PIPELINE INSPECTION

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Stolt Offshore
The agenda for today’s presentation.

Agenda:
- Why Inspect
- Regulations
- The IMR Cycle
- What is a pipeline
- Inspection Methods
- Data Acquisition
- Data Processing
- Reporting
- The Future
- Conclusions
- Questions
Why Inspect?

• This is the famous pipeline inspection expert Sherlock Holmes checking a marble pillar for signs of corrosion!
• Notice his dress, this is what passed for PPE in Victorian times!
Why Inspect?

- Car = Major asset, £10K’s
- You want to keep it in condition
- Retains value & operates well
- Maintenance = servicing
- Inspection = MOT
- MOT ➔ Fit for purpose
- MOT ➔ Road Tax & Insurance

If not maintained it’s:

- Unreliable
- Not fit for purpose
- Fails the MOT
- Worth nothing
- Costs you money
- SORN & £1000 fine
- Delays you: walk or bus.

- Society (Government) recognises that cars must be fit for purpose & drivers have duty of care to the public
- Hence there are Acts & Statutory Instruments to ensure this happens.
- For cars this means: MOT, Insurance & Road Tax.
Why Inspect?:

• Major Asset worth £10 - £100M’s
• Owners have a vested interest to...
  – Maintain pipeline in efficient condition.
  – Duty of care: environment & marine users
• It will retain its value, less depreciation
• Sold on to next field owner / operator
• Just like you & your car

Huge downside if not in good condition:

• Contents may stop flowing or leak out!
• Environmental clean up
• Business Interruption
• £1M’s DTI / HSE Fines
• £10M’s lost production - daily
• £??M's Law suits, Litigation

• Pipeline operator has a vested interest in keeping the line in good condition.
• If the don’t the contents may stop flowing or even leek out!
• Just as the government has lawful MOT regulations for cars.
• So they have lawful regulations - statutory instruments - for pipelines.
• The MOT is actually the “Fitness for Purpose Assessment”, the FPA
Regulations

To ensure pipelines are maintained:
- Pipelines Safety Regulations, 1996.
  = Statutory Instrument 1996/825
  - Obligatory to keep lines in good condition.
  - Must Inspect, Maintain & Repair.
  - "Fit for Purpose Assessment" = MOT
  - The pipeline is then insurable
  - Just like your car

• The Ten Commandments, an early example of regulations.
• The rules governing inspection are the Pipeline Safety Regulations.
• Compulsory to keep pipelines in good condition.
• You must service them, like your car.
• That is you Inspect, Maintain & Repair them.
• The MOT for pipelines is the Fitness for Purpose Assessment.
### Pipelines Safety Regulations

#### Up to 1996:
- Various regulations
- E.g. SI 1513
- Complex
- Ambiguous
- Prescriptive
- Open to interpretation

#### Post 1996:
- **Pipeline Safety Regulations**
  - SI 1996 / 825
  - Aligned with HSWA
  - Simple
- Goal setting: Clause 13
  - “The operator shall insure that a pipeline is maintained in an efficient state, in efficient working order and in good repair.”
- PSR facilitated:
  - Risk Based Inspection
  - Cost savings & efficiency
  - Innovative systems

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- Up to 1996 there were various regulations including SI 1513.
- They were very prescriptive, open to interpretation and not working well.
- Regulations were revised and consolidated resulting in PSR - SI 1996/825
- Written so that it was aligned with the Health & Safety at Work Act 1974.
- This brought with it a shift from prescriptive to goal setting legislation.
- The crux of the PSR legislation is Clause 13 - a “one-liner”, 21 words.
- The legislation sets goals: I.e. prove the pipeline is in good condition.
- Owners have responsibility to put systems in place to achieve that.
- The new regulations enabled a move to Risk Based Inspection.
- Freed inspection contractors to provide solutions, systems, technology, and to innovate.
The IMR Cycle

- RBI
- IMR (Repair)
- IMR (Routine)
• **RBI: Risk Based Inspection**
  
  • An inspection regime such that you are confident the asset will be in the same condition at the next inspection interval.

  • Permits flexibility & efficiency, cost effective solutions.

  • Allocate inspection effort where it is most effective & required.

  • Explore alternative survey methods / strategies

  • Permits new technology & innovation

  • Customised IMR for each asset.

  • Based on risk assessment, trend analysis & experience

• This is one definition of a Risk Based Inspection - quite succinct, good.

• The move to RBI, facilitated by the Pipeline Safety Regulations 1996, was liberating.

• It allowed the Operators, Integrity Managers and the survey / inspection contractors to develop suitable, cost effective & efficient, techniques and systems.

