Hydrogen Pipelines -

Why a Digital Engineering Approach is Required

Peter Cox
Group Sector Lead Upstream, Midstream & LNG Worley
Oct 2025

worley
DELIVERING SUSTAINABLE CHANGE

Agenda

- H_2 Pipeline Digital Delivery:
- European Hydrogen Backbone
- H_2 Pipeline Design Considerations
- H_2 Pipeline Digital Drivers
- Digital Design Tools & Systems
- Digital Construction Management
- Digital Integrity Management

European H_2 Backbone

European Backbone plan envisions:

- **11,600km of H_2 pipelines by 2030**
- **40,000km by 2040**

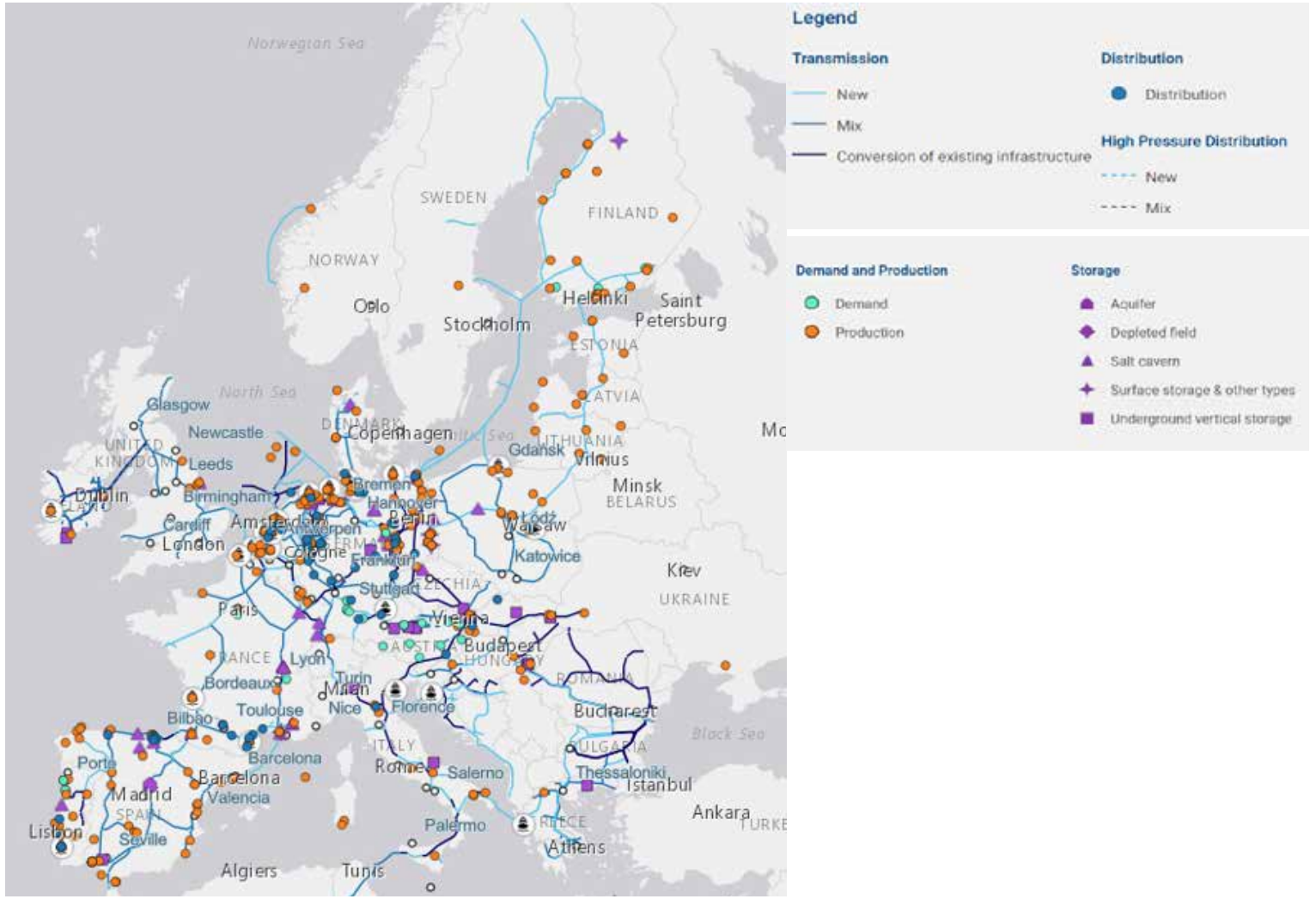
~50/50 mix of new build and repurposing

€30bn committed to date from European/UK governments

Pipelines enable upstream investment & customer conversions

Projects are proceeding in Germany 9,000 km approved

UK: Cadent Hynet & East Coast Pipeline, National Gas Project Union



Design of H_2 Pipelines

Design of H_2 pipelines is hinged on **fracture control**, preventing **hydrogen embrittlement**

