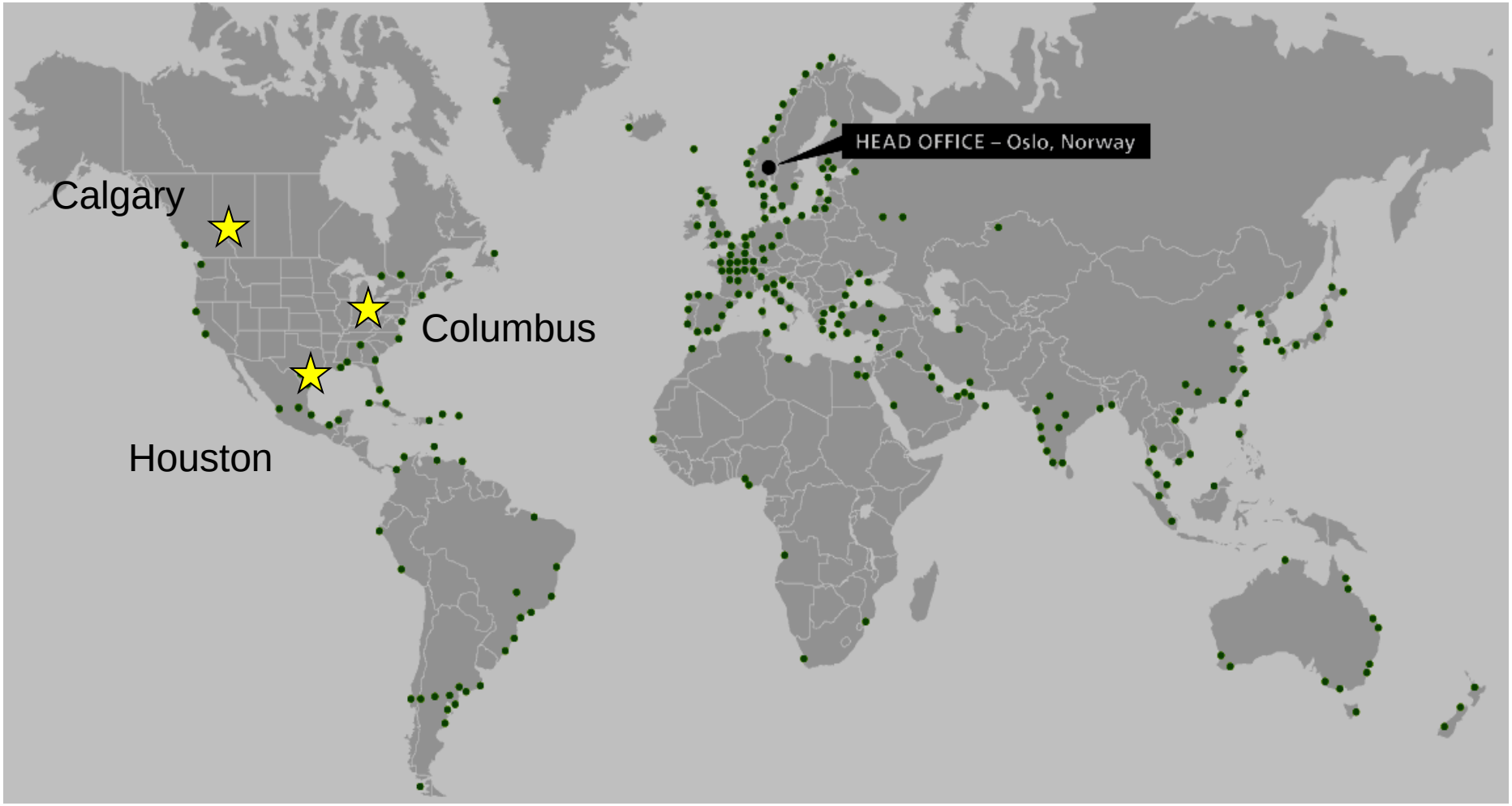
DNV Onshore Pipeline Services

Colin Scott, DNV Materials and Corrosion Technology Center

MANAGING RISK

Onshore Pipelines and Facilities

DNV Worldwide



DNV Columbus

DNV Columbus – Clients worldwide

- BP
- Buckeye Pipelines
- Chevron
- Colonial
- Conoco Phillips
- Enbridge
- ENI
- Enogex
- Enterprise
- Explorer
- Exxon Mobil
- Kinder Morgan
- Marathon
- NiSource / Columbia Gas
- Pacific Gas and Electric
- Pembina
- Petrobras
- PHMSA (Pipeline Hazardous Materials Safety Administration – Federal Authorities)
- PRCI (Pipeline Research Council International)
- Southern Gas
- Talisman Energy
- TOTAL
- TransGas

DNV Columbus – Problem Solving

DNV Columbus Organization

- Asset Risk Management
  - Integrity Solutions
    - Integrity Management
    - Risk Management
  - External Corrosion Services
  - Internal Corrosion Services
  - Welding Technology
  - Inspection Services
- Materials and Corrosion Technology Center
  - Laboratory Services
  - Research
  - Failure Analysis
  - Litigation Support Services

