Distributed Acoustic Sensing (DAS)

Seismic Survey Design and Best Practice

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IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani

Introduction

This presentation describes the necessary requirements for performing an active seismic survey, with particular emphasis on performing tasks from a remote location

The presentation covers the following areas:

- Basic aims of an active seismic survey
- Pre-job planning
- Equipment requirements including installation, connections and set up
- Networking best-practices
- Depth calibration
- Typical job workflows, QC and deliverables
  - Continuous acquisition with shot extraction
  - Triggered acquisition
  - Vibroseis sources
- Seismic QC and Common Issues
- Considerations and limitations for performing jobs remotely

Active Seismic

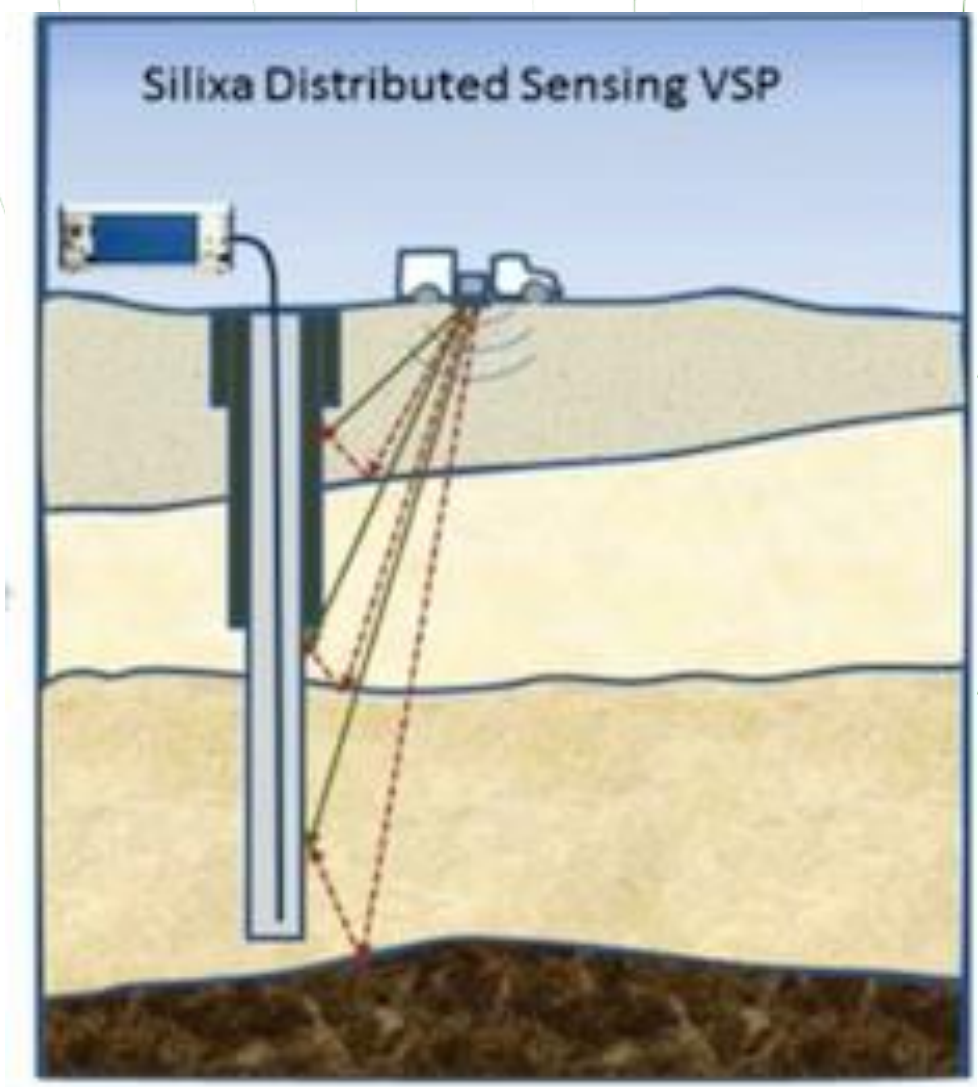
- Overall aim: To map subsurface layers of rock, and to detect changes over time

- Methods:

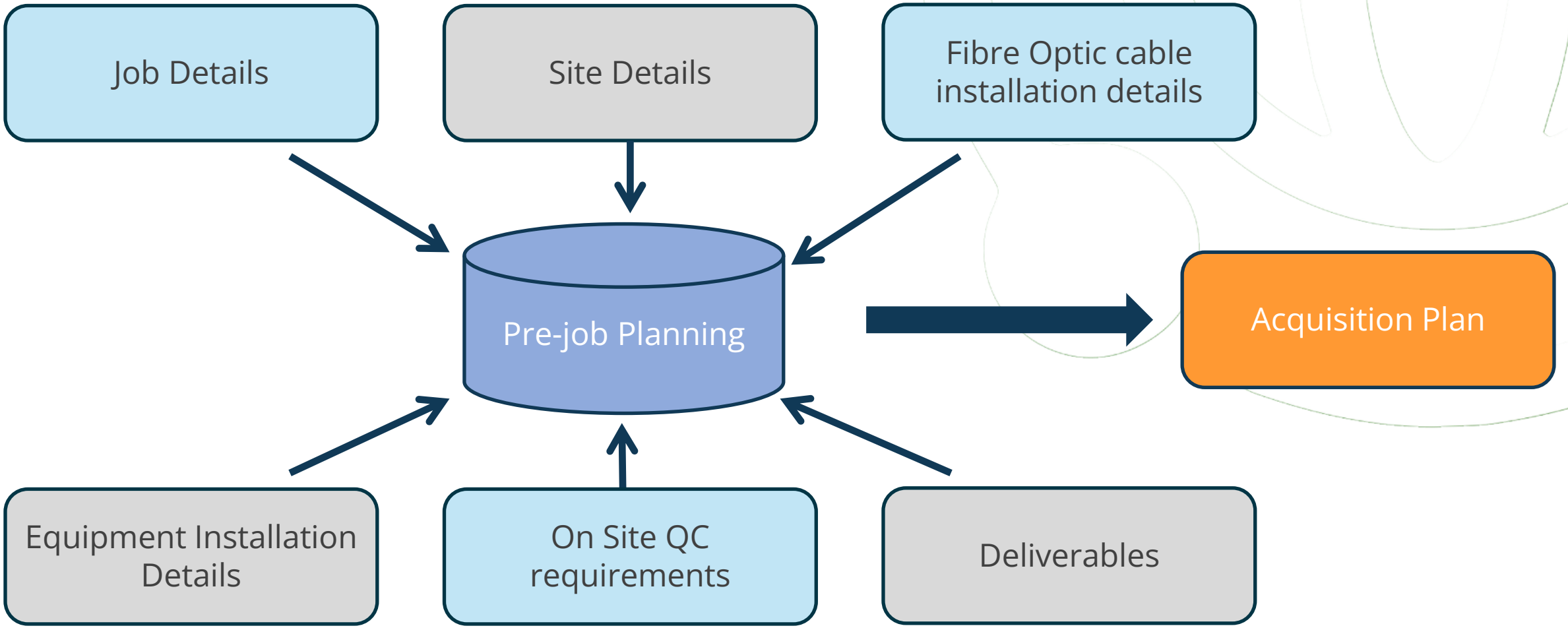
    - Measure direct travel times of the sound from the surface to each receiver

    - Use sound that reflects from the boundaries between each layer to create an image

- Common Deliverables:
    - In field QC plots and shot files
    - Early-stage processing (e.g. corridor stack for ZOVSP)
    - 3D imaging
    - 4D difference



Pre-job Planning Elements



Pre-job planning

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Job Details

- Aim of the survey (including the size, depth and orientation of the imaging target)
- Type of survey, e.g. Zero-Offset, 2D, 3D, 4D
- Source details (frequency range, power, control)

Site Details

- Location: How to get you and equipment there, local weather etc, what infrastructure is there?
- Well details: locations, completion diagrams, deviation surveys
- Trench layout if applicable (e.g. GPS coordinates)

Fibre Optic cable installation details

- Cable type, number and types of fibres
- Installation method
- Access to fibre

Equipment Installation Details

- Power supply, temperature, humidity, vibration
- Internet access
- Desk or rack space
- ATEX areas