1. **Hydrogen service leads to a reduction of ductility**

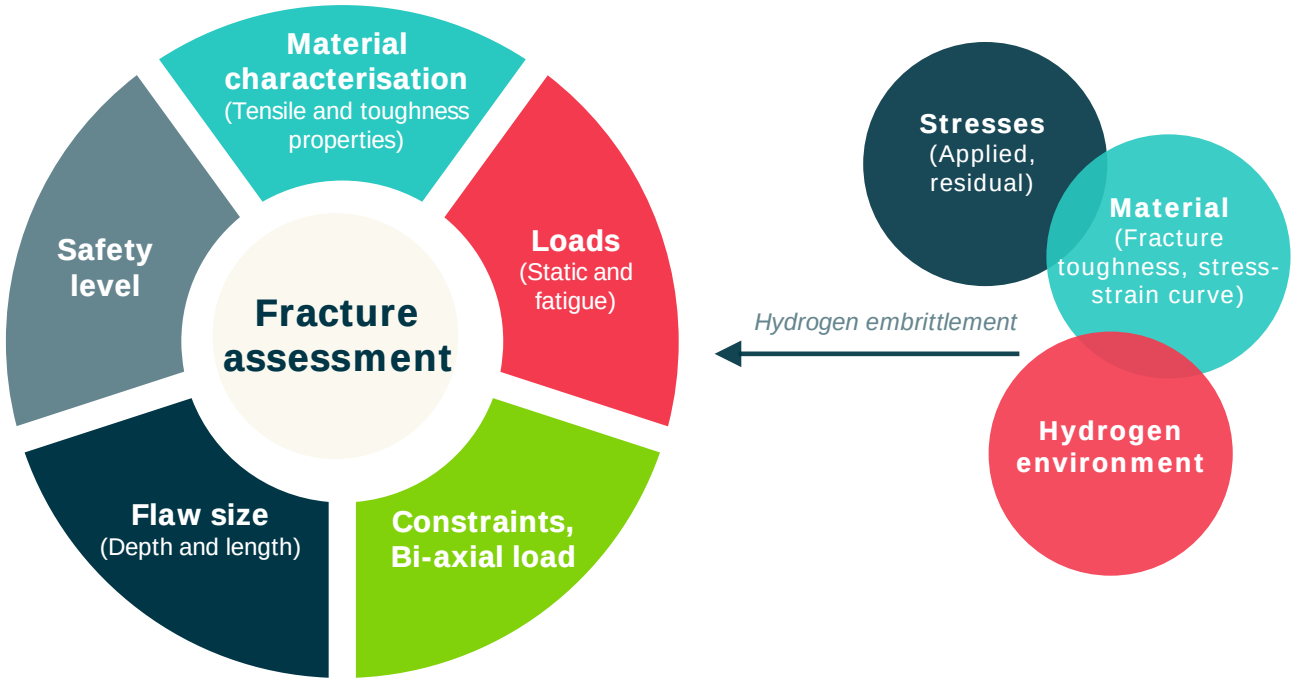
- Higher steel grades are more susceptible but can be made to work
- Offshore or difficult terrain requires high ductility for external loads

2. **Reduction of fracture toughness (normally measured by crack initiation stress intensity factor, K_{IH}, or Crack Tip Opening Displacement)**

- Imposes constraints on hardness
- Considered achievable for high quality line pipe but testing is controversial
- Becomes a factor for welding – Engineering Critical Assessments important

1. **Acceleration of Fatigue Crack Growth Rate**

- Hydrogen-assisted crack growth is order of magnitude faster
- Potential for reduced crack initiation threshold
- Process of low motion fatigue
  - Triggers: buckling/spanning/pulsations
  - High Stress Utilization – increase in Delta-K



H_2 Pipeline Design Development

Standards are still developing and there are significant differences in approaches. Research is ongoing, and Lessons are being learnt from projects.