• Importantly:- a Customised Inspection & Maintenance Routine means you don’t have to inspect every component of the asset infrastructure every time.
**IMR: Inspection & Maintenance Routine.**

<table>
<thead>
<tr>
<th>Customised for each “asset”</th>
<th>Sets out for each asset:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cover asset infrastructure:</td>
<td></td>
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<tr>
<td>- Wellheads</td>
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<tr>
<td>- Platforms</td>
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<td>- Risers</td>
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<td>- SSIV’s</td>
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<td>- Pipelines</td>
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<td>- Umbilicals</td>
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<td>- Cables</td>
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<td>- Landfalls</td>
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<tr>
<td>- Links &amp; nodes</td>
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<td>- Surface &amp; subsea</td>
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</tbody>
</table>

- **Risks & probability**
- **Pipeline anomaly criteria**
- **Types of inspection (Controls)**
  + Recommended:
    - **Interval - each inspection type**
    - **Interval - each asset component**

  = planned inspection schedule.

**They can be revised:**
- Through trend analysis.
- Life cycle: new - mature - old (dead or even re-incarnated!)
- Change of use

• **IMR = document, customised for each particular asset.**
• Describes all the infrastructure of an asset
• Notice - logical sets of structures - logical to use different inspection techniques.

• To create the IMR each component of the asset is risk assessed.
• Maximum conditions are set above which they are anomalous.
• The IMR is designed, based on:
  - RBI philosophy
  - Engineering - predicted deterioration of components
  - Experience & Common sense.
Inspection
Maintenance
& Repair

Integrity Management Consultants:
• Analysis & Assessment
• Recommendations
• Fit for Purpose?

Survey & Inspection Contractors:
• Gather data
• Report
• Solution providers

Operators:
• Accountable
• PSR Clause 13
• Manage Budget
• £££’s & ITT

PSR
RBI
FPA

Pipe’s

Maintenance

Inspection

Visual representation of how regulations & parties involved in IMR interact.
• Survey & Inspection Contractors survey & report pipeline conditions.
• Reporting according to condition & anomaly limits: anomalies.
• IMC’s assess the results & advise on pipeline condition.
• They issue the “Fitness for Purpose Assessment”
• Operators are accountable for pipeline integrity per Clause 13 of PSR 1996.
• Operators manage the cycle in the light of the recommendations.
• They set budgets for Inspection and invite bids to conduct Maintenance & Repair work as it is needed.

• Finally, we need someone to police the whole system and that is……
• The Health & Safety Executive inspectors = Traffic Warden.
• Seen here slapping an improvement notice on an Oil Exec’s car.
• Their experts will visit & audit IMC’s & operators and audit FPA’s.
• If they find things are not in order, they will issue an Improvement Notice.
• And they keep everyone on their …….Toes.

• This is a closed loop - epitomises much of what happens in IMR.
• It is commonly called the IMR cycle
2 Year Inspection Cycle - GI

- Consult the IMR
- Develop workscope, conduct inspection, acquire data.
- Assess data onboard the vessel.
- Determine anomalies (damage & conditions which threaten integrity)
- Report from the vessel (7 - 14 days)
- IMC’s then assess the data & make recommendations
- = Closed cycle

- Information from year 1 is carried into Year 2
- IMR Schedule plus year 1 findings determine Year 2 workscope.
- Reviewed & adjusted by IMC’s / Operators.
- Survey & Inspect - gather data.
- Determine anomalies & monitor items
- Monitor items = anomalies that are no longer anomalous but need monitored
- Report from the vessel (7 - 14 days)
- IMC’s then assess the data & make recommendations
- = Closed cycle
1 Year Inspection Cycle - 2 Surveys, GI & GVI.
• Consult the IMR for GVI inspection requirements
• IMR Schedule plus year 1 GI findings determine year 1 GVI workscope.
• Written by inspection contractor.
• Reviewed & adjusted by IMC’s / Operators.
• Survey & Inspect - gather data.
• Assess data onboard the vessel.
• Determine anomalies & monitor items
• Report from the vessel (7 - 14 days)
• IMC’s then assess the data & make recommendations
• Closed cycle

• Build up database of pipeline conditions that are assessed.
• Subsequent inspections: planned based on IMR schedule & historic data
There are various cycles & feedback loops in the IMR cycle:

• Yearly
  – By Inspection type
  – Between inspection types.

When you are out inspecting, there is the daily cycle.
Which looks like this.
On Groundhog Day the people of Seaway Petrel consult Punxsutawney.

If he sees a shadow that means another 2 weeks of survey………………...

• = Groundhog day.

• Inspection can be a little bit repetitive………..