On Site QC requirements

- Real-time visualisation
- SNR, timing, signal quality
- Operational QC (missed shots / triggers)

Deliverables

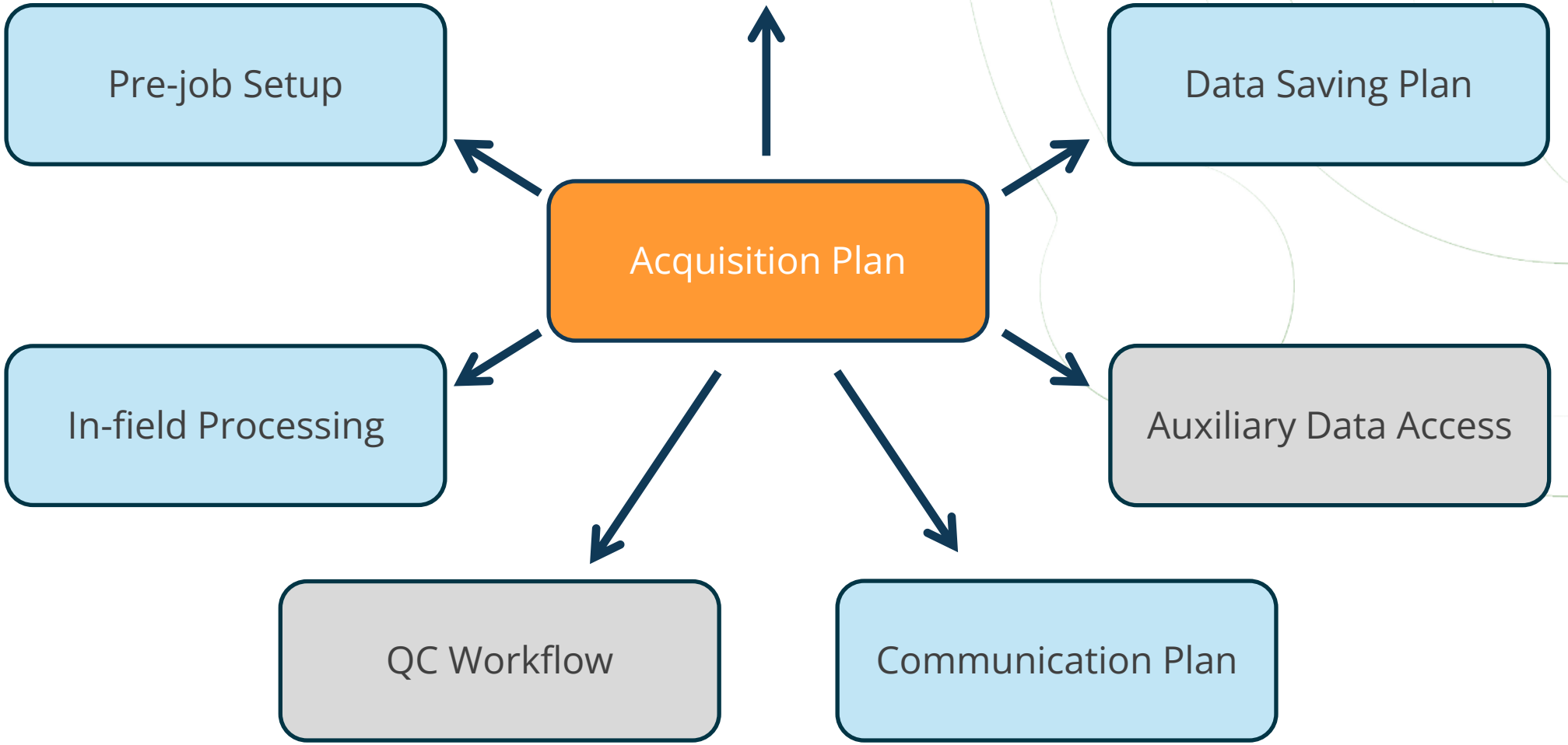
- Data: file format, file length, delivery method, number of copies
- Reports: Presentations, word documents, auxiliary files (e.g. NAV files)
- Deadlines

Get as much information as you can

This may require talking to lots of different parties

Start thinking about potential problems and how to mediate

Pre-job planning Elements



Acquisition Plan

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A good acquisition plan saves time and money during the survey

Get it right first time and avoid delays or having to come back and reshoot!

Pre-job Setup

- How long will it take? (normally at least 1 day, maybe 2)
- Where will equipment be, where is power coming from?
- How will depth calibration be completed?

Acquisition Settings

- Sampling frequency, gauge length
- Continuous or triggered acquisition
- Data rates

Data Saving Plan

- File format
- Folder structure
- Required disk space
- Backup plan

Auxiliary Data Access

- NAV file format and contents
- How will these files be transferred to you?
- Do those files need manipulation before SW can read them?

In-field Processing

- Shot extraction required?
- Data curation e.g. decimation, common mode filtering
- Correlation, Stacking
- SEGY header formatting and customisation

QC Workflow

- What QC plots will provide the right information?
- Shot / Receiver gather, SNR, frequency spectrum
- How will those be generated?

Communication Plan

- How to communicate with others on site about what is happening and when?
- What is the current shot point? When should we start / stop recording?
- What should happen in the event of issues? How are decisions made?

Equipment

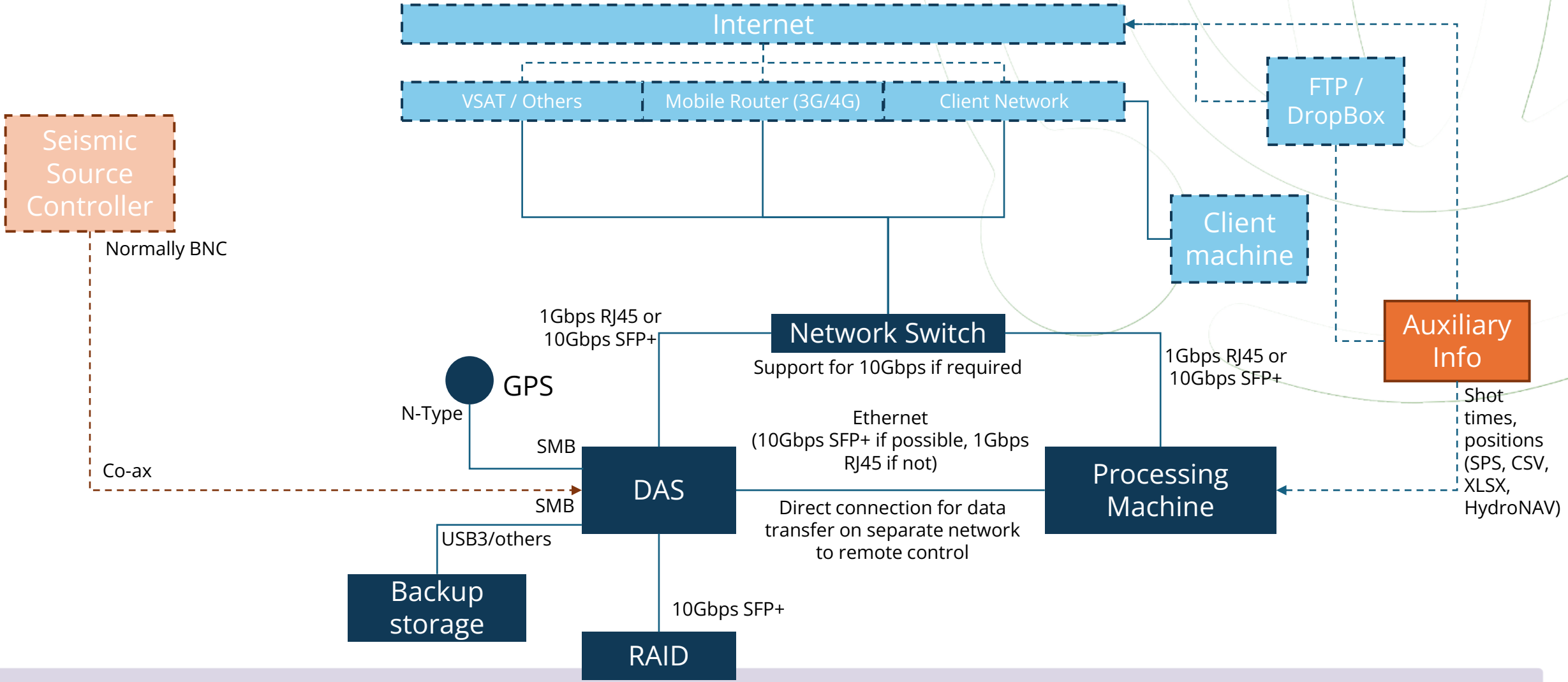
Make sure you have everything you need!