Energy Transition Projects

- Over 5,000 Energy Transition Projects
- Over 20 H_2 & CO_2 Pipeline projects
- Repurposing Project experience

Joint Industry Projects

- H2PIPE Joint industry Project
- CO2SafePipe Joint Industry Project

Research Organizations

- FFCRC 7 years of pipeline research in future fuels – 119 projects
- APGA's Hydrogen Code of Practice
- Tripartite PRCI, EPRG, and APGA
- PRCI Committees

Standards

- CSAZ662 H2 & CHMC Task forces
- AMPP Hydrogen Committee
- AMPP Carbon Capture and Storage Committee
- DNV RP F123

Partners

- Mitsui
- STATS Group
- Aixima
- Construction Contractors
- Irth Cognitive Integrity Management

H_2 Pipelines Key Issues Addressed

- Applicable codes & standards
- Calculations tools & software
- Hydrogen impacts on linepipe
- Material selection & testing
- Maximum Available Operating Pressure
- Bends

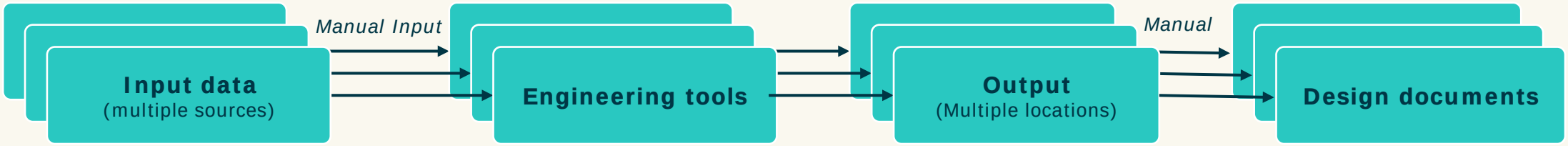
Cyclic Loading:

- Fracture & Fatigue Assessment
- Engineering critical assessment of welds
- Residual Stress impacts on seam/girth welds

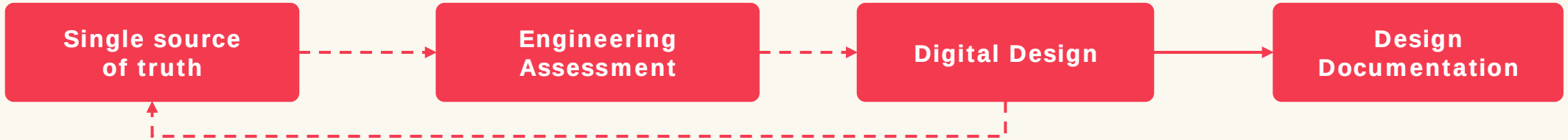
- Flow Assurance
- Repurposing to H_2 & CO_2 service
- H_2 Compression
- Valves and Fittings
- Integrity Management
- Emergency Response

Why do we want to a digital engineering approach?

Traditional Pipeline Design



Digital Design



Integrated Pipeline Design Suite OmniSight™

30% to 70% efficiency gains on projects

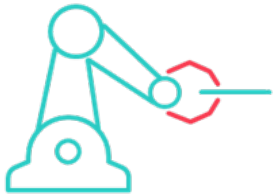
Automated route selection

Automated, paperless pipeline & gathering design

Secure web-based access data management

Electric engineering review and approval

Automated materials take-offs (eMTO)



Digital delivery to construction

Installed cost estimates (eMTO, eBOQ)