• But, inspection being inspection, there is always something that comes along that is interesting.
• This certainly broke the daily cycle!
• This is a “UXO” anomaly, an unexploded object.
• A 3000 pound air dropped mine.
• Dropped sometime in the 1960’s.
• When we find one of these we:
  – DO NOT touch it……!
  – Photograph it.
  – Call the Royal Navy bomb squad.
  – Make it stable - if it isn’t - we sand bagged this one.
  – Stay on site until Navy or a guard boat comes out.
  – If we’re lucky we see the explosion.

• There are some more UXO slides later.
• Other interesting thingss:
  – Usually find 1 or 2 of towed sidescan & pinger fish each year.
  – A coffin - assumed a burial at sea.
  – Plenty of marine life: lobsters, big monkfish etc.
What is a Pipeline?

In its simplest form a pipeline comprises:
- Risers
- Spoolpiece
- Sealines
- Landfall

There are analogies to human anatomy:
- Pumping oil = heart
- SSIV = valves
- Pipeline = arteries
- Umbilicals = nerves
  - electro - hydraulic umbilcals
  - fibre optic cables (optical nerve)

• The oilfield is not dissimilar to the human body
• It’s lifeblood is the flow of oil and / or gas through pipelines.
• Burst or clogged arteries are unhealthy as are burst or clogged pipelines.
• An SSIV is a subsea isolation valve, an automatic stop valve.
• They were made compulsory after Piper Alpha, 6/7/88.
• 167 people lost their lives then.
• There is no better reason than that to inspect, maintain & repair.
• Safety is paramount.
• Here is a diagram of a very simple pipeline system.
• It shows the 3 main sections of a pipeline.
• In reality oil & gas infrastructure is much more complex.
• “Pipeline” is a misnomer, we inspect linear & point features of infrastructure.
• There are many different types of point and linear features.
Risers can degrade rapidly due to
- Instability
- Current
- Wave Action
- Corrosion - electrical & chemical
- Wave Action / Movement
- Impact

Inspection options:
- Above sea level - RATS
- Splash Zone - RATS / divers
- Subsea - DP Vessel & ROV’s
- Subsea - Platform based ROV’s

• The pipeline is at its most vulnerable in the splash zone.
• Subjected to alternative wet & dry cycles at different intervals.
• Tidal cycle (12 hour - diurnal) and wave cycle (seconds).
• Above the splash zone it is impacted by salty air.
• And also subjected to sunlight & temperature cycles & wind action.
• Which are the enemies of paint and the allies of corrosion.
• Riser is very susceptible to impact by supply vessel.

We also see the Rope Access Technicians at work.
• They inspect, clean, repair, maintain and lift heavy objects
• Usually to be found swinging from platforms or vertical cliff faces.
• It must be great when your job is your hobby!
• RAT inspection & intervention teams are an innovation:
  – Safer than scaffolding - offshore scaffold operations are very dangerous.
  – Quicker, more efficient
  – They can get into places scaffolding can’t
  – Cost effective solution.
• There are thousands of km’s of pipeline in the north sea.
• Carry varying products, including water - injected for enhanced recovery.
• Some are still operating, efficiently & safely, beyond original lifecycle.
• Some 30+ years old, still operating due to over-engineering & good IMR.

• These are the main risks to which they are exposed.

• Unlike a car, you can’t wheel pipelines into a garage for inspection / MOT.
• You have to go out & look at them somehow.
• You need survey & sensor platforms: vessels & remotely operated vehicles.
• Usually the vessel will have “DP” capability, i.e. Dynamic Positioning.
• This permits “follow-sub” mode: i.e. “station-keeping” on the moving ROV.
• It also facilitates a means of positioning the ROV.
• Sensors are mounted on the ROV which substitute for your eyes and ears.
• Knowing vessel & ROV position & attitude lets you position the sensors.
• Sensor data is then “added” to give you positioned pipeline condition data.
LANDFALLS
- TOB to @ 3km offshore.
- Through the inter-tidal zone.
- Buried, rock-dumped or in conduit.
  - Protected

At Risk From
- Anchors & Trawl gear
- Munitions
- Very Strong Currents
- Wave Action - to seabed
- Erosion / Deposition
- Beach activities
- Corrosion - chemical & electrical

Survey Platform:
- Shank’s Pony
- Inshore survey vessel

Sensors:
- RTK back pack
- Radio-detection tools
- Innovation:- Divining rods
- RTK, SVS, SBP, SSS
- Divers, Mini ROV
- CP (Trailing wire / snake)

•This is a professional landfall survey team, working very hard.
•PPE = work boots & sun-block!
•A pleasant way to spend a month in summer.

