCALE 1:80



SECTION H-H
185°
IDP & DO PROTECTION ASSEMBLY
NX 00024430 & NX 00024434
CABLE - JB/WJ/IDP/A
SCALE 1:80



SECTION I-I
10°
STRAIN GAUGE PROTECTION ASSEMBLY
NX 00024437
CABLE - JB/BWJ/SG/B + STRAIN GAUGES
(5°, 50°, 95°, 140°, 185°, 230°, 275°, 320°)
SCALE 1:80

SG - STRAIN GAUGE
T - TORSION
B - BENDING
C - COMPRESSION

Approved for Construction

Rev 2: Position E revised to suit fabrication.

Rev 3: Position E revised to allow safe installation of straingauges before completion of the fieldweld.

ENGINEERING CHANGE ORDER No		REVISION	3
EDGES OF UNCONTROLLED SHAPE ISO13715	+0.5 -0.1 -0.5 -0.1	3rd ANGLE PROJECTION	DRAWING INTERPRETATION BS8888

		NAME	DATE
MATL SPEC	N/A		
MATL FORM	N/A	DRAWN BY LJB	23/11/2016
FINISH	N/A	CHECKED DJC	24/11/2016
FINISH SPEC	N/A	APPROVED SJR	24/11/2016
MASS	N/A	TITLE 0527	

DRAWING UNITS - MILLIMETRES UNLESS OTHERWISE STATED

GENERAL TOLERANCES (UNLESS OTHERWISE STATED)

DIM	0.5	3	6	30	120	400	1,000	2,000	4,000
TOL	±0.2	±0.1	±0.2	±0.3	±0.5	±0.8	±1.2	±2.0	±4.0

ANGLE ±1/2°

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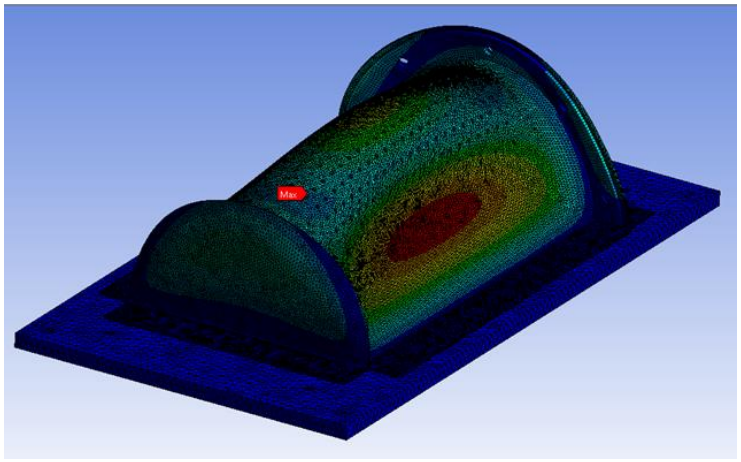
A2-07 Instrumentation Installation

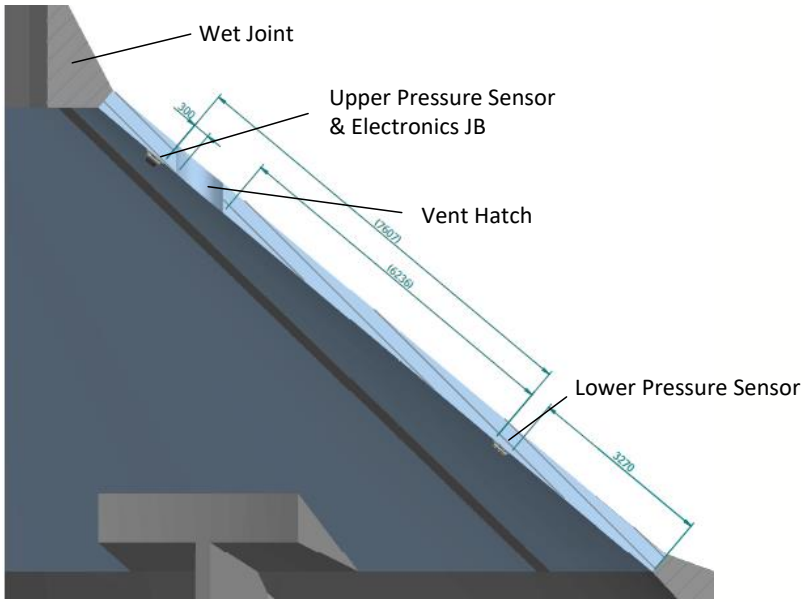
DRAWING No. NX 00031570

SCALE 1:125 SHT No 1 OF 1 A1

Caisson Pressure Sensors

- Upper sensor mounted near vent (sea reference)
- Lower sensor mounted near top of slipform
- 3 sets of 2 mounted at 120˚ spacing
- 4Hz sample rate





