



Composite Hybrid Flexible Pipe

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Next Generation Composite Flexible Risers

GE Oil & Gas Wellstream Flexibles

- ✓ **30%** lighter
- ✓ **20%** savings on total installed cost
- ✓ Deeper water and higher pressures
- ✓ Free-hanging catenary in 3000m water depth

GE's high-performance carbon fibre reinforced thermoplastic pressure armour is a direct replacement for the traditional Flexlok™ armour wires. This new pressure armour equips our pipes with a superior strength to weight ratio, delivering considerable benefits from manufacture to operation

Benefits

- Top end tension reduction
- Reduced buoyancy requirements
- Installation time saving
- Optimised platform capacity vs. number of risers

Collaboration

- GE has been working closely with key flexibles users globally, to develop robust methods for design and qualification

Technology

- High pressure capacity
- Well-known and trusted materials
- State-of-the-art manufacturing
- Simplified design
- Flexible and fatigue resistant
- Mature and proven end terminations



Flexible Pipe Construction

3km - 8"ID - 12ksi
Layer Weight

Carcass – Inner metallic layer prevents collapse due to hydrostatic pressure

20%

Fluid Barrier – Chemically resistant polymer boundary for conveyed fluids

5%

Pressure Armour – Interlocked metallic layer resists internal pressure loads

32%

Tensile Armour – Provides axial support for the entire riser

38%

Insulation Layer – Prevents excessive heat loss in bore fluids during operation

1%

Outer Shield – Protects the pipe against seawater ingress and external damage

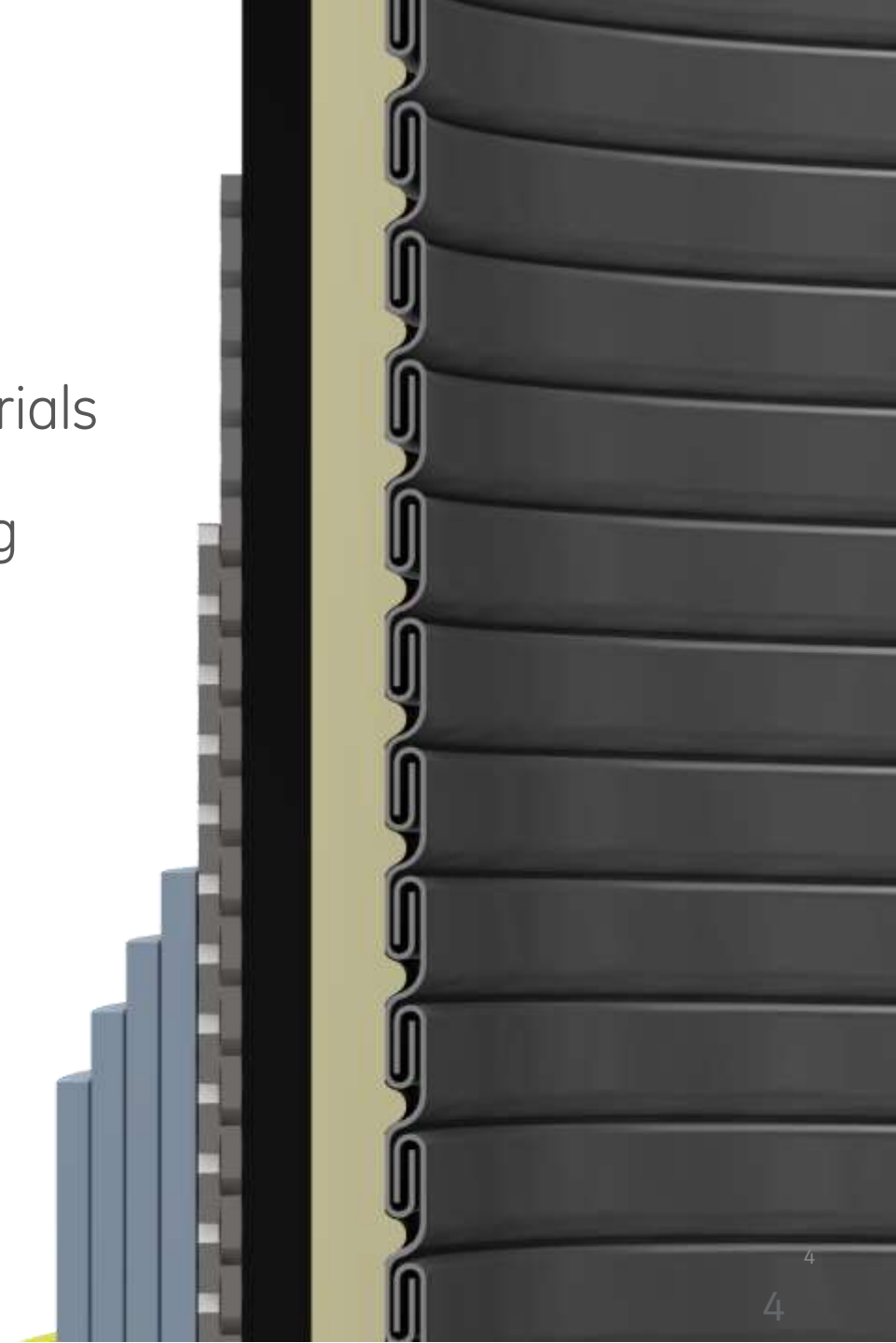
4%



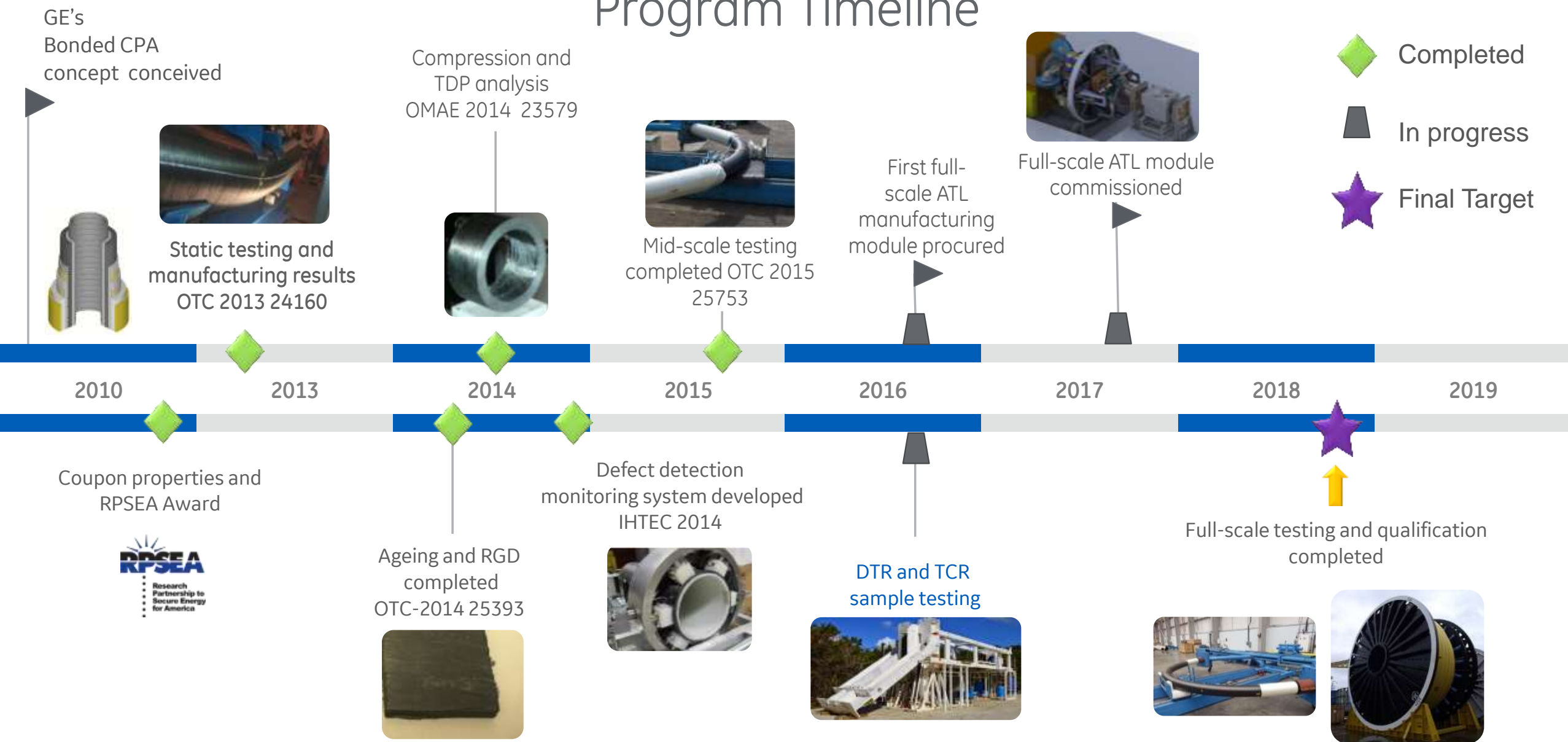
Composite Pressure Armour



- High pressure capacity
- Well known and trusted materials
- State of the art manufacturing
- Simplified design
- Optimised material usage
- Flexible and fatigue resistant
- Mature and proven end terminations



