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20ksi 350F HPHT EVDT Development: **Simplify, Eliminate, Integrate**

Thiago Lusquinos
Lead Engineer
TechnipFMC

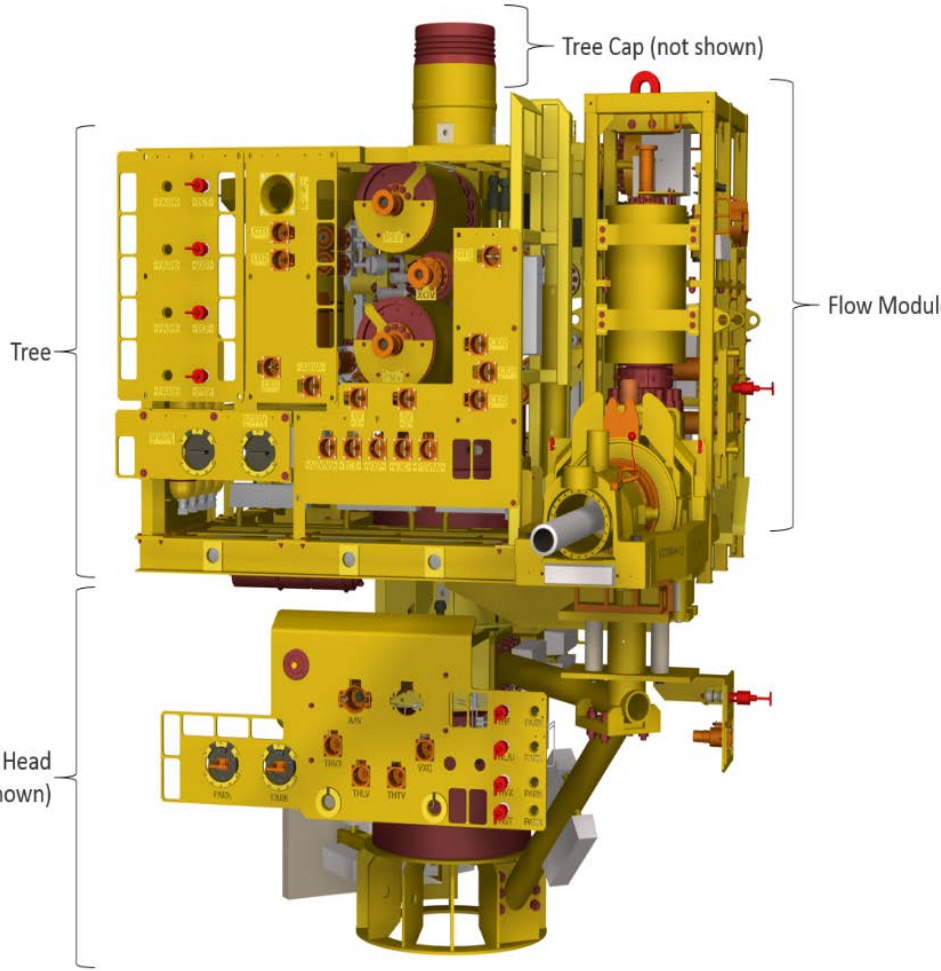
Co-authors: Allison Weber, Erik Van Mook, and Matt Keller

Agenda

- Overview of System
- Design Philosophy: Simplify, Eliminate, Integrate
- Design Process:
  - FMECA
  - Prototypes
  - Verification
  - Validation

System Requirements

	HPHT Fullbore EVDT
Water Depth	500ft to 10,000ft
Pressure Rating	20ksi
Production Bore Size	5-1/8”; Production Stab ID 4.82” min
Annulus Bore Size	2” nominal
Temperature Rating	35F to 350F
Material Class	HH-1.5psi Trim (Production Bore) EE (Annulus Bore)
PSL (ISO 10423 / API 6A)	PSL 3G
Downhole Capability	11 hydraulic and 4 electrical downhole lines



Scope of Development

Materials testing and qualification

Design and qualification:

- Elastomeric seals
- Metallic seals
- Gaskets
- New family of bolted flanges
- New family of gate valves, actuators, and choke
- Connectors