- DAS and fibre optic cables
  - Fibre cleaner
  - RAIDs (spare hard drives)
  - Keyboard/mouse/monitors and cables
  - Power cable
  - GPS kits (check connectors)

- Processing PC
  - Laptop/Server/Desktop PC
  - Keyboard/monitor/mouse
  - Network cables

- Misc.
  - Multiplug sockets (country adapters)
  - Back up hard drives and caddies (USB3?)
  - Hand tool kit
  - Network switch
  - Splicer, OTDR
  - Surface cables, patch cords, splice cassettes etc

Equipment Set Up
(Single iDAS, single processing machine)



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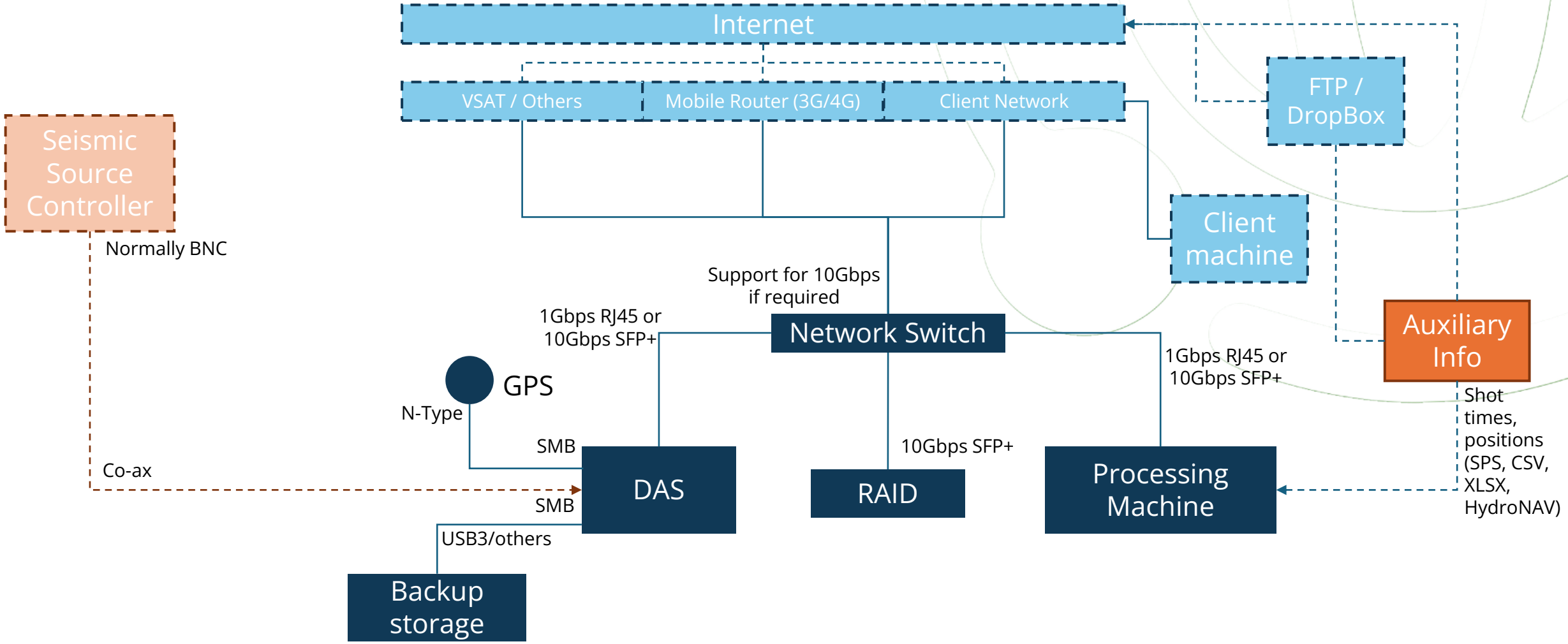


The process of calculating the real-world position of the fibre receivers

Pre-requisites

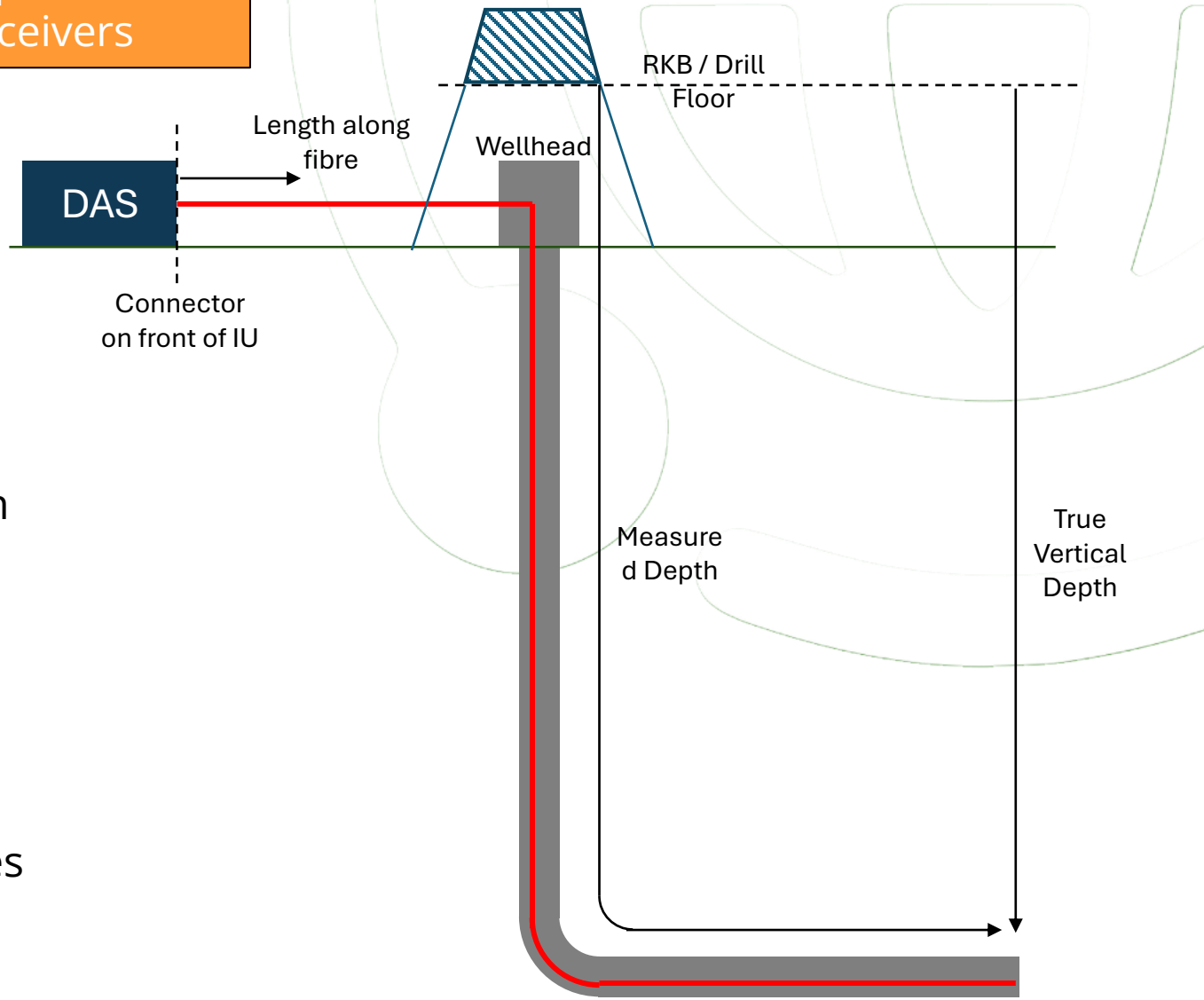
- Fibre path
  - Including any discontinuities in the fibre path