Program Timeline



Multi-scale Qualification

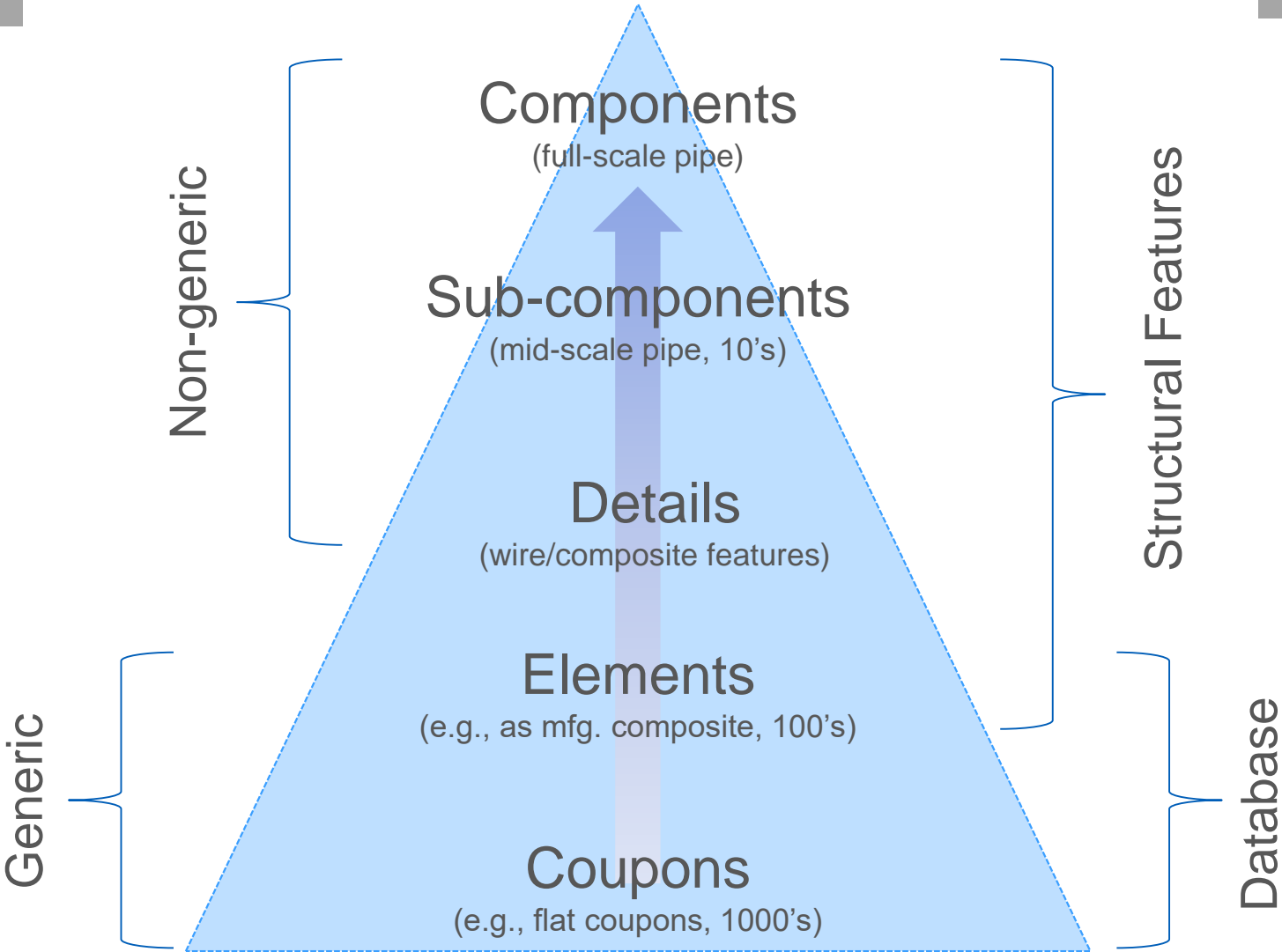
Hoop / Pressure



pressure

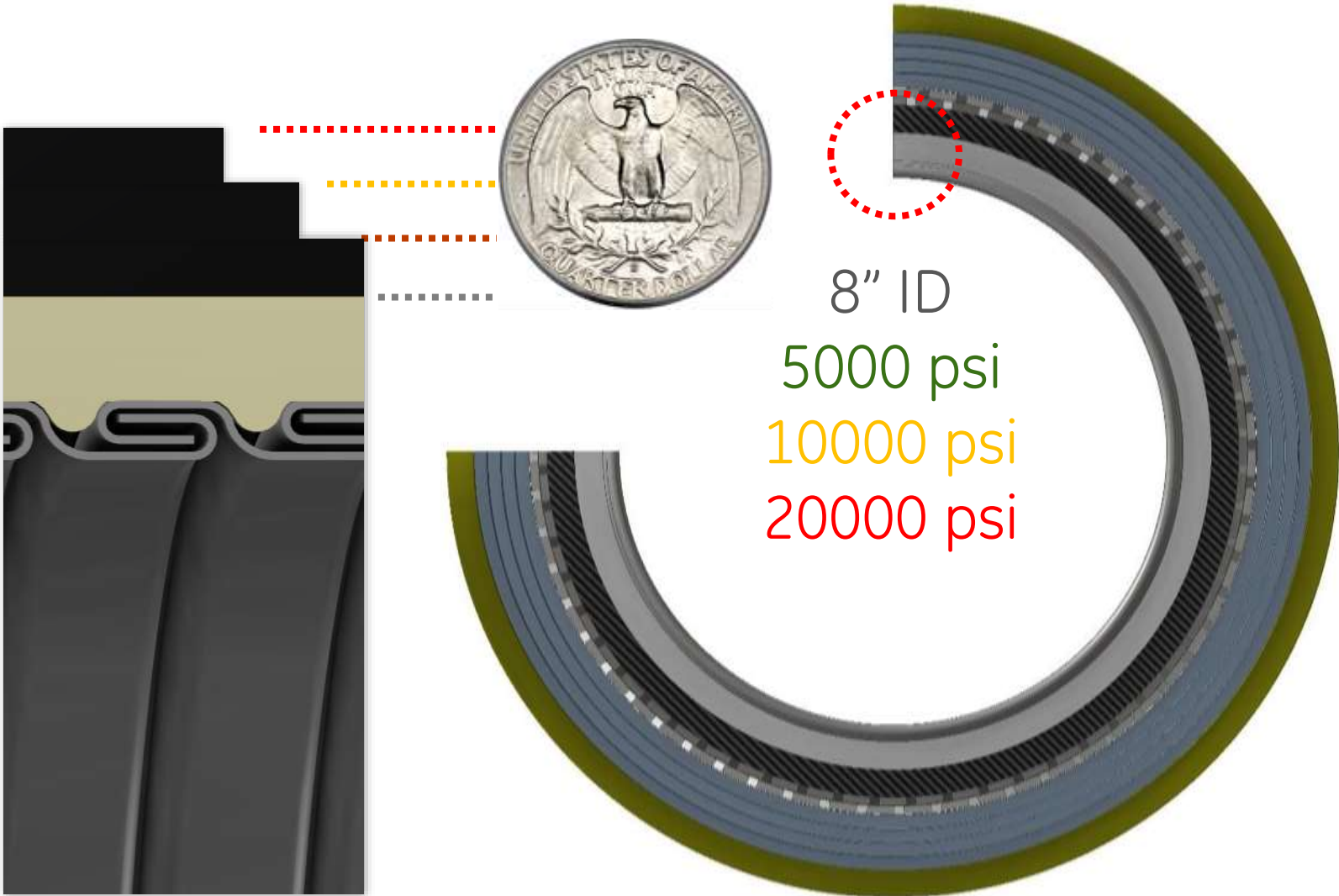
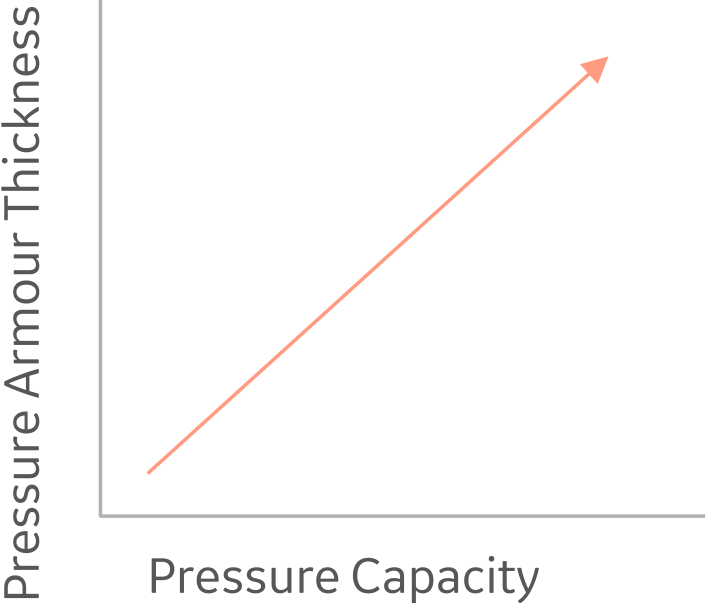


