



# Carbon Storage and Management

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3–4 SEPTEMBER 2024 | KUALA LUMPUR, MALAYSIA

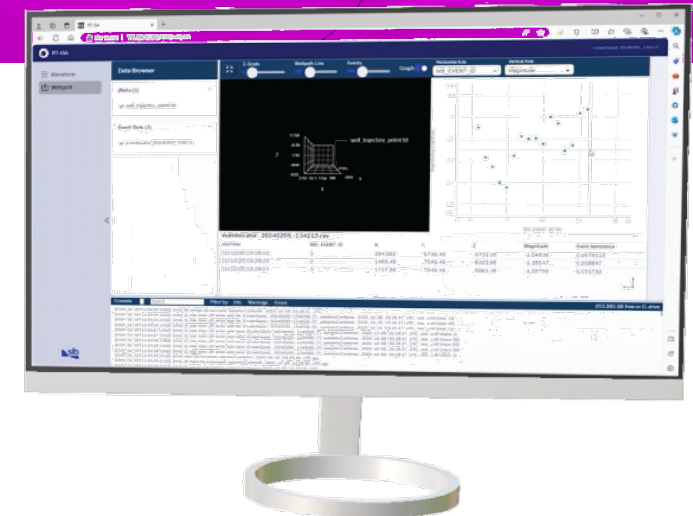
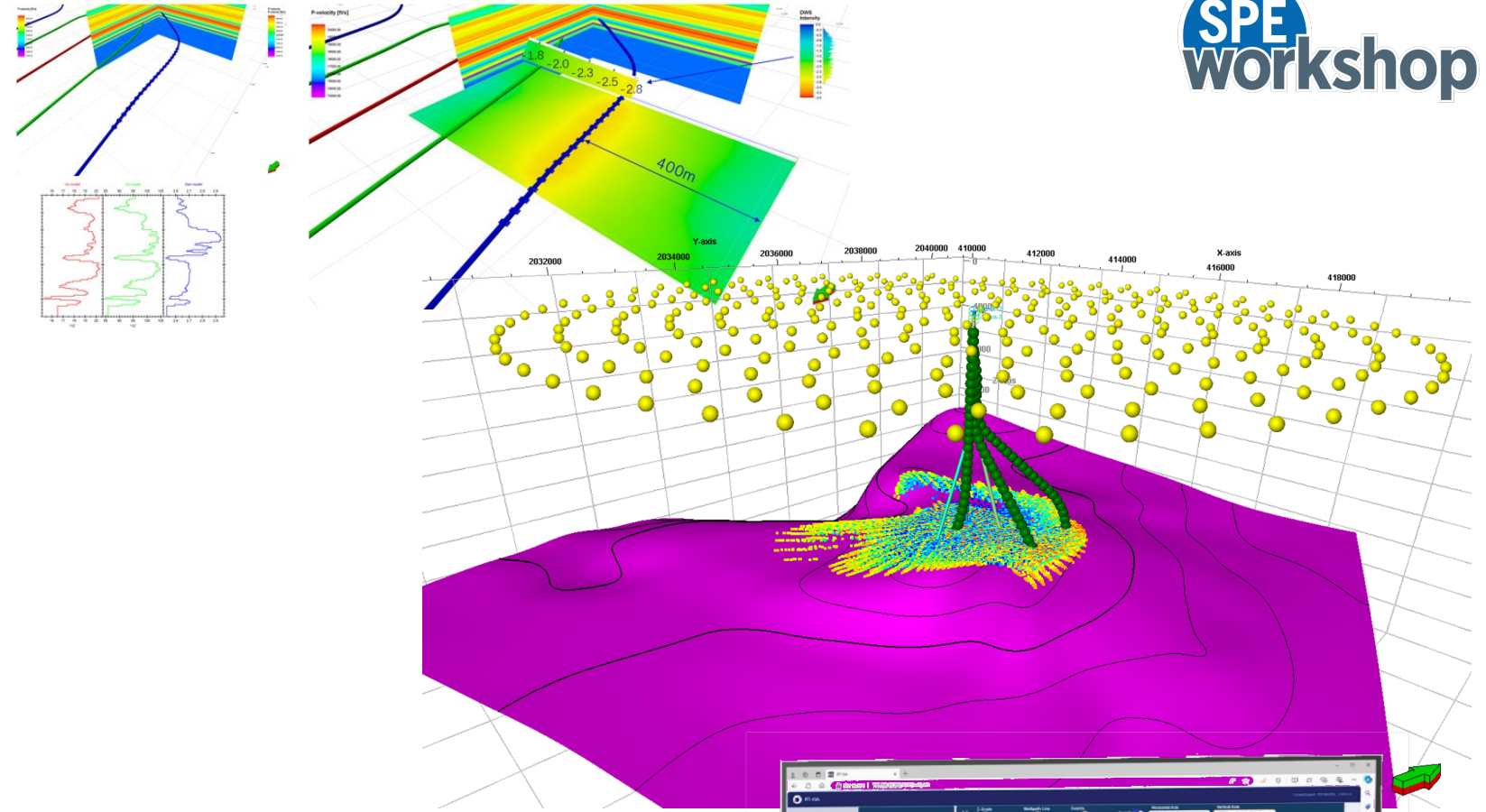
## Revolutionizing Subsurface Monitoring in Oil, Gas, and CCS with Digital Fiber Optics

Pierre Bettinelli (PhD)



