PII Pipeline Solutions

How To Develop & Deliver Thick Wall Multi-diameter Offshore Inspection Solutions: A Case Study

Martin Bluck
Product Line Leader

PPSA Seminar
14th November 2012
Aberdeen, UK

H2 develop & deliver thick wall multi-diameter offshore inspection solutions

Abstract:

This paper includes three brief case studies on successful inspections of deep sea pipelines, highlighting the technical challenges faced and the critical aspects of solution development and inspection program delivery.

In addition, a generic approach will be described for the development of complex off-shore applications that helps manage the technical & commercial risk for both operator & ILI vendor in delivering a holistic in-line-inspection solution

1. BP Mardi Gras: Challenge

Design, manufacture, and test an MFL tool to inspect BP Mardi Gras system

Mechanical challenge:

- negotiate multi-diameter lines (24/28/30), asymmetric unequal vertical wyes, jumpers, flex-joints

Electronics challenge:

- water depth leads to max working pressure of 400 bar at seabed (2 x current tool design pressure)

Physics challenge:

- Inspect very heavy wall pipe - wall thickness up to 1.375" (35mm)

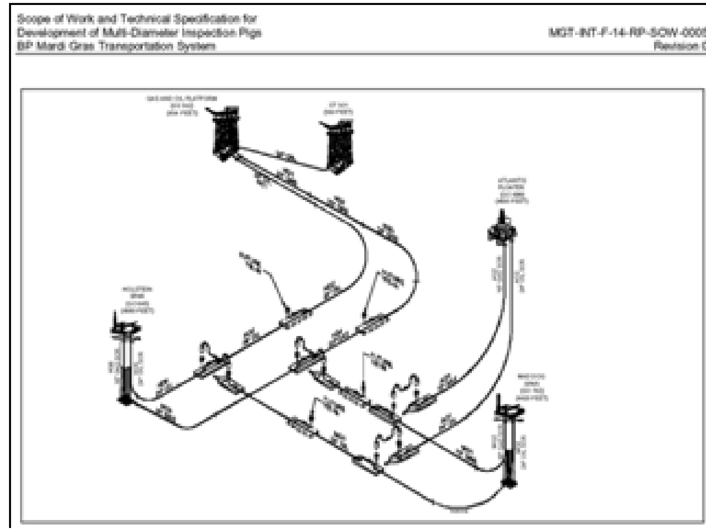


Figure: MARDIGRAS TRANSPORTATION SYSTEM LAYOUT

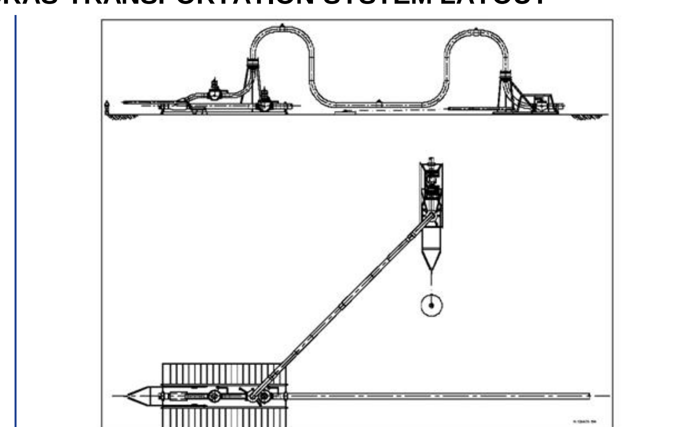


FIGURE A6: VERTICAL 28-INCH ASYMMETRIC TO JUMPER AND PLET

1. BP Mardi Gras: System Design

Magnetic Vehicle (MV)

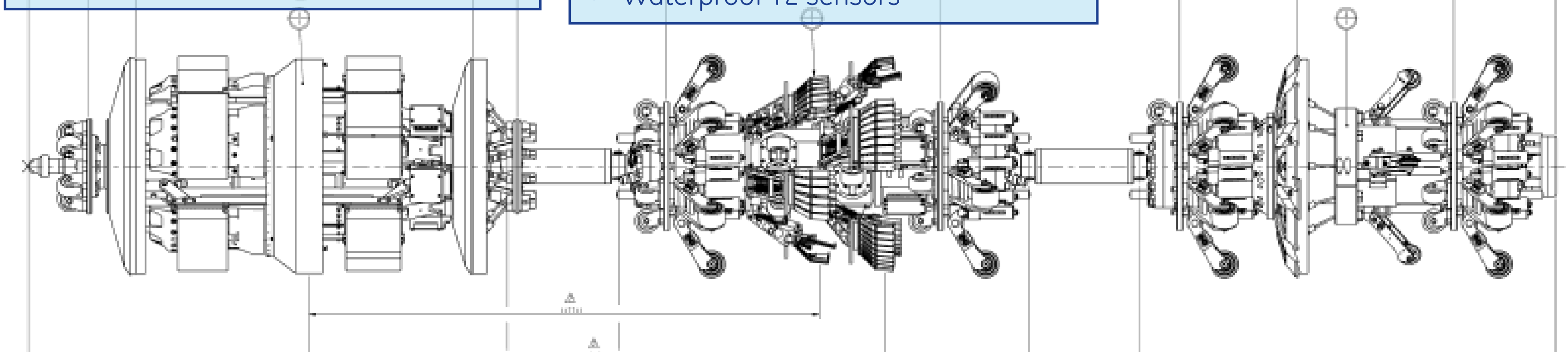
- Enhanced flux magnet bar design
- **Articulating MC (T1) sensor ring for 24-30" coverage**
- Waterproof external electronics
- Drive flaps

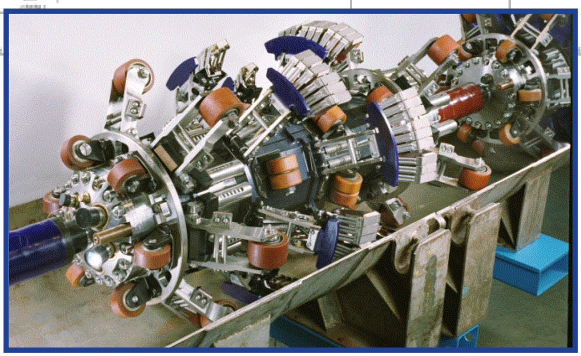
Instrument Vehicle (IV)

