Overview of Geologic CO2 Storage

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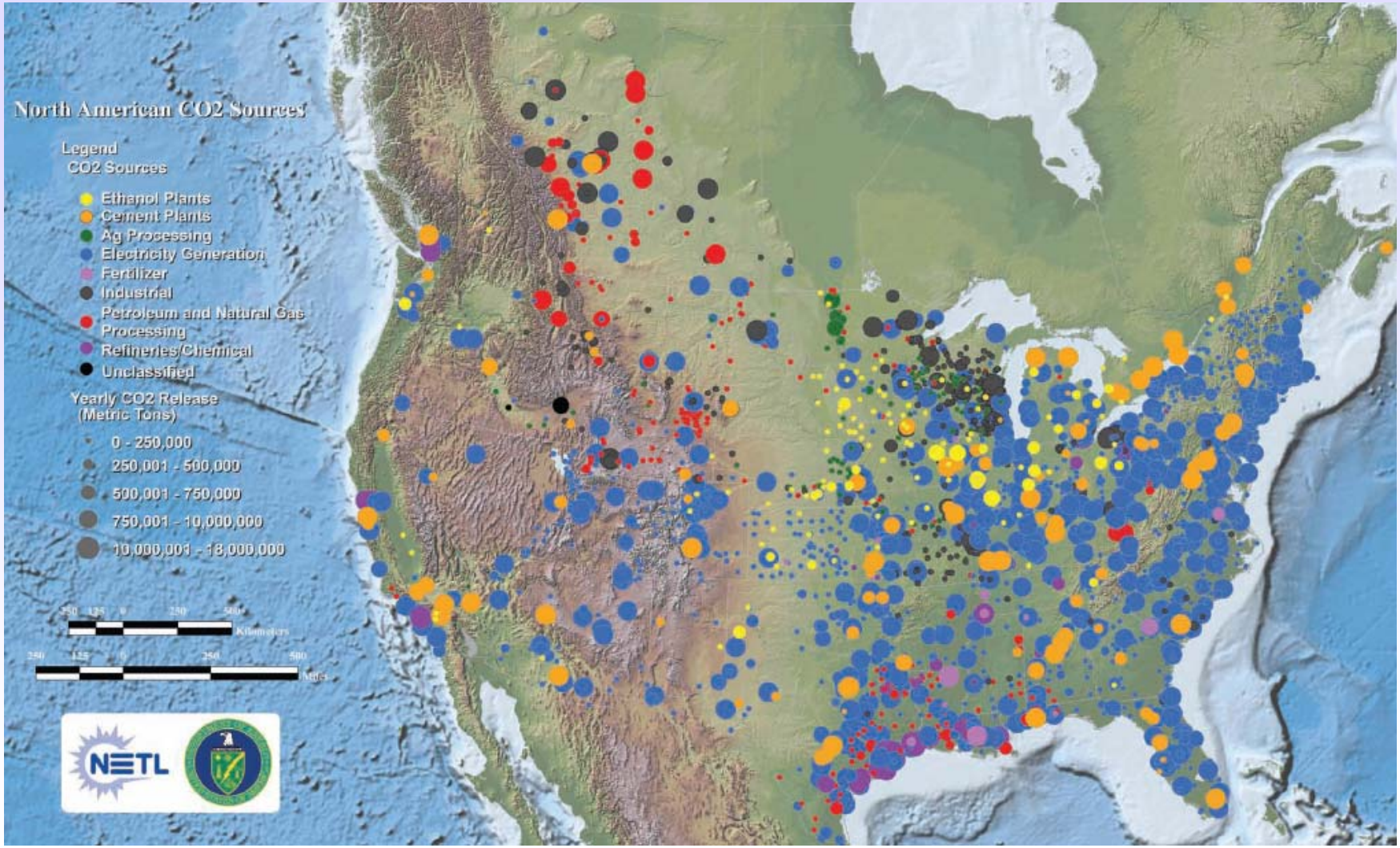
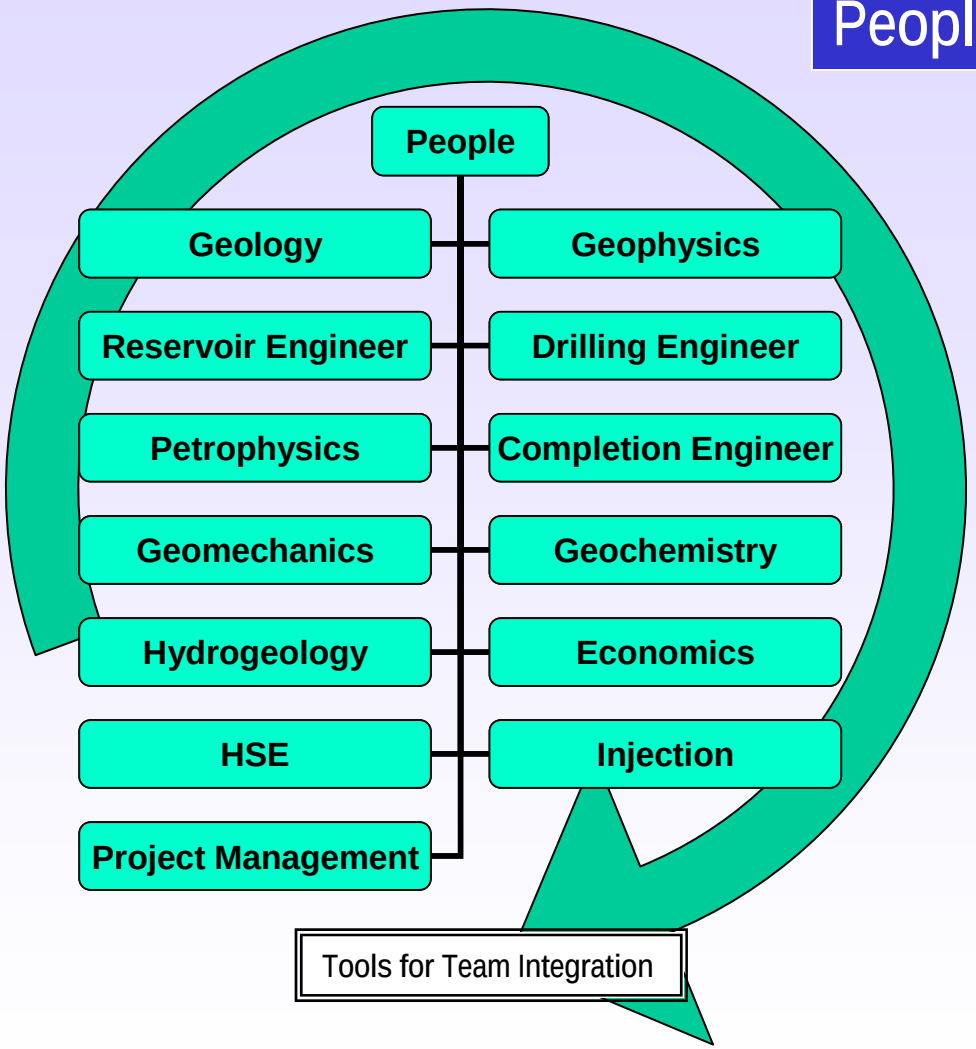
Schlumberger Carbon Services