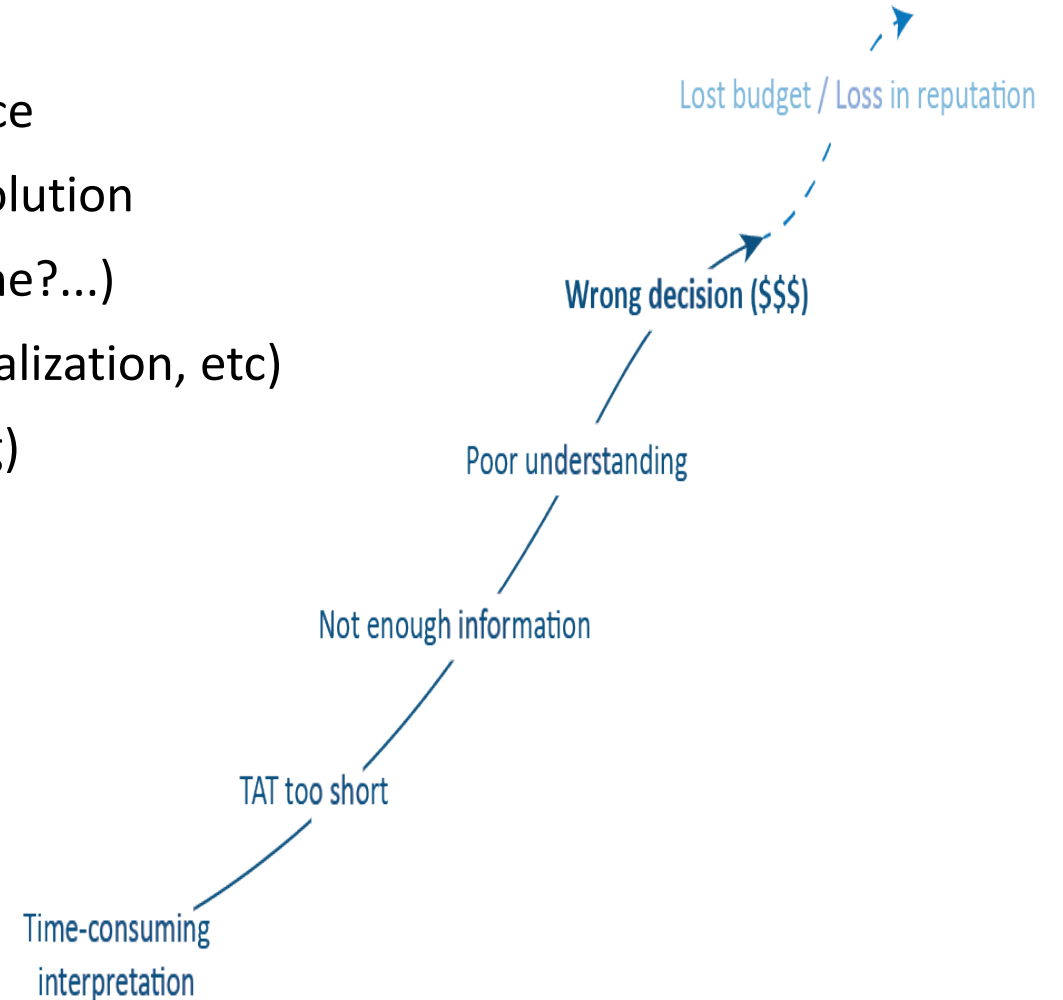
# Agenda

- Motivations
- End-to-End solutions
  - Borehole Geophysics
    - VSP
    - Microseismicity
- CCS case study
- Way forward
- Conclusion



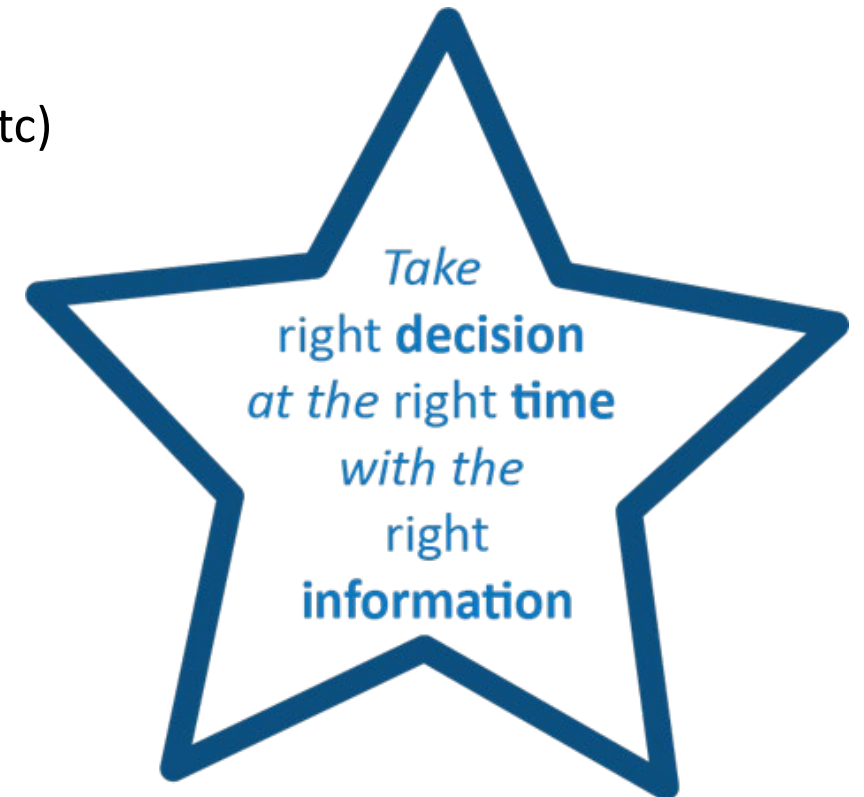
# Motivations

- Reduce the cost of reservoir monitoring / surveillance
- Acquisition/processing on demand with highest resolution
- Get answers with the best TAT (real-time? Just in time?...)
- Optimize production (bypassed zones compartmentalization, etc)
- Integrate information (e.g., velocity models, imaging)



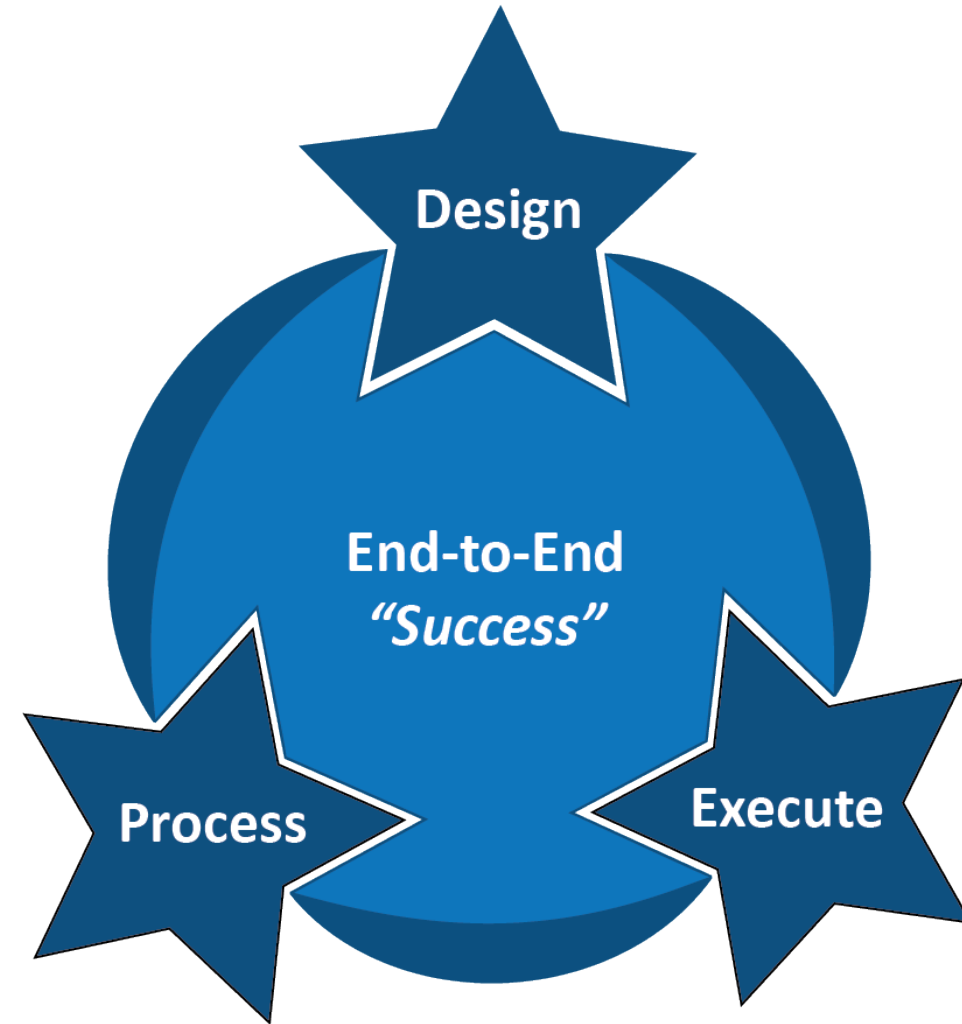
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# End-to- End solution