- Indirect measurement of depth
- Also can calculate period
- Triangulation may permit direction measurement
- Comparison after calculation with other wave data on site.
- Data corrected for Atmospheric variation

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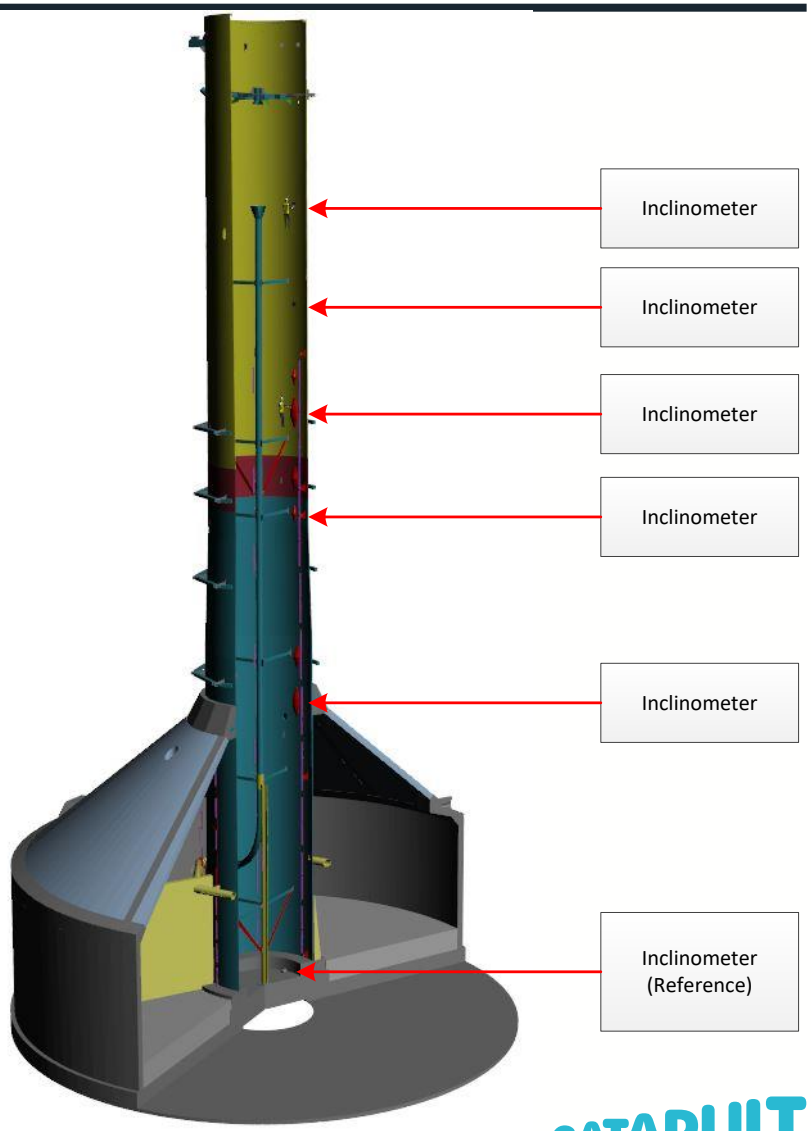
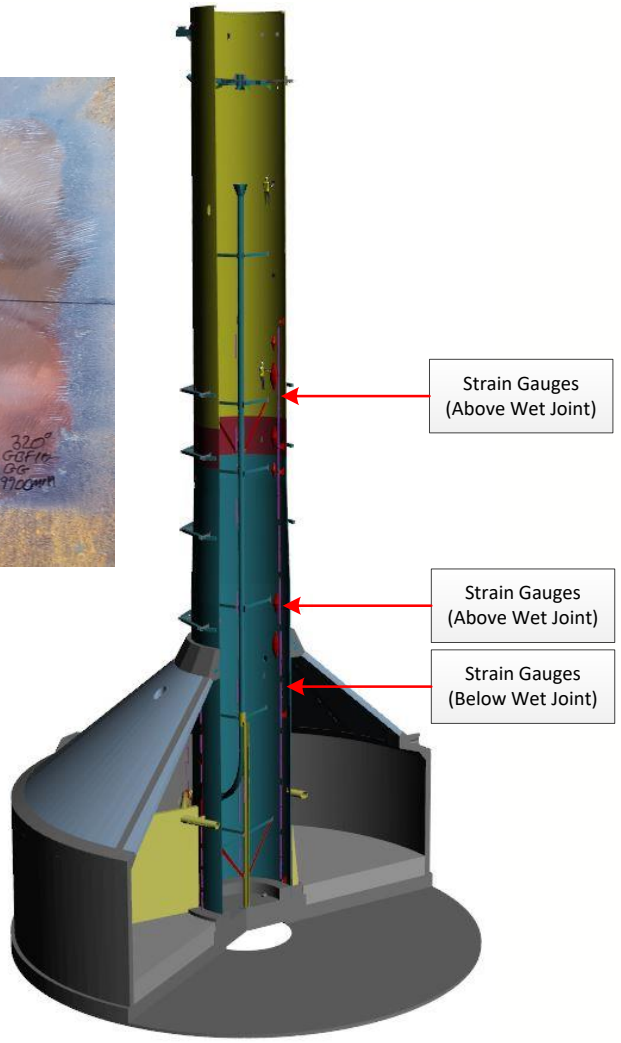
Inclination and Mode Shapes