North American CO2 Sources



What Resources Will Be Needed?



People & Technology

+

CO2 Technology
Seismic Services
Wellbore Integrity Evaluation
Drilling & Completion
Cementing
Logging, Testing & Sampling
Lab Analysis
Data Processing
Modeling & Prediction
Data Management
Monitoring

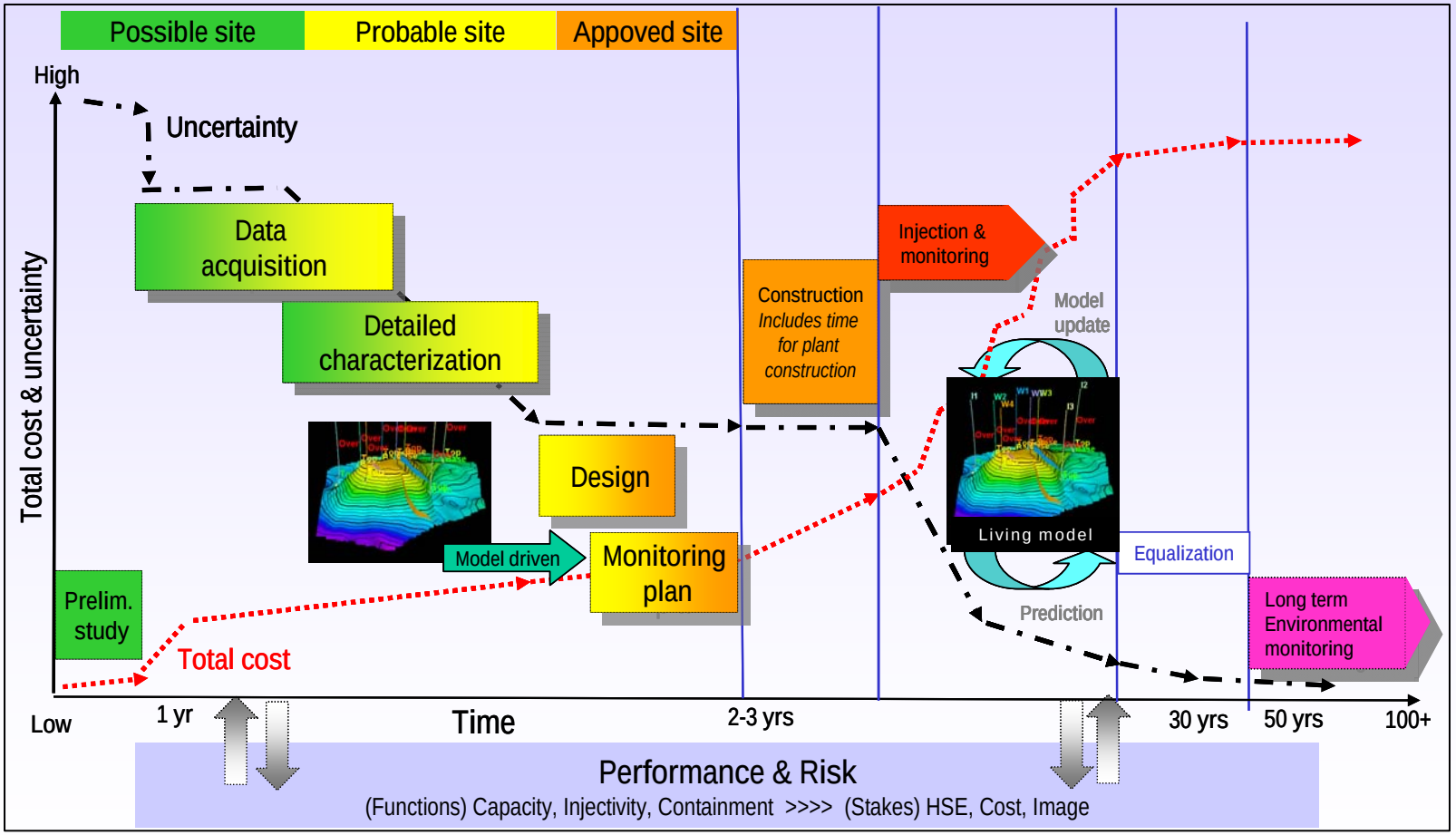
Storage Timeline

- Area of review estimate
- Ownership?

- Area of review refined
- Permit application?

- Periodic review?