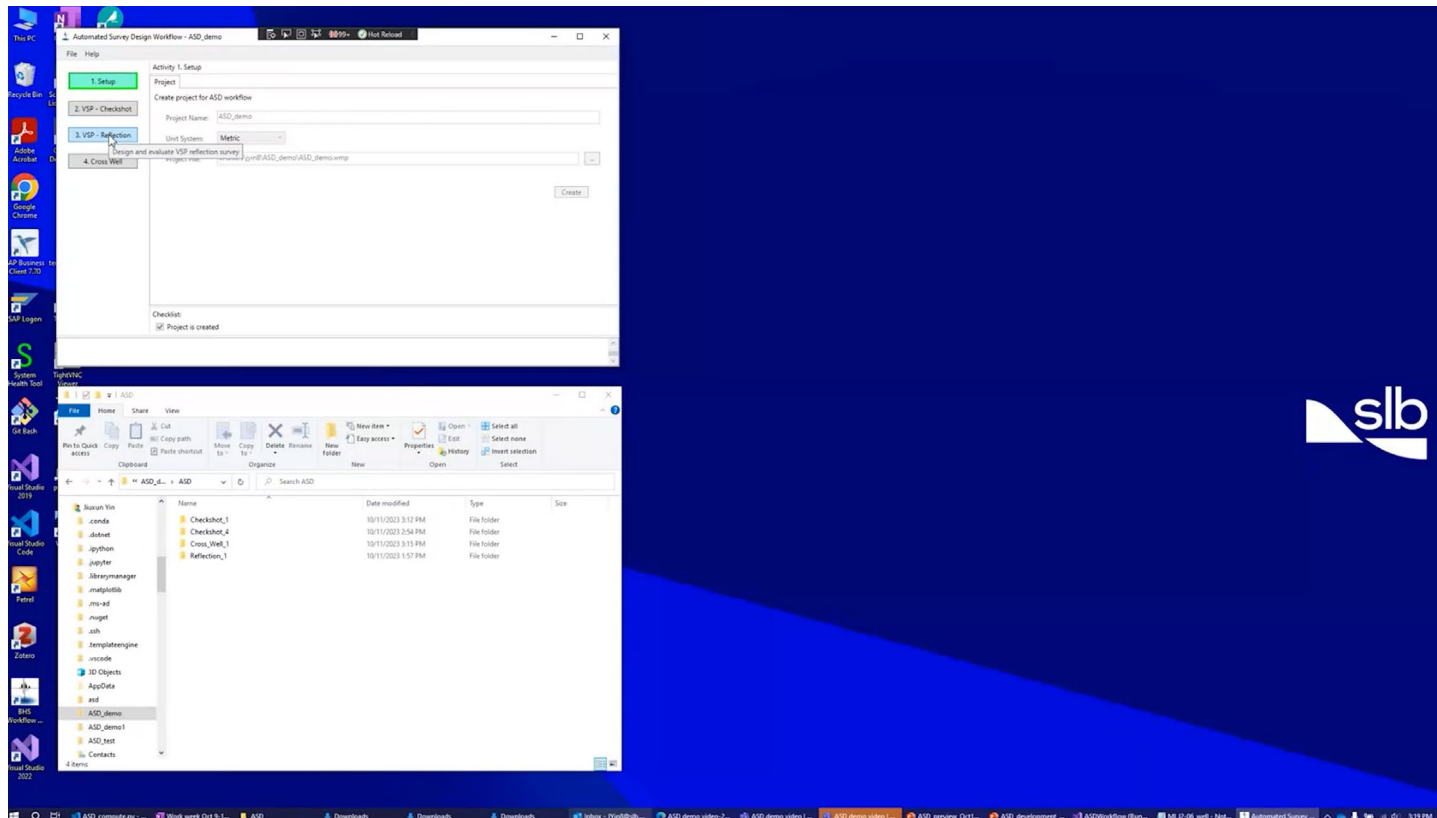
- Leveraging Distributed Measurements
  - Cost-effective approach
  - TAT reduction
  - CO<sub>2</sub> reduction