- High stability servo inclinometers
- Measurement range of +/-14.5˚
- Resolution of 0.001˚
- Positioned to match ANSYS AQWA modelling nodes
- Positioning is critical to interpretation of data



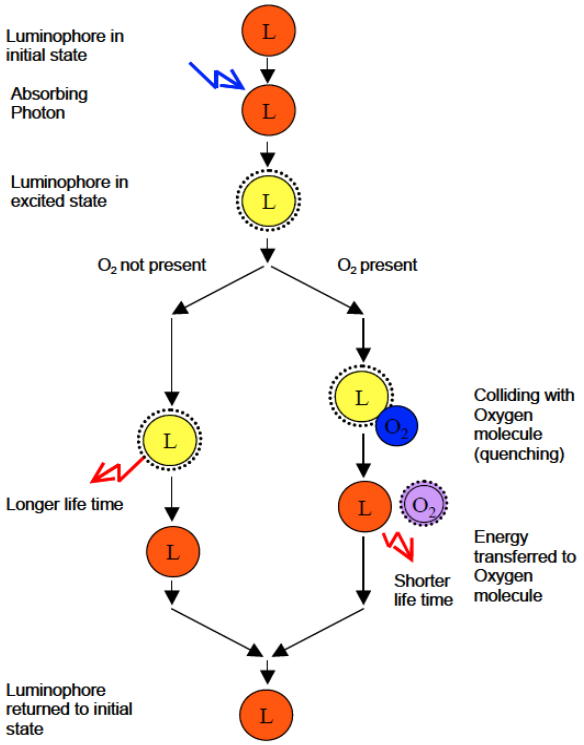
Load Paths

- Initially aimed to installed SGs into Concrete, however not possible
- Structure can be analysed through load paths rather than direct loads
- Bending, Compression and Torsion are independently assessed
- Loads measured above and below "Wet Joint" – calculation of loads into caisson roof
- Loads measured at field weld to establish effect of loads from turbine and torsional loads



Corrosion

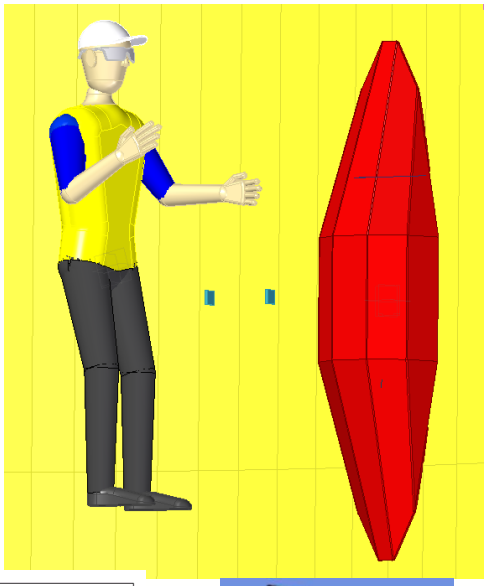
- Structures are filled ballasted with sand and seawater flooded below LAT
- Water is expected to have slow transit rate through structure, leading to oxygen depletion
- Dissolved Oxygen sensors are installed to monitor
- Water level in shaft is monitored for comparison
- DO Sensors use dynamic luminescence quenching rather than an EC sensor