- Position information
  - Comes from client e.g. completion diagram
  - Depth of known points

Two-stage process

1. Map Fibre Distance to Measured Depth (or length along the “Facility”)
   - Tap test
   - Optical features e.g. reflections, splices
   - Acoustic features e.g. valves, changes in pipe diameter

2. Measured Depth/Facility Length to 3D coordinates
   - Deviation survey
   - Wellhead or trench vertex coordinates
   - Trench elevation profile



Depth Calibration

Common procedure (Permanent Fibre in-well)

- For each vertex in the fibre path
  - Wellhead/Tubing hanger
  - Valves/splices in fibre path
  - Bottom of well (end of fibre or fibre turnaround)

Goal: Collect the list of reference points.
- *Fibre distance from connector*
- *Measured Depth for each point*

1. *Tap test at wellhead*
   - See both out-going and return leg of double-ended
   - Correct wellhead tap test location for fibre wraps around tubing hanger (TH)
     - Tap is normally above the TH (e.g. on wellhead outlet)
     - Add approximate fibre length to location below TH
     - Find depth of point below TH from completion diagram

2. *Valves/splices in path at positions within the well*
   - Valves might make noise, use acoustic view
   - Splices show up in OTDR, compare OTDR distance with iDAS distance to find positions in iDAS
   - Components will likely have additional fibre wrapped above and/or below them. Reference point above and below is required

3. *End of fibre/Turnaround*
   - End reflection
   - Turnaround point in acoustics
   - Half-way point between tap test locations

Depth Calibration

Goal: Collect the list of reference points.
- *Fibre distance from connector*
- *Measured Depth for each point*

Common procedure (Intervention)
- For each vertex in the fibre path
  - Wellhead/Tubing hanger
  - No discontinuities
  - Bottom of well (end of fibre or fibre turnaround)

1. Tap test at surface
   - If tap test is not at wireline zero then measure distance between tap location and zero

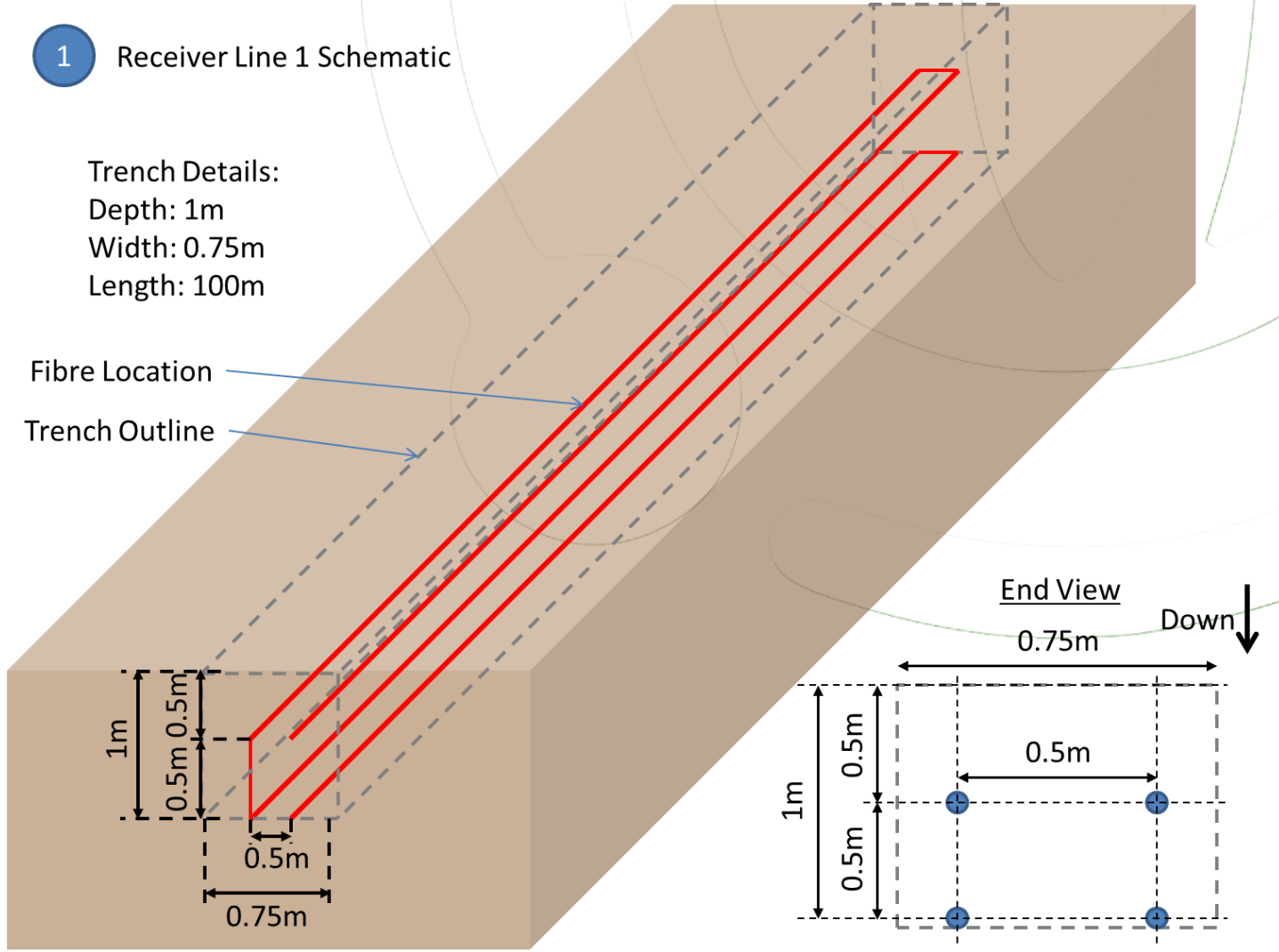
2. End of fibre/Turnaround
   - End reflection
   - Turnaround point in acoustics
   - Half-way point between tap test locations
   - Need to know amount of fibre in the head
   - Need to know the difference between fibre end/turnaround and cable TD

Depth Calibration

Common procedure (Trenched Fibre)
- For each vertex in the fibre path

1. Tap tests at every vertex
   - Look at acoustic data to find positions
   - Account for any additional fibre in junction boxes
   - Map out each fibre, if more than one connected in series

Goal: Collect the list of reference points.
- *Fibre distance from connector*
- *GPS coordinate (X,Y,Z) for each point*