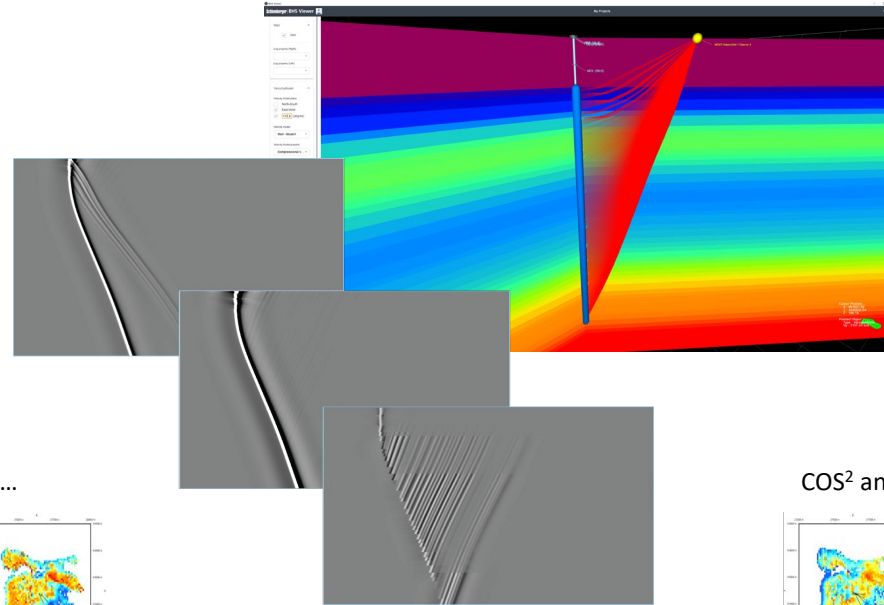
# Pre-survey modeling

- DAS VSP – Automated or not

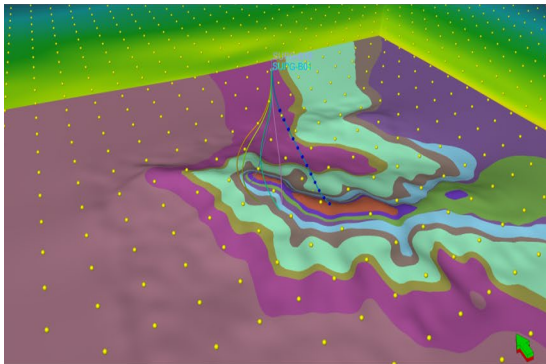
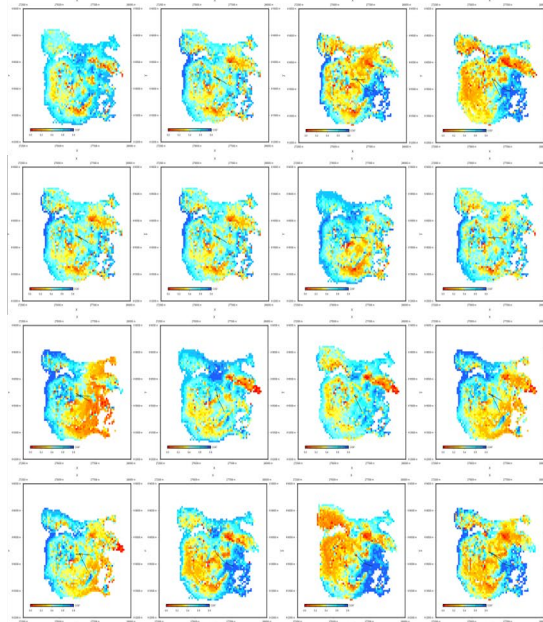


# Pre-survey modeling

- DAS VSP

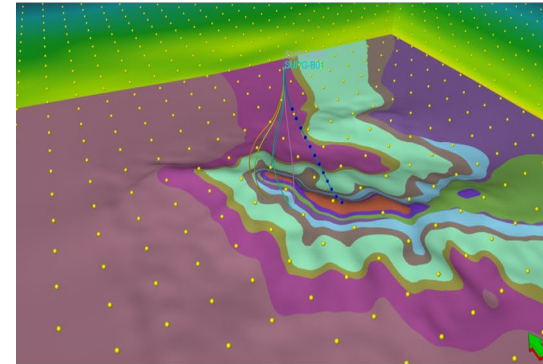
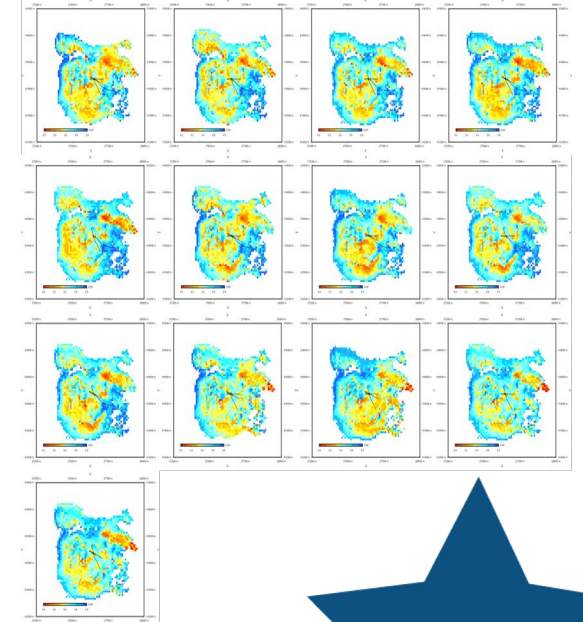


COS<sup>2</sup> analysis on Direct-P and P2P, P2S, ...



- 1 box used

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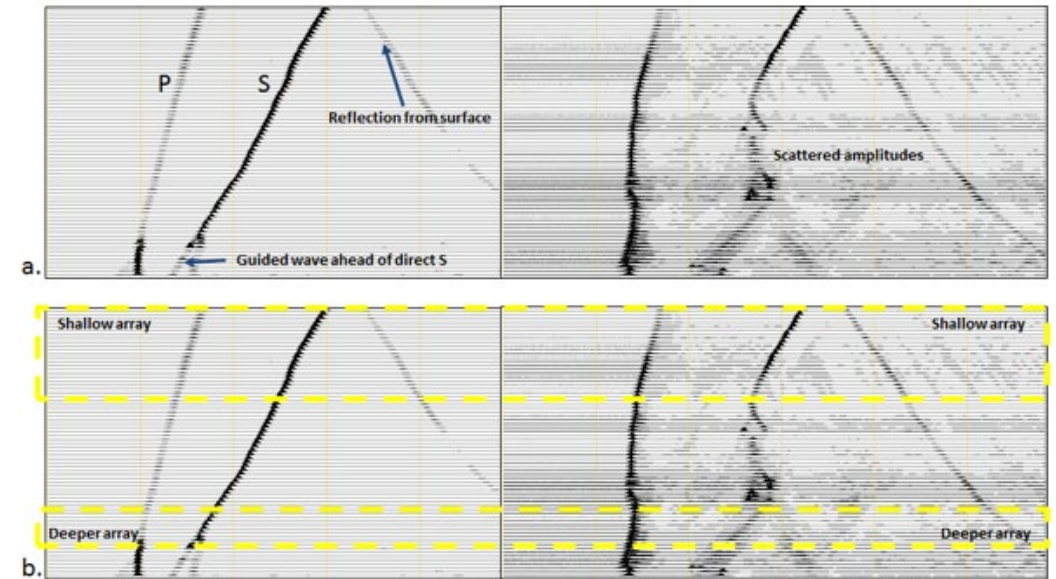
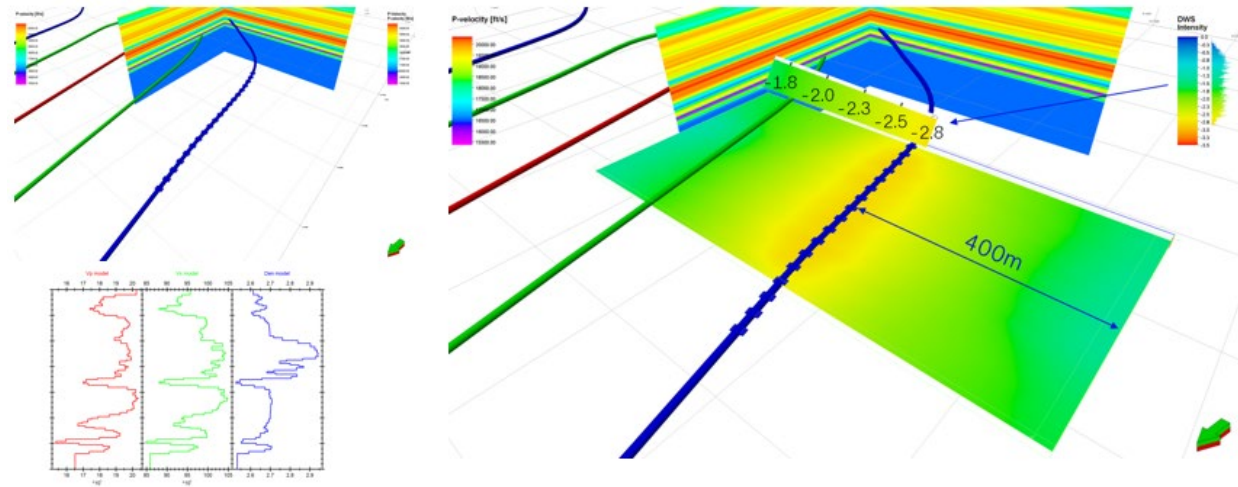
- 2 boxes used
- 3 boxes – all well recorded