Interface with flow modeling software

Digital Integrated Pipeline Design Suite

Digital Backbone

Digital Basis Of Design

Align

Automated Alignment Sheets

InLine

Pipeline Design

InBuck

Global Buckling Design

InSpan

Span Design

InStab

Stability Design

3D Scene

View 3D Scene

InSpool

Tie-In Spool Design

InFlow

Flow Assurance

InOps

Operations

InCorr

Corrosion Modelling

PDG

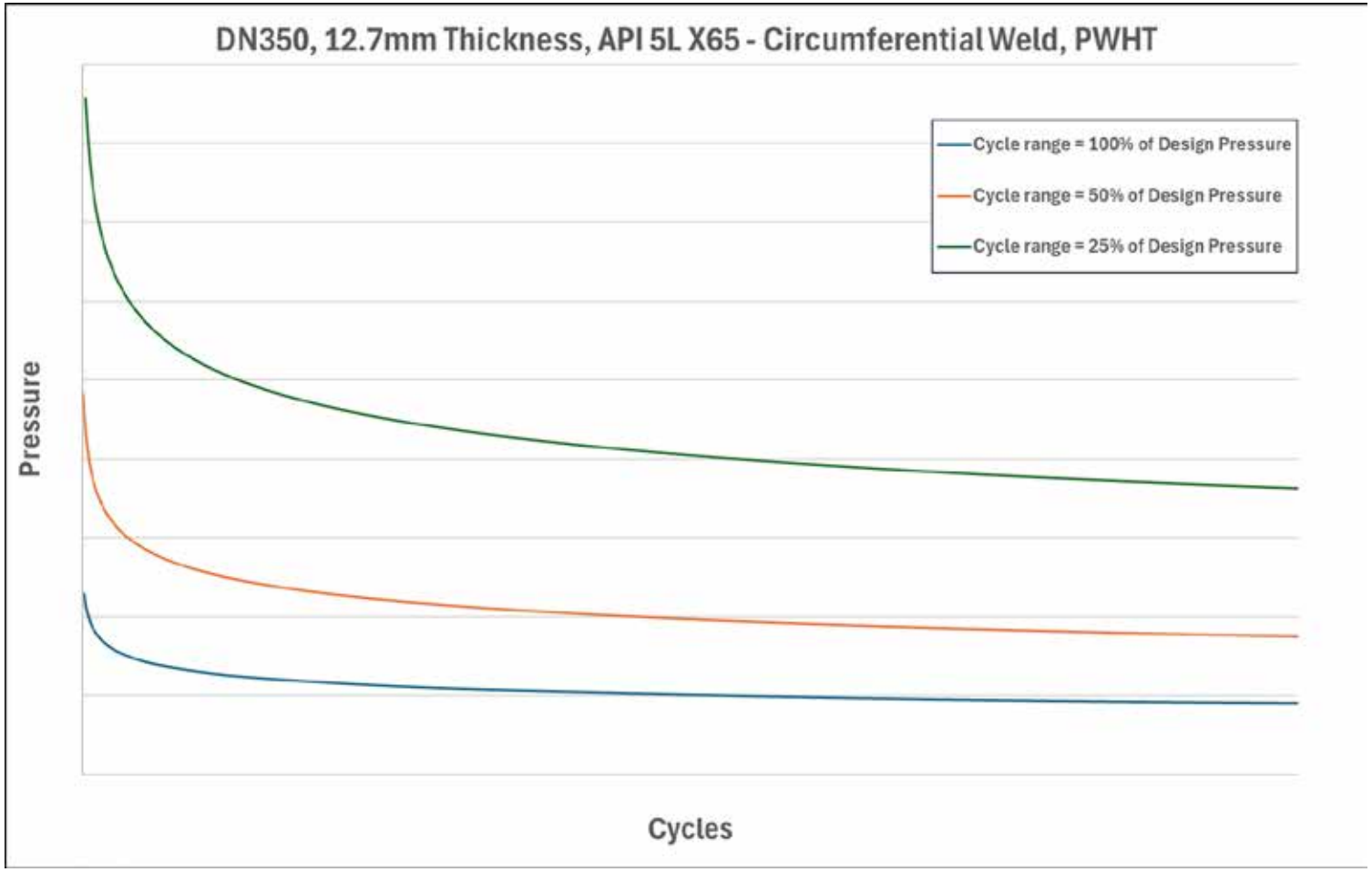
Pseudo Dry Gas Technology

OmniSight™

Digital Fracture Mechanics Analysis

Fracture mechanics assessment is performed per the following codes and standards:

- ASME BPVC VIII Div. 3 - Article KD4 and Article KD10
- ASME BPVC Code Cases 2938-1
- API 579:2021 - Part 9
- ASME 2019 Pressure Vessels & Piping
- ASME Section VIII-3 Code
- PRCI PR-214-104505-R02
- PVP2024-122529



Digital Construction Management

Receive Data
Data, received from tablet-based inspection reports, is processed back in the office after approval by CM