Depth Calibration

Entry into SeiBer

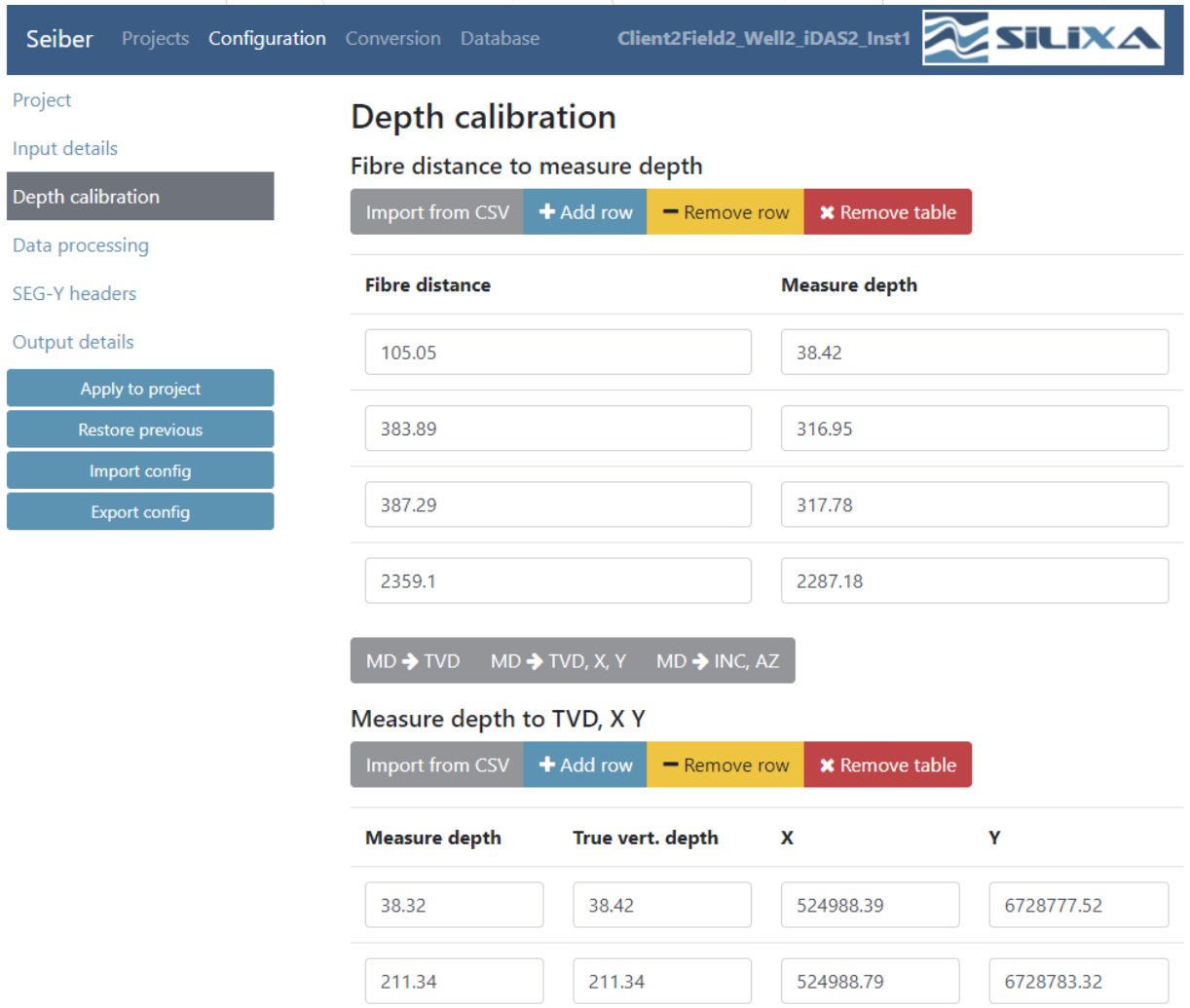
- Two-stage process

1. Map Fibre Distance to Measured Depth (or length along the “Facility”)
   - Fibre Distance to measure depth table

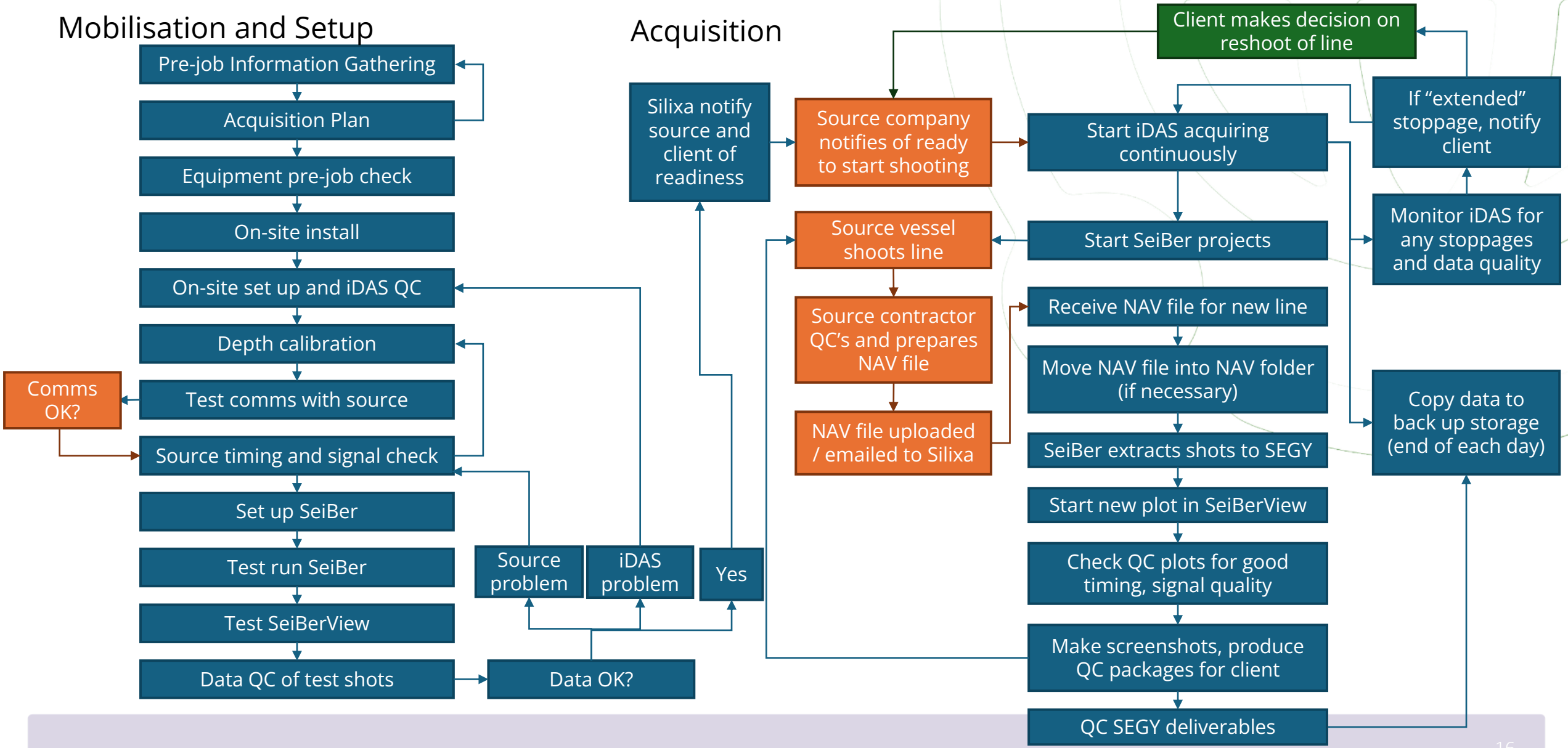
2. Measured Depth/Facility Length to 3D coordinates#
   - MD > TVD (, X, Y) or MD > Inc, Az

SeiBer performs linear interpolation to calculate the position of every receiver channel