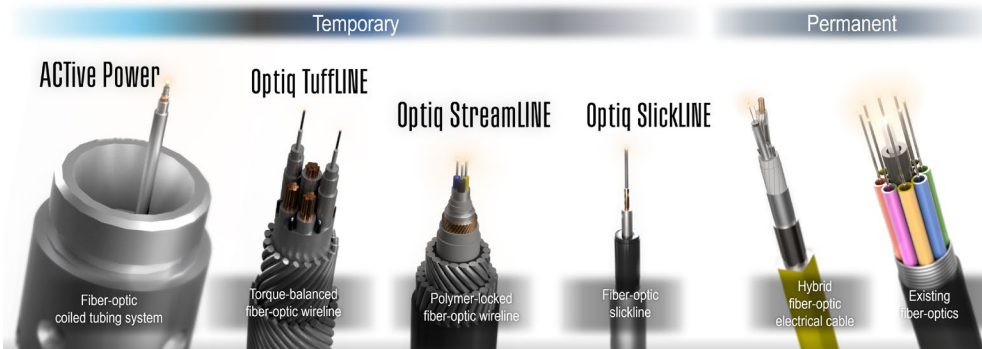
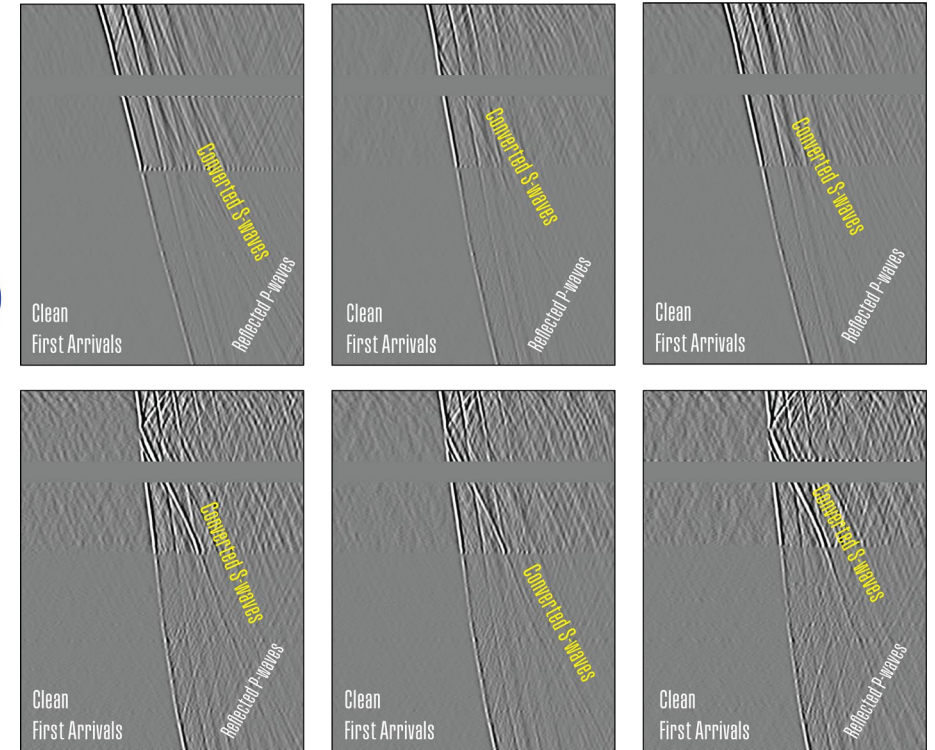
# Pre-survey modeling

- DAS Microseismic



# Acquisition (HW & SW)

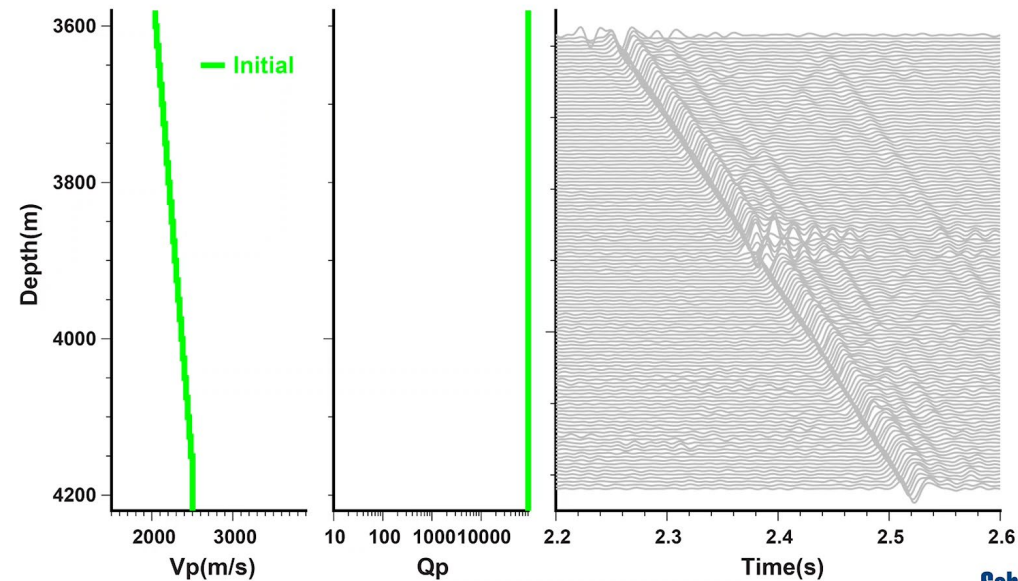
- Continuous improvement
- Source driven mode
  - Real-time stacking
  - Real-time QC
- Source interfacing
- Source positioning embedded into SEG Y
- 2 Fiber Optics recorded simultaneously
  - Hardware stacking
  - Minimizing asset mobilization