Integrity Management

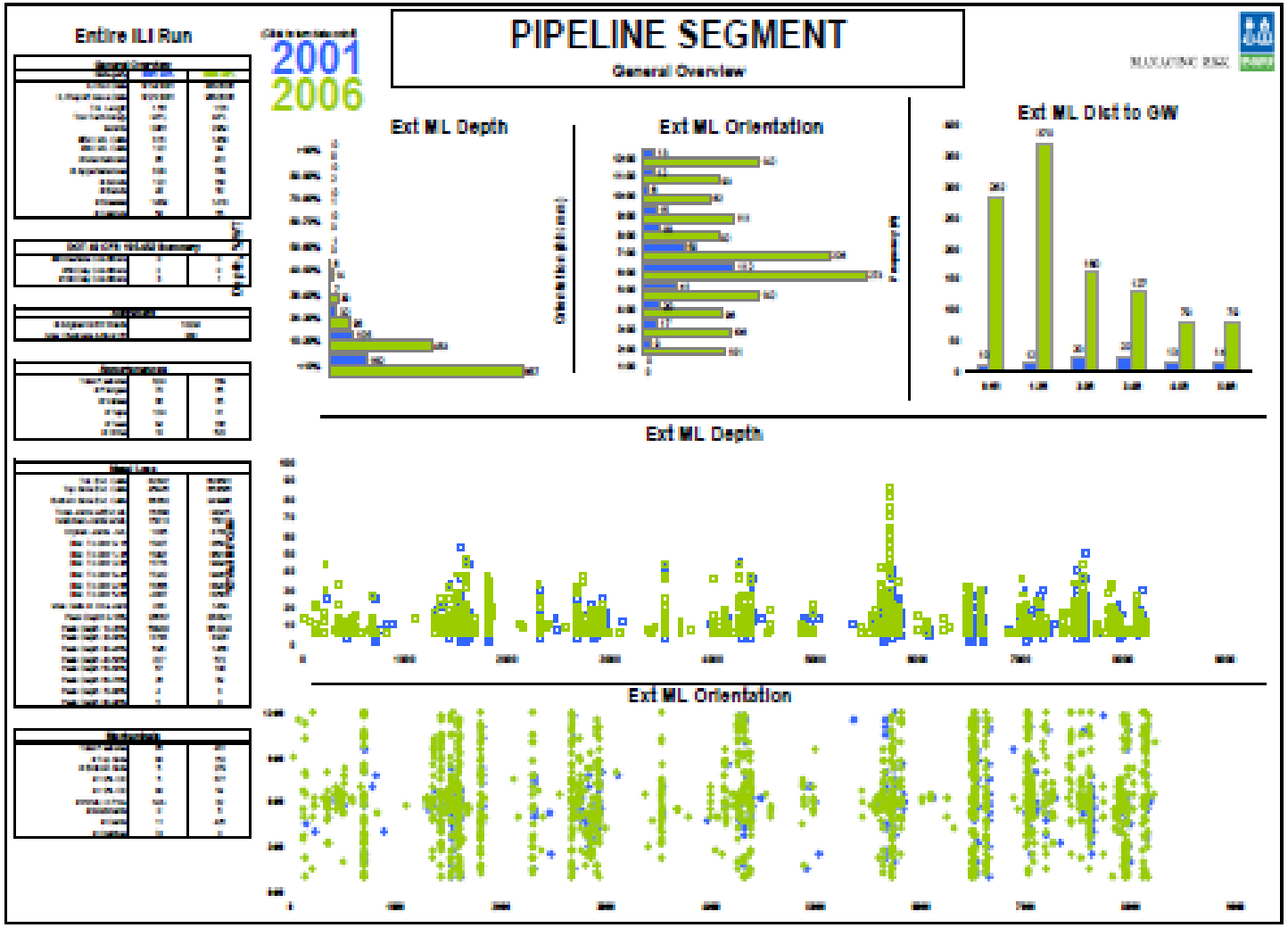
- Integrity Management Program Support
  - Planning – threat assessment, implementation strategies
  - Program validation, gaps analysis and audit support
  - Interpretation and application of regulations, standards, and industry practice
  - Process and procedure audits
  - Regulatory compliance

- Risk Informed Decision Making
  - Threat assessment for pipelines and facilities
  - Software tools to model and measure the likelihood and consequence of failure
  - Computer and laboratory simulations
  - Incident investigations
  - Risk management

Integrity Management (2)

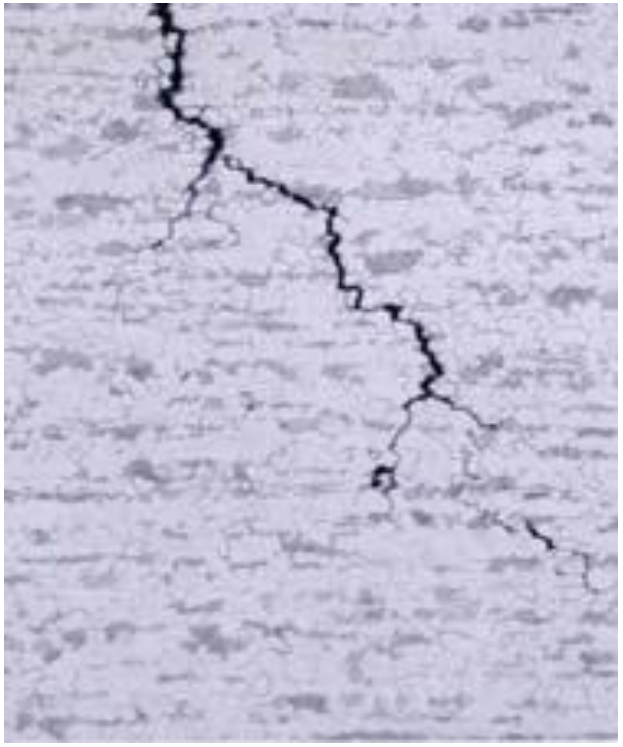
- In-Line Inspection Support
  - Data alignment and interpretation
  - Remediation planning, prioritization
  - Run comparisons – statistically active corrosion
  - Remaining life, time to failure calculations
  - Inspection intervals
- Direct Assessment (ECDA, ICDA, SCCDA)
  - Program feasibility, planning, execution
  - Data integration
- Hydrostatic Testing
  - Review of pipeline operations and service failure history
  - Establish remaining life of “just surviving” defects
  - Determine effects of fatigue
- Training and workshops