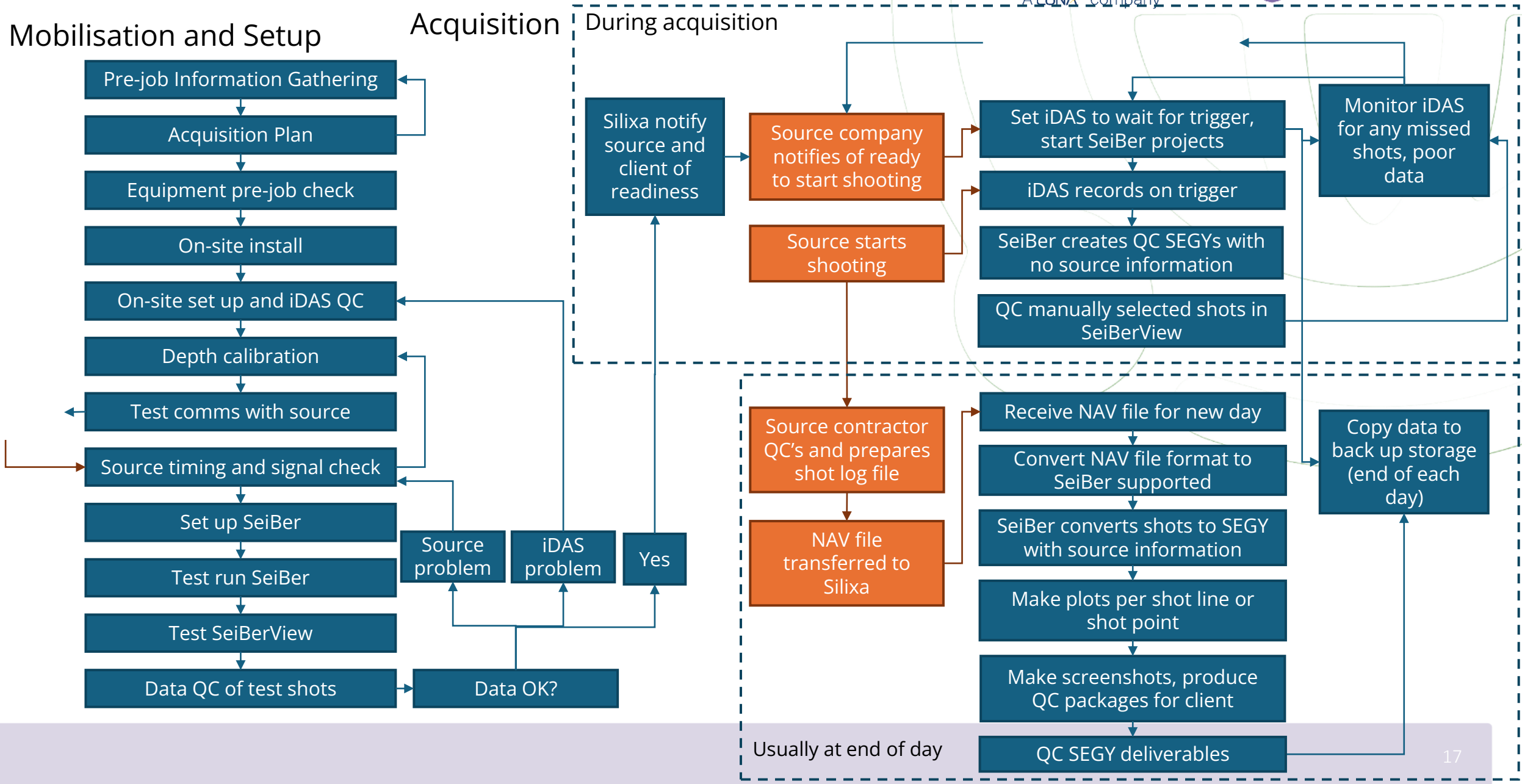
Goal: Enter the reference points into the software



Continuous Acquisition + Shot Extraction Survey Workflow, e.g. Marine



Triggered Survey Workflow, e.g. Land Seismic



DAS QC – Noise Floor

- There are two ways to check how the measured noise floor compares to the expected noise floor

- A dashed red line is shown on the Frequency Spectrum graph at the bottom of the Acoustic mode window

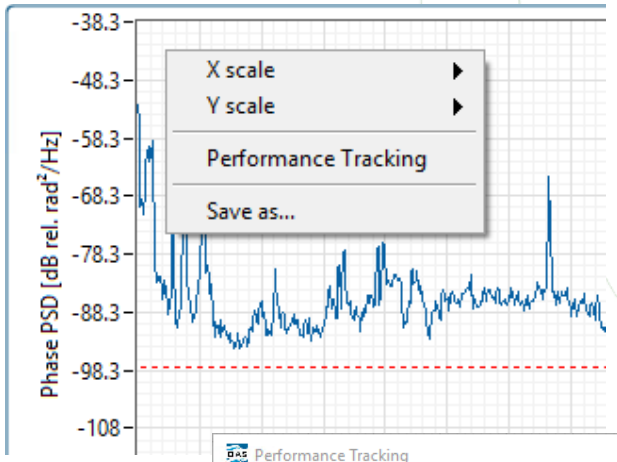
    1. Turn on Acoustic vs Time
    2. Turn on Integrate
    3. Select X Scale = Linear
    4. Select a distance to display using the red cursor on the top graph
    5. FFT graph at the bottom displays the

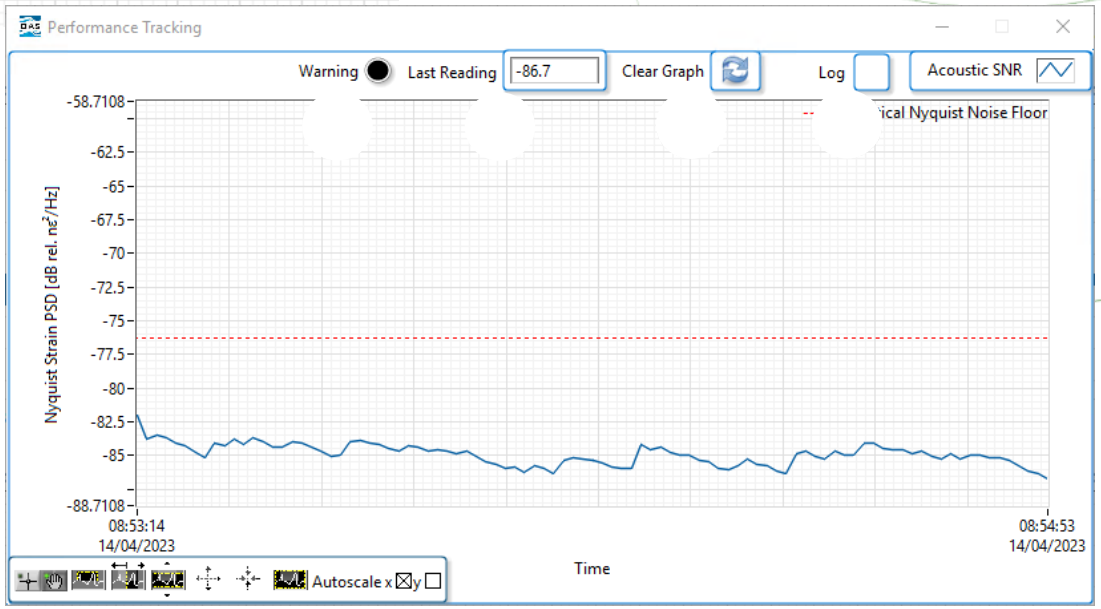
Ensure the noise floor is below the red dashed line at the Nyquist frequency

DAS QC – Noise Floor

- The pop out Performance Tracking tool will track the noise level over time

    1. With Acoustic vs Time and Integrate turned on
    2. Position the red cursor on the top graph in acoustic mode at a location you want to monitor (this can be changed at any time)
    3. Right click on one of the graphs in acoustic mode
    4. Select Performance Tracking
    5. The Performance Tracker will display the acoustic noise level over time and a dashed red line





Ensure noise floor is below the red dashed line

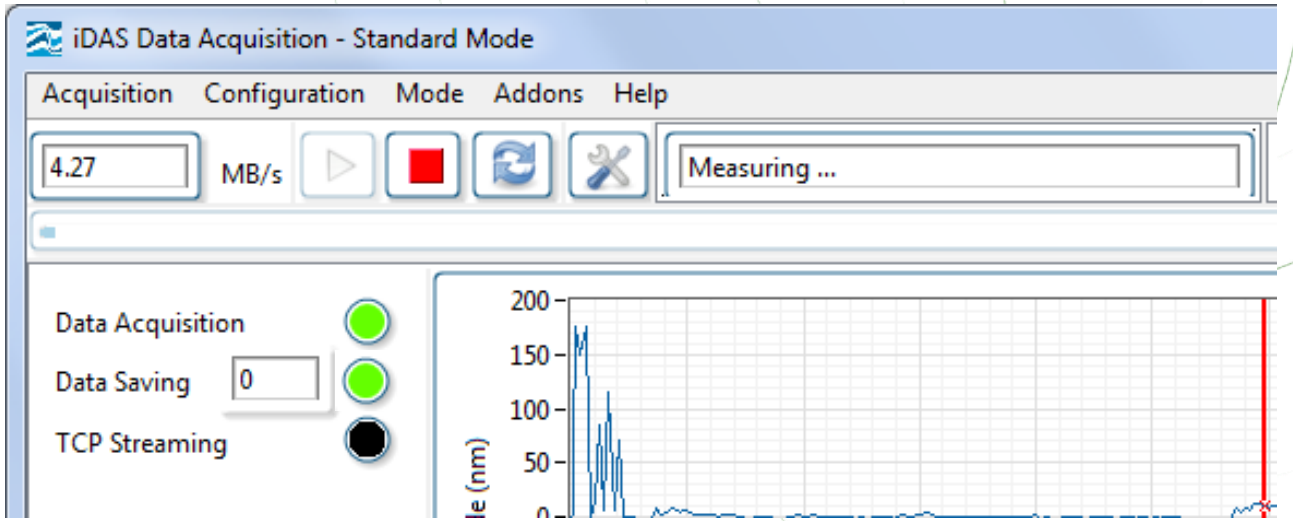
DAS QC

1. Ensure the DAS status message says “Measuring …” during acquisition

2. Ensure the Data Acquisition LED is Green.
   - If it flashes RED for a couple seconds this is OK
   - A constant red LED means the acquisition cannot be maintained and should be stopped and troubleshooted