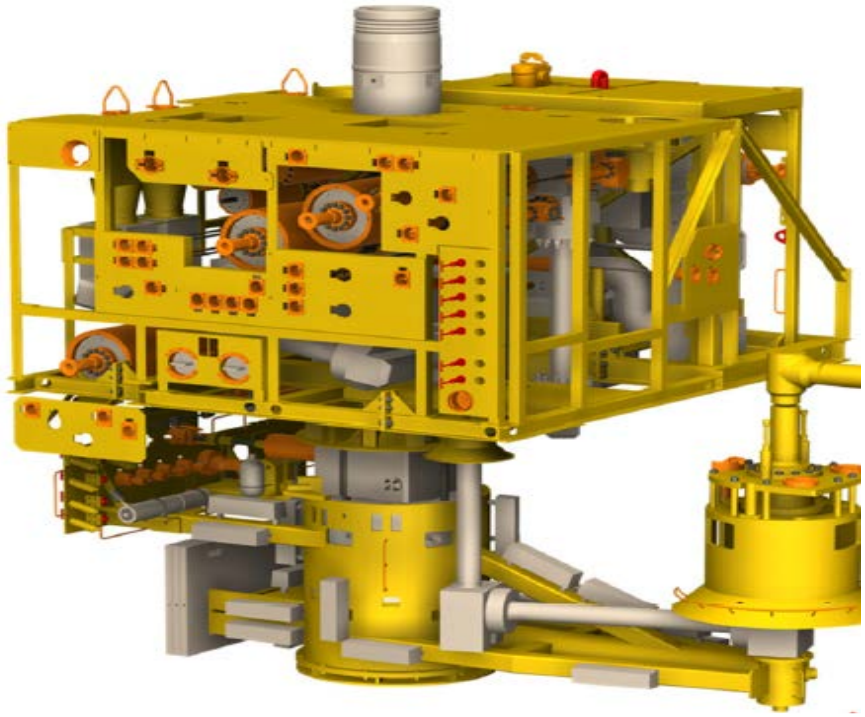
+ FMECAs, prototype testing, validation testing, and I3P review

Design Philosophy

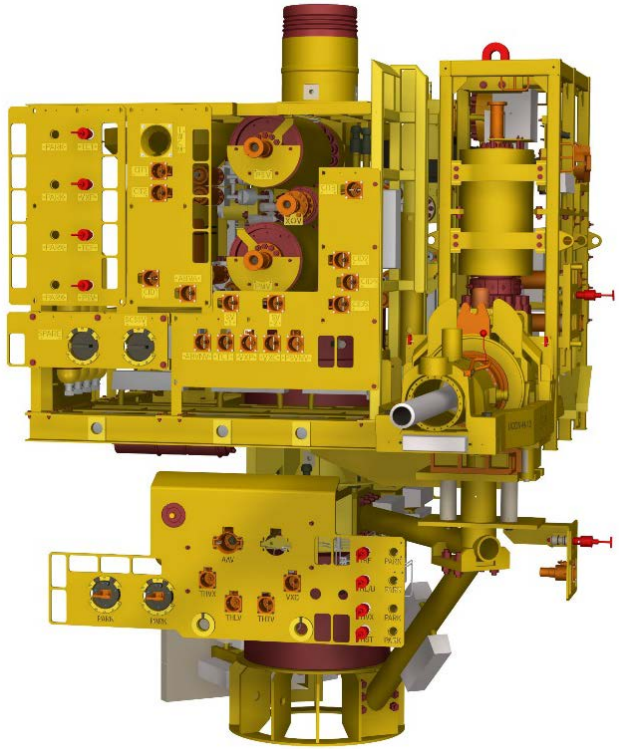
"**Simplify**, **Eliminate**, and **Integrate** without comprising functionality"