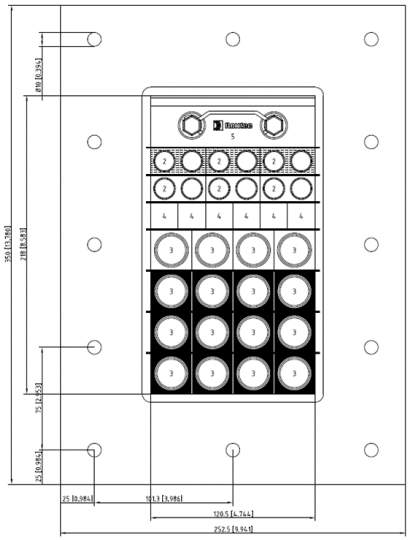


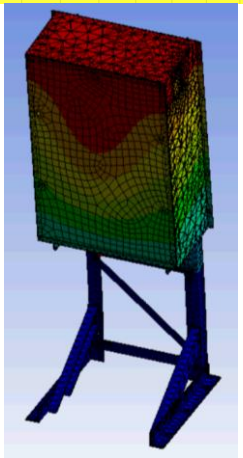
From AADI 4330 manual

Connection and Protection

- Instruments are useless if they don't work or give questionable data
- Welding and Bolting were not permitted by the designer
- All instruments are permanently bonded, but need a temporary method of attachment until the adhesive "grabs"
- Protection needed against ballasting force
- Protection against settlement
- Subsea-grade cables and connectors
- Full epoxy fill to instrumentation systems







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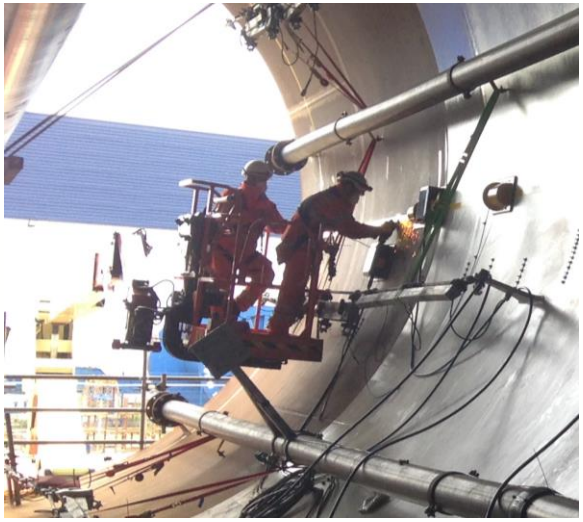
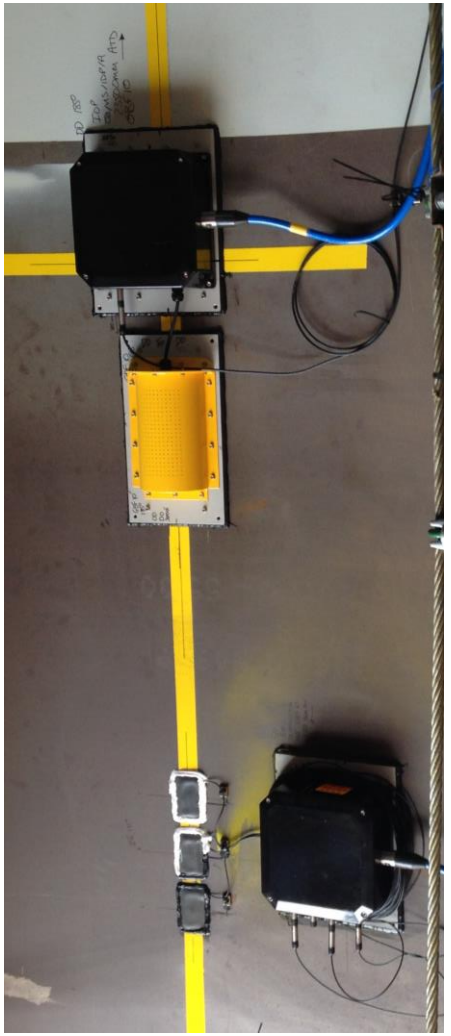
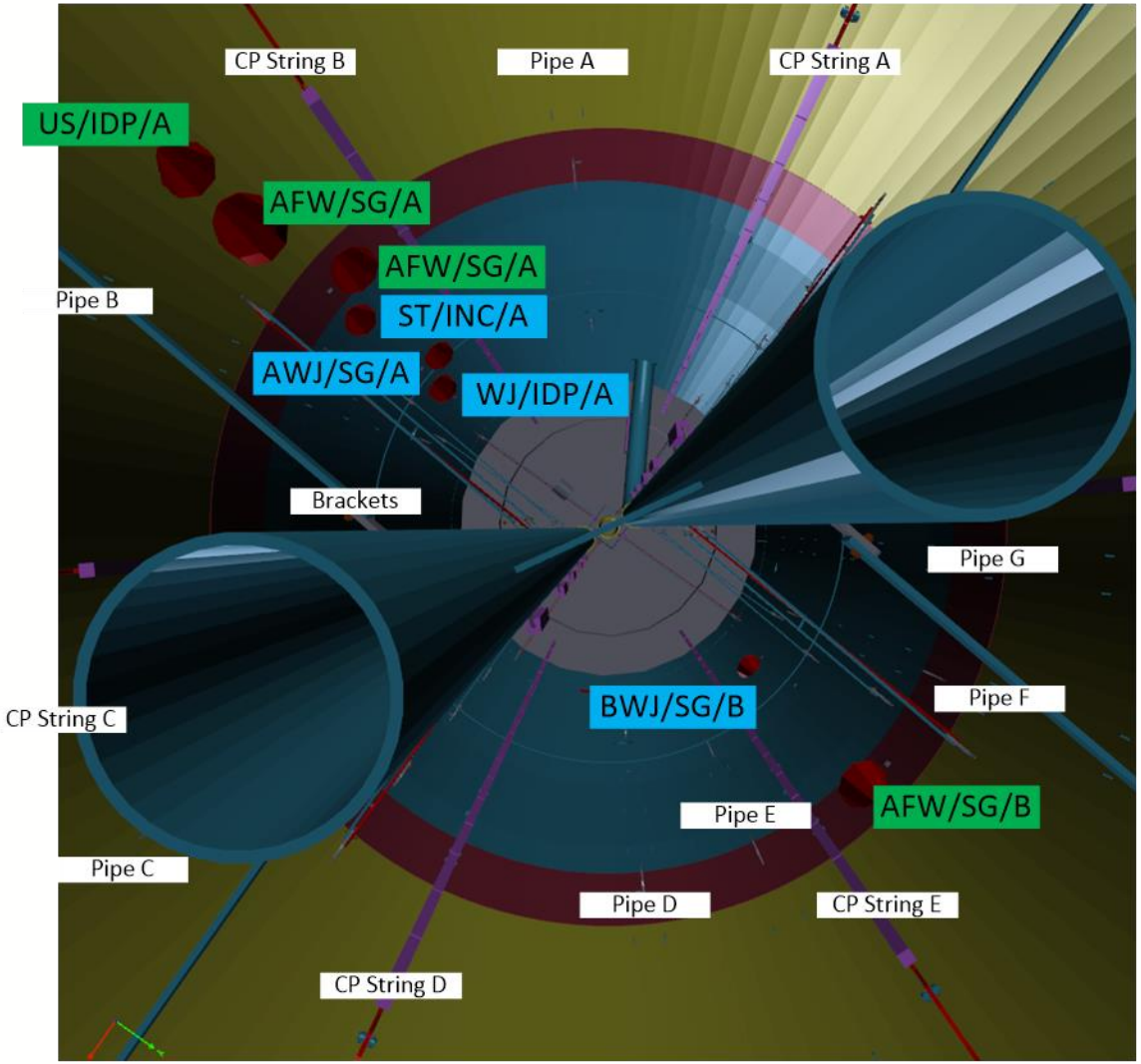
Installation Challenges