Flexural/Bending



Capability – Composite Pressure Armour

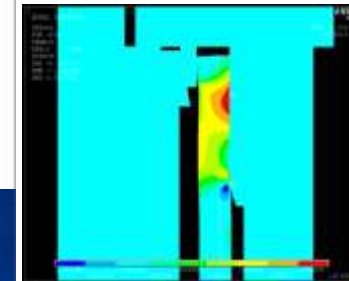
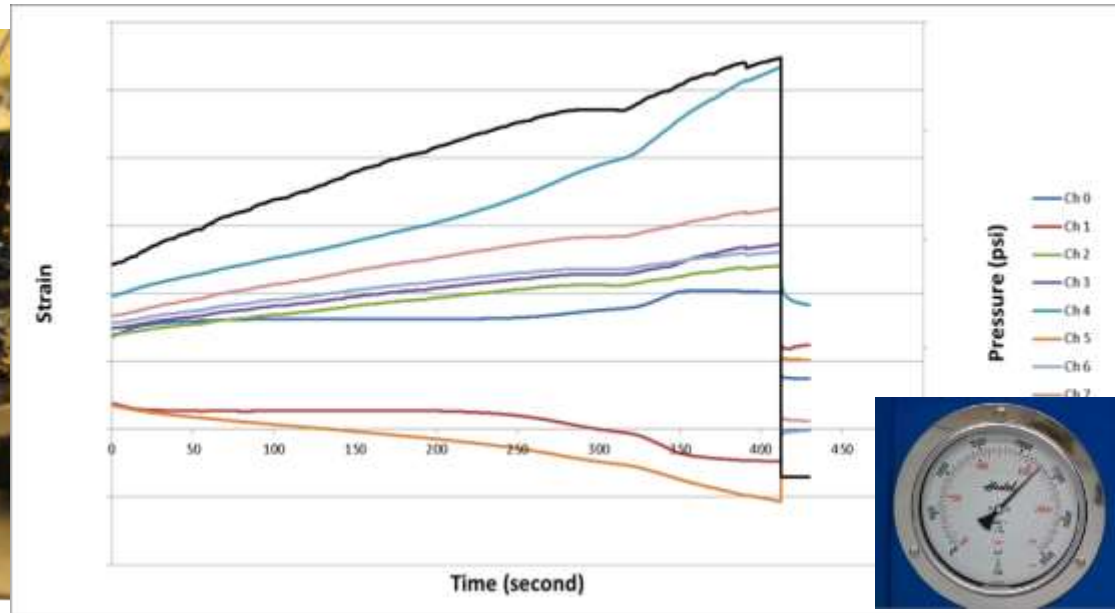
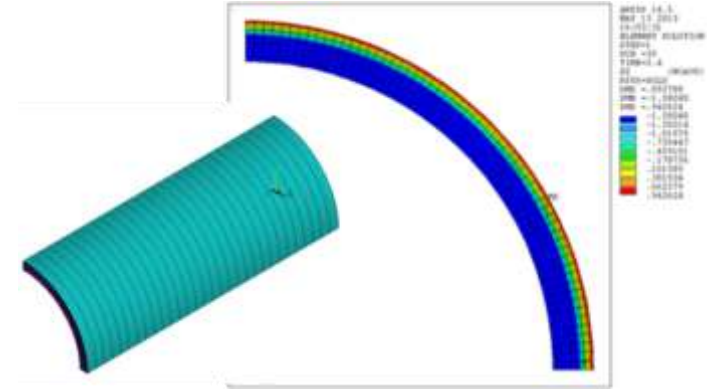
Single material qualification to cover entire pressure range