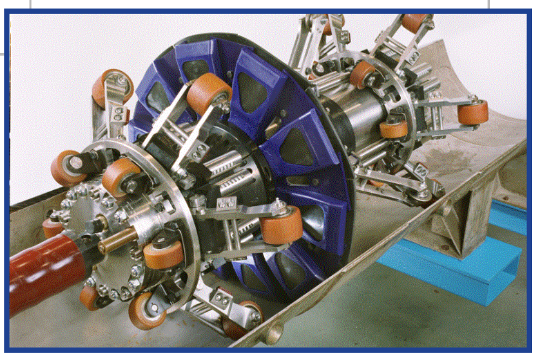
- 020 data processing & storage
- Signal conditioning & multiplexing
- **Elevating sensor assemblies**
- **Semi-rigid tow-bar links to MV & BV**
- Waterproof T2 sensors

Battery Vehicle (BV)

- L600 battery chassis (for range)
- Waterproof velocity and power harnesses
- **Drive flaps**







1. BP Mardi Gras: System Test & Inspection Program

Figure: BP Mardi Gras System Integration Test

Feature	Qty in typical run	Qty passed in SIT trials	Comment
Flex joint	2	54	*27 runs with 2 flexjoints (zero and five degrees) each run*
Sub-sea jumper	1	13	*27 runs with "half" a jumper (4 x 5D bends) each run*
24" x 28" taper	1	17	*17 runs with 1 taper per run*
28" x 30" taper	1	27	*27 runs with 1 taper per run*
24" x 24" wye (trunk line)	1	9	*9 runs through the 24x24 trunk line*
24" x 24" wye (lateral)	1	8	*8 runs through the 24x24 lateral*
24" x 28" wye (trunk line)	1	17	*17 runs through the 24x28 trunk line*
24" x 28" wye (lateral)	1	10	*10 runs through the 24x28 lateral*
Launch & Receive (pair)	1	27	

Inspection System

- 3 module train ... 5.38m ... 2,120kg
- Bend passing 3D (30") and 5D (24")
- Max pressure 400bar
- Inspection range 433km/ 180 hrs
- Max speed 1.7 m/s
- Wall thickness up to 35mm
- Detect 5/8 & Depth Size 80% +/-10%

Inspections

BP Mardi Gras system

- Mad Dog-Ship Shoal 24" x 134km
- Proteus-Endymion 24/28/30"x 256km

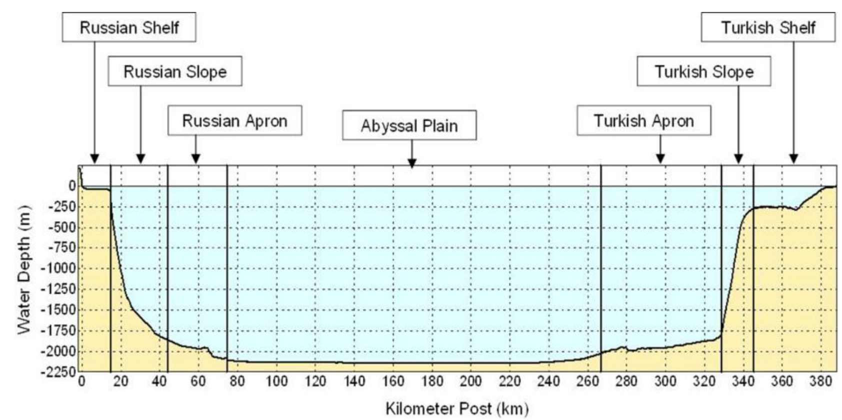
Pig development in parallel with pipeline design and build ... collaboration throughout

2. Blue Stream: Challenge

Inspect Blue Stream interconnector pipelines: Geometry, Metal Loss (MFL), Mapping

- Durability … 24" x 380km & 387km Interconnector Pipelines
- Pressure … 250 bar (3,625psi) @ depth max 2,140m (7,021ft)
- Wall thickness … 32mm with 47mm Buckle arrestors
- Geometry … ball valves, barred tees, reduced bore tees (83% OD)
- Internal epoxy coating … must not damage
- Cleanliness

Figure: BSPC Interconnector Pipelines



2. Blue Stream: Ancillary Requirements

Pig Recovery/Rescue

- MFL pig designed to be driven from rear should drive elements fail
- Rescue/recovery pig designed to push MFL pig out of pipeline if required

Pig Tracking x 3

- Electromagnetic Transmitter (22Hz) fitted to the tool as standard
- Magnetic sensitive timer boxes at strategic positions ONSHORE
- Acoustic monitors fitted at Launch & Receive sites to enable tracking of pig

Figure: Rescue/Recovery Pig Design

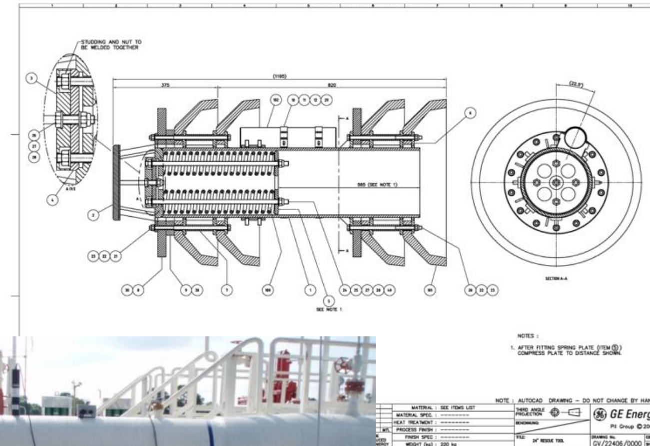


Figure: Acoustic Monitors & Pig Tracking Equipment

2. Blue Stream: Inspection Program

Inspection program summary

- All pigs launched in Russia & received successfully in Turkey 3 days later
- 24" x 380km & 387km pipelines inspected & reported to BSPC
- Pigs tracked from trap to trap using acoustic monitoring technique
- Recovery Pig NOT required

Lessons Learnt :

- Openness & co-operative approach by BSPC/partners key to success
- Time & complexity of licences, permits, import & export