•Landfall is often defined as from top of beach to @ 3km offshore.
•The 3km offshore is not a hard and fast rule.
•In the southern north sea it’s the sort of safe distance that you can comfortably bring a large vessel into the beach.
•Given that you are going to do an inshore survey with a suitable inshore vessel then why risk the large offshore vessel to unnecessary risk, hence 3km.
•In some places a large vessel can get within 10’s of metres of the shoreline.
• Inshore, the effects of tidal forces are amplified by shallow water effects.
• Strong currents, erosion & deposition, long shore drift, high energy zone.
• Shallow water means waves impact on seabed: churning it up.
• It is not unusual to see 2 metres of seabed erosion between yearly surveys.
• Various cycles: diurnal tides, seasonal - winter storms, yearly.
• Currents: example here of Bacton, this shows 1.2ms = 2.3 knots.
• They can be a lot stronger than that, e.g Shetland - 7 knots in places.

• Surveyed once a year.
• What would you find if you:
  – Monitored daily?
  – Or before & after a storm.
  – What impact will coastal defence policies have on east coast landfalls?
• A few examples of pipeline landfalls.
• LHS: landfall somewhere sunny, a perfect survey / inspection location.
• Top & Middle RHS: Landfall Shetland.
• We use divers at these locations due to local seabed topography & kelp.
• Acoustic methods can’t get through the kelp.
• Bottom RHS: Landfall somewhere with no Working at Height policy.
• You would not get away with this in the north sea = safety is paramount!
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Survey / Inspection Methods

• This was probably taken in the 19th century sometime, somewhere.
• Maybe on the railroads in the wild west of America.
• The clothes may look daft to us but it is obvious that they are wearing work clothes fit for their activity, i.e. PPE, good for them.
• The instrument on the left is an astroblade.
• Today that would be an intergalactic, in line, roller skates or a rocket powered skateboard.
• The tripod, table & telescope on the right is what was called a “Plane Table”.
• Based on tacheometry, it is a fast method for conducting detailed survey.
• The present day equivalent would be the Total Station or RTK backpack.
• In the next few slides we’ll look at the main inspection modes: GI & GVI.
• GI = General Imaging = side scan sonar, acoustic inspection
• GVI = General Visual Imaging = cameras = visual inspection
• Plus the types of sensors utilised for each type of survey
### Inspection Methods

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Survey Platform</th>
<th>Type / Method</th>
<th>Component</th>
<th>Notes / Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RATS</td>
<td>Platform based</td>
<td>Visual - cameras NDT techniques</td>
<td>Riser</td>
<td>Down to splash zone Weather</td>
</tr>
<tr>
<td>Diver</td>
<td>Platform or DP vessel based</td>
<td>Visual - cameras NDT techniques</td>
<td>Riser, Pipeline, Point structures, Landfalls</td>
<td>Depth, Current Weather, Sea state HSE</td>
</tr>
<tr>
<td>Landfall GI</td>
<td>Inshore survey vessel</td>
<td>Hull mounted Acoustic CP snake</td>
<td>Pipelines</td>
<td>Inshore only Weather, tides Sea state @ 1m Fishing gear</td>
</tr>
<tr>
<td>Structural GVI</td>
<td>Oil platform or DP survey vessel 3 X Eyeball ROV’s</td>
<td>Visual – cameras NDT techniques FMD</td>
<td>Legs, Structural members, Risers</td>
<td>Weather Sea state @ 2m Current, Visibility</td>
</tr>
<tr>
<td>Pipeline GI</td>
<td>Survey vessel ROV</td>
<td>Towed SSS Acoustic</td>
<td>Pipelines, Structures</td>
<td>Seafloor structures only Cannot stop Current restrictions Sea state @ 2m</td>
</tr>
<tr>
<td>Pipeline GVI</td>
<td>DP survey vessel WROV</td>
<td>DP follow sub Visual – cameras CP</td>
<td>Riser, Pipeline, Structures</td>
<td>Current restrictions Visibility Sea state @ 4.5 – 5 m</td>
</tr>
</tbody>
</table>

This table summarises the common types of survey we have conducted historically.

- **GI** = General Imaging inspection = side scan sonar
- **GVI** = General Visual imaging = cameras
- **NDT** = Non Destructive Testing
- **FMD** = Flooded Member Detection
- **CP** = Cathodic Protection:
  - A zinc anode is attached to the structure.
  - It corrodes = oxidation, loss of electrodes = sacrificial anode.
  - Structure protected by small electric current.
  - CP inspection tool is basically a current meter.
  - Proximity & contact tools determine milli-volts
  - Determines the status of the CP system: is it working

Certain methods require a vessel with Dynamic Positioning capability:
- To keep station next to structures or relatively over a moving vehicle
- To position the subsea survey platform (ROV / Diver) & sensors
## Inspection Methods