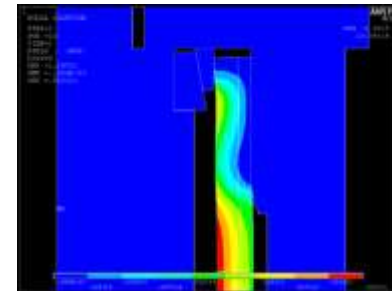
Burst Performance: Mid-scale Pipe Testing and Modelling

Burst tests – 12 ksi design pressure with analysis model validation

- Proven burst performance for 24 ksi /~160 MPa
- FE modelling was used to accurately predict failure point



Axial strain

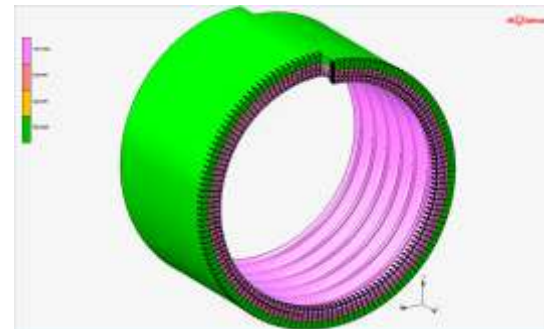


Hoop strain

Mid-scale: Collapse performance of Composite pipe



- 3 Product A samples were tested at 10 inch.
- 3 Composite pipe samples were tested at 10 inch.
- Currently, 6 inch product A and composite pipe samples are being tested.
- Composite pipe increase the collapse performance of carcass/Product A by 30 – 90%, scaling based on thickness of composite layer
- Currently developing a 3D model to accurately predict the observed collapse behaviour.



Mid-scale: Thermal Cycle test

- Thermal cycling rig (TCR test) :-
- RPSEA composite pipe End termination exposed to 50 thermal cycling load cases (-10°C to $+120^{\circ}\text{C}$).
- As shown sealing surface and contact area successfully passed testing conditions (No unexpected movements). i.e. sealing performance is not effected by thermal loads or presence of bonded composite pressure armour layer.



Mid-scale: Rotating Bend Fatigue Testing



Mid-scale rotating bending fatigue.

- Low strain, high fatigue cyclic loading.
- Captures the tri-axial stress state.



Cross-section of sample after 1 million cycles in rotating bend fatigue rig.

- Both composite and interface layers were checked before and after testing.

Large-scale Dynamic Testing - Combined Loading Testing



Full-scale dynamic fatigue test rig at ETA International

Inside diameter	254.00 mm
Max tension	500 kN
Storage bend radius	3.9m
Operating bend radius	3.9m
Weight empty in air	77.16 kg/m
S/W filled in air	133.34 kg/m

Full-scale pipe and test parameters

- A full-scale dynamic testing rig (DTR) sample will consist of carcass, barrier, composite pressure armor, tensile armor and wear layers.
- In addition to testing tensile-fatigue-critical tensile armour layers, the effect of bending loads on the composite pressure layer can be studied.
- Additionally, the effect of the interaction between the tensile and composite pressure armor will be captured.
- Changes in friction factor and its effect will be studied.

Samples has finished 1 million cycle load cases.

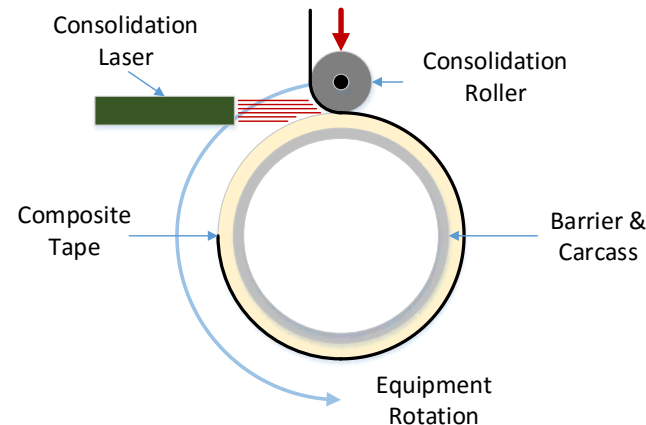
Dissection to be performed to assess performance of composite pressure armour layer after 1 million bending cycles, representing a 25 yrs. service life.



Manufacturing Readiness & Timeline

Module 1 Composite Pressure Armour Production Line

The bonded composite manufacturing line will be a modular system consisting of several identical Automated Fibre Placement (AFP) heads on a rotating platform. This equipment will be used to 'layer' and weld carbon composite tapes to form a variable thickness composite pressure armour. Module 1 is the first of these AFP machines and due to the modular nature of the final production machinery, can and will be used to produce a qualification product that is identical to that which will be produced on the final production line.