In Line Inspection Data Analysis

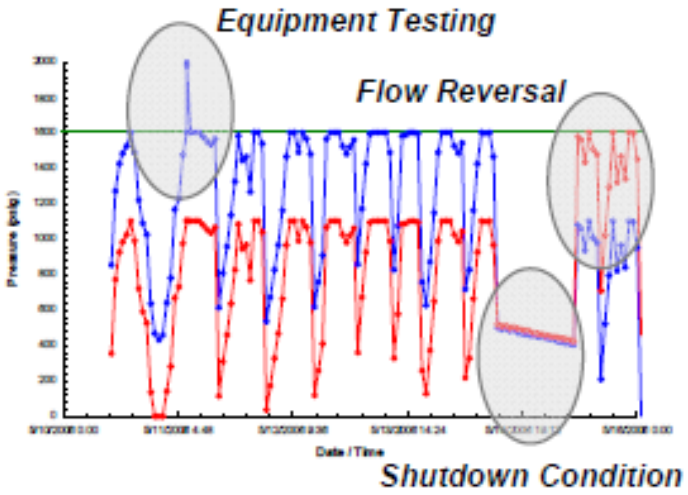


Failure Avoidance and Asset Life Extension

- Fitness-for-Service / Engineering Critical Assessments
- Defect assessments
  - Corrosion
  - Cracking
  - Mechanical damage
- Failure pressure calculations
  - AMSE Remaining Strength
  - API 579 Assessments
  - BS 7910 Assessments
  - DNV OS-F101 ECA
  - DNV's proprietary CorLAS™ Software
  - Dent / bending strain calculations



Failure Avoidance and Asset Life Extension (2)



Pipeline Pressure Data (Sample)
(1 year of 5-minute readings desired)

- Fatigue Analysis
  - Rainflow cycle counting
  - Monte Carlo simulations
- Fatigue crack growth rates
  - In air
  - Stress corrosion cracking in both neutral and high pH environments
  - Sulfide stress cracking in hydrogen sulfide service
- Calculation of re-assessment intervals

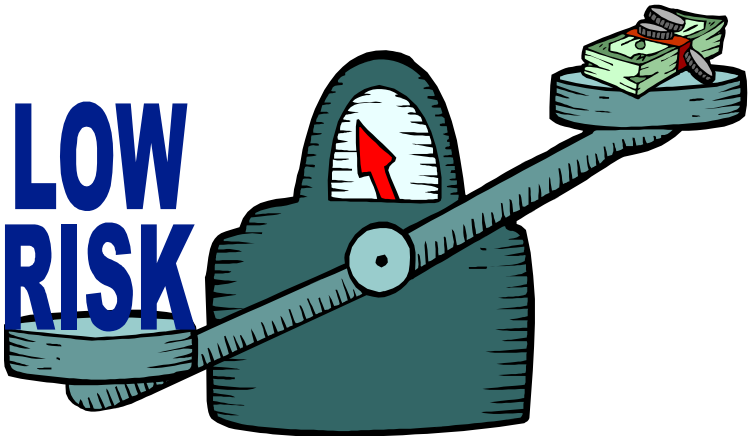
Risk Management

- "Risk" considers both "probability" and "consequences" of failure

Probability Ranking (PoF)		Risk Category				
5	**Expected failure (>10^{-2})**					
4	**High (10^{-3} -10^{-2})**				A	
3	**Medium (10^{-4} -10^{-3})**			B		
2	**Low (10^{-5} -10^{-4})**	C				
1	**Negligible (<10^{-5})**					
Consequence Category		A	B	C	D	E

Risk Management (2)

- Threat identification
  - External corrosion
  - Internal corrosion
  - Third party mechanical damage
  - Natural forces
- Determine probability and consequences of failure (= RISK)
- Determine risk ranking for pipelines / components in a given system