Results

Original Tree System



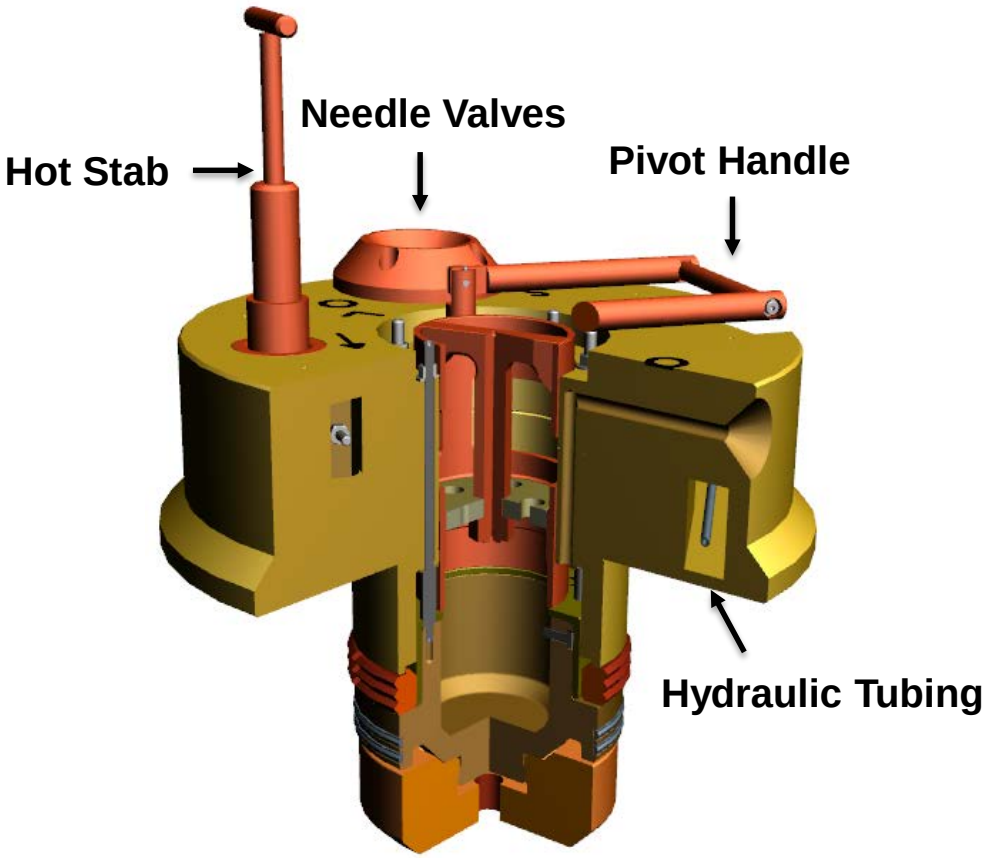
Optimized Tree System



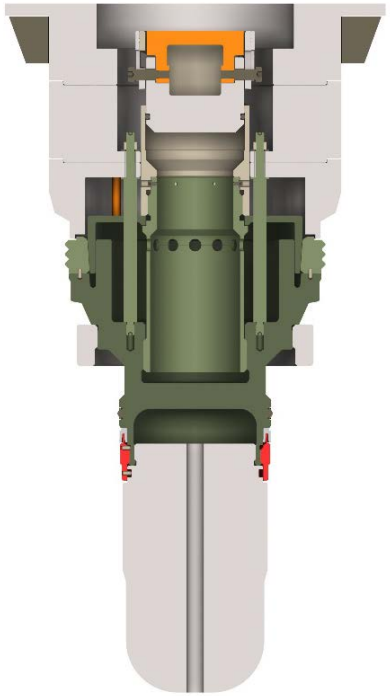
33% Weight Reduction
30% Size Reduction

Simplify & Eliminate

Original Design **XT Cap** Simplified Design

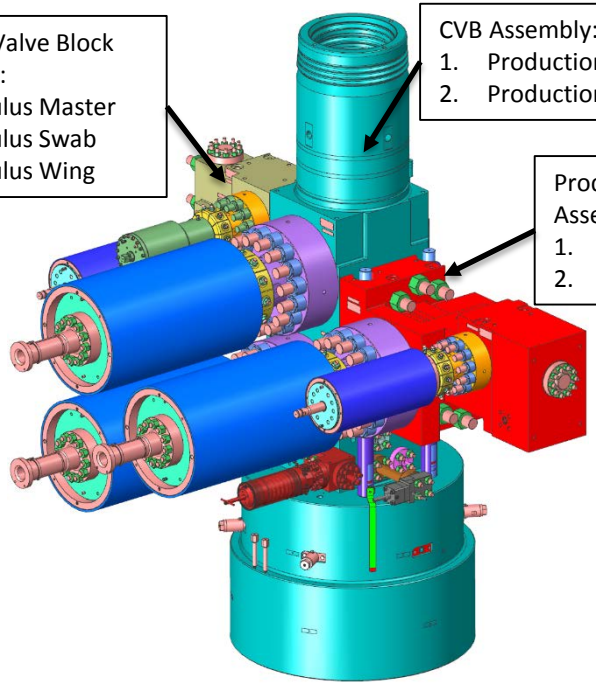


15% Weight Reduction
50% Part Count Reduction

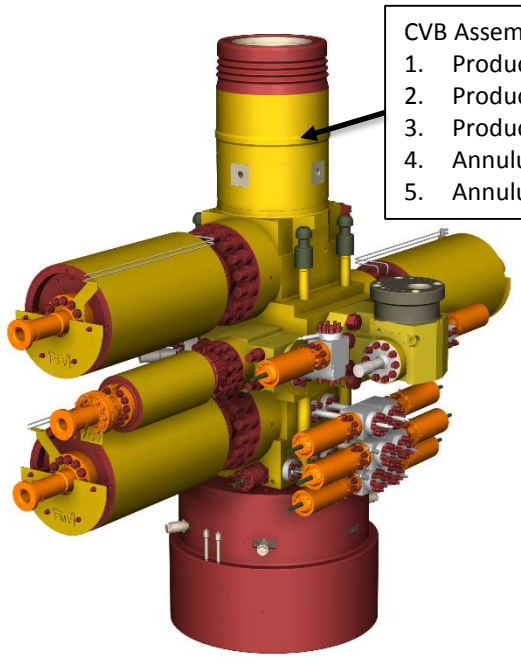