Pipe / Technology Qualification

- Manufacturing qualification samples on the production line equipment is a key requirement of the industry regulations for flexible pipe
- Equipment is required to complete the final elements of the technology & product qualification.

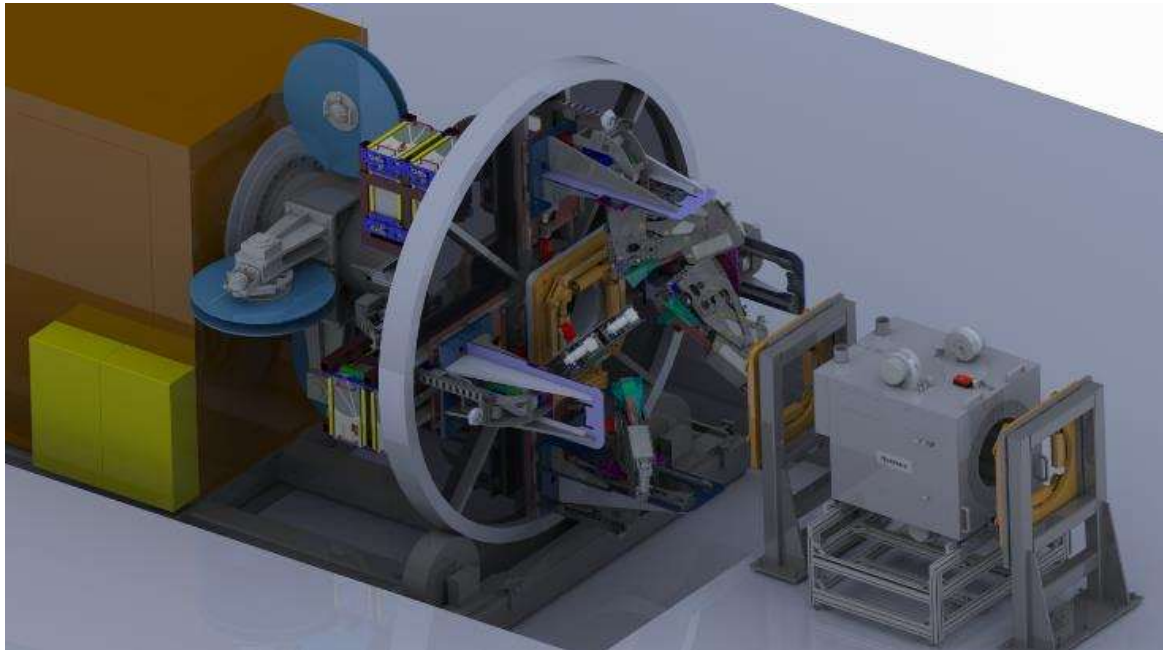
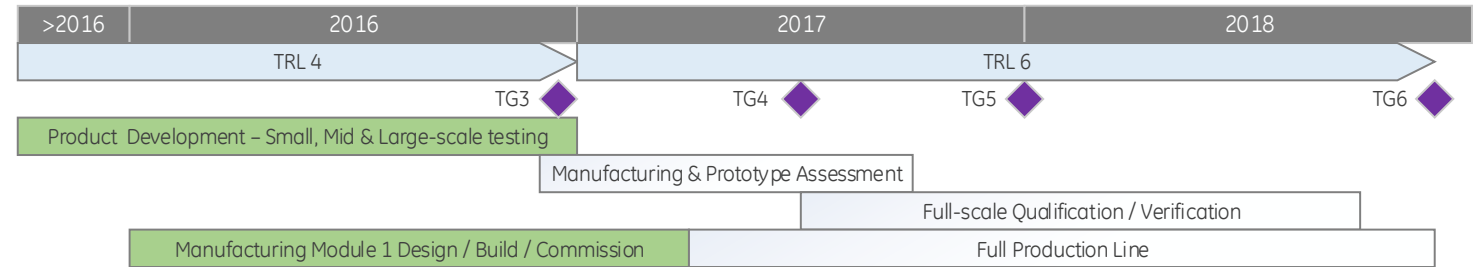
Factory Qualification

- Manufacture pipe in significant lengths to prove the stability of the manufacturing process
- Ensure that the logistical element of manufacturing this new product has been proven before the product release.