3. Ensure the Data Saving LED is Green
   - If it flashes RED for a couple of seconds this is OK
   - A constant red LED means the data saving cannot be maintained and should be stopped and troubleshooted

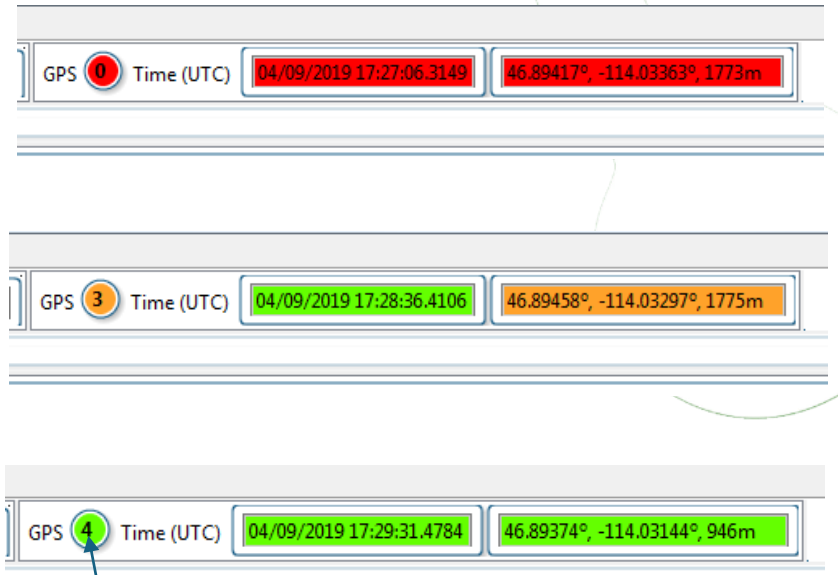
4. Ensure the saving rate of your measurements is below 250MB/s
   - If it is not, it is likely that the incorrect settings have been used



If the LED’s stay red, stop and check the acquisition settings and the status of the data storage device

DAS QC

- Monitor the GPS status panel to ensure timing synchronization is good
- GPS satellites should be:
  - Good = 3+
  - Minimum = 1+
- Panel LED's should be green to show a good cable connection



Number indicates how many satellites are connected

If any of these indicators aren't green the GPS cable connection should be checked

DAS QC – iDAS Saving

- Checking the file integrity and timestamps in saved data is another good way to QC if iDAS is saving data correctly

- If recording continuously, all files should be the same size and the timestamps should be separated by the same interval
  - If a GPS antenna is connected, the timestamps of the files should all have the exact same millisecond value

Name	Date modified	Type	Size
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202208.568.tdms	17/07/2019 21:22	TDMS File	401,744 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202240.434.tdms	17/07/2019 21:22	TDMS File	236,969 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202340.131.tdms	17/07/2019 21:24	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202410.130.tdms	17/07/2019 21:24	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202440.130.tdms	17/07/2019 21:25	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202510.130.tdms	17/07/2019 21:25	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202540.130.tdms	17/07/2019 21:26	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202610.130.tdms	17/07/2019 21:26	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202640.130.tdms	17/07/2019 21:27	TDMS File	585,031 KB
DOE_BM101A_FOWL5_SMF_2mGL_P10_UTC_20190717_202710.130.tdms	17/07/2019 21:27	TDMS File	585,031 KB

Millisecond value

Different file sizes and gaps between timestamps indicate saving stopped and restarted

Later files all the same size and have exact same millisecond value

DAS QC – File Headers

- Open a file in DAS Viewer (available on the DAS)
- Go to Tools > Properties to view the file headers