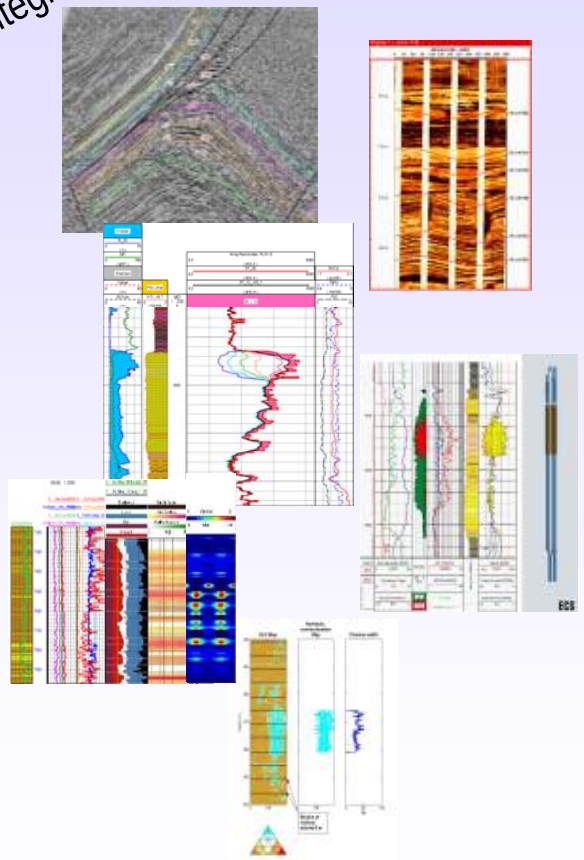
- Closure?
- Release of Liability?



Designs Will Be Site Specific

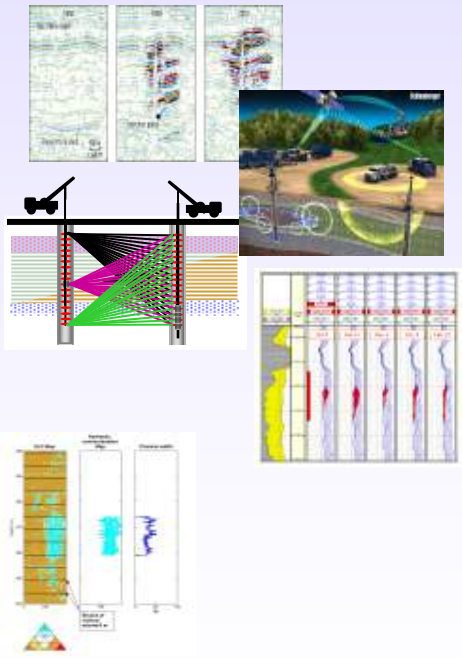
Characterization Tools

	Reservoir Structure & Geology	Petrophysics / Mineralogy	Geomechanics	Fluid Properties	Well Integrity
Seismic / VSP	X		X		
Imagers	X		X		
ρ, Pe, Φ_N, Rxo, Rt			X	X	X
Spectroscopy		X			
Sonics		X	X		X
Sampling			X	X	
Coring	X	X	X	X	
Ultrasonic					X
Corrosion					X