Figure: BSPC Cleaning Pigs

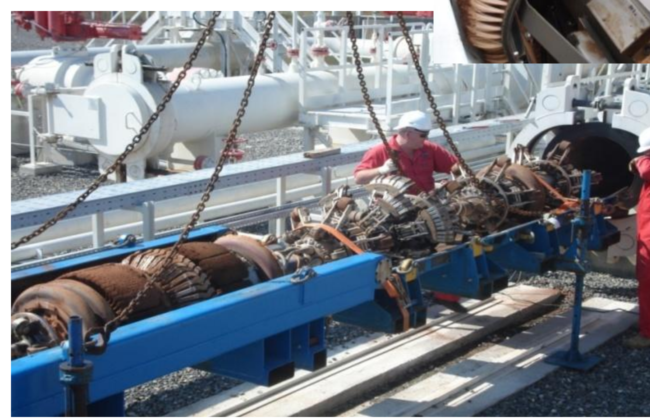


Figure: BSPC MFL Pig at Receive

Phased approach ... holistic solution

3. CATS: Challenge

Cleaning and Metal Loss (MFL) inspection of CATS pipeline

- Durability … 36” x 412km
- Thick wall … landline 34mm, sea line 28mm
- Multiple Tees … 6 in total 4 used from Andrew, ETAP, Banff, J-Block
- NRV at riser base (1,400kg clapper) not locked open
- ‘Tees Tunnel’ section
- Dent due to anchor drag
- Vertical launch
- Cleanliness … never been pigged

Figure: Central Area Transmission System (CATS) Pipeline

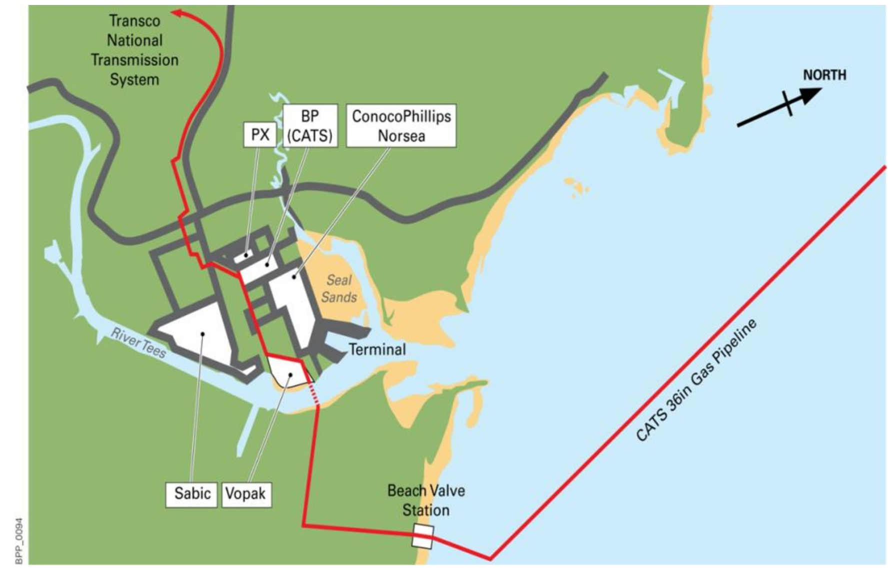
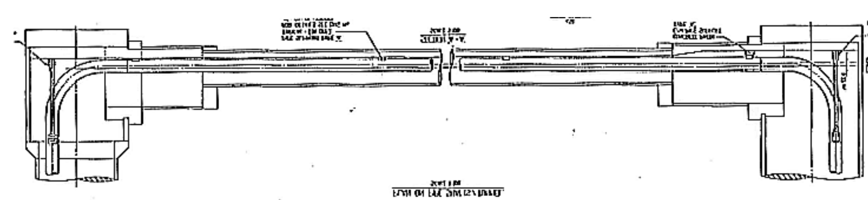


Figure: ‘Tees Tunnel’ Section



3. CATS: Risk Mitigation & Testing

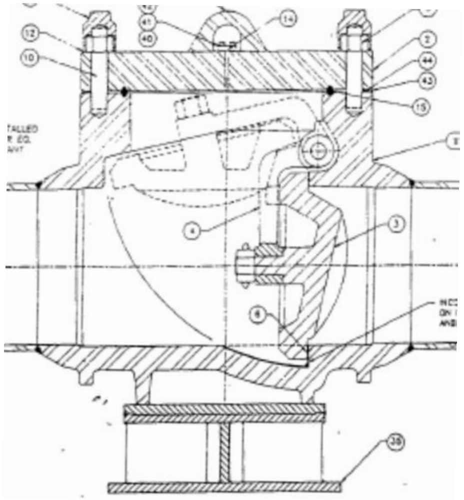
Magnetic History Effect

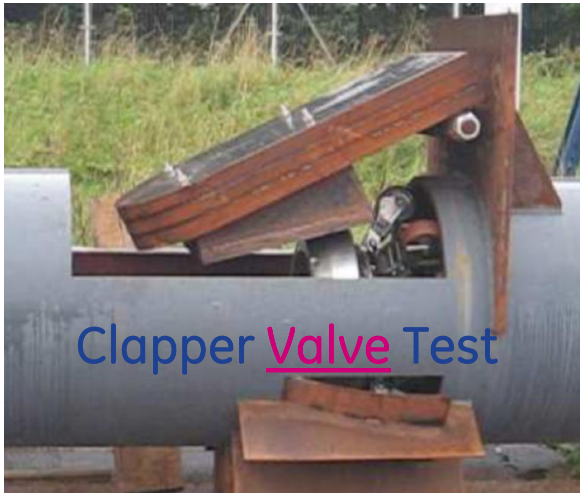
- Impacts defect sizing in thick-wall pipelines not previously inspected
- Repeat pull throughs in each wall thickness to calculate effect
- Effected pull through data excluded from sizing model data-set
- Magnetic pre-conditioning recommended

Sub-Sea NRV (Clapper Valve) Test

- ID to match pipeline, top hinged, Clapper ~1400kg, NOT locked open
- Cleaning, Profile, & MFL inspection systems pulled through

Figure: Tom Wheatley Sub-Sea NRV





3. CATS: Inspection Program

Inspection program

- Proving/profile runs x 3
- Cleaning runs x 4
- Magnetic pre-conditioning run
- MFL inspection run (412km)
  - Launch 17:05 13th Nov
  - Run time 58 hours
  - Pressure 133 bar (at launch)
  - Flow rate 464 ksm3/hr (2 m/s)
  - Data download/DQA good
  - Pig returned to PII Cramlington
- Preliminary & final reports