<table>
<thead>
<tr>
<th>INSPECTION TYPE</th>
<th>GI</th>
<th>GVI</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Vessel:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>DP</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DGPS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Seapath</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gyrocompass</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>MRU</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sensor Platforms:</td>
<td>ROTV</td>
<td>WROV</td>
<td>WROV</td>
</tr>
</tbody>
</table>

| SENSOR PLATFORMS |
|------------------|----------------|----------------|
| Platform:        | ROTV | OBS ROV | WROV |
| Sensors:         | Acoustic only | Visual | Visual & Acoustic |
| Responder        | Poor tracking | ✓ | ✓ |
| Gyrocompass      | X   | X   | ✓ |
| MRU              | X   | X   | ✓ |
| SSS              | ✓   | X   | ✓ |
| OAS              | X   | X   | ✓ |
| Bathy            | X   | ✓   | ✓ |
| Allimeter        | X   | ✓   | ✓ |
| Camera           | X   | 1 maybe 2 | 3 |
| Lighting         | X   | ✓   | ✓ |
| Scanning Profilers | X   | X   | ✓ |
| Bathy / Profiling | X   | X   | ✓ |
| CP Contact       | X   | ✓   | ✓ |
| CP Continuous    | X   | ✓   | ✓ |
| CTD              | Overside | N/A | ROV-mounted |
| Manipulators     | X   | 1-limited | 2-multi function |

Historically - single mode GI or GVI inspection cruises:
- **GI** - Spring - general inspection X sidescan
- **GVI** - Summer - detailed inspection X camera

**Fast ROV ‘GI’**:
- Facilitated by WROV & DP vessel combination
- Increased SSS target accuracy < +/- 5m
- Can stop & conduct GVI on detected damage
- Can intervene if necessary
- Multi-tasked cruises with GI & GVI capability

**GI**: towed SSS survey, fish or ROTV, low tech, DP not necessary.
- Fast method of amassing general information about pipeline condition.
- Looking for spans, exposures, movement, large anomalies / damage.
- No detail on localised anomalies: cracks, bare metal
- Conducted at start of year - results used to plan GVI workscope.

**GVI**: ROV sensor platform positioned by HiPAP / transponder system.
- Visual camera inspection plus acoustic sensors.
- Looking for detailed damage to pipelines & structures.
- Conducted in summer using information from the GI.

**The advent of fast ROV’s, Solo I & Solo II, along with custom built ROV survey vessels led to the fast ROV GI survey: speeds up to 8 km/hour.**
- Importantly, the ROV / DP vessel combination lets you slow down & stop.
- I.e. you can conduct both inspection types on the same cruise.
- As long as you carry the correct sensors.
- Surveys have started to merge into combination GI / GVI inspections.
- Though still generally planned as GI & GVI.
Seaway Petrel:
• State of the art ROVSV, built 2003.
• Dual Independent HiPAP 500 DP
• Fast RO: GI at @ 8kmh.
• Solo II survey WROV
• Internal ROV hangar
• Custom built Hydrolift launch facility
• Also carries Eyeball ROV
• Operations in sea state of 4.5m+

MV Humber Surveyor:
• Originally Firth of Forth Passenger Ferry
• Catamaran - operated by ABP
• Humber Estuary Survey vessel
• Utilised for inshore survey - landfalls
• Hull mounted sensors

RRS Ernest Shackleton:
• Antarctic Research Vessel
• Ice breaker
• 2005 GI / GVI cruise platform

Old Survey Vessel:
• Converted fishing vessel.
• ROTV survey vessel
• Superceded by FAST ROV solution

“Survey Platform” = what you deploy your Sensor Platform from = vessel
“Sensor platforms” = vehicle you deploy your sensors on..

**Solo II WROV New Tech.**
- Stolt Offshore
- Custom built GI & GVI fast WROV
- Weighs @ 6 tonnes
- GI speed to @ 8kmh
- Inspection & Intervention capability.

**Solo II WROV New Tech.**

**SeaEye Lynx**
- Observation ROV
- 1 forward looking camera
- Probably another camera on it.
- Manipulator - limited intervention

**ROTV - Old Tech.**
- Steerable frame with SSS transducers
- Superceded by Fast WROV solution
- Using Seaway Petrel & Solo II.

**Solo 2 WROV:**
- Good view of camera booms
- EM3000 mounts
- Stills cameras.
- Obstacle avoidance sonar
- Camera booms, cameras & lights
- No manipulators - not installed.

**Solo 2 Workclass Survey ROV:**
- Steerable frame with SSS transducers
- Superceded by Fast WROV solution
- Using Seaway Petrel & Solo II.
Combination GI / GVI Inspection Spread

Solo II Sensors:
- Responder - position via HiPAP
- Gyrocompass - heading
- MRU - pitch & roll
- Bathy Unit - depth below sea level
- Altimeter - height over seabed
- Pipetracker - track pipe & DOB
- Profilers / Swathe - cross profiles
- CP - Field gradient & potential
- GI SSS Systems - acoustic
- GVI Camera Systems - visual

• This is now the combination of survey & sensor platforms we conduct inspection with, whether for GI or GVI.