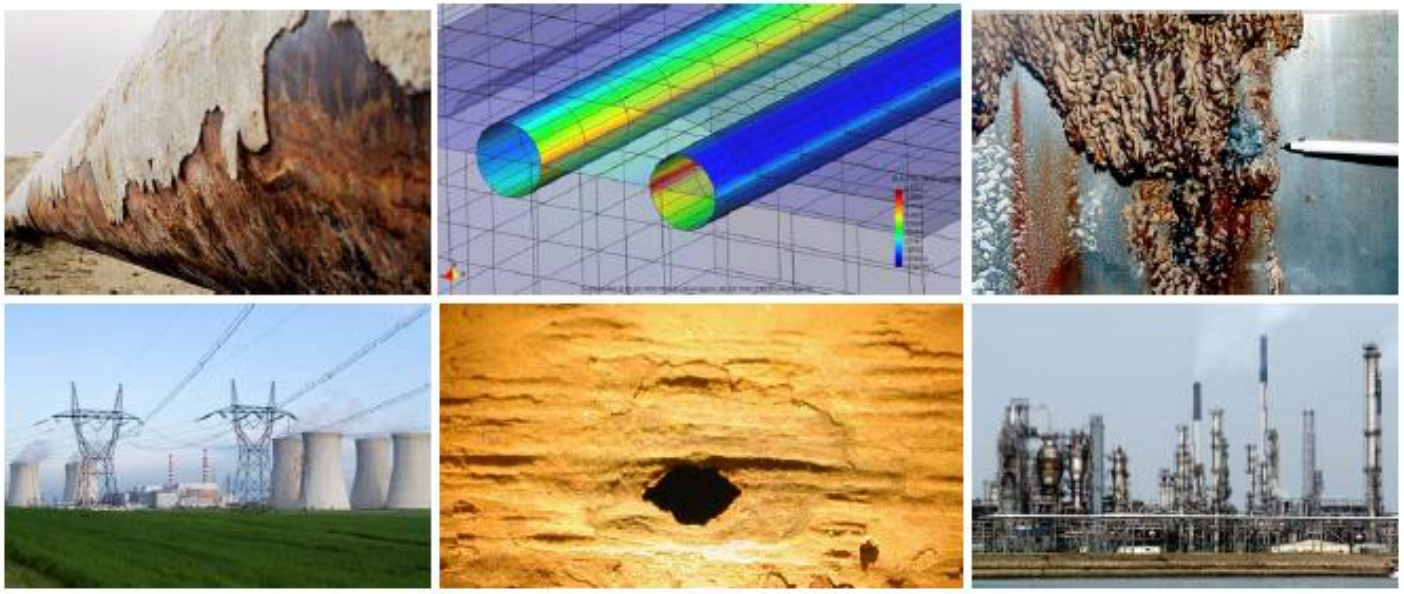
- Focus on high risk
- Focus on high consequences
- Focus on high risk reduction
  - Where should money be spent to gain the most benefit??

External Corrosion Services

- External Corrosion Direct Assessment support
- Cathodic protection system, design and review
- Close interval potential surveys
- Stray current surveys
- Coating evaluation
- Soil testing
- Anode testing
- Corrosion monitoring / coupon analysis

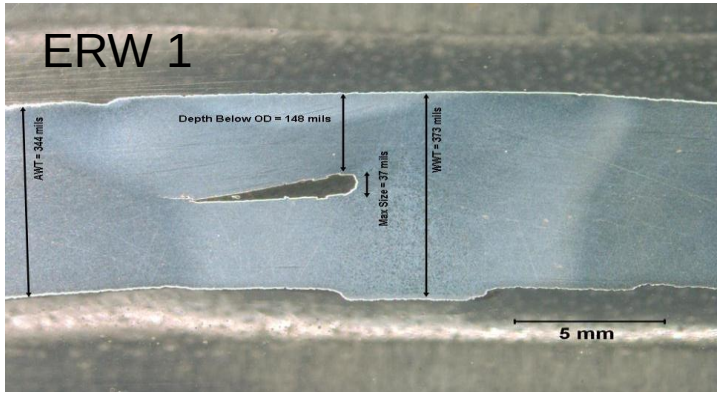
Internal Corrosion Services

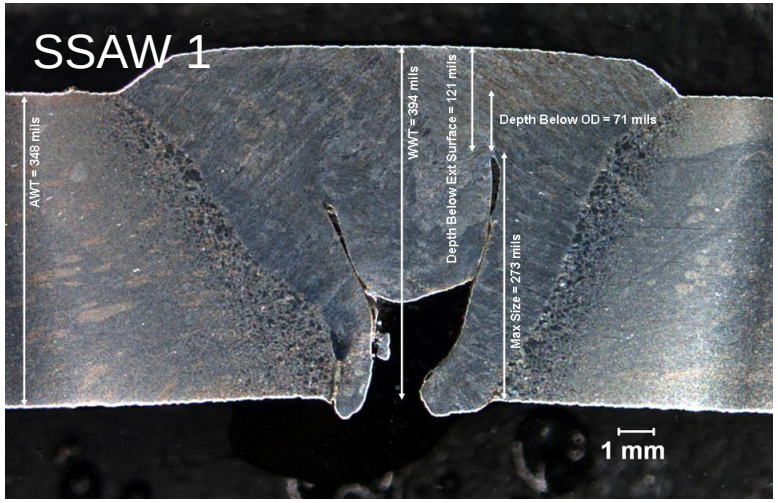
- Internal Corrosion Threat Assessment
  - Review of in-line inspection data
  - Review of inhibitor use
  - Internal corrosion decision tree
  - CorrMD software
- Internal Corrosion Direct Assessment
  - Review of current operations
  - Flow modelling
  - On-site dig support
  - Determine re-assessment intervals
  - Identify areas for cost savings
  - Corrosion monitoring / coupon analysis



Welding Technology

- Design of welding procedures
- Review of welding procedures
- QA / Auditing of pipe mills
- Examination of failed welds
- Repair strategies