Figure: CATS Profile Tool Run

Figure: CATS Cleaning Run 1

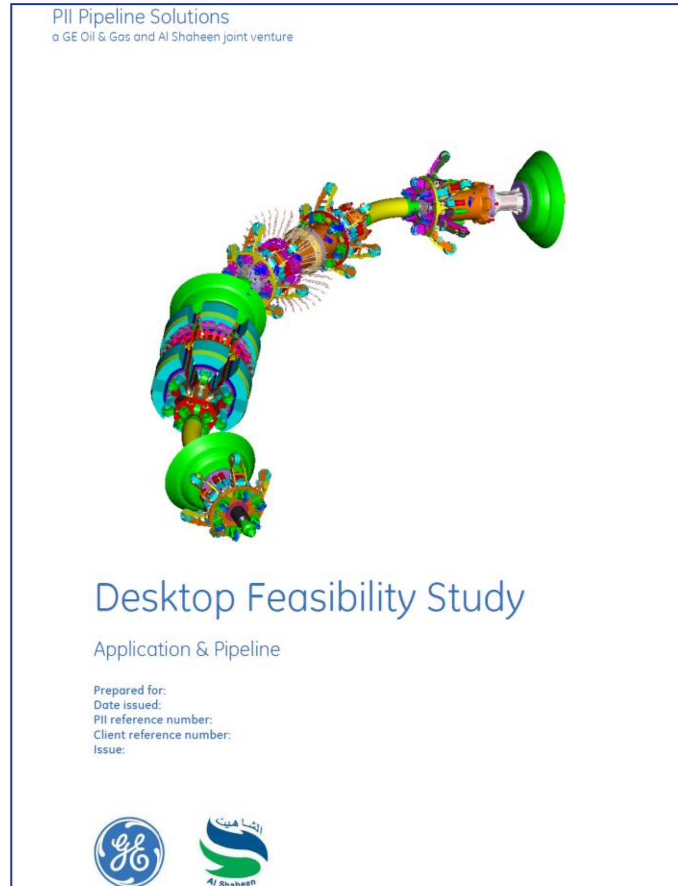
Figure: CATS Vertical Launch

Figure: CATS Final Tool Preparation

Good planning … focused & novel testing … progressive pigging

4. Generic Approach …
Desktop Feasibility Study

Contents



PII Pipeline Solutions
a GE Oil & Gas and Al Shaheen joint venture

Desktop Feasibility Study

Application & Pipeline

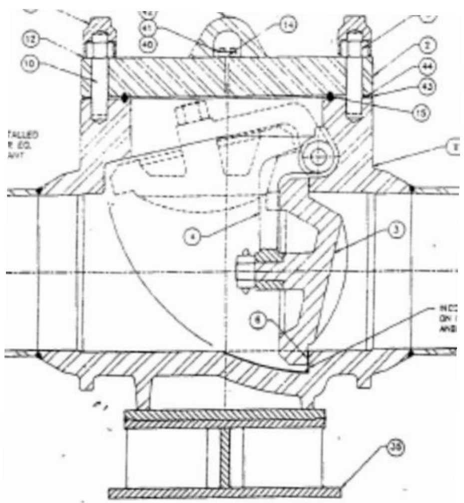
Prepared for:
Date issued:
PII reference number:
Client reference number:
Issue:

4i. Data Gathering & Risk Assessment

Pipeline geometry

- Lengths, diameters, wall thicknesses, bends, bore, transitions, valves, off-takes, wyes etc.
- Fixture size, location, orientation, & design

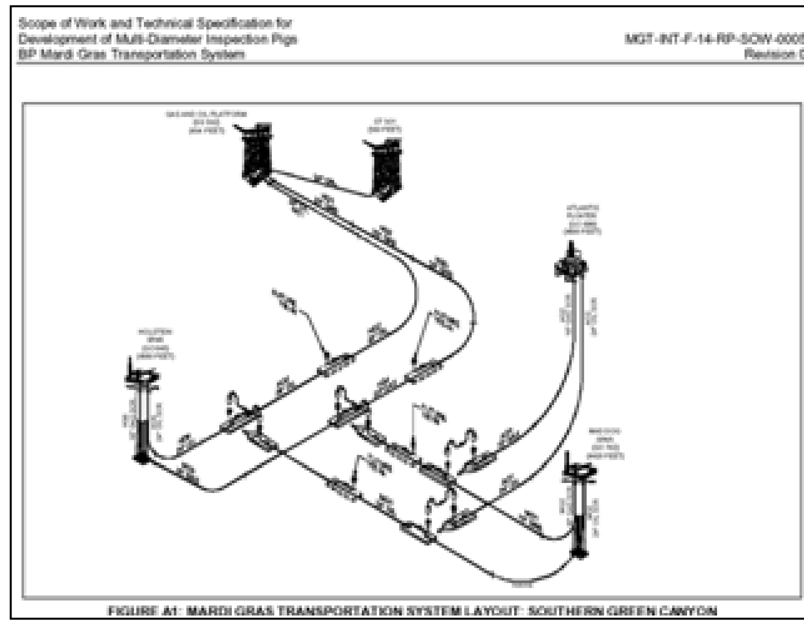
Figure: Tom Wheatley Sub-Sea NRV



Operational parameters

- Product, temperature, pressure, flows etc.