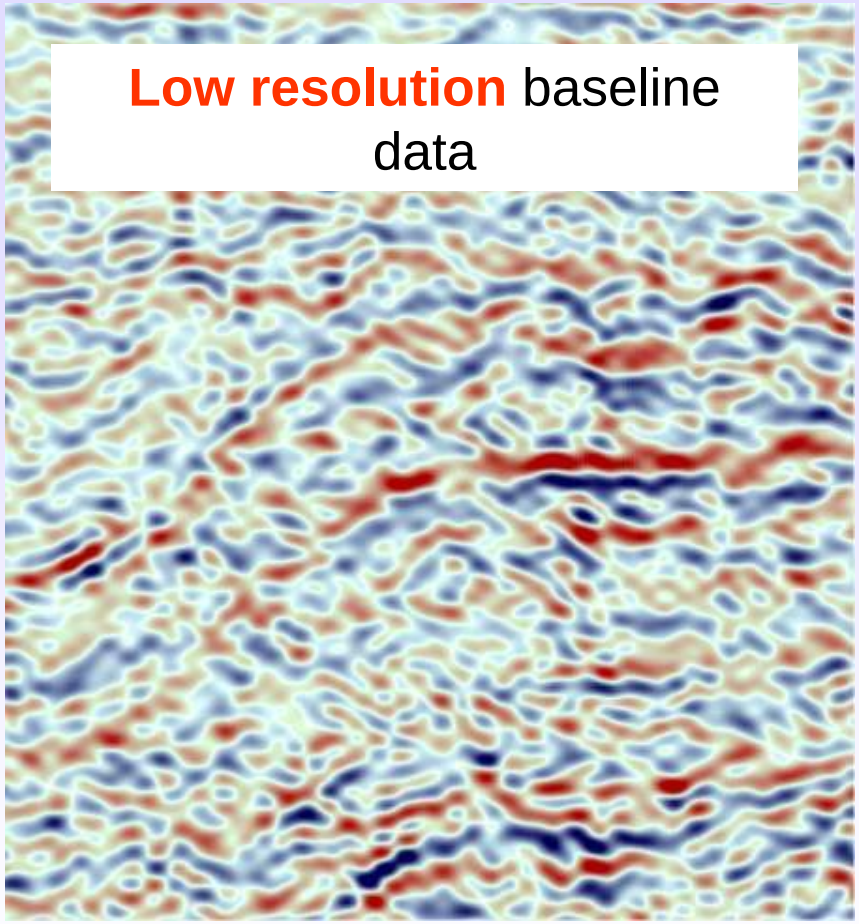


Monitoring Tools

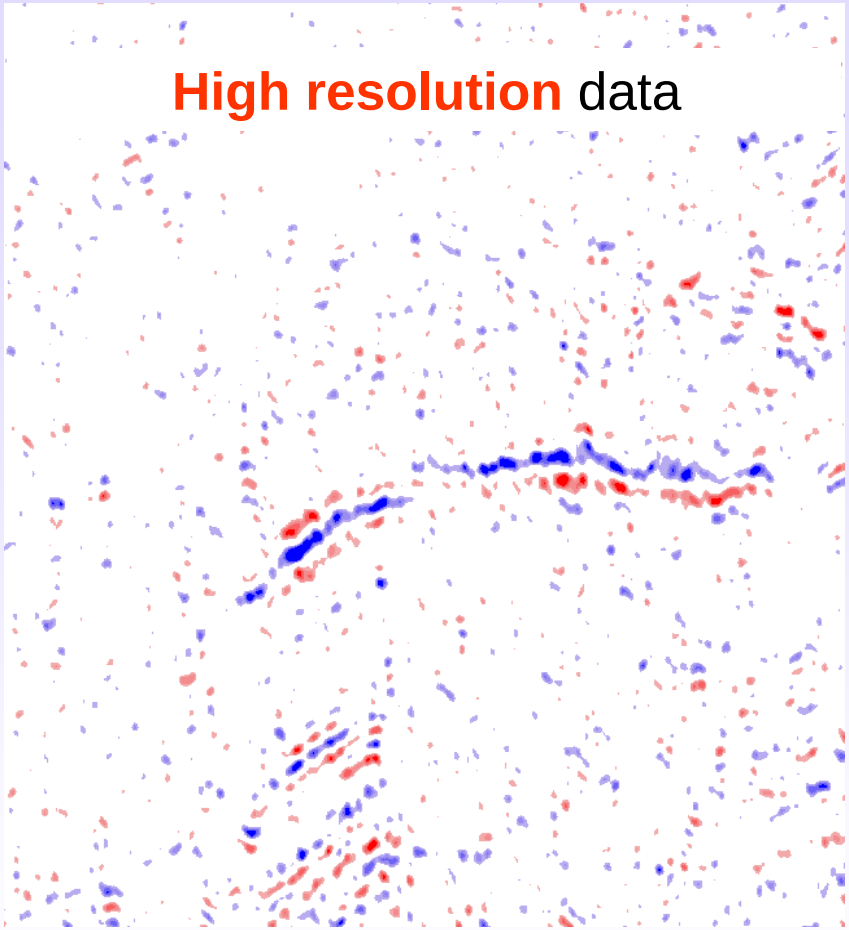
	Operation Monitoring	Verification Monitoring – CO2 Displacement	Verification Monitoring – Cap rock integrity	Verification Monitoring – Well Integrity	Environment Monitoring
P,T, Volume, Rate	X				
Seismic / VSP		X	X		
Microseismicity	X	X	X		
EM Surveys		X			
Cased hole logging		X			
Sampling		X			X
Pressure tests			X		
Sonics				X	
Ultrasonic				X	
Corrosion				X	