Integrate & Eliminate

Original Valve Block



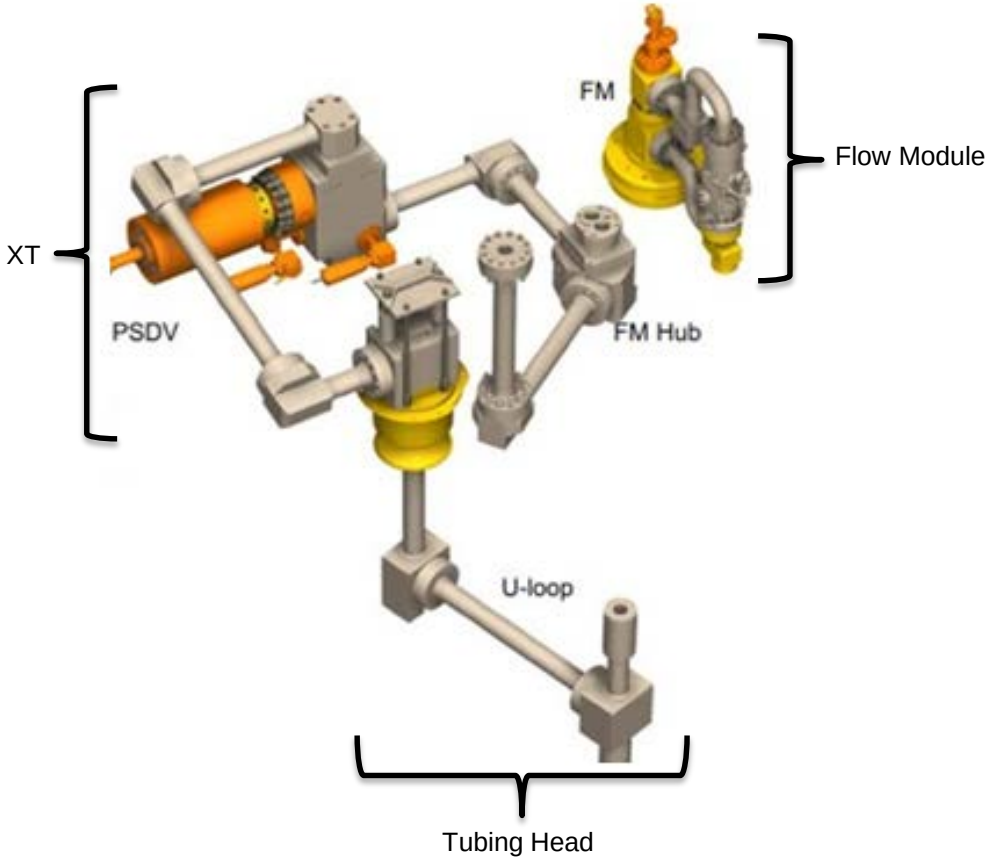
Integrated Valve Block



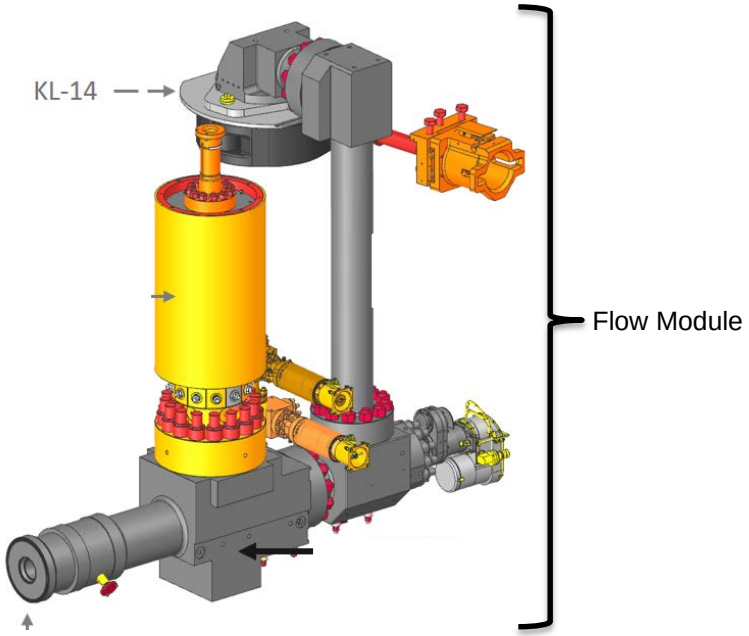
50% Weight Reduction

Simplify & Eliminate

Original Flow Path



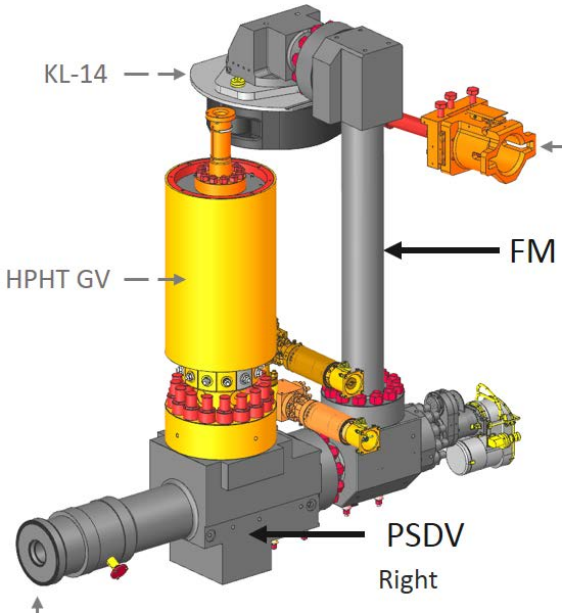
Simplified Flow Path

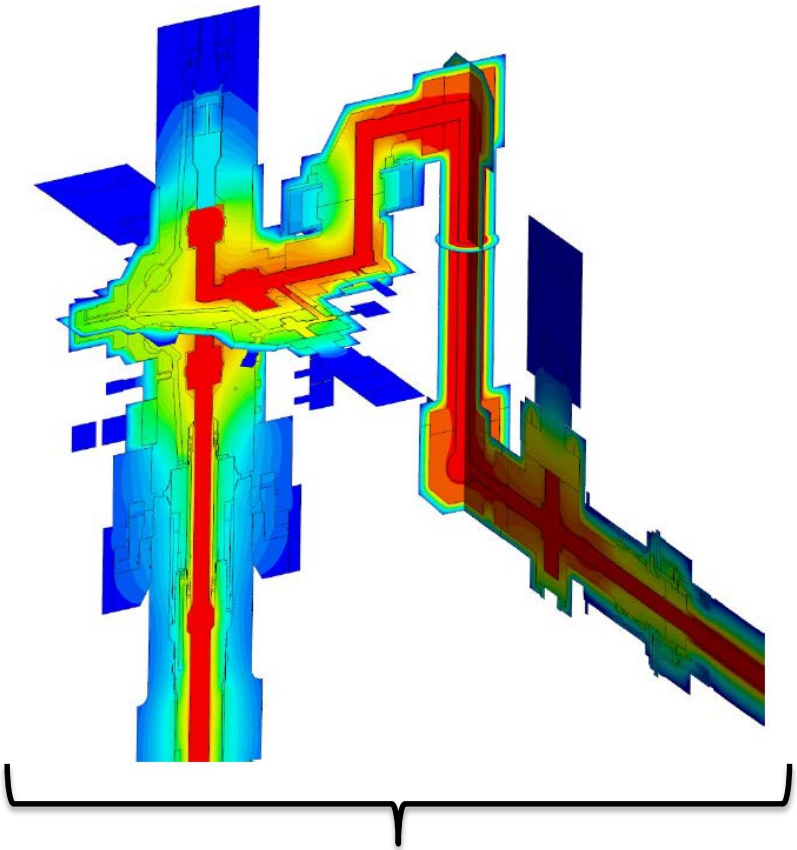


42% Weight Reduction
63% Part Count Reduction