Figure: MARDIGRAS TRANSPORTATION SYSTEM LAYOUT



Joint site surveys effective at reducing gaps in knowledge

4i. Data Gathering & Risk Assessment

- Compare data gathered with known system capabilities & constraints
- Identify risks and assess level (Low, Medium, High)
- Identify initial risk mitigation actions e.g. gather more data
- Re-assess risk level post initial risk mitigation

Figure: Example FMEA (Failure Modes & Effects Analysis)

Part/Function	Potential Failure Mode(s)	Potential Failure Effects	SEV	Potential Cause(s)/Mechanism(s) of Failure	OCC	Current Design Controls	DET	RPN	Recommended Action(s)	Responsibility & Target Completion Date
What are the process steps/ parts	In what ways can the process step/parts go wrong?	What is the impact of the Failure Mode on the customer?	How severe is the effect on the customer?	What are the causes of the Failure Mode?	How often does the Cause or Failure Mode occur?	What are the existing controls and procedures that prevent the Cause or Failure Mode?	How well can you detect the Cause or Failure Mode?	Calculated	What are the actions for reducing the occurrence, decreasing severity or improving detection?	Who is responsible for the recommended action?
MV:Sensor fingers	loss of finger	loss of inspection data, material left in pipeline	5	crushing	5	partial shields fitted	4	100	Test during pump throughs	

An informed & collaborative risk assessment is critical to project success

4ii. System Design … Mechanical

Focused & experienced multi-disciplinary engineering team utilizing latest tools

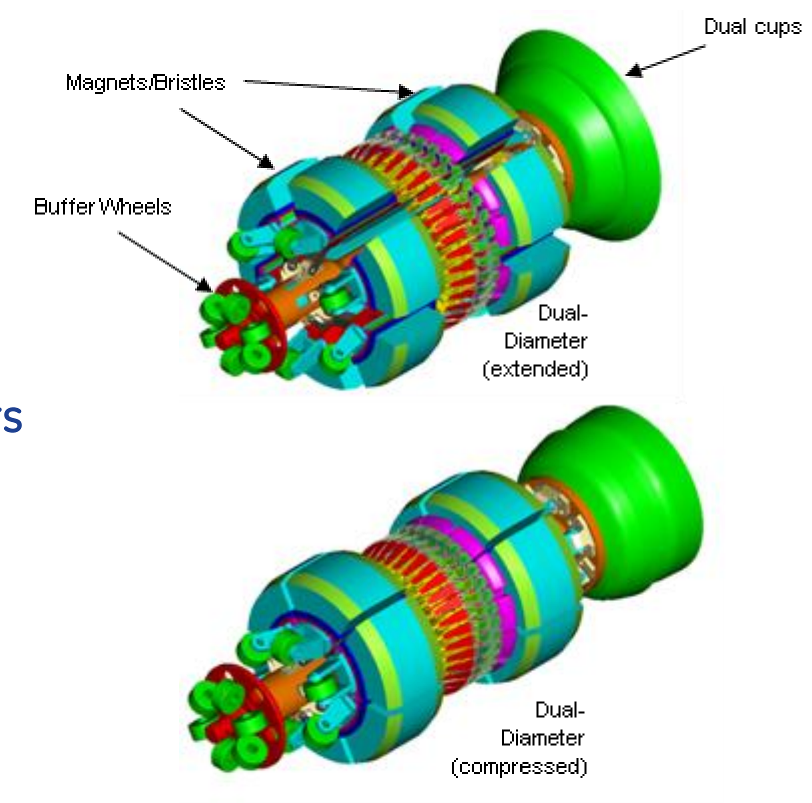
- 3D CAD modelling techniques
- 3D printer for rapid prototyping

Start with MV design as most complex

- negotiate complex pipeline geometry
- saturate pipe wall in range of diameters & wall thicknesses
- protect main corrosion sensors from fixtures & fittings

Numerous design iterations required to identify issues & optimize trade-offs

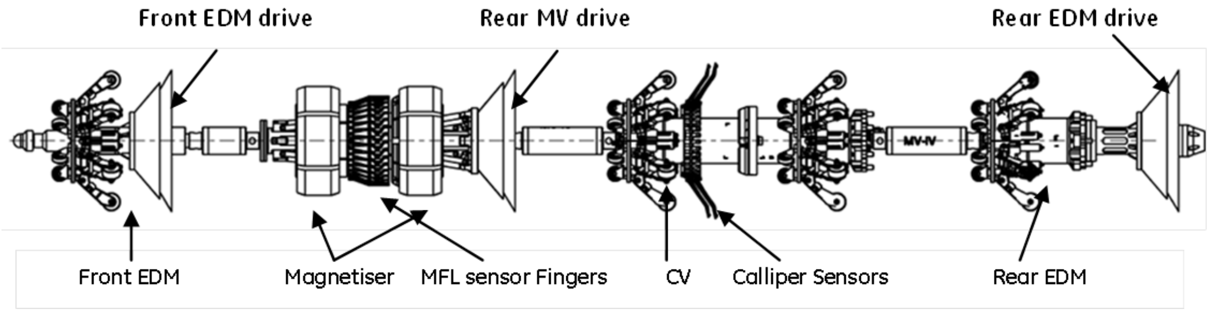
Figure: Example Dual Diameter MV CAD Layouts



4ii. System Design … Mechanical & Electrical

- MFL systems driven from front (MV) … additional drive required to navigate off-takes/wyes
- Drive from rear requires solution to avoid system jack-knifing e.g. flexible semi-rigid tow-bar

Figure: Example Overall Vehicle Train



- Electronics sensor marshalling typically mounted externally, with data acquisition in the CV/IV and the rear EDM pressure vessels
- Multi-diameter pipelines add complexity if performance to be maintained in all diameters
- Detailed electronic system drawings & wiring diagrams ensure viable electronics system

4iii. System Performance (Predicted) … Mechanical & Operational

Quantify mechanical performance

- Derived directly from 3D CAD models developed
- Simulate passing of challenging features e.g. bends, bore, off-take/wye

Quantify operational performance

- Maximum & minimum values for temp, pressure, speed, range etc.
- Derived from detailed calculations & proven performance