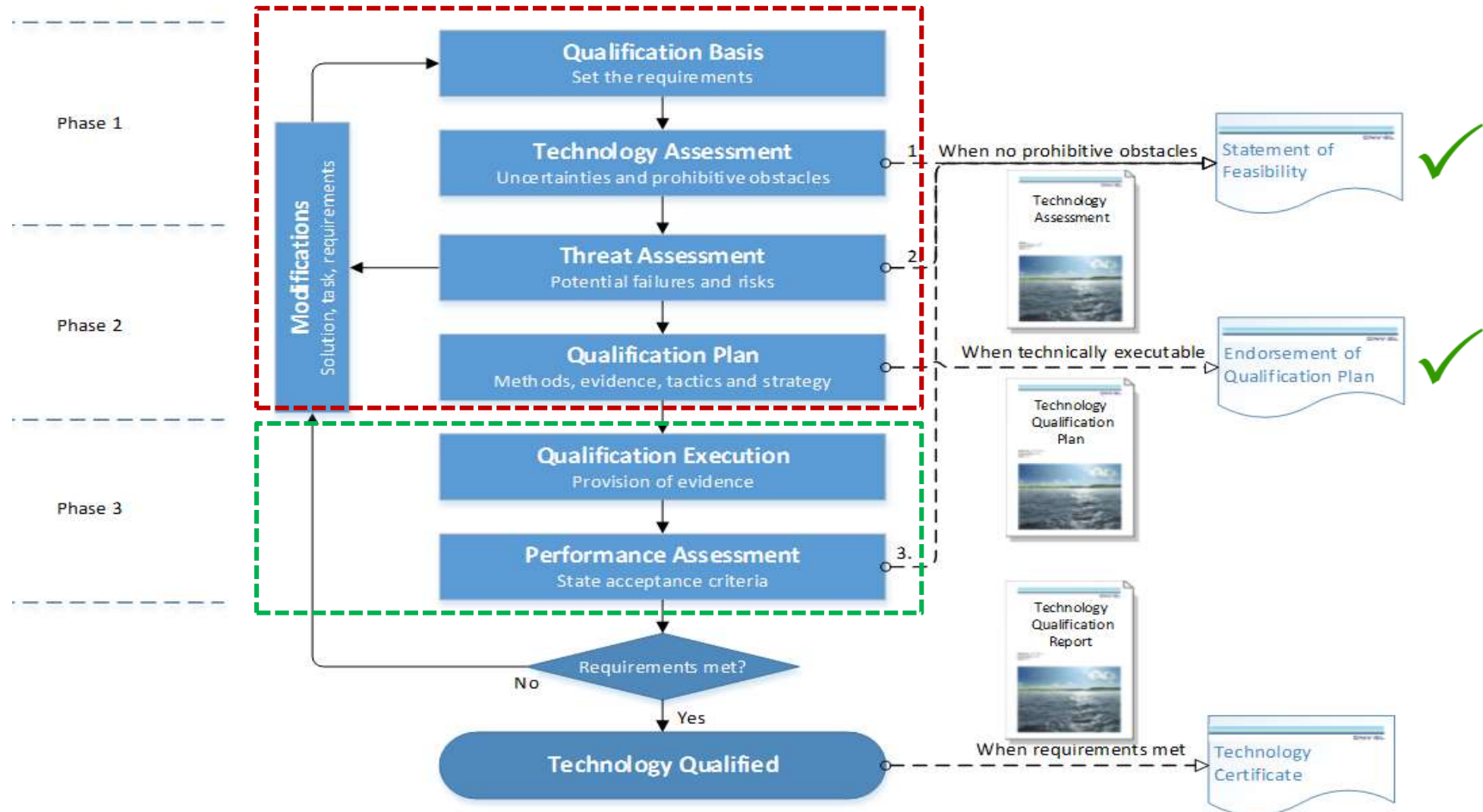


Manufacturing Readiness & Timeline

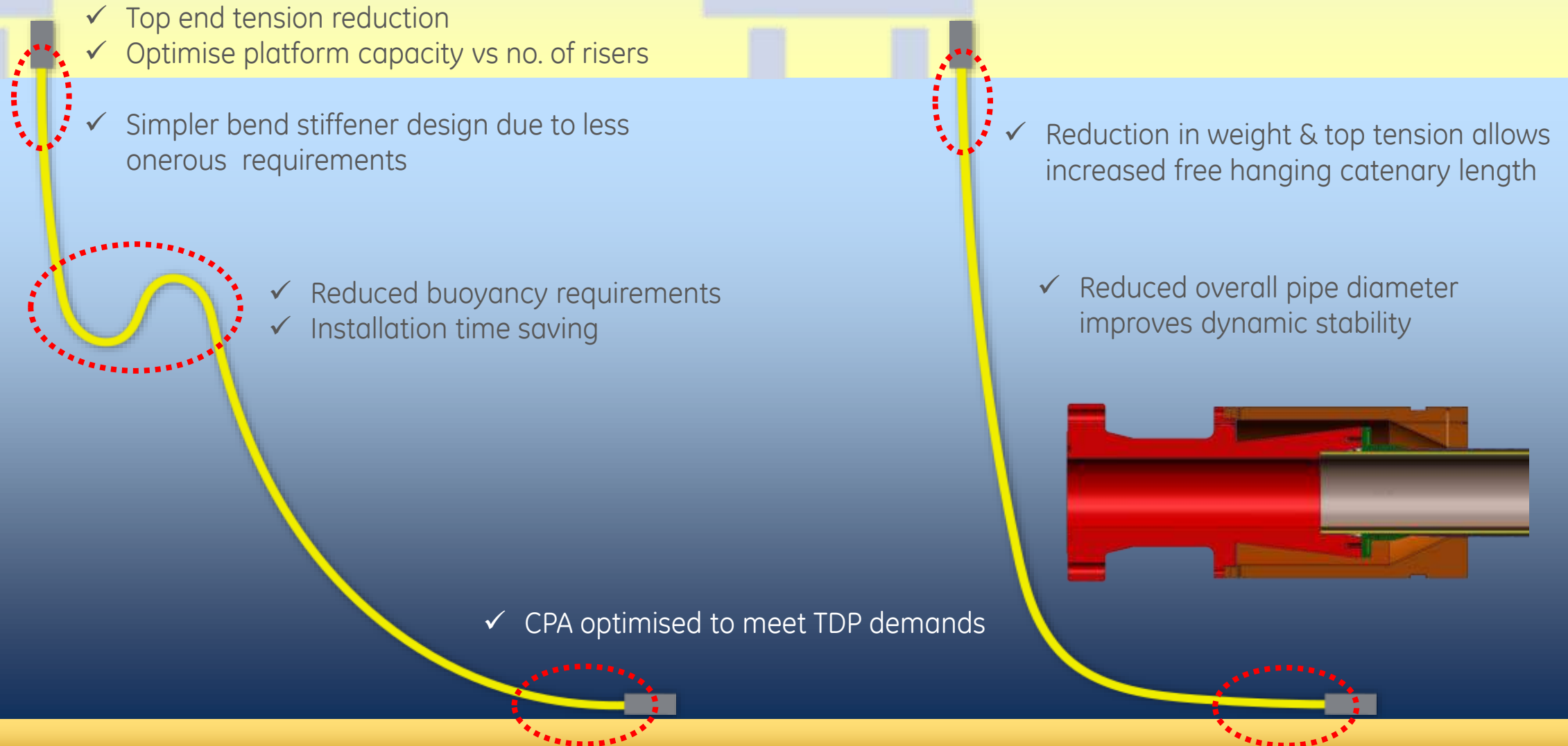
- Module 1 installed May 17
- Final Commissioning – June 2017
- Full scale qualification samples to commence manufacture by end Q3