Simplify & Eliminate

Eliminated welded Flow Loops

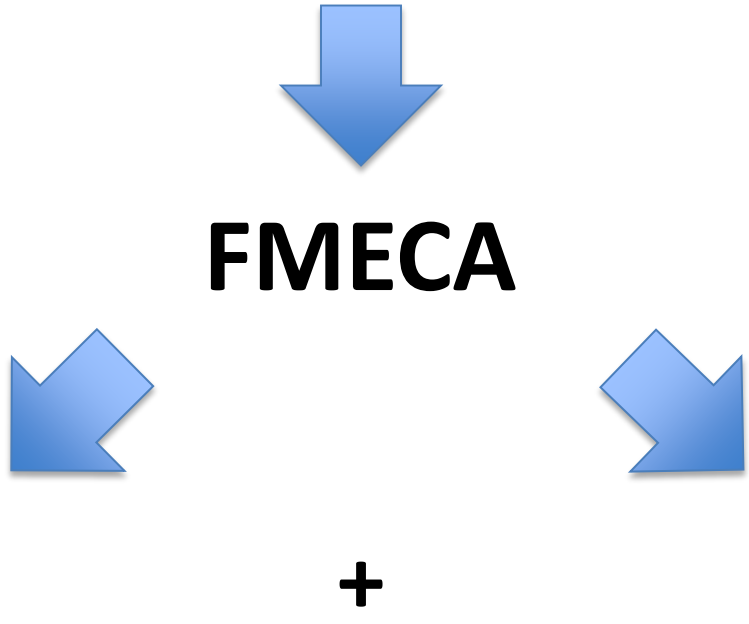




Reduced number of bends: improved cooldown time and erosion resistance

Failure Mode, Effects, and Criticality Assessment

After conceptualizing where the design could be simplified



Failure Mode, Effects, and Criticality Assessment

FMECA

outputs