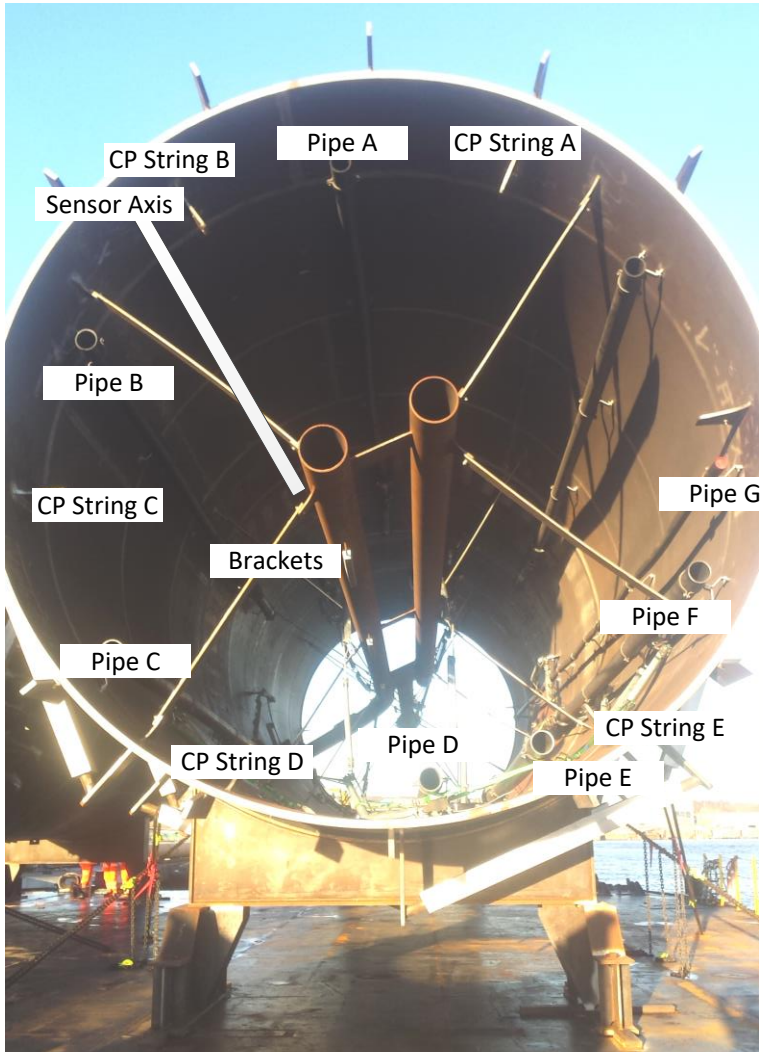
- Vertical installation requires significant additional time and risk management
- Installing delicate sensors; to fine tolerances; in the wet; hanging from a rope…
- Horizontal installation challenging without the ability to roll or traverse
- Location Referencing
- Novel and Evolving design
- Fitting research into a complex and time-critical construction project