• Someone, somewhere, at sometime during the survey is going to ask us to undertake GI when we are conducting GVI or vice versa.

• So we equip the vessel & ROV to accommodate both modes.
• This is the online ROV & Survey room on the Seaway Petrel
• The ROVERS always get the plushest chairs.
• A busy place when inspecting

**LHS: Online ROV:**
- L to R:
  - Co-pilot, pilot, inspection engineer seats.
  - ROV systems PC’s & monitors
    - Power management
    - System status, power, thrust etc.
- Video: 2 X 3 VCR banks - hot swap
- Pipe-tracker control
- Obstacle Avoidance Sonar (OAS)
- ROV camera monitors

**RHS: Online survey station:**
- DGPS:
  - GPS receivers, Multifix 4
  - Decoders / demodulators
- NaviPac: positioning
- NaviScan: sensor data logging
- Helmsmans PC
- PC’s & surface control units for:
  - Profiler, E.g. TriTech
  - Swathe. E.g. EM3000
  - Bathy / Altimeter
  - Coda
  - Analogue & digital video control
  - Video encoders - digital video
- ROV camera monitors: port, centre, starboard
Data Acquisition

The future of acquisition & processing?
Acquisition is the first part of a sequence of parallel and sequential processes that form the A-P-I-A-R.

This table is a simplified version of the sequence.
Acquisition - Sensors

Basics (very):

- Transducers = underwater speakers & microphones.
- Sound pulses emitted, reflected & multiple return pulses timed.
- 2 way travel time & speed of sound in water known.
- Distances to reflectors calculated: sets of data points.
- Referenced to sensor electrical centre
- Sensors referenced on survey platforms via offsets
- Vessel (DGPS) & ROV (HiPAP) position known
  + Platform attitude: heading & orientation data
  = Geospatial data set referenced by time (GPS 1 PPS signal)
  = Fixed in XYZ framework: geodetic reference system

- Echo-sounder
- Side Scan Sonar
- Sub-Bottom Profiler
- Scanning Sonars
- Scanning Profilers
- Multibeam-swathe bathy
- Multibeam-profilers

These are the basics of acoustic inspection detection / positioning in none too technical terms.

The import points are that:
- Sensors collect discreet patterns of points / data
- These can be positioned, absolutely, through positioning of sensors & survey platforms.
- As long as they are synchronised.
## Acquisition - Position Determination

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<thead>
<tr>
<th>Platform/System/Sensor</th>
<th>Measures:</th>
<th>Determines:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Vessel DGPS Systems</td>
<td>= XYZ position</td>
<td>= 1. GPS antenna position</td>
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<tr>
<td>1. GPS Antenna Position</td>
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<tr>
<td>2. Vessel Gyrocompass</td>
<td>= Vessel bearing</td>
<td>= 2. HiPAP CRP position</td>
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<tr>
<td>3. MRU5</td>
<td>= Vessel pitch &amp; roll</td>
<td>Origin for HiPAP XYZ measurement</td>
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<tr>
<td>4. Vessel offsets GPS A e - HiPAP CRP</td>
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<tr>
<td>HiPAP CRP position</td>
<td>= Vessel bearing</td>
<td>= 3. ROV position (Responder)</td>
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<tr>
<td>1. MRU5</td>
<td>= Vessel pitch &amp; roll</td>
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</tr>
<tr>
<td>2. HiPAP 500 range, vertical &amp; horizontal angles HiPAP CRP - responder</td>
<td>= XYZ separation</td>
<td>The common link to position ROV sensors</td>
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<td>ROV</td>
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<td>1. ROV responder position</td>
<td>= ROV bearing</td>
<td>= 4. ROV Sensor positions (SSS Port / Starboard)</td>
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<tr>
<td>2. ROV Gyrocompass</td>
<td>= ROV pitch &amp; roll</td>
<td>The common link to position SSS targets</td>
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<td>3. ROV Offsets to survey sensors (SSS)</td>
<td>= XYZ separation</td>
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<td>ROY - ROV sensors</td>
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<tr>
<td>4. ROV Sensor positions</td>
<td>= Bearing to SSS target</td>
<td>= 5. SSS target positions</td>
</tr>
<tr>
<td>5. SSS Altimeter</td>
<td>= SSS - seabed height</td>
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<tr>
<td>6. SSS slant target ranges</td>
<td>= SSS - target slant range</td>
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</tbody>
</table>

This is a more quantitative & qualitative version of the previous slide.