Action plans based on probability and severity rankings :

- Prototype
- Verification
- Validation

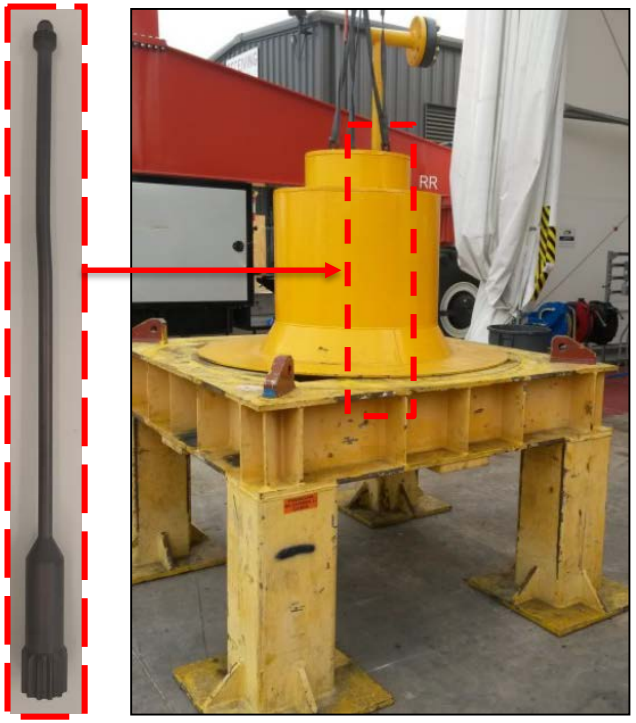
Prototypes

- Prototypes enabled the team to make key design decisions and improvements.
- Small scale prototypes were used during the conceptual phase of the project.
- Allowed simpler explanation and comparison of concepts during design reviews.