How close are models to their physical counterparts?





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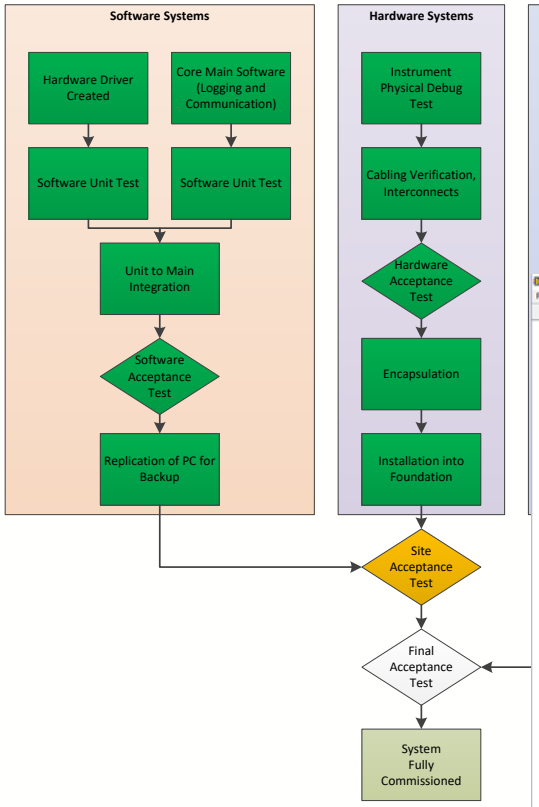
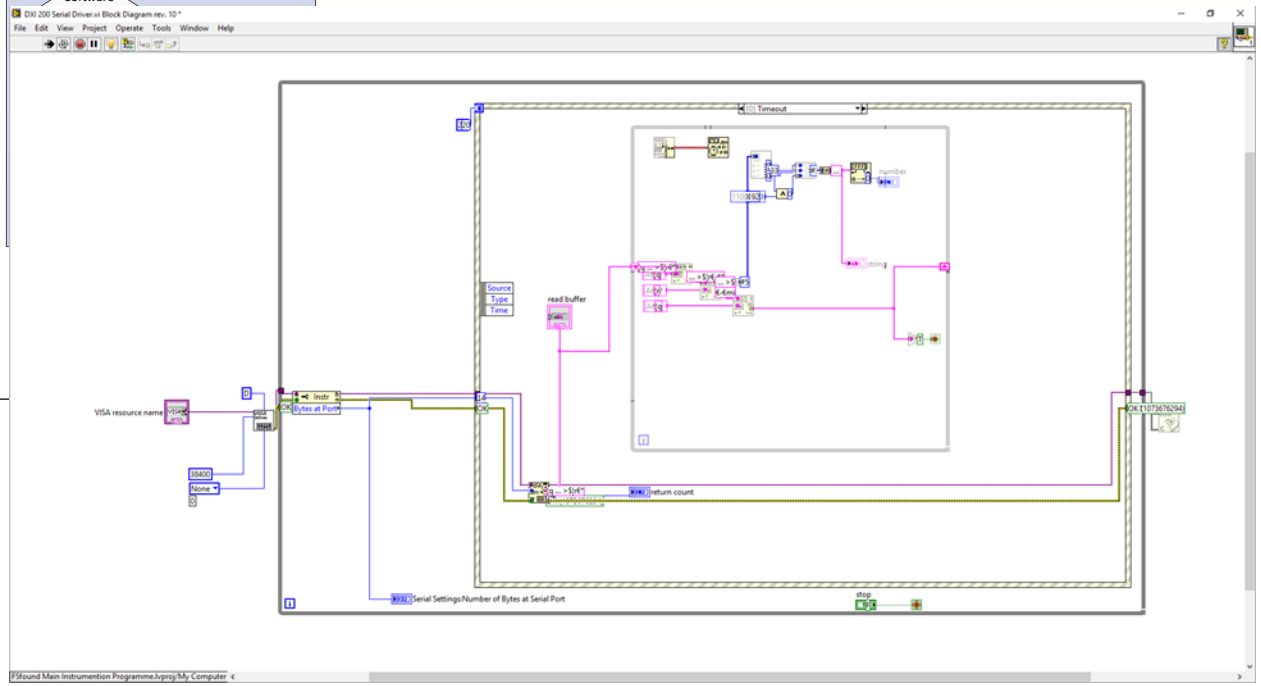
Software Systems