Laboratory Services

- 3,000 m² facility
  - Failure analysis laboratory
    - Metallography
    - Stereo microscope
    - Scanning electron microscope
    - Energy dispersive X-ray spectroscopy for chemical analysis of alloys and corrosion products
  - Sour service laboratory; exposure, fracture and fatigue testing in hydrogen sulfide
    - Over 50 autoclaves for high pressure / temperature testing
  - Electrochemistry; potentiostatic, galvanostatic testing
  - Sacrificial anode testing
  - Flow loop - 4 inch diameter, up to 1 MPa and 130 °C, inclined

Research – Stress Corrosion Cracking Near Pipeline Dent

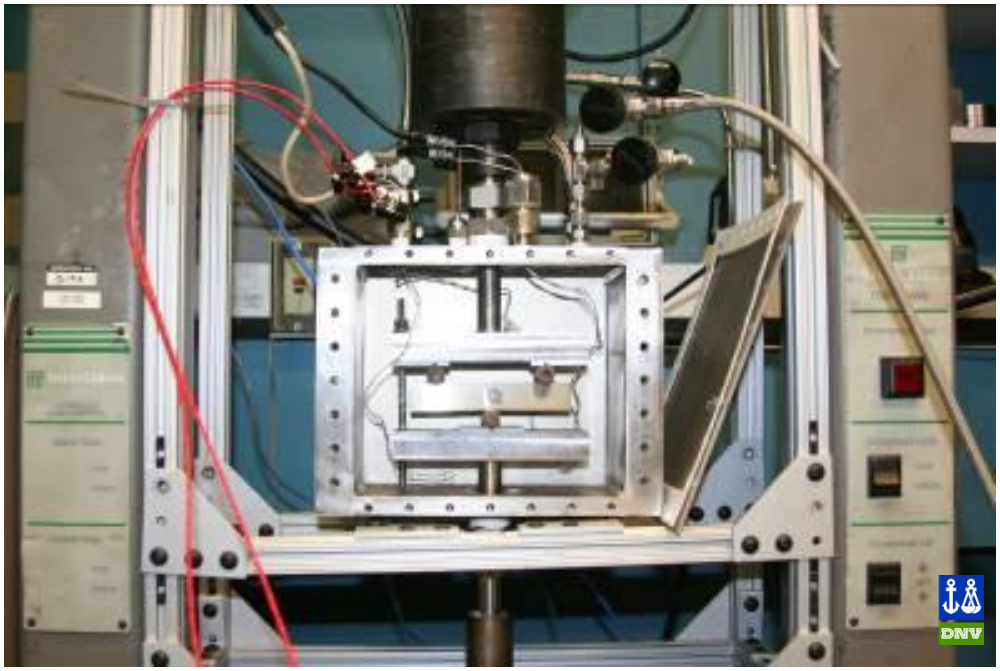
- Simulated rock dent introduced to a length of pipeline
- Crack introduced in the shoulder of the dent, fatigue pre-cracked

- Pipe ends are sealed and clip gages attached to defect
- Pipe hydrotested with cycling pressure to study crack near dent

Research – Fatigue in Hydrogen Sulfide Service

Critical Issues

- Reeling operations to install pipelines in hydrogen sulfide environments could pose potential design issues due to corrosion fatigue
- Determining the knockdown factors in design is critical to inspections and operation.



Solution

- Develop corrosion fatigue measurement capability in hydrogen sulfide environments.
- Determine fatigue behaviour of reeled pipe in hydrogen sulfide environments.
- Determined that the knock down factor due to reeling was within the design parameters of the pipeline.

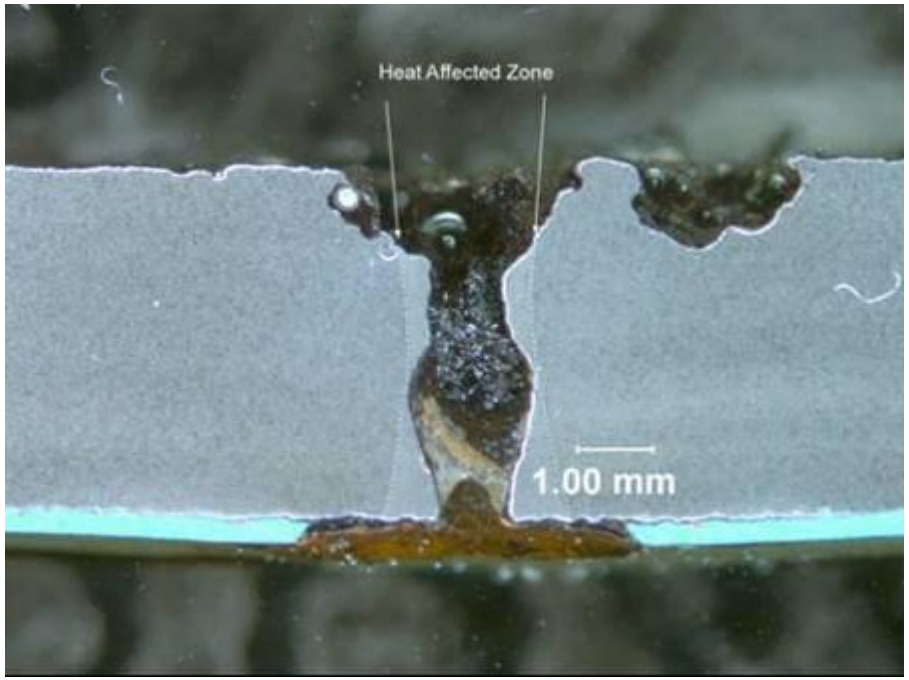
Failure Analysis – majority pipeline / facilities related