Small Scale Prototype

Prototypes

Proof of Principle Prototype:
ROV Position Indicator

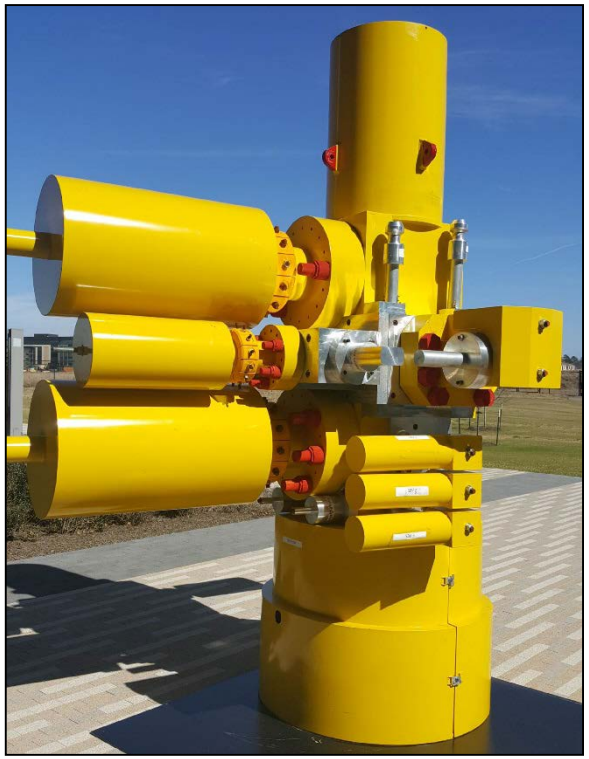


Proof of Principle Prototype:
Rod Assembly

Prototypes

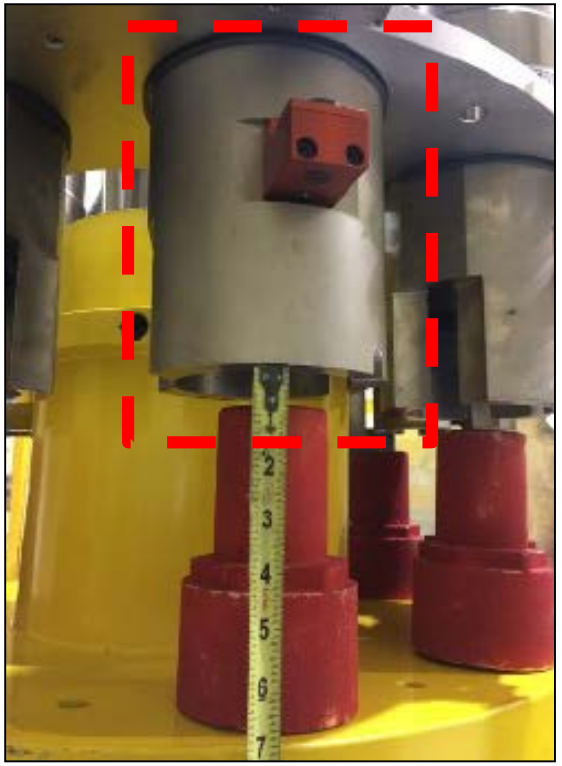
Full scale visual prototype XT block assembly:

- Technicians able to mimic workshop operations
- Assembly and test proven and optimized



Prototypes

Additional Handling Points



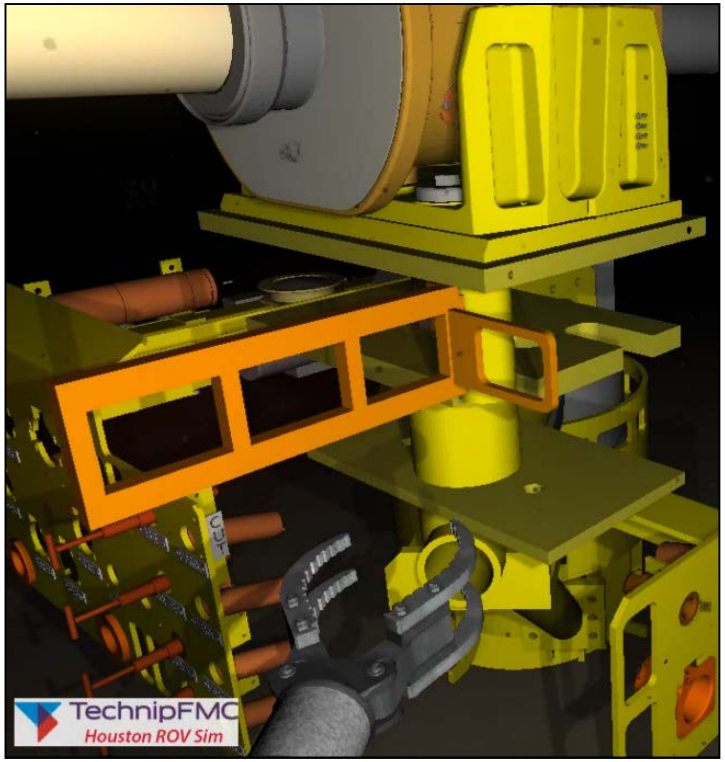
Tool Clearance / Access

Virtual Simulations

ROV simulation simulating realistic subsea conditions.

Benefits:

- ROV-friendly features early in design.
- Reduction in subsea operation time which is a key cost driver for a project.