Report
Reporting to client on earned value is near real time on a weekly, bi-weekly, or monthly basis

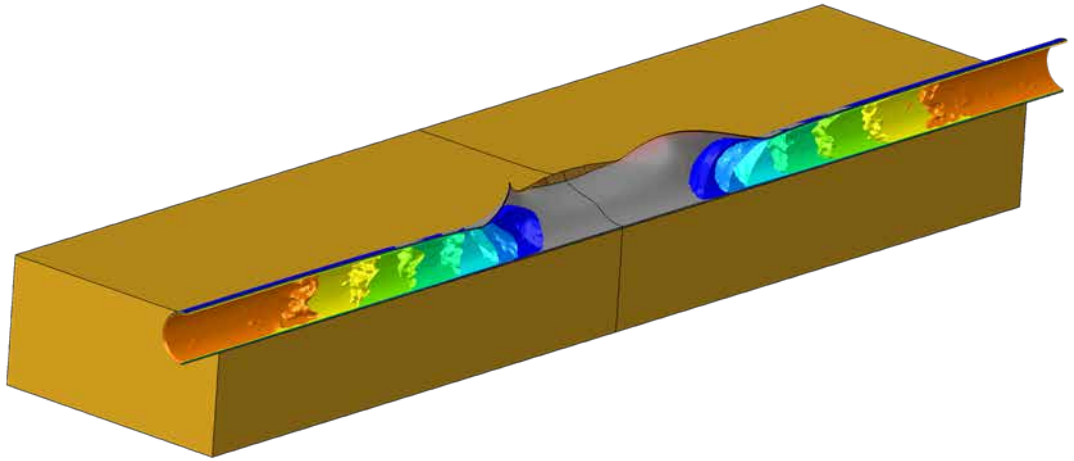
Invoice
Contractors used our tables for invoice back-up.

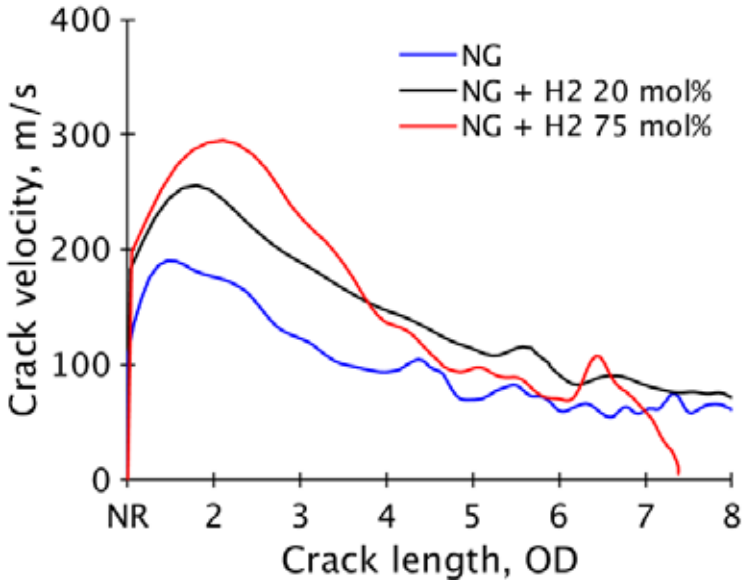
Identify Trends
Identify positive or negative trends early on when best mitigation is still available

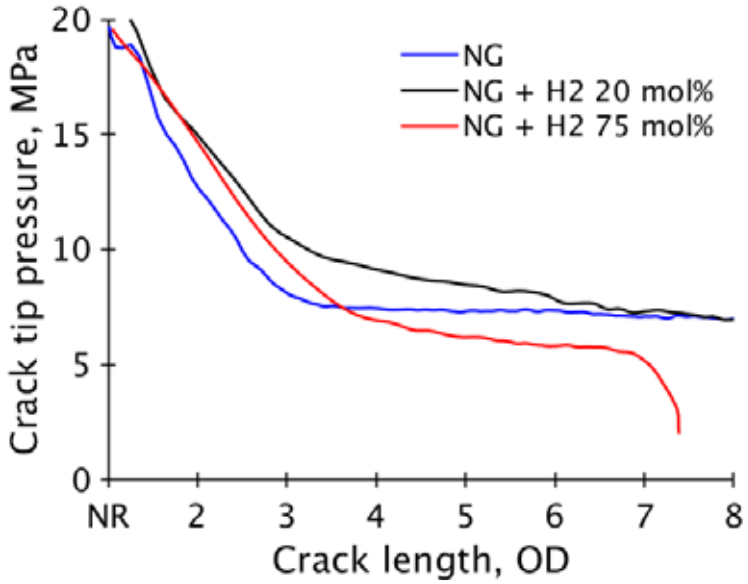
Fluid-Structure Interaction Model

Working with Aixima / OTH Regensburg to predict fracture propagation and arrest:

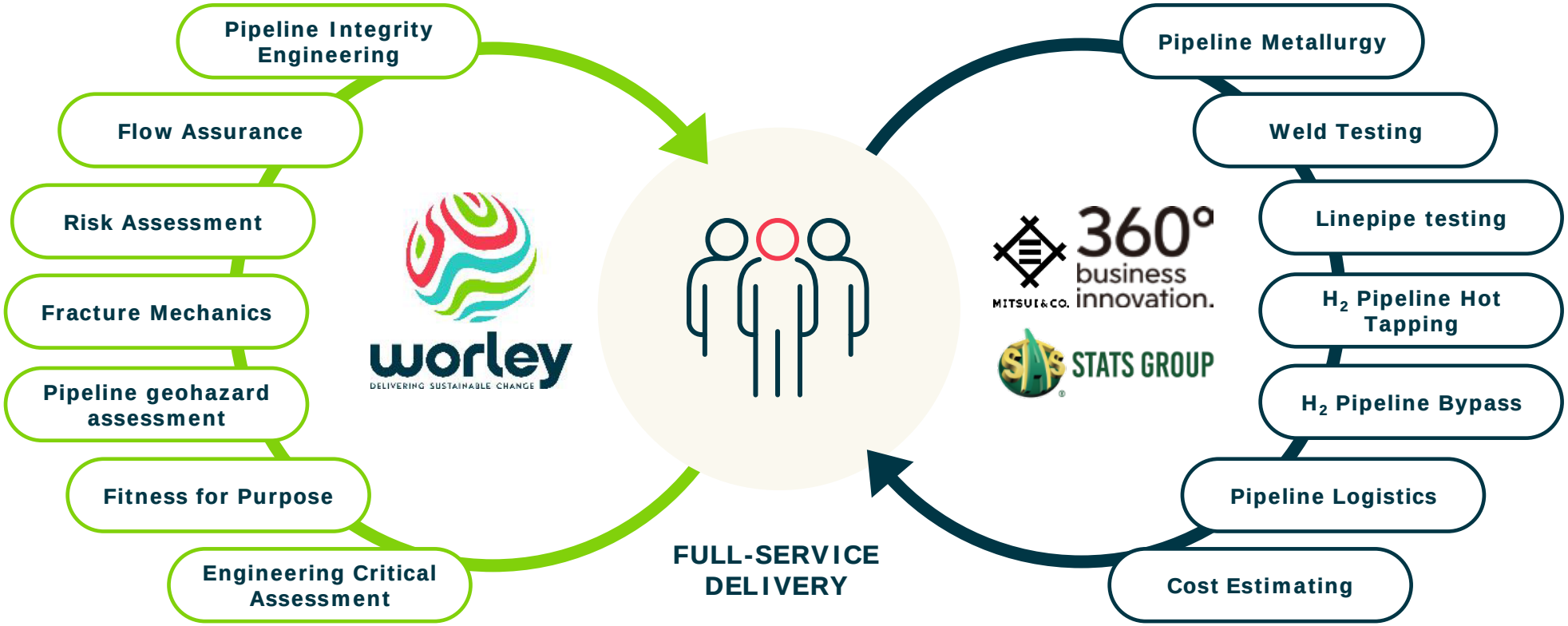
- Due to faster decompression, crack tip pressures up to 2 MPa lower with a higher H_2 concentration of 75 mol%
- The influence of H_2 on decompression behaviour compensates for the toughness degradation due to the HE mechanism