Hi-resolution Seismic for Monitoring

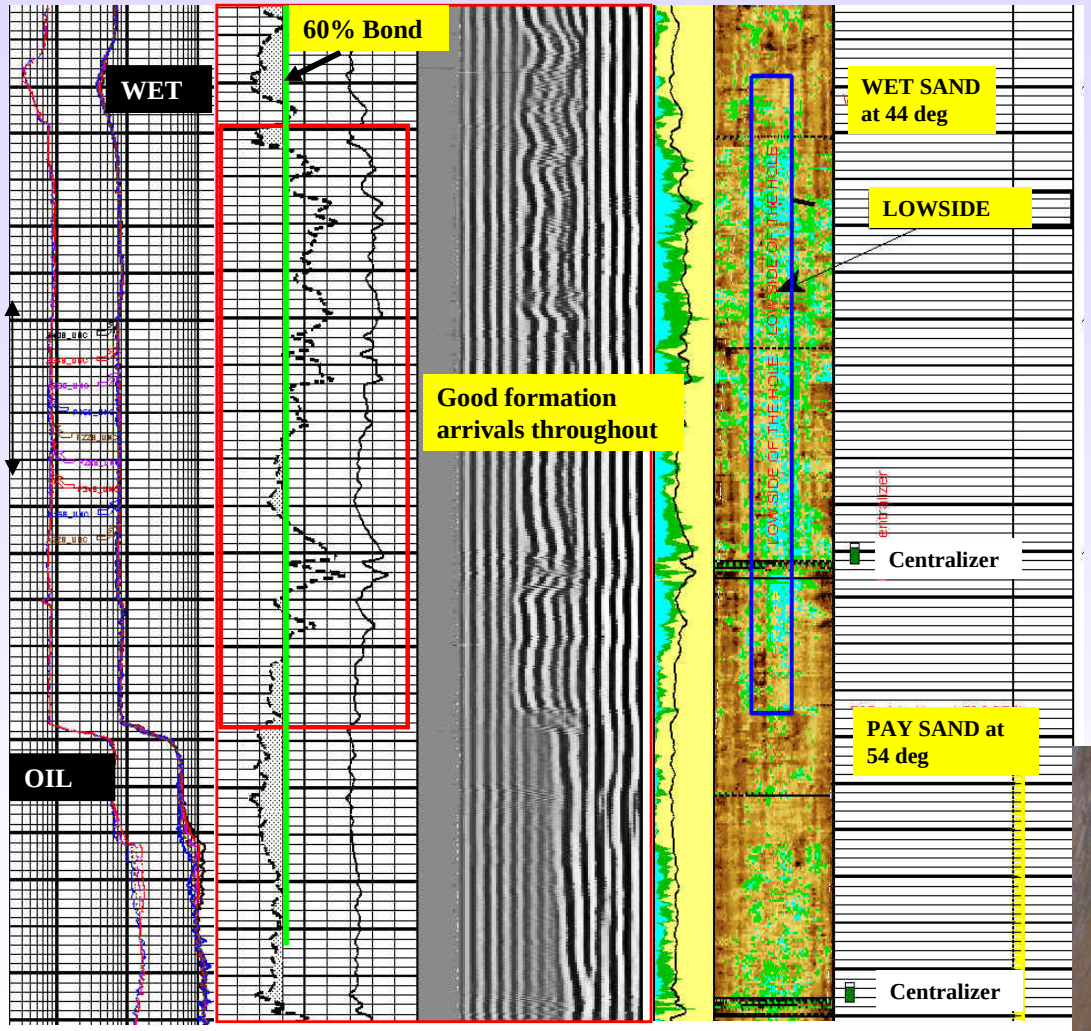


Overlay of 1992 & 2001 data

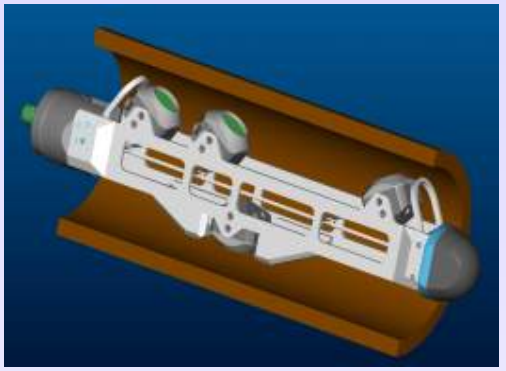


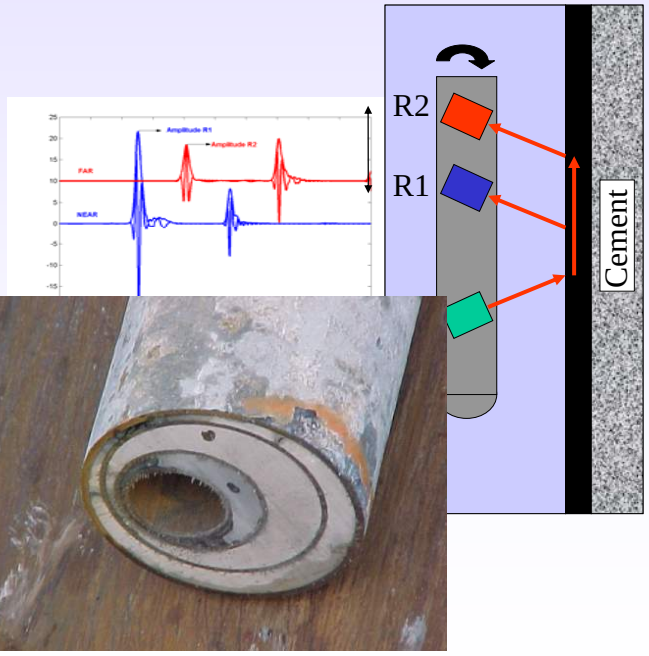
Overlay of 2001 & 2003 data

Evaluating Wellbore Integrity



Isolation Scanners





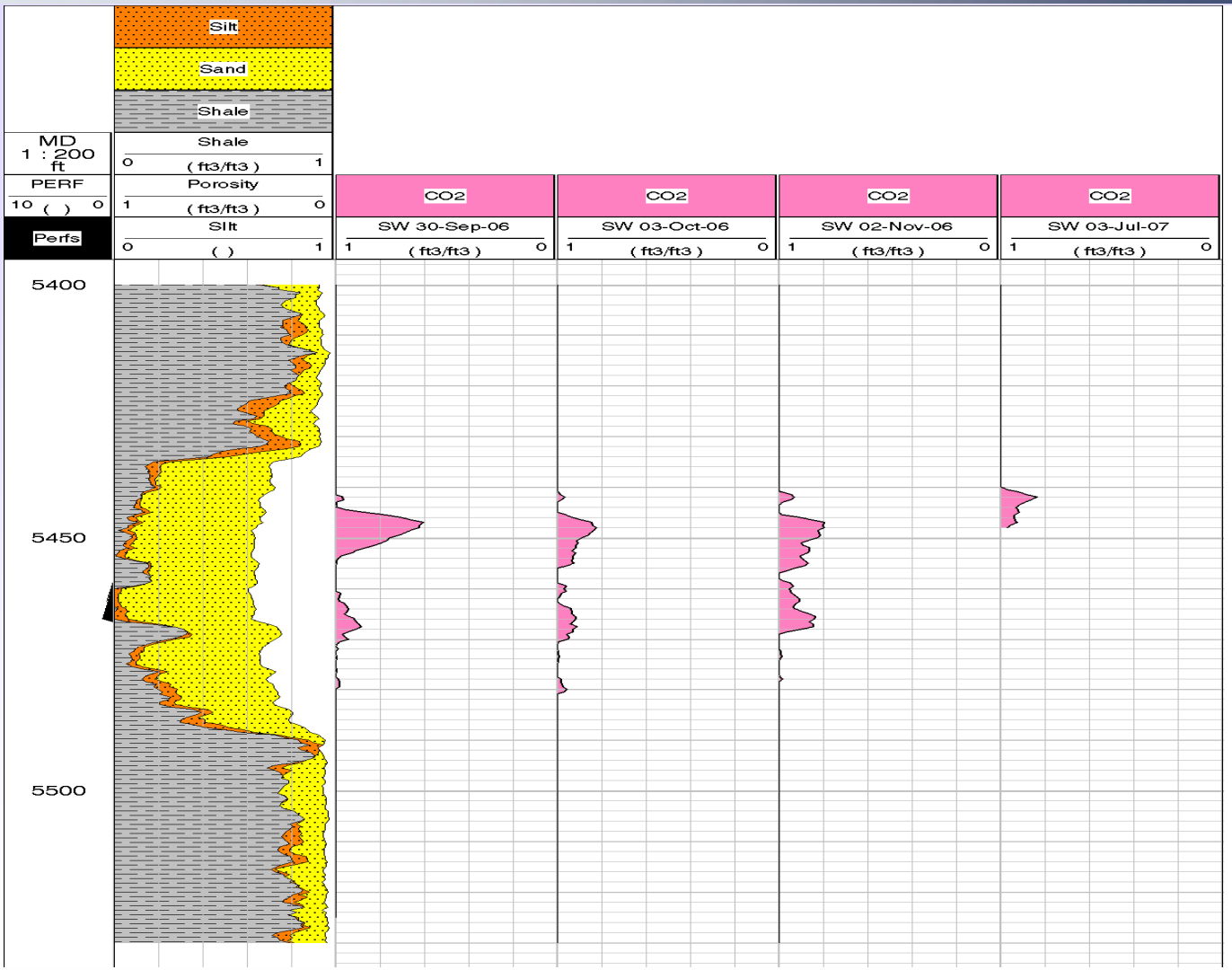
Measurement Deployment Example

Well type	Measurement	Interval	Usage	Tool
All		All	Define space available for storing CO2, or points for accumulation above storage zone	
All		Zones and caprock	Correct porosity measurements for lithology effects, input to geochemical models, input to geomechanical model, input to seismic design	
All		All	Correlation between wells, water salinity estimation	
All		Zones and caprock	Calculate injectivity, movement, and seal	
Injection		Zones	Set initial reservoir conditions, calculate storage potential	
All		Zones	Geochemistry, CO2 saturations	
Injection		Zones and caprock	Flow studies, porosity, permeability, geochemistry studies, lithology, deposition	
All		Zones and caprock	Identify faults, open and healed fractures, formation structure, deposition	
Injection		Zones and caprock	Caprock toughness, injection pressure limits, seismic survey design, build geomechanical model	
Injection		Zones and caprock	Reservoir heterogeneity, static stress field, seismic survey design and interpretation	
All		Zones	Estimate capillary trapping, “sweep”, irreducible water saturation	
All?		Zones and caprock	Image structure away from wells, image faults, time/depth tie, surface seismic design, time-lapse plume imaging in specific directions	
All		All	Verify isolation, cement/casing interface, cement/formation interface	
All		All	Internal corrosion, external casing corrosion, packer/plug seat evaluation	
All		Zones and caprock	Baseline and time-lapse plume height and saturation, leakage into “accumulation zone”, linear sensitivity to CO2 saturation	
All		Zones and caprock	Stress anisotropy changes, very sensitive to low CO2 saturation changes	
Injection		Zone	Injectivity profile over perforated interval, their zone identification	
Injection		Zone and caprock	Calibrate frac initiation and closure pressures for reservoir and the seal	
Monitor		Zone and caprock	Image plume development away from the injection well	
Injection		Zone	Input to model reservoir injection rate and pressure response, reservoir barrier analysis	