Assess & optimize system design Vs captured requirements

Figure: Example 16/20 in Local Full Bore

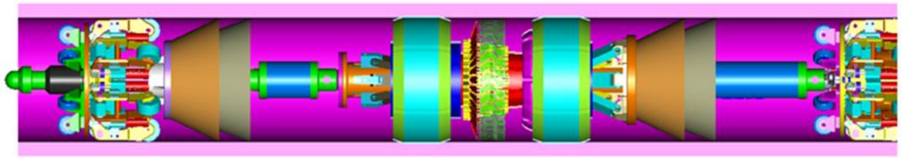


Figure: Example in 16" Bend

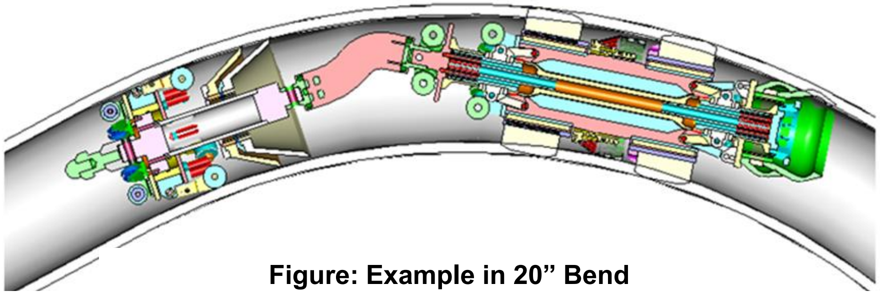
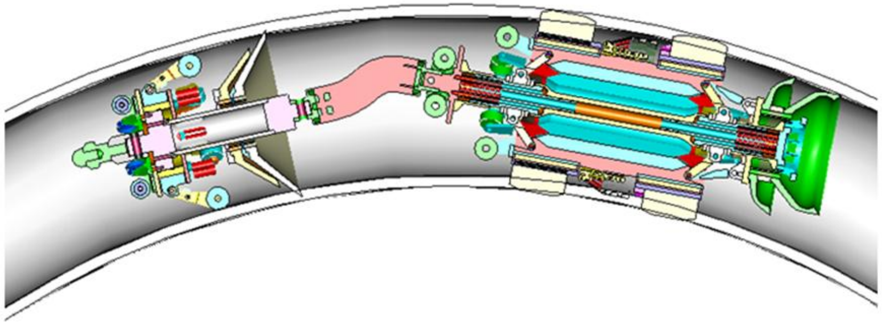


Figure: Example in 20" Bend



4iii. System Performance (Predicted) … Magnetic

- Detection & sizing limited by magnetic performance
- Typical magnetic models for single diameter with solid body return path
- Multi-diameter lines require segmented body with articulated magnetizer
- High speed gas requiring variable by-pass add further complexity
- Predict performance over range of diameters, wall thickness, & speeds
- Sound magnetic models & experienced Physicist essential

Figure: Magnetic Modeling

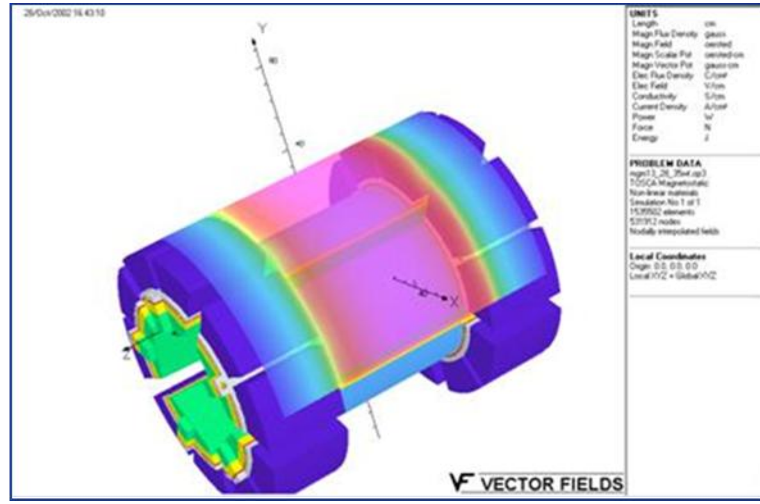


Figure: BP Mardi Gras Predicted Performance

Diam	Min sizing model WT / mm (Inch)	Mardi Gras Min WT / mm (Inch)	Mardi Gras Max WT / mm (Inch)	Max sizing model WT / mm (Inch)
24 Inch	22.9 (0.90)	24.7 (0.97)	33.5 (1.32)	35.0 (1.38)
28 Inch	23.8 (0.94)	26.5 (1.05)	34.9 (1.37)	35.0 (1.38)
30 Inch	16.0 (0.63)	18.1 (0.71)	25.4 (1.00)	25.4 (1.00)

4iv. Ancillary Requirements

Safe and successful inspection requires

- Line cleaning
- Line proving
- Handling equipment
- Launch & receive equipment
- Waste management
- Etc.

… and should consider

- Pig tracking
- Pig recovery
- Etc.

A holistic solution design is required
… not only an in-line inspection system

Figure: Vertical Launch

Figure: Example Profile Pig Design

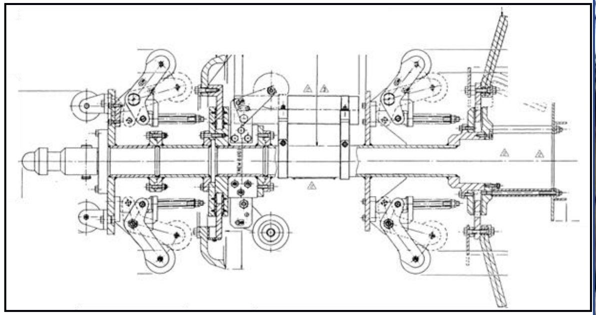
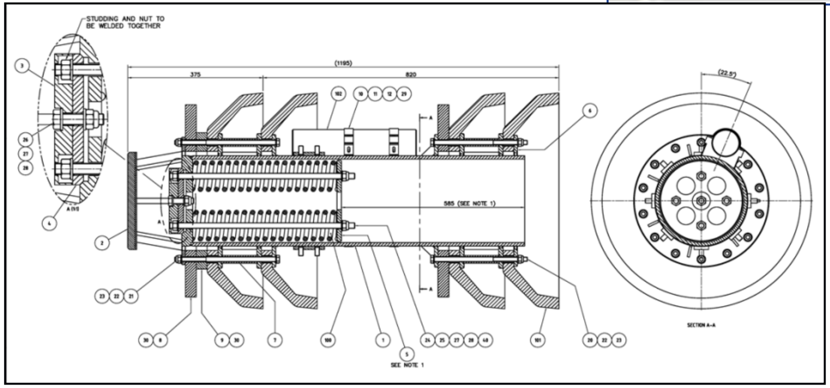


Figure: Example Rescue Pig Design



4v. Design Verification & Testing

- Component/Assembly Level
  - Pressure & temperature
  - Shock & vibration
  - Force deflection
  - Dynamic
  - Life