# Zero-Offset FWI

- Provide Time-Depth relationship &  $Q_p$  profile in quick TAT
- Results:
  - ZOFWI performed in few minutes

## Zero-Offset Visco-Elastic Waveform Inversion

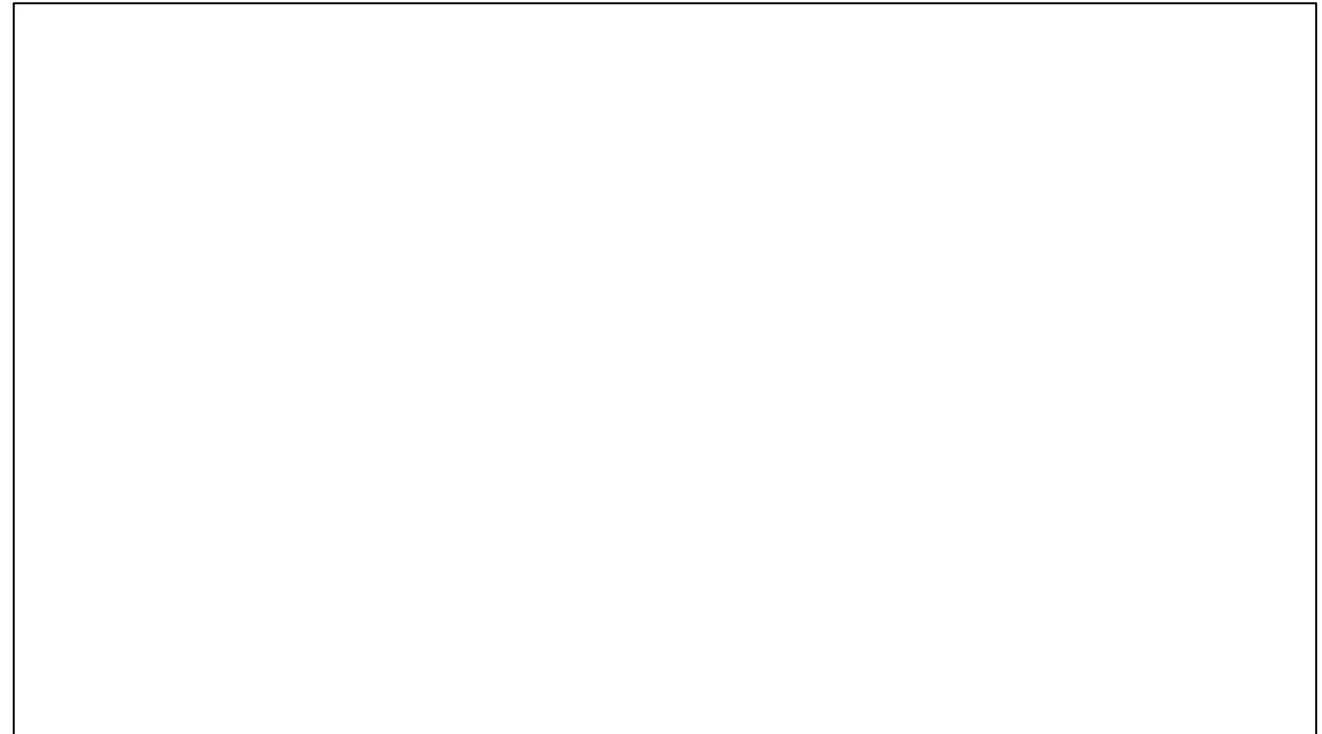


Schlumberger



## 2D eFWI

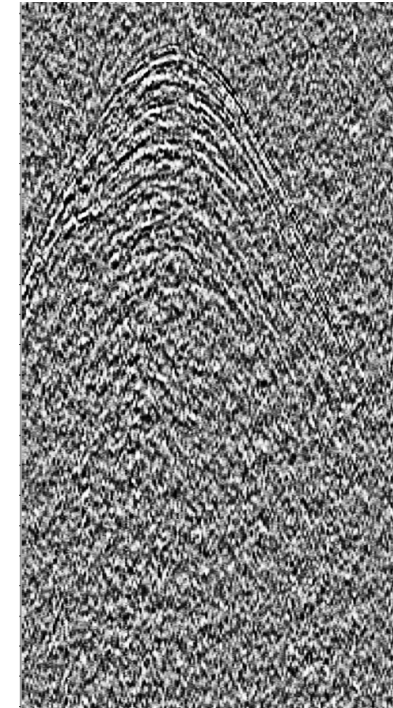
- Provide 2D tomograms in quick TAT
- Results:
  - Full E2E workflow
  - Provided VIVSP in less than 2hrs while running CBL – 1 descent 2 logging runs
  - eFWI performed in less than 24hrs



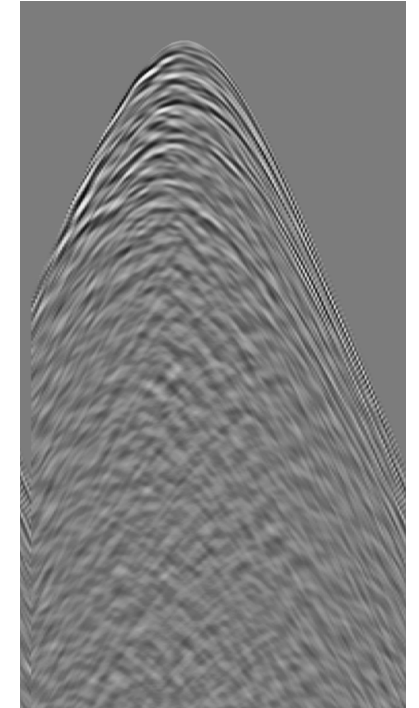


# 3DVSP

- Digital – Processing and short TAT from simple to complex design
- Challenge: To process 3D VSP recorded simultaneously in 4 producing wells while reducing rig time by 88 days in order to optimize field development plan without interrupting production
- Result:
  - x4 3D VSPs
  - Noise attenuation due to flow in producing wells, ~ 1 month processing per well (traditional approach)