- Incident response to assist with evidence preservation and site investigation

- Dimensional analysis
- Examination of fracture surfaces by stereo-microscope and scanning electron microscope
- Examination of microstructures by metallography
- Chemical analysis by optical emission spectroscopy and energy dispersive X-ray spectroscopy
- Mechanical testing – tensile testing, Charpy V-notch impact, and hardness
- Photo and video documentation

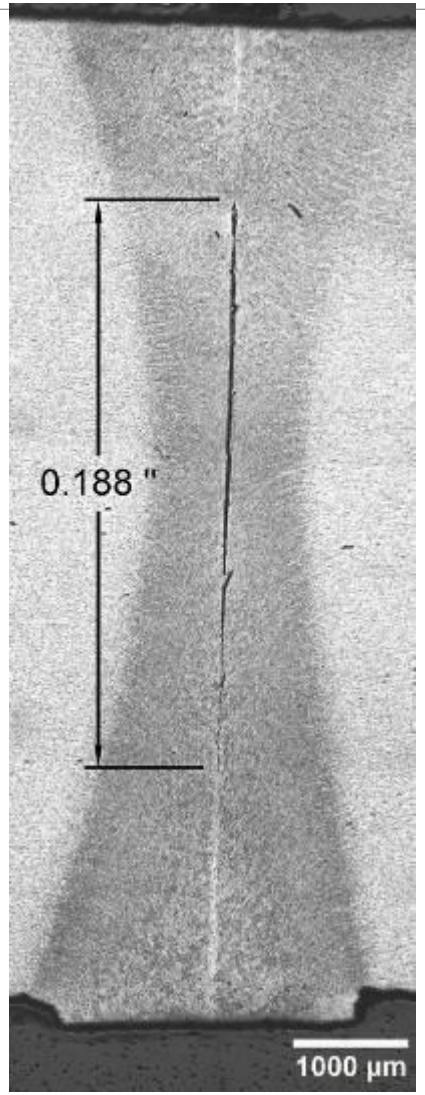
Failure Analysis – Assist Pipeline Integrity

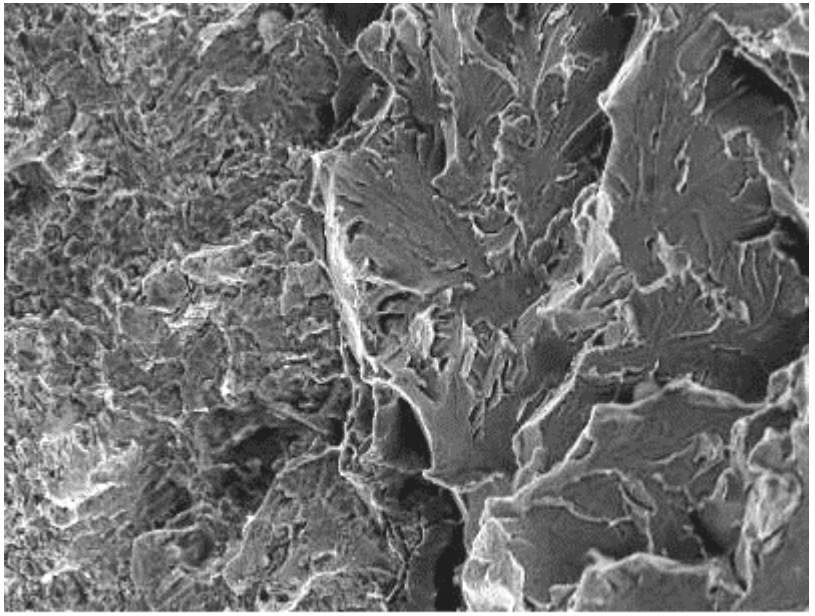
- Internal corrosion of pipeline used to gather water-saturated natural gas
- Pitting susceptibility exacerbated by high residual stress in non-PWHT seam weld



- Leak occurred in gasoline line operating at only 39% MOP
- External corrosion through-wall pitting due to CP shielding and MIC

Failure Analysis – Welding Defect





- Leak occurred in petroleum pipeline operating at 83% MOP
- Analysis revealed pre-existing manufacturing defect in ERW weld seam