Figure: Flexible Semi-Rigid Tow Bar

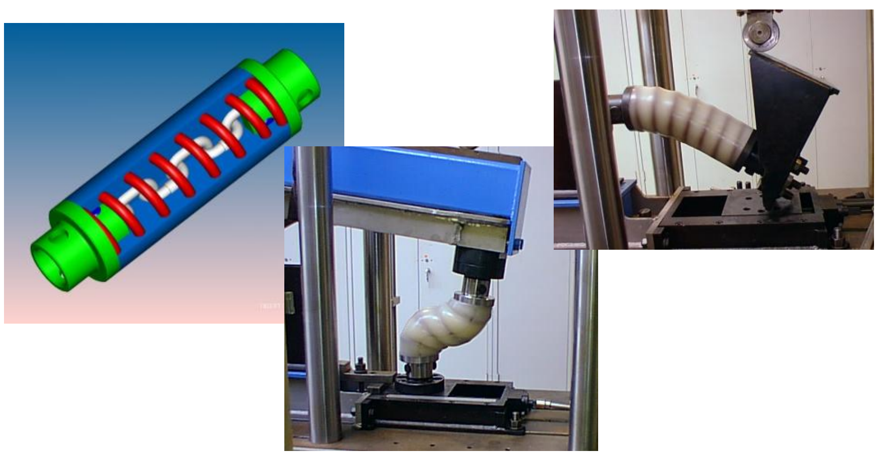
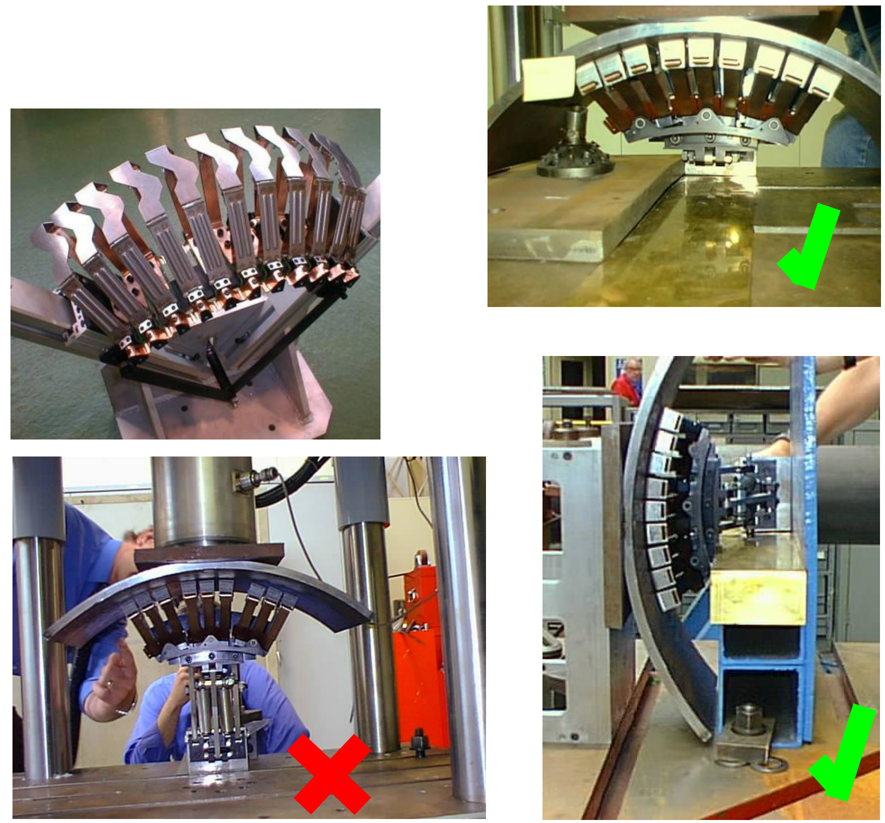


Figure: Example Z-Sensor



4v. Design Verification & Testing

- System Level
  - Pump through (blow-over, leakage, by-pass)
  - Mechanical proving
  - System Integration Tests (SIT)
  - Database pull through tests

Figure: BP Mardi Gras Mechanical Pull Test Rig

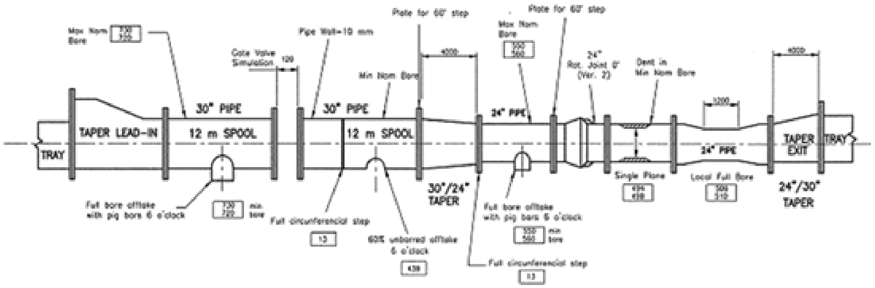
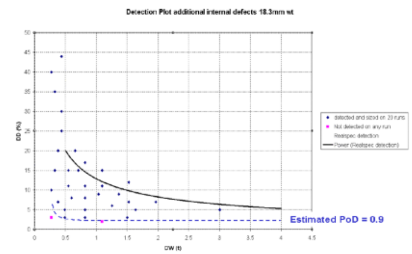


Figure: BP Mardi Gras System Integration Test Rig

Figure: Example Blow-Over Test

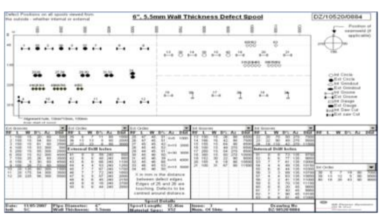
4v. Design Verification & Testing

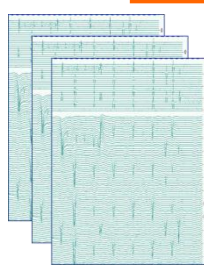
- System Level
  - Pump through (blow-over, leakage, by-pass)
  - Mechanical proving
  - System Integration Tests (SIT)
  - **Database pull through tests**



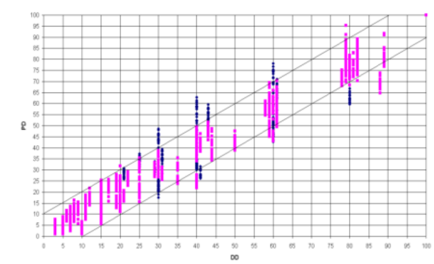
PoD Assessment

Design database spools → **Pull through test** → **Generate signal /defect database** → **Modelling** → **Implement**