Raw data



Processed data

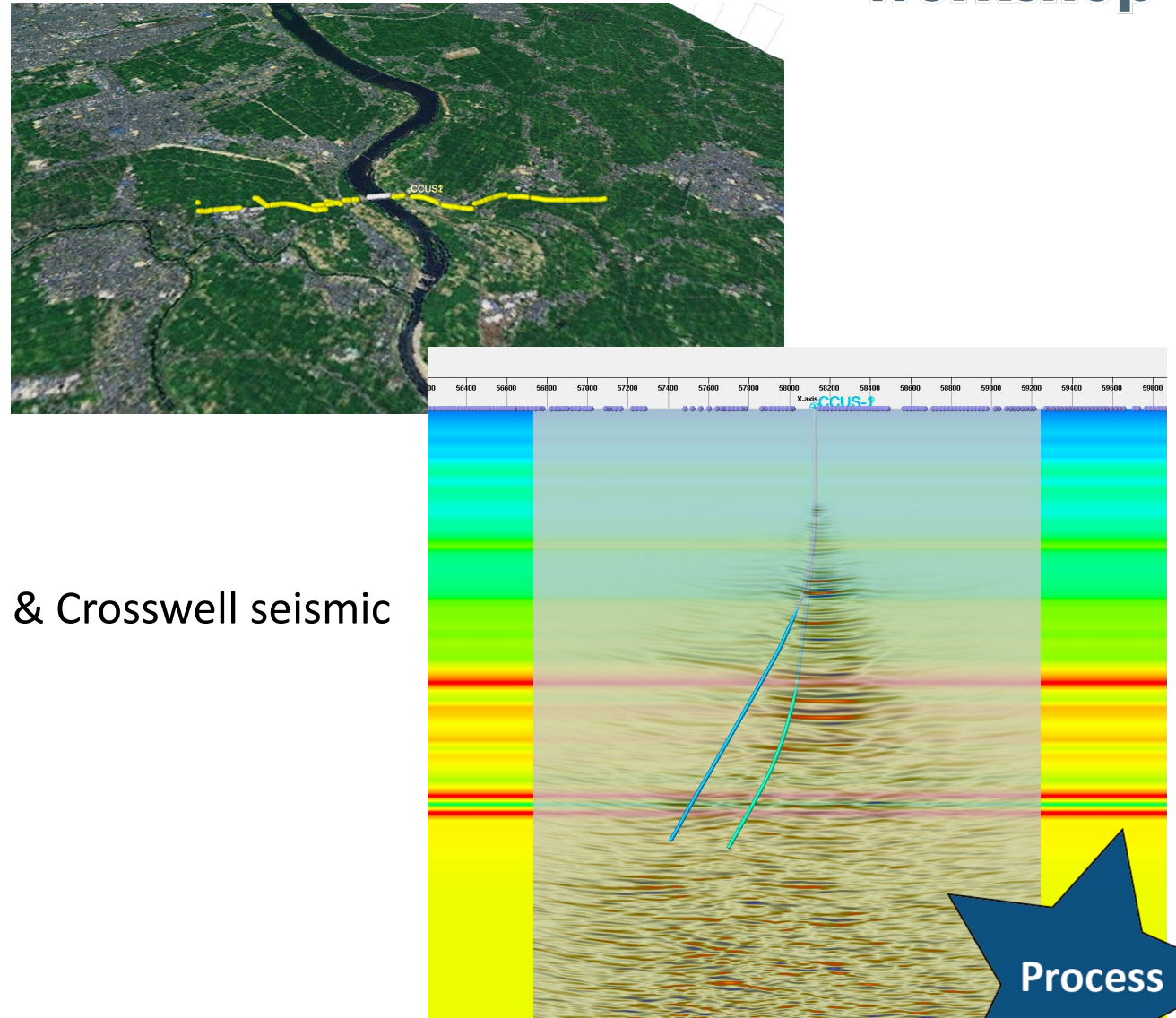
Near-well line common receiver raw (left) and processed wavefield after production denoising (right).





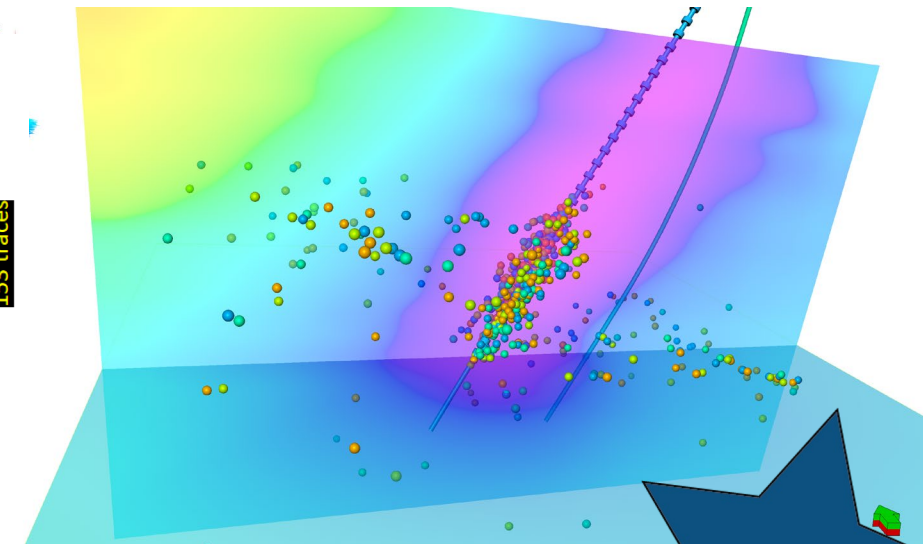
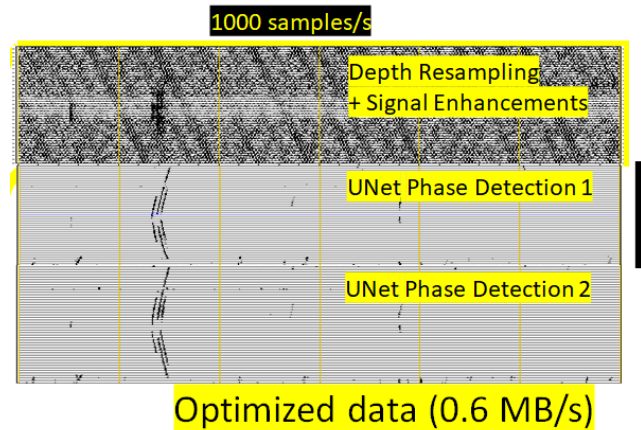
# CCS case study

- Fiber Optics permanently installed
- Cemented behind casing
- DAS ONYX System used
- Pre-injection
  - Source triggered (vibroseis & airgun)
  - 7.7 Tb of data between Walkaway VSP & Crosswell seismic
  - Offsite processing