ROV Simulation

Design Verification Methods

Designed to API 17TR8 and TechnipFMC internal requirements:

For each pressure containing component:

- FEAs per ASME VIII Division 3
- Fatigue assessments based on component criticality

(S-N analysis and/or fracture mechanics)

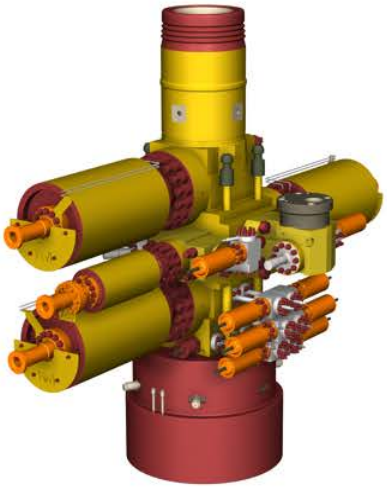
Extensive material testing program performed to generate fatigue design curves and fracture toughness data in representative environments.

Validation Testing

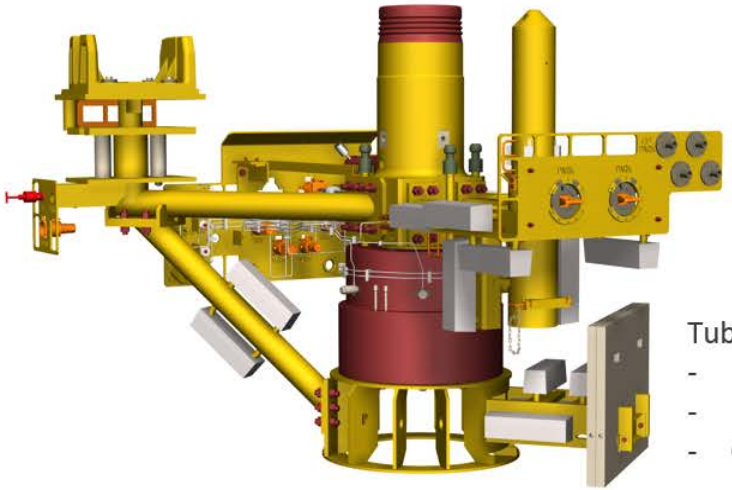
Over 50 qualification tests completed within the XT scope

Tree Cap:
- Lock Mechanism
- Metal and Non-Metallic Seals

Tubing Hanger:
- Lock Mechanism
- Fine Alignment Key
- Rough Alignment Key
- Metal and Non-Metallic Seals
- Coupler Preps



Tree:
- Flanges & Gaskets
- Metallic Seals
- Connector
- Valve Assemblies
- Choke

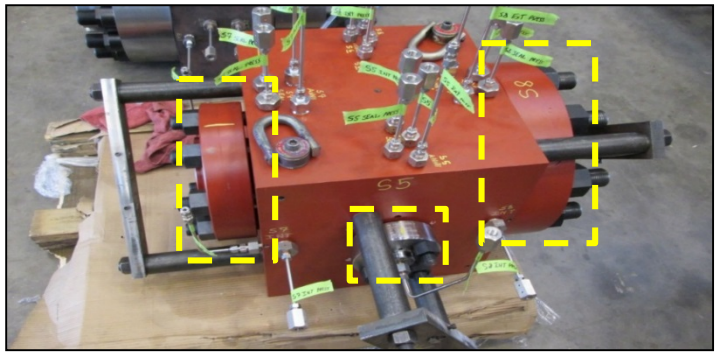


Tubing Head:
- Flanges & Gaskets
- Non-metallic Seal
- Connector

Validation Testing Example - Flanges

Validation of weld neck, multi-gasket, and swivel flanges ranging from ½” to 5” bore sizes:

- Testing over entire temperature range with cycles and holds to demonstrate verification of FEA predictions.
- Confirmation of hub separation limits used in verification.



4-Flange Pressure temperature Cycling

External Load and Hub Separation tests

Independent 3rd Party Review

I3P required by BSEE when a development is considered technically complex. The scope of this review for the 20 ksi system included:

- component specifications,
- FMECAs,
- design verification,
- design validation,
- quality specifications and plans,
- and system testing plans.

The majority of the documentation review time focused on design verification and validation.

Conclusions

- The design philosophy of “simplification, elimination, and integration” resulted in a system that is 30% smaller and 33% lighter than the original tree layout
- The FMECA Process was critical to the success
- Prototypes were used to support the design team in pushing boundaries to package the tree system in a simpler way.

Acknowledgements / Thank You / Questions

The authors would like to thank the management and technical staff of TechnipFMC and our partners for permission to publish this paper.

The project was executed in a collaborative manner which enabled the development to be successful and exemplifies TechnipFMC core values.