The point is that everything must be linked:

- Physically
- By time synchronisation
- By measurement

If this is in place the system becomes automated and massive data sets can be recorded.

If you don’t achieve this, or miss something the data can be useless.
This is a schematic diagram showing the acquisition of data & information during GI SSS inspection.

There are 2 elements of the system:

• Positioning & attitude data
• Sensor data

All acquired raw data is logged on networked mass data storage (NAS / RAID) and backed up to tape.
Data Processing

This is what you can end up with if you don’t get data processing right!
Once the data is logged it has to be processed.

This involves:
- **Eventing**: SSS data & video data.
  - Done digitally
  - Data is replayed and the records are marked with electronic event tags.
- **Smoothing of ROV position data**
- **Smoothing & eventing of X-profile data (GVI)**
- **Apply tides & smooth depth data (bathy / altimeter)**
- **Merge data sets by time stamp / event**:
  - Events
  - Position
  - X-profiles
  - Bathy

- This is done using copies of the raw data, never work on original data.
- Raw data is regularly backed up to tape or other mass storage medium.
<table>
<thead>
<tr>
<th>Step</th>
<th>Process / Description</th>
<th>LP</th>
<th>From</th>
<th>To</th>
<th>Timescale</th>
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<tbody>
<tr>
<td>1</td>
<td>SSS Data Eventing</td>
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<td>ASAP</td>
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<td>Nav Data Processing</td>
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<td>3</td>
<td>Coda Data Merge / Event QC</td>
<td></td>
<td></td>
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<td>ASAP</td>
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<tr>
<td>4</td>
<td>Assign Anomalies &amp; MI</td>
<td></td>
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<td></td>
<td>ASAP</td>
</tr>
<tr>
<td>5</td>
<td>PRISM Export &amp; QC</td>
<td></td>
<td></td>
<td></td>
<td>ASAP</td>
</tr>
</tbody>
</table>

This does not have to be read in detail.

This is a SSS survey internal deliverables process list
There are 38 internal deliverable in this list.

It’s here to indicate why:
– Everything must be time-synchronised.
– The survey process must have structure.
– Everyone involved must be very clear of their deliverables
– Everyone must know where & who they are getting data from
– Everyone must know where & who they sending their data to.

This is all set out in the procedures.
These are the reports co-ordinators.
Reporting - Deliverables

Deadlines:
• Anomalies threatening integrity: immediate
• Significant features - 24hrs - daily call

From asset completion:
• Anomalies - 7 days
• Survey report - 4 weeks, including:
  – PRISM Files
  – “Complete” Reports
  – “Single Pager”

To achieve these goals the reporting process must:
• Automate repetitive tasks
• Be fully auditable
• Be systematic - no repetition
• Conduct QA & QC
• Have a clearly defined structure from the start

• Any pipeline condition that may have an immediate threat on asset integrity must be reported immediately.

• Every day there is a daily conference call - ship to shore - to discuss the last 24 hours summary findings (after safety issues discussed).

• We work to a 4 week deliverables schedule for reporting: I.e. for delivering a final, QC’d, collated report & QC’d PRISM files.

• The acquisition, processing & interpretation process delivers listings at an early stage in the sequence. Because of this we provide simple listings as early as we can. Hence the 7 day anomaly deliverable.
• PRISM files are the main deliverable.
• PRISM = Pipeline Reporting Inspection System Multimedia.
• It is an interactive computer graphic representation of the pipeline.
• Evented pipeline conditions are indicated by suitable symbols.
• (Looks like some creative eventing here - fish, seahorse, toucan)
• An anomalous event is indicated by a red number.
• A monitor item is indicated by a negative - blue number.
• PRISM contains all of the pertinent data from the inspection.
• The slide shows the PRISM pipeline data sheet.
• Linked to the pipeline data are:
  – Anomaly reports
  – Inspection datasheets
  – Profiles: long profiles & individual X profiles
  – Photographs
  – FHR’s - First hand reports
  – Images: side scan data & video images.
  – SSS & Video clips
• PRISM is a database with flexible user defined reporting.
PRISM - Anomalies

• This is an example of anomaly data available through the pipeline data sheet

• RHS: Pictures of the anomaly

• LHS: Engineering assessment of the anomaly with recommendations.
• PRISM is very flexible in its reporting output.
• The report control box - RHS is used to configure reports.
• KP limits to narrow the search / report
• Can look at:
  – 1 pipeline, 1 year
  – 1 pipeline, many years
  – Multiple pipelines
  – Select individual data: anomaly types / conditions
This is a PRISM pipeline plan position screen.

The graphic shows 3 sequential years pipeline data.
• This is the PRISM structural data sheet.

• Structural anomalies are represented on drawings by numbered hot spots.