Signal variables → Sizing Model Transfer Functions → Defect Dimensions



Revised int model (Pink – PH, PT, GC, Blue – Grooves)

Sizing Performance

4vi. Inspection Methodology … Progressive Pigging

- Optimize pigging program as pipeline conditions & circumstances dictate
- Evaluate outcome of each run before the next pig is launched
- Modify next pig and/or run conditions as required
- Build up a picture of the pipeline over several runs
- Learn from each previous run to clearly target/focus the following run

Progressive & flexible approach maximizes program effectiveness & probability of success

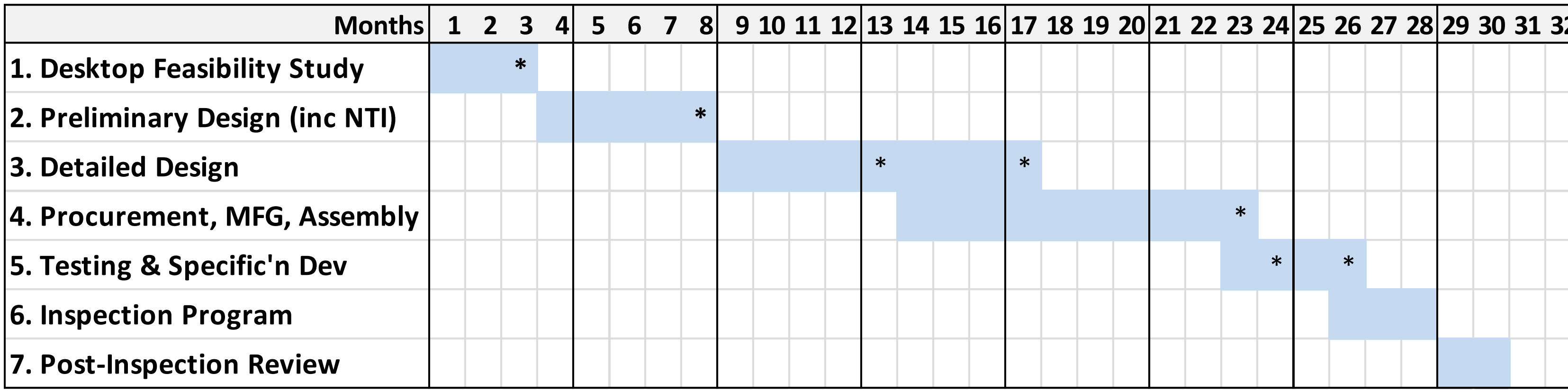
Indicative program

- Pig Type 1 (Soft Body Poly Cleaning Pig)
- Pig Type 2 (Soft Body Poly Cleaning Pig & Gauge Plate)
- Pig Type 3 (BIDI with Gauge Plate)
- Pig Type 4 (Hard Body Cleaning Pig)
- Pig Type 5 (Calliper with drive elements)
- Pig Type 6 (MFL Inspection Train)

Figure: CATS Cleaning Run 1

4vii. Program Phasing & Milestones

Figure: Example Program Phasing & Milestones



- ‘Desktop Feasibility Study’ includes best case/worst case cost & timeline for project, and defined price & scope for next phase ‘Preliminary Design (inc NTI)’
- Risk Tollgates (*) provide the opportunity to highlight any gaps in data or risks before moving on to the next phase
- Detailed scope, timeline, deliverables, & price are agreed for next phase, with revised estimates for remaining phases
- Timeline & Cost estimates tighten up for the remaining project as Risks are progressively reduced and retired

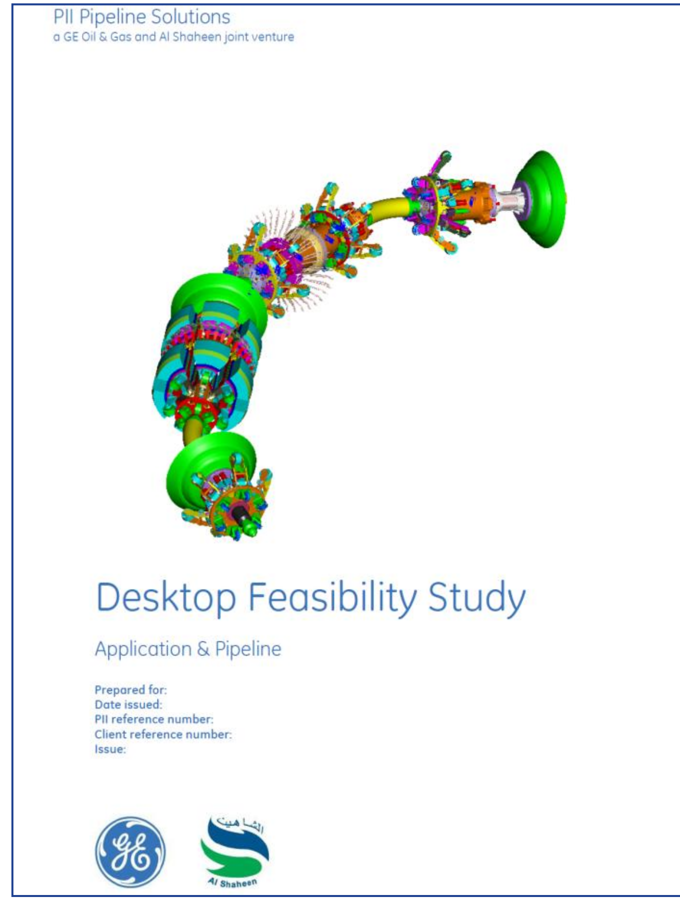
Technical & commercial risk understood throughout … no surprises

5. Conclusion … success criteria

The case studies prove the technical challenges of inspecting off-shore pipelines can be overcome

Success requires:

- an early start, ideally in parallel with pipeline design & construction
- sustained engagement between pipeline owner/operator & ILI vendor
- ILI technology, skills, & experience harnessed through a proven methodology
- phased approach with formal approval of risk tollgates & major milestones
- initial Desktop Feasibility Study to ensure risks are understood & expectations aligned early



An early start and collaboration are key to success

Q&A