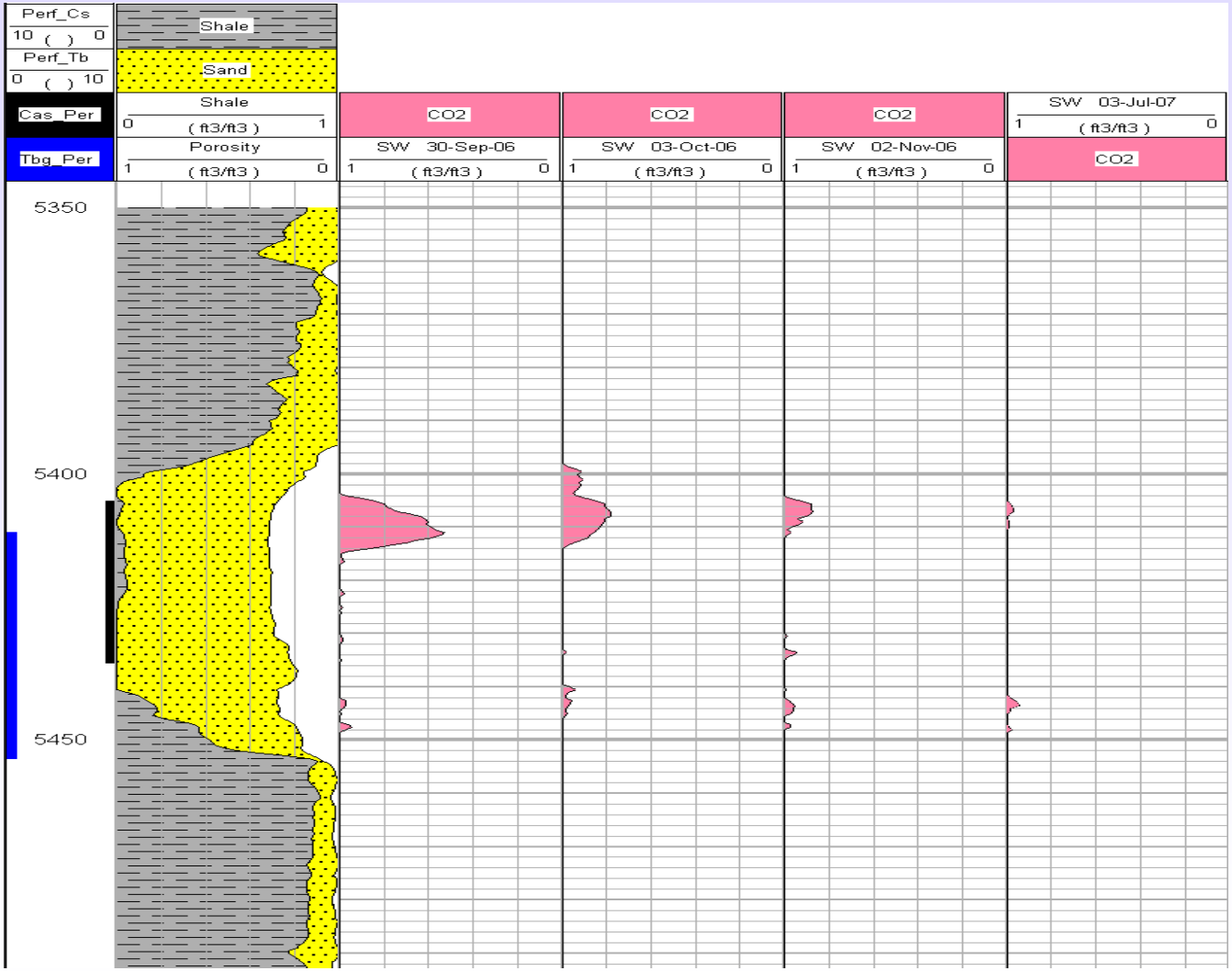
Measurement Deployment Example

Well type	Measurement	Interval	Usage	Tool
All	Porosity	All	Define space available for storing CO2, or points for accumulation above storage zone	Platform Express, CMR, Sonic Scanner
All	Rock lithology	Zones and caprock	Correct porosity measurements for lithology effects, input to geochemical models, input to geomechanical model, input to seismic design	Platform Express, ECS, Sonic Scanner
All	Resistivity and SP	All	Correlation between wells, water salinity estimation	Platform Express
All	Permeability	Zones and caprock	Calculate injectivity, movement, and seal	CMR, PressureXpress, MDT
Injection	Fluid pressure	Zones	Set initial reservoir conditions, calculate storage potential	PressureXpress, MDT
All	Fluid samples	Zones	Geochemistry, CO2 saturations	MDT sampling
Injection	Core samples	Zones and caprock	Flow studies, porosity, permeability, geochemistry studies, lithology, deposition	Rotary cores
All	Borehole images	Zones and caprock	Identify faults, open and healed fractures, formation structure, deposition	FMI
Injection	Rock mechanical properties	Zones and caprock	Caprock toughness, injection pressure limits, seismic survey design, build geomechanical model	Sonic Scanner, Density from Platform Express
Injection	Anisotropy	Zones and caprock	Reservoir heterogeneity, static stress field, seismic survey design and interpretation	Sonic Scanner
All	Pore size	Zones	Estimate capillary trapping, “sweep”, irreducible water saturation	CMR
All?	Borehole seismic	Zones and caprock	Image structure away from wells, image faults, time/depth tie, surface seismic design, time-lapse plume imaging in specific directions	Zero offset and offset VSP’s
All	Cement evaluation	All	Verify isolation, cement/casing interface, cement/formation interface	Isolation Scanner, CBL
All	Casing corrosion	All	Internal corrosion, external casing corrosion, packer/plug seat evaluation	Isolation Scanner, multi-finger caliper