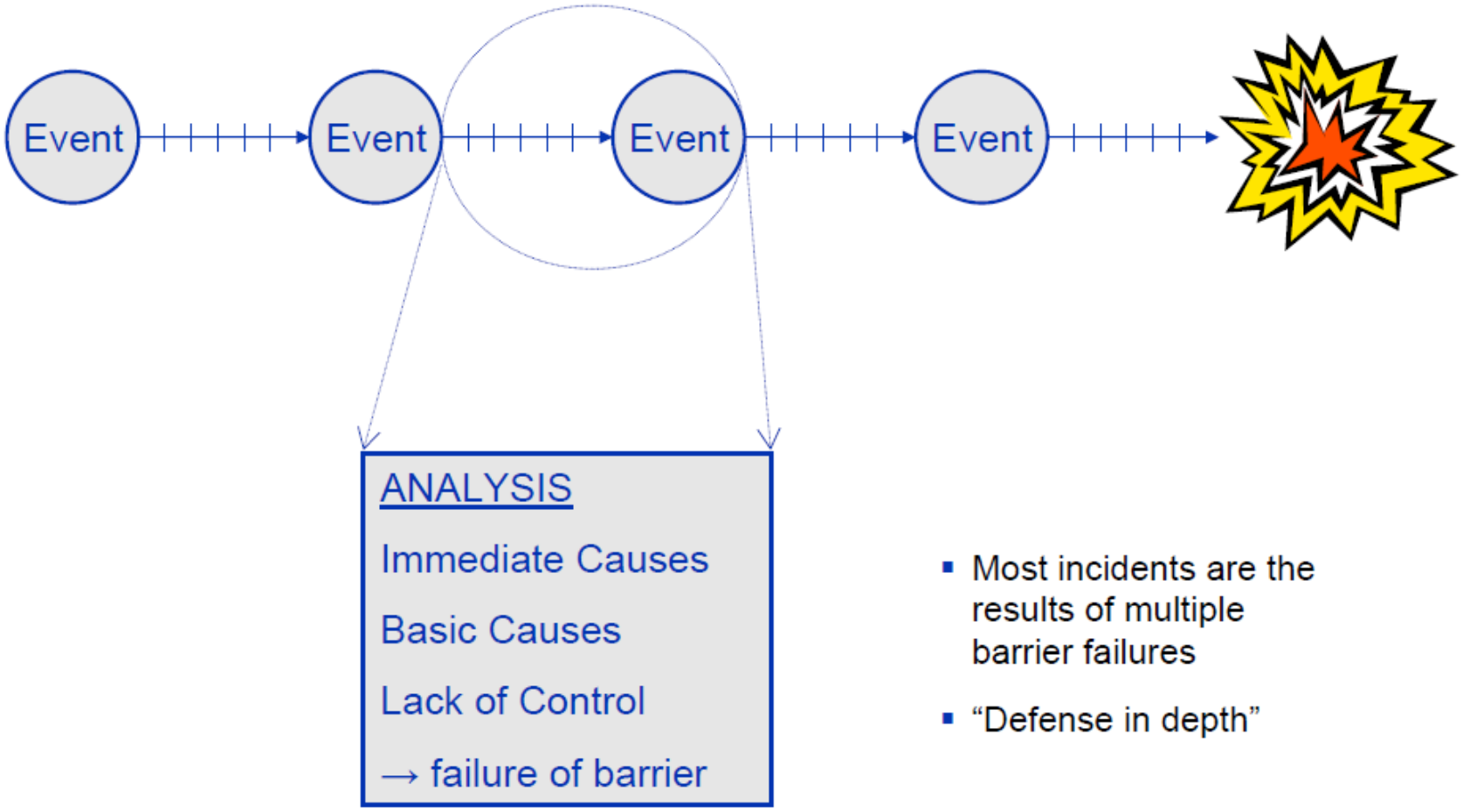
Litigation / Regulatory Support

- Incident response
- Accident site investigation
- Evidence preservation
- Forensic engineering / science
- Expert witness
- 24/7 Emergency Hotline

Forensic Investigations – pipelines and facilities

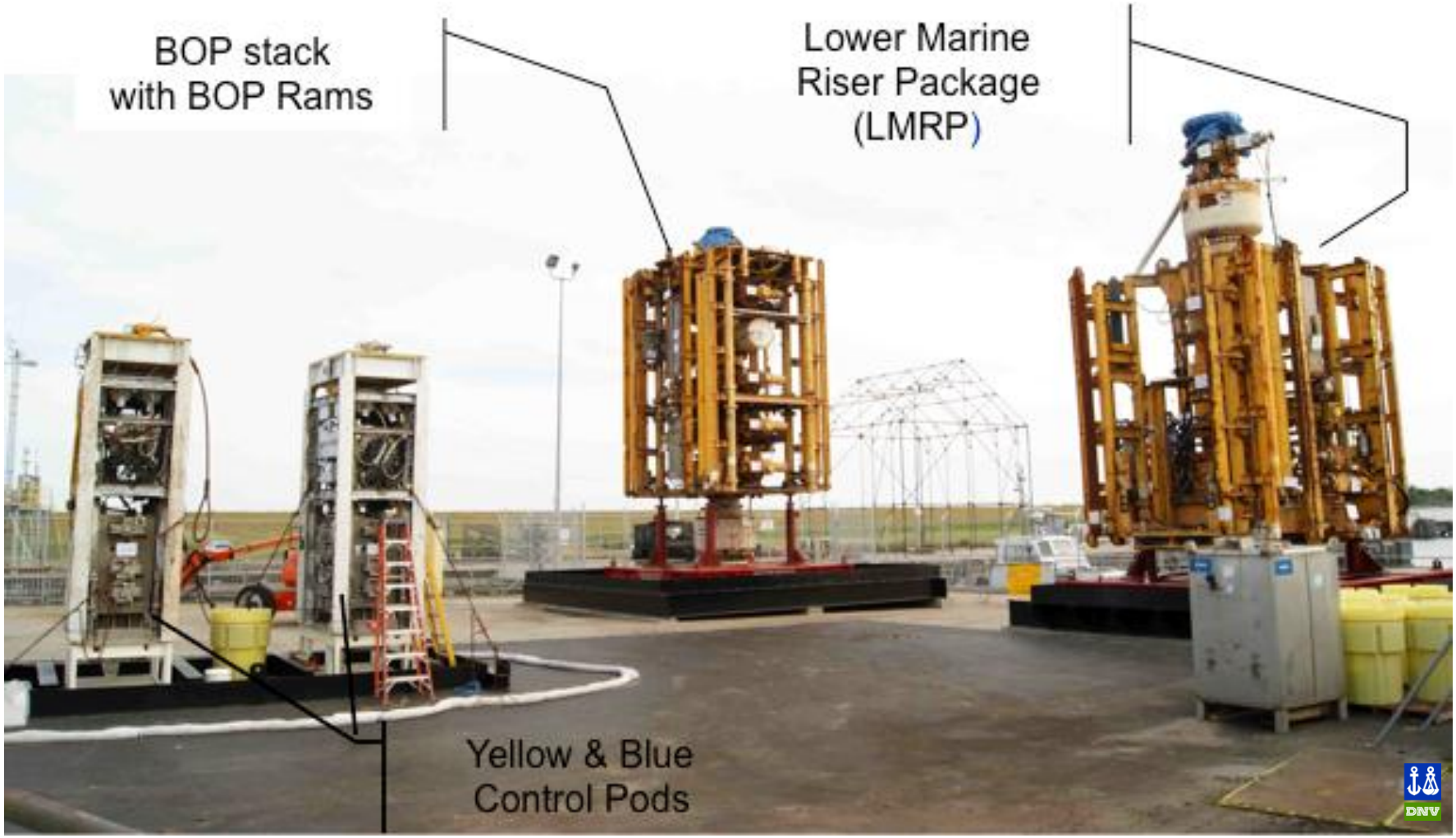
Forensic Investigations – facilities (2)