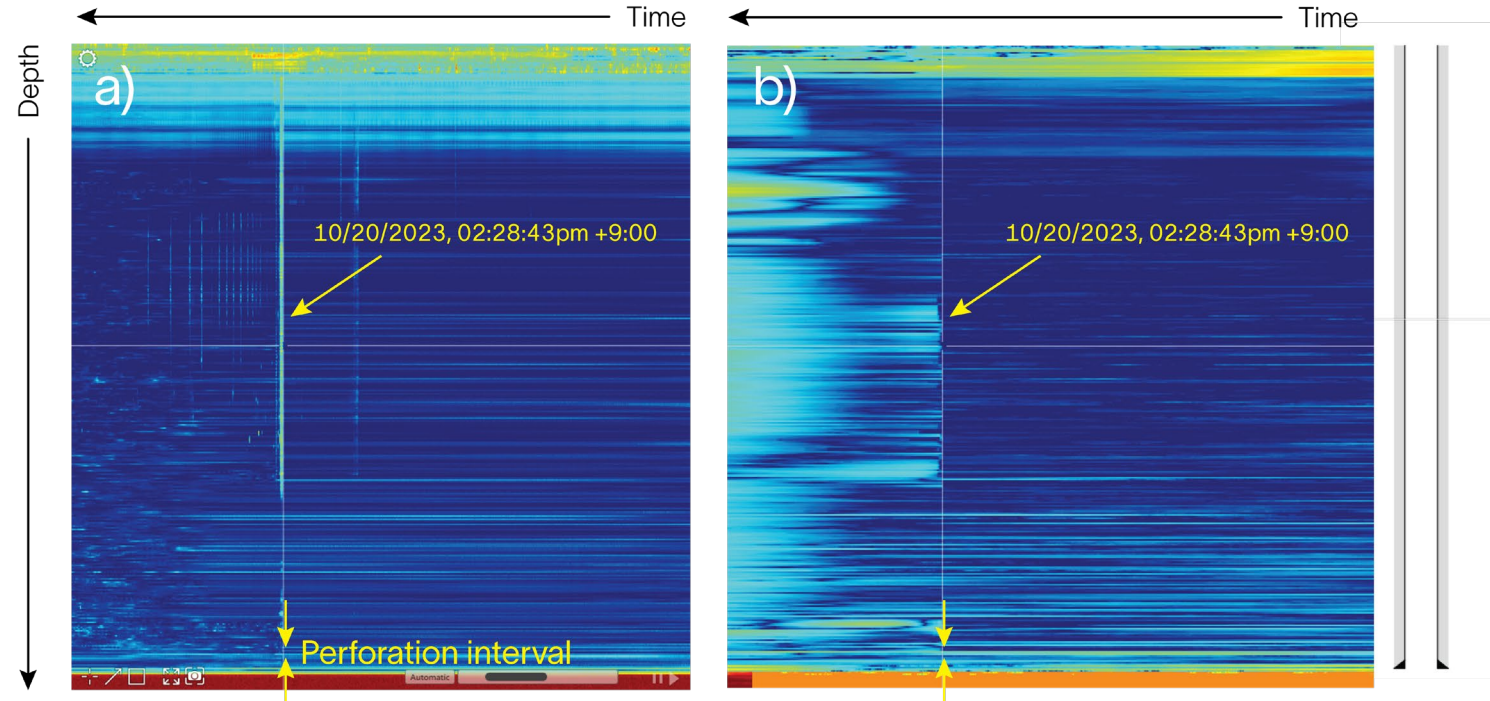
# CCS case study

- Fiber Optics permanently installed
- Cemented behind casing
- DAS ONYX System used
- Pre-injection, Injection
  - Continuous recording
  - 50 Tb raw data recorded
- RT-ISA Gen#1 transmission
  - Well 1: 914 Gb
  - Well 2: 822 Gb



# CCS case study

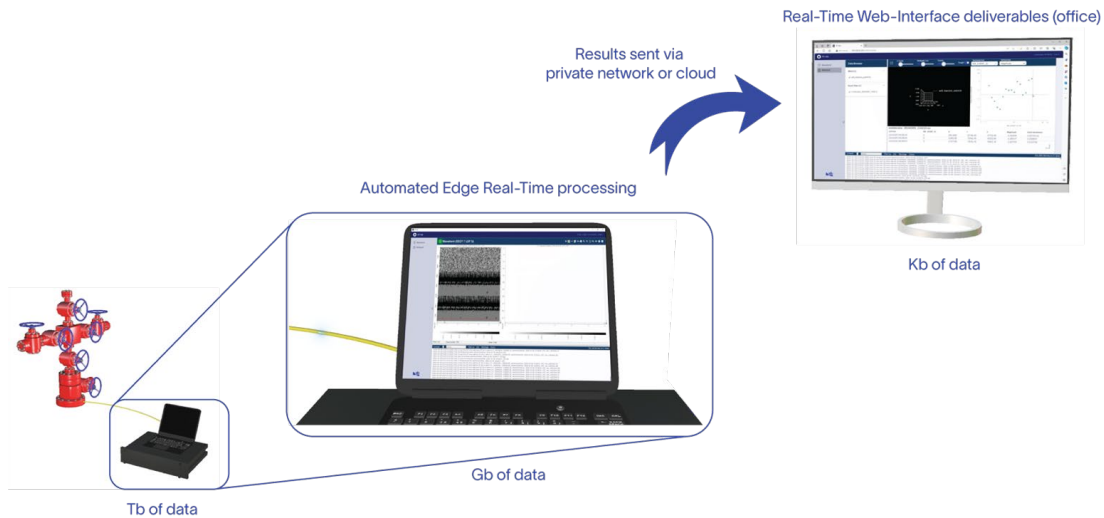
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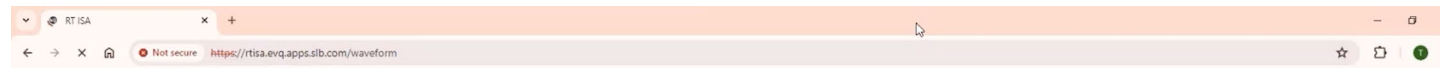
# Way forward

- DAS microseismic
  - Processing & Deliverables Overview



# Way forward

- DAS microseismic
  - *Human free DAS microseismic event detection at edge delivered on WebApp.*





# Conclusion

- Success = Fulfilling all critical steps including
  - short TAT, no deferred production, minimize CO<sub>2</sub>, integrate with existing projects (e.g., OBN, etc.)
- Full End-to-End workflow
  - Proper design
    - Know what to expect
  - More than just an interrogator and a fiber
    - Proper real-time acquisition QAQC
    - Source-driven mode - Stacking
  - Proper processing strategy
    - TAT to take decision in time
    - Edge processing to avoid sending Tb of data