All	Through-casing pulsed neutron	Zones and caprock	Baseline and time-lapse plume height and saturation, leakage into “accumulation zone”, linear sensitivity to CO2 saturation	RST
All	Through-casing sonics	Zones and caprock	Stress anisotropy changes, very sensitive to low CO2 saturation changes	Sonic Scanner
Injection	Production logs	Zone	Injectivity profile over perforated interval, their zone identification	PS Platform
Injection	Mini-frac	Zone and caprock	Calibrate frac initiation and closure pressures for reservoir and the seal	MDT mini-frac
Monitor	VSP	Zone and caprock	Image plume development away from the injection well	VSI, vibe trucks, processing
Injection	Injectivity and falloff test	Zone	Input to model reservoir injection rate and pressure response, reservoir barrier analysis	Well test

Logging Example: RST in Frio II Injection Well



RST in Frio II Observation Well



Keys to Success

- Pick the Right Site
  - Non-complex, depth, porosity, perm, extent, structure, caprock…
  - Some existing wells, but not many
  - Access and capability for: 3-D seismic acquisition, logs, core, fluids, background
- Use the Right Technology
  - Proper density, resolution, noise limits, area of review
  - Value equivalent uncertainty reduction
  - Has impact on performance and risk
- Properly Integrate the Data
  - Requires an experienced, skilled, multi-disciplinary team.
  - Unified modeling environment
  - Shared earth model, easily updatable - “Living”

Summary

- Non-technical factors are key to progress
- Clear regulatory guidelines and and long term liability protection are needed for commercial involvement.
- Resource requirements will be large
- Uncertainties and risks can be lowered with technology.
- Technology must be valued
- Proper baseline characterization is the key to reducing cost:
  - Number of wells, frequency of monitoring
  - Public acceptance