DNV Qualification – Composite Pressure Armour



System optimisation



CONVENTIONAL



30% INCREASE IN REEL CAPACITY | REDUCED MOBILISATION COST & TIME | REDUCED SHIPPING COST | REDUCED INSTALLATION TIME & ANCILLARIES | PLATFORM OPTIMISATION & FHC

COMPOSITE



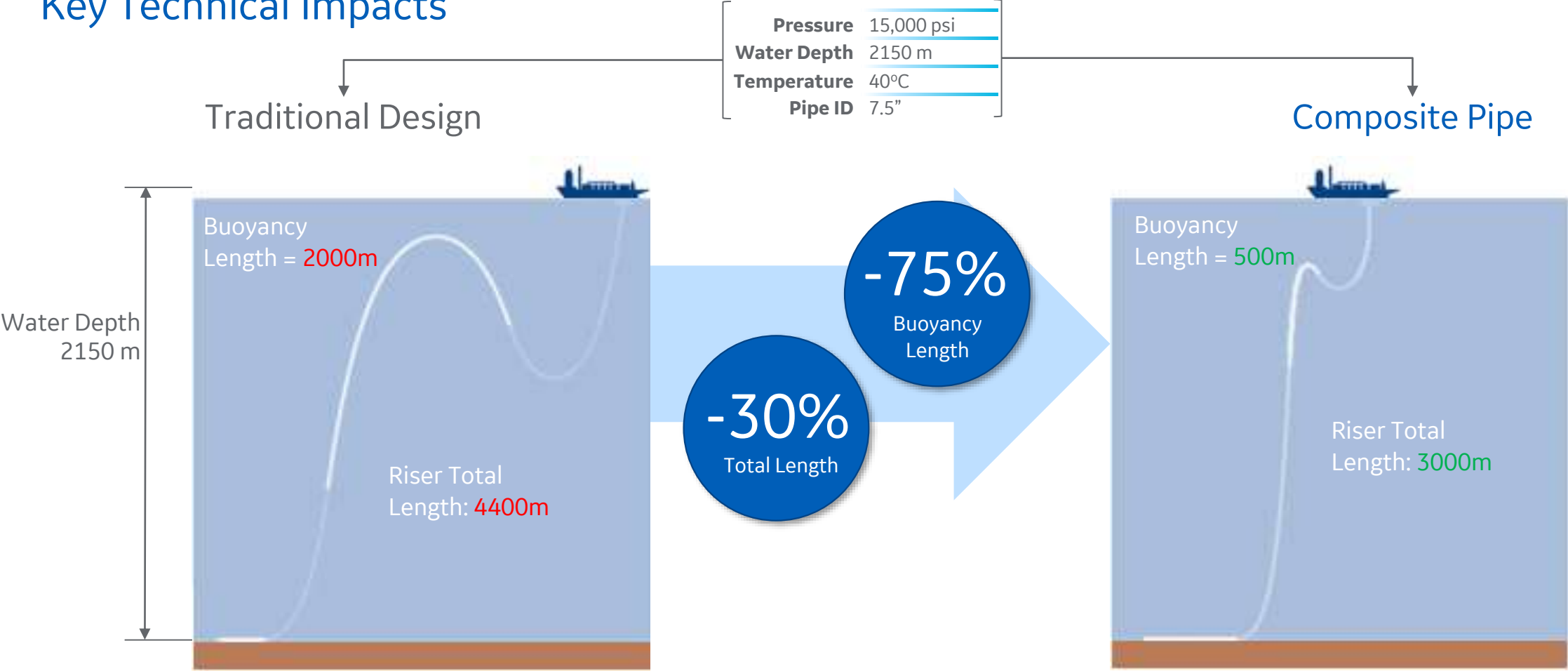
20% reduction in total installed cost

WHEN MOVING FROM LAZY WAVE CONFIGURATION TO FREE-HANGING CATENARY



Live Case Study: Customer GoM HP Water Injection Riser

Key Technical Impacts



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