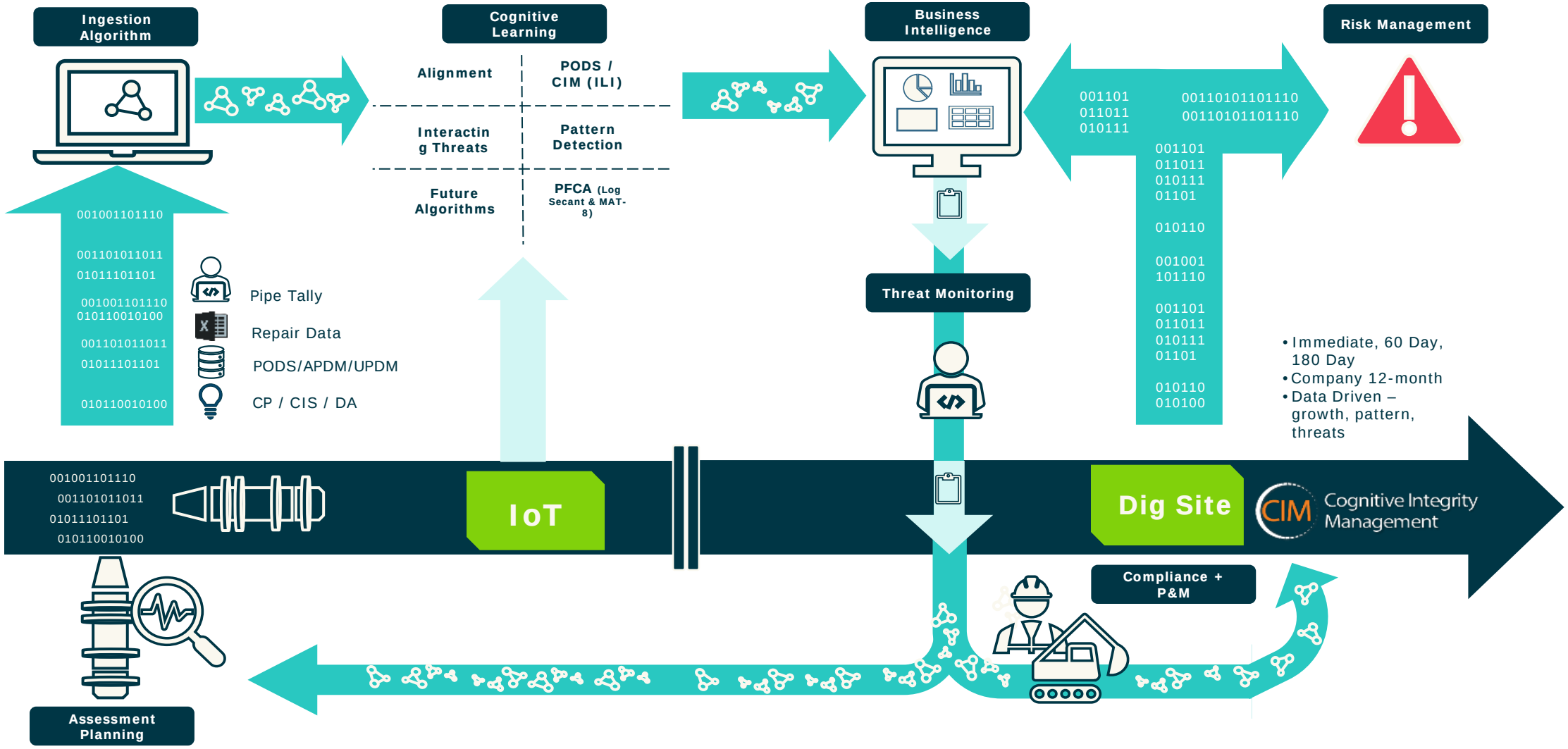




Digital Pipeline Repurposing to H_2 Service



Digital Pipeline Integrity Management - Irth



Conclusions

- Creating a new global H_2 pipeline network is imperative to minimise climate change
- H_2 pipeline backbone enables hydrogen production projects to connect with the market
- H_2 pipeline backbone enables industry to access lower carbon fuel to convert their plant
- H_2 pipeline backbone will require significant capital and needs to be constructed in record time
- Unless cost and schedule is optimised, we will see more delays to the roll out
- A fully integrated digital approach to design, construction and operations will reduce cost and schedule to fast track the H_2 pipeline development

worley

DELIVERING SUSTAINABLE CHANGE

Contact Us:
N: Peter Cox
E: peter.cox@worley.com

worley.com