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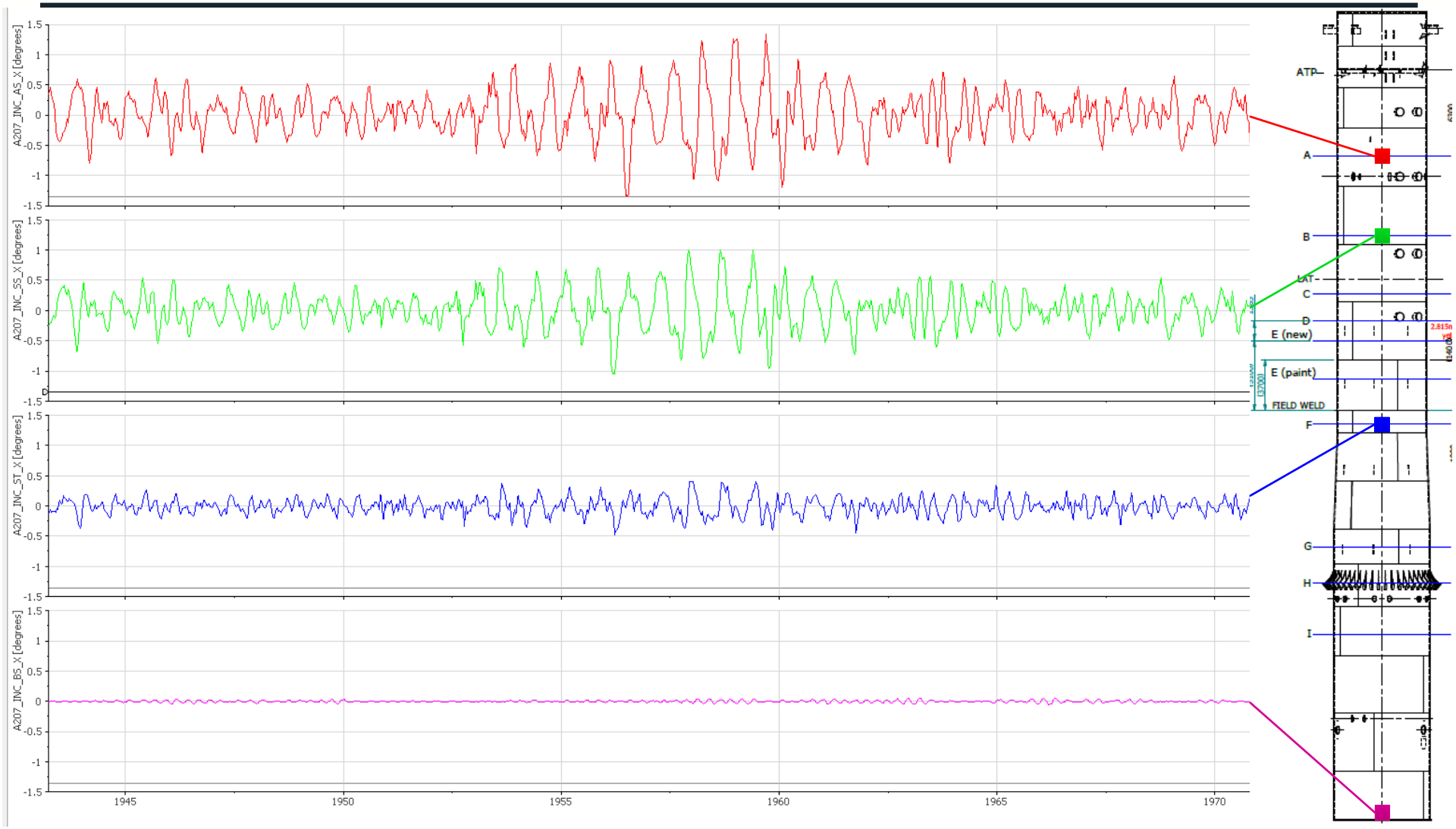
Example Data – Inclinometer Profile