Root Cause Analysis – DNV SCAT



- Most incidents are the results of multiple barrier failures
- "Defense in depth"

Deepwater Horizon - Gulf Oil Spill –Blowout Preventer



Shale Gas

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Summary of shale gas projects in ANEUS

- Houston Solutions: asset integrity and process safety assessment systematically identifying potential, major accident hazards in a gas gathering system. The project is driven by internal client requirements and some OSHA regulation.
- Houston Solutions: SHE management system audit, some help with regulation and help with an accident investigation.
- Houston Solutions: Development of a risk screening tool for shale gas and coal bed methane wells related to the risks of an environmental hazard such as an accidental emission or spill
- Deepwater Technology: Assessment of potential damage to equipment following an explosion
- Columbus Asset Risk Management: Regular onshore pipelines project: Corrosion studies related to the relatively high amount of oxygen in unconventional gas pipelines
- Columbus Technology Center: Failure investigation related to fatigue of equipment for hydraulic fracturing.

Safeguarding life, property and the environment

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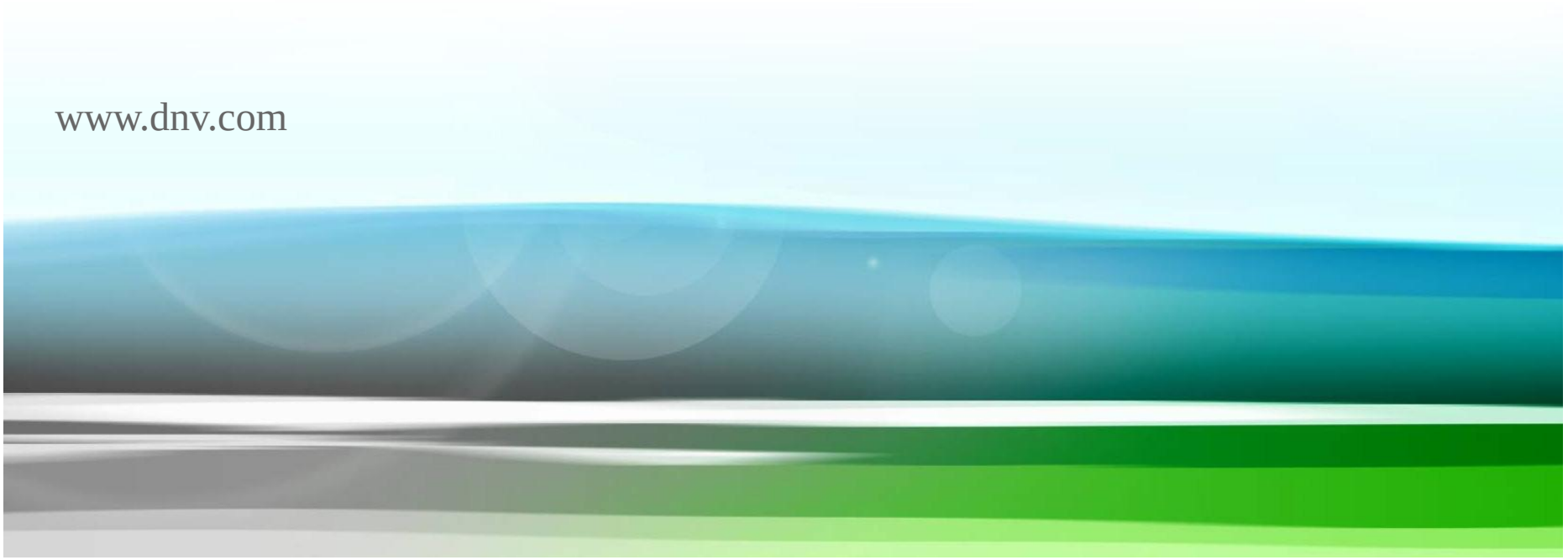

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