• A linked set of drawings at various scales & component levels allows you to drill down into more & more detail.

• Linked with the anomaly hot spots are anomaly datasheets, reports, pictures etc.
• Example of the 1st level of drill down.

• The red numbers are the hot spots where you drill down further.

• Diagrams plus data boxes at the bottom of the screen.
• We have looked at data acquisition, processing and reporting.
• This is the survey spread for the combined 2005 GI / GVI Cruise.
• It is a schematic diagram of the systems required for:
  – Data acquisition
  – Interpretation & processing
  – Reporting:

• Survey Platform: RRS Ernest Shackleton
• Sensor Platforms: WROV = Solo II & Lynx.
• 120 days multi-function operations including:
  – GI pipeline inspection
  – GVI pipeline inspection
  – CP Inspection
  – Seabed structures spot dives
  – Platform & riser inspection
  – Platform 500m zone debris surveys
  – Pipeline route corridor surveys
  – Out of straightness survey
Some Examples:

• Anomalies
• Data

C/O
The Reporters

No comment!
Sonar Image Pipeline Movement

- Sonar image - pipeline movement.
- Pipes can move by the action of currents
- They also expand & contract - moving much like a snake.
- The ridges are where sediment has built up beside the pipe before it has moved.

Note:
- displaced & intact stabilisation - mattresses.
- Fully exposed V buried pipeline
• This is the plotted position of the pipeline in the last sonar image.

• The top line is the original position of the pipeline “as-laid”

• The bottom line is where it has moved to.

• This was quite an impressive example of movement & the operator took immediate action to conduct remedial stabilisation work on the line.
A sample digital SSS image.

A & D shadows of where pipeline enters the structure - not anomalous.

B - pipeline

C - some snatch on the record - where there has been some pull on the fish or survey platform.
• This upheaval buckle was detected during a GI - acoustic SSS survey.

• This is classic SSS image of an upheaval buckle - it pokes you in the eye.

• It screams “anomaly” - we were ecstatic when we discovered it.

• As the GI survey platforms were DP survey Vessel & WROV it was possible to stop and conduct GVI - visual inspection.

• The client took immediate remedial action - rock dumping.
GVI of Upheaval Buckle:

Top left:
ROV on seabed
Looking under pipeline.

Estimated height 4 metres.

• These are video grabs of the same upheaval buckle.

• Based on GI & GVI inspection & first hand reporting the client was able to take immediate action to remedy this anomaly.
Port, centre & starboard & suitable lighting & suitable camera angles.

E.g. Where there are spans you would back light with 1 camera to silhouette the bottom of the pipe - cameras pointing inwards..

E.g. Movement - you would position cameras to look ahead to see sediment ridge build up - this can be 2 to 3 metres away from the pipe & you may miss it on if cameras are looking inward.
Where a pipe is layed in a trench you may have to raise the profilers to see over the spoil heap to the natural seabed.
• This is a sample of CP data.
• It’s a black art.
• It’s obvious where the CP (Cathodic Protection) anomalies are though.
• CP values: contact & continuous are available in the CP data box on the PRISM pipeline data sheets.
Examples of damage:

• Top left: pipeline slipping through weightcoat.
• Top right: anchor damage - 20” pipeline, dragged 450 metres offline.
• Bottom left: anchor under 4 inch line - resulted in immediate remedial action.
• Weightcoat loss around joint / weld - monitor.
• Close up of UXO shown earlier - air dropped mine.
• The tether is the silk parachute cord.
• And again, same UXO.
• Another UXO.

• Which ones the bomb & which ones the pipeline?

• Answer on last slide plus one!
• Close up of the last UXO c/w scale - 10 centimetre divisions..
(Back to) The Future

- PRISM on Internet (rolled out 2004)
- Live data to client PC via internet - video & SSS?
- Digital cameras to supercede analogue - when?
- = Another magnitude of data storage?
- Laser profilers?
- Move full reporting process onshore?
- Get rid of paper report?
- Greater emphasis on data rather than report.
- Digital cameras & software: new imaging techniques
- AUV’s for GI survey?
- Coastal defense policy - consequences of erosion?
- Intelligent infrastructure: build in inspection?
Conclusions

- Pipeline inspection is a mature business but continues to embrace new technology.
- Management of change: adapting to new systems.
- Digital age has almost eclipsed the analogue age.
- Days of pure GI / GVI cruises gone: the multi task GI / GVI cruise is here.
- Client (in the office) is getting closer & closer to live raw data.
- Control of multiple surveys through one contractor produces consistent results
- Inspection / survey must be fun!
To continue on the “Catchphrase” / pictorial pun theme.

Here is the last offering.

“Our are the eyes in Inspection, Maintenance and Repair.”
No difficult ones!

Any Questions?