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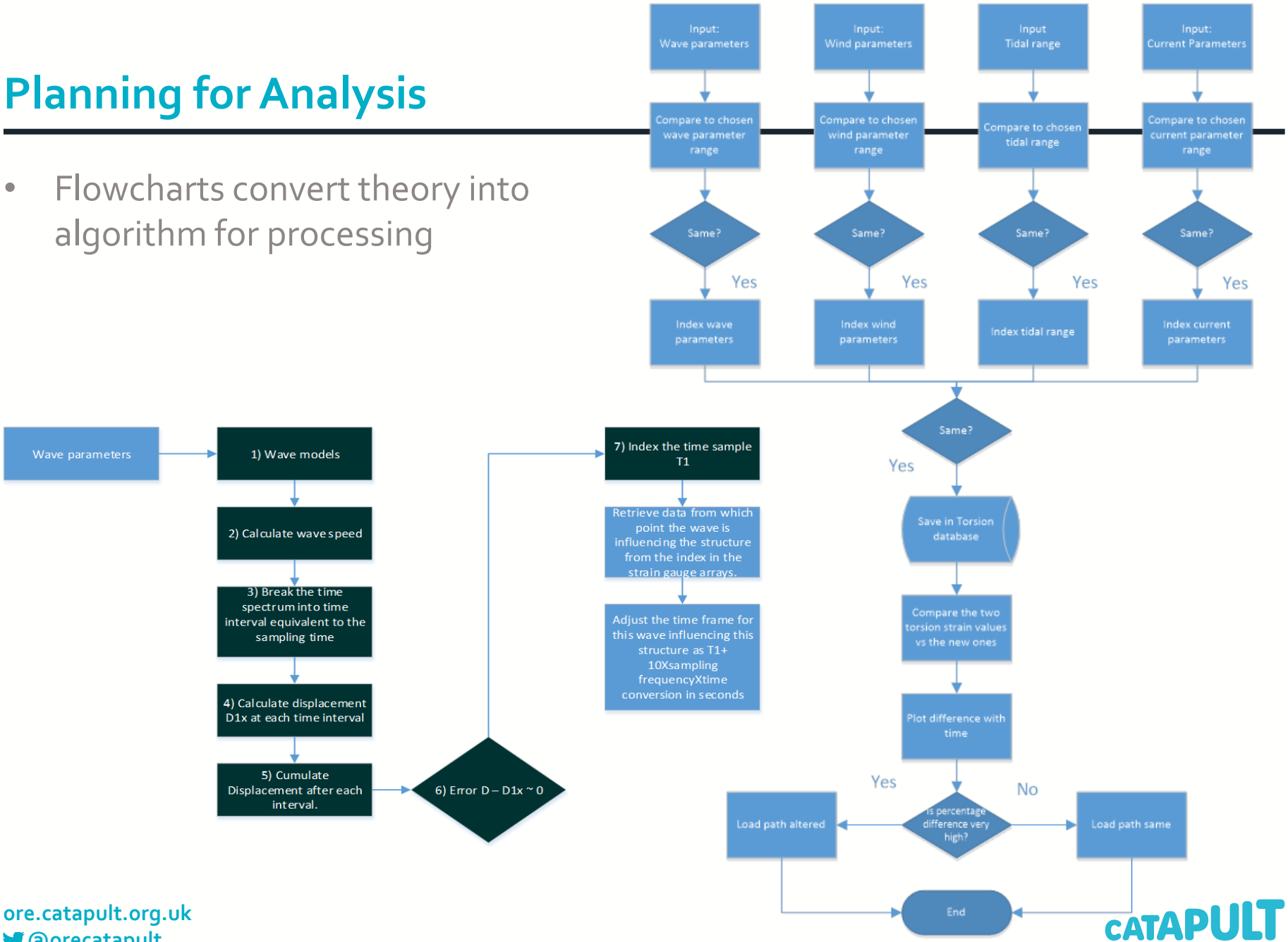
Planning for Analysis

- Flowcharts convert theory into algorithm for processing



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Why is Research in a Commercial Project so challenging?

Commercial Ideals

- Strong "proven" technical solution
- Warrantable performance allowing for "tight" contracts
- No unexpected outcomes

Research Ideals

- Cutting Edge "novel" technical solution
- Project technical output comes before programme
- Unexpected outcomes are interesting (isn't that why we do it?)

The best common outcomes only come through

- Close collaboration between practical and theoretical work
- Novel techniques but proven technologies and strong theoretical base
- Trial and error (more trials, fewer errors!)

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