Check to ensure the values displayed are the same as those set in the software

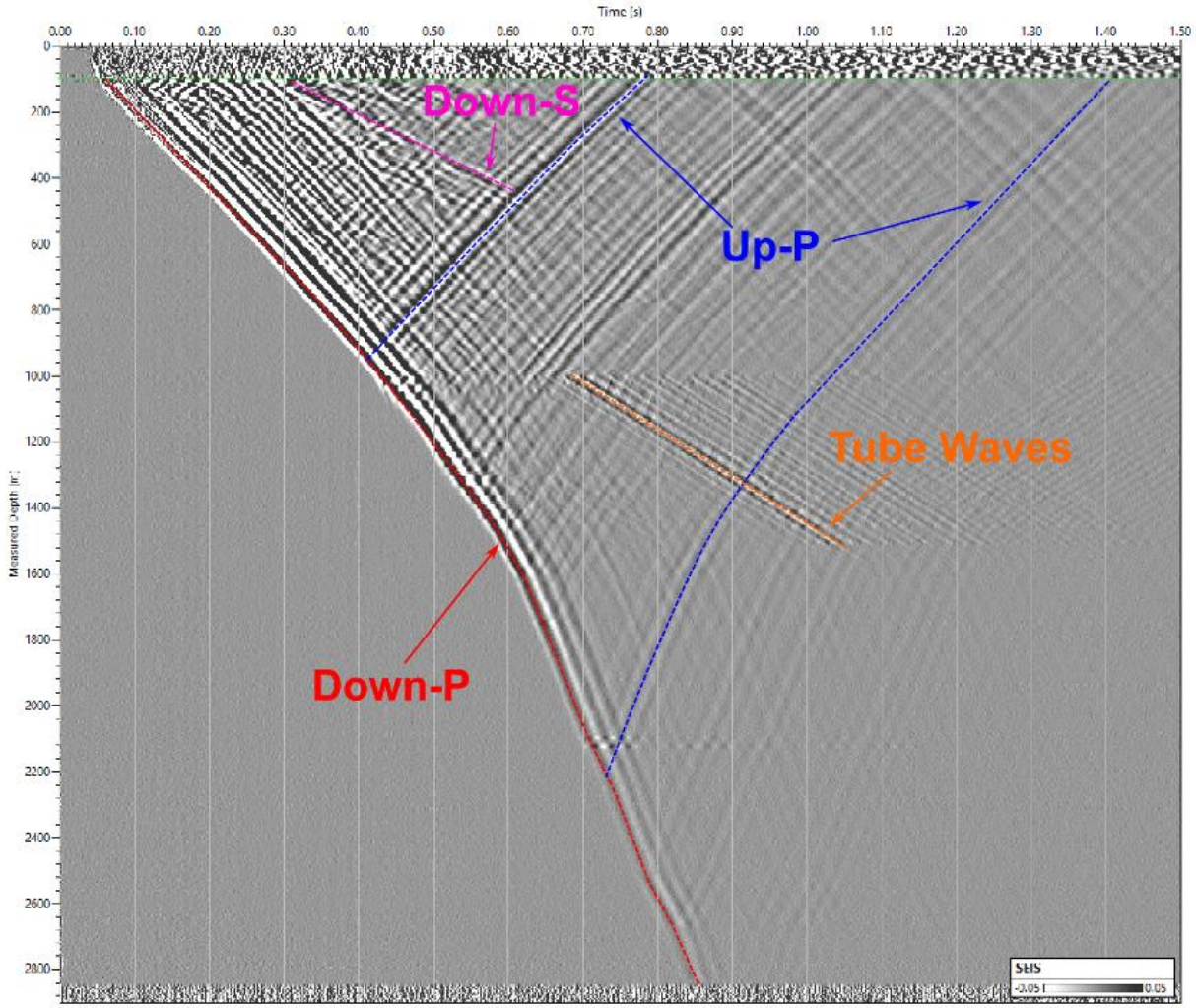
DAS Viewer | Data Properties

Property Name	Property Value
SamplingFrequency[Hz]	2000
SpatialResolution[m]	1
Fibre Type	Constellation
Zone Type	Single-Zone
Start Distance (m)	485.845716
Stop Distance (m)	2183.68953
StreamTime[s]	3
Continuous Mode	True
StartPosition[m]	1
MeasureLength[m]	1664
Precise Sampling Frequency (Hz)	32000
Zones	
Power Decrement	0
Source Mode	Normal
Time Decimation	16
OutputDecimation[bool]	2
P	11
P Coefficients	1.000000;1.000000;1.000000;1.0(
Integration Cut Off (Hz)	3.14
Normalization	True
Decimation Filter	True
Acoustic Output	Differential
Diagnostic Output	R, S, As & dP
Window	0
Physical Fibre Length (m)	2080.626108
PeakVoltage[V]	3.5
Pulse 2 Delay (ns)	40
PulseWidth[ns]	140
Reference length	1
SavingBandwidth (MB/s)	710
Reference Level 1	45058
Reference Level 2	51975
Reference Level 3	65535
FibreIndex	1.4682
Fibre Length Multiplier	1.020952
UserZeroRef	0
Unit Calibration (nm)	116
Diff Amplify Factor	0
Attenuator 2	2.093
Fibre Length per Metre	1
Zero Offset (m)	485.845716
Receiver Gain	0;0;0

Data QC

Signal QC

- Good data contains different wave propagation modes
- P-waves are faster than S-waves (slope of arrival tells you the speed)
  - General rule is Vs = Vp x sqrt(3)
- P-wave will be the first arrival at the fibre, S-waves behind
- Due to changes in speed at different rock layers and deviation in the fibre trajectory a seismic arrival is very rarely straight
- Tube waves follow the same path as the fibre and are therefore normally straight
  - Their speed is due to the speed of sound in the fluid they are moving in e.g. water or oil
  - Normally slower than P-waves but can be similar to S-waves
  - Tube waves are noise for seismic, signal for production!
- Also check the noise before the signal. Is it quiet? Are there artefacts?



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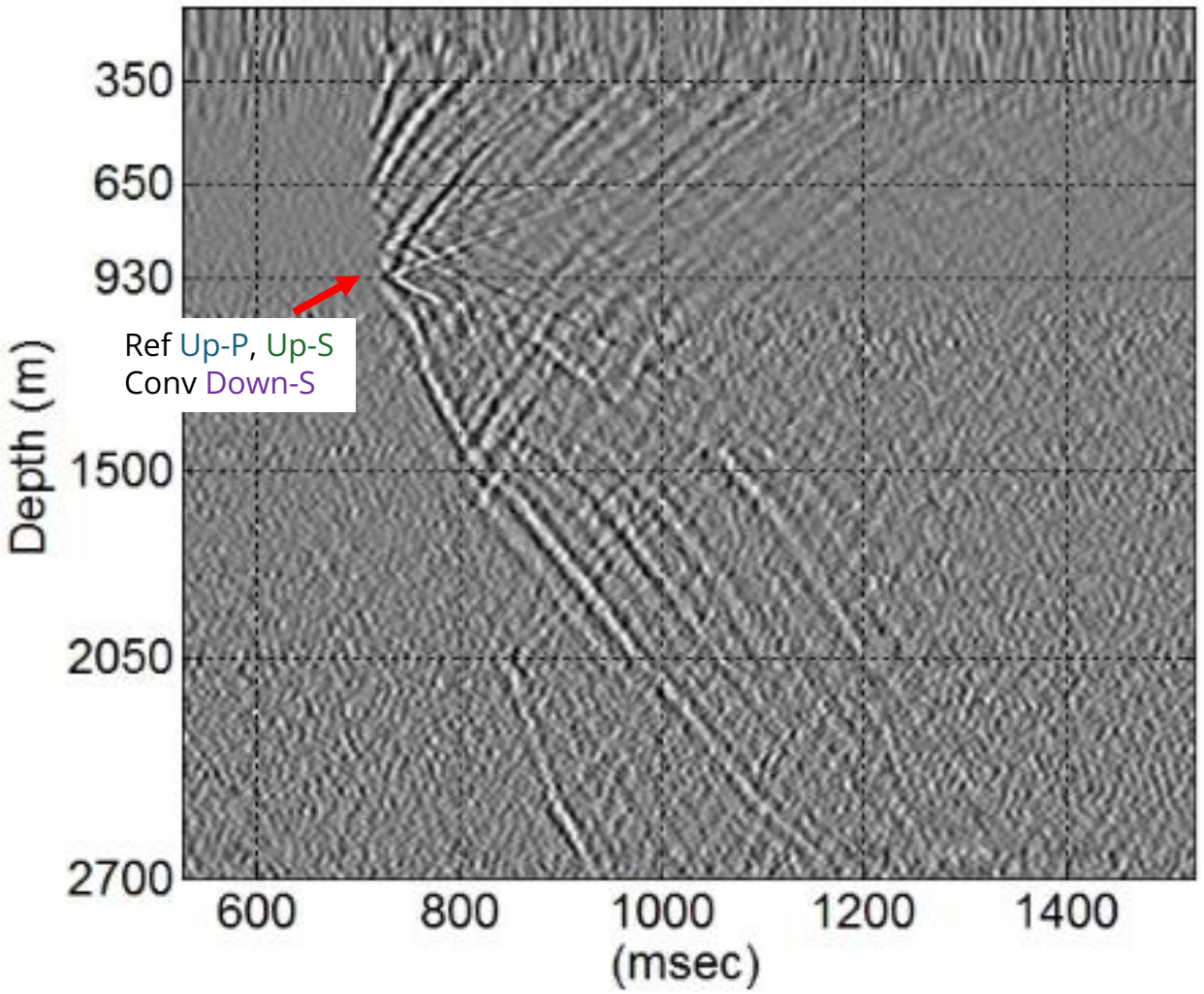
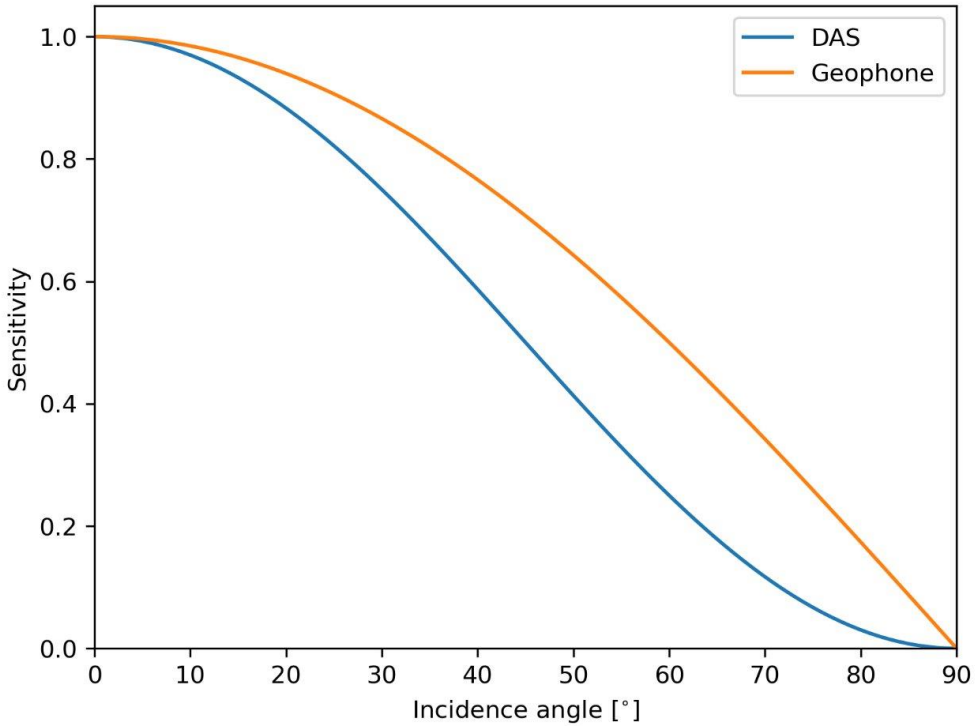


Data QC - Directivity

- P-wave
- DAS = $\cos^2\Theta$
- Geophone = $\cos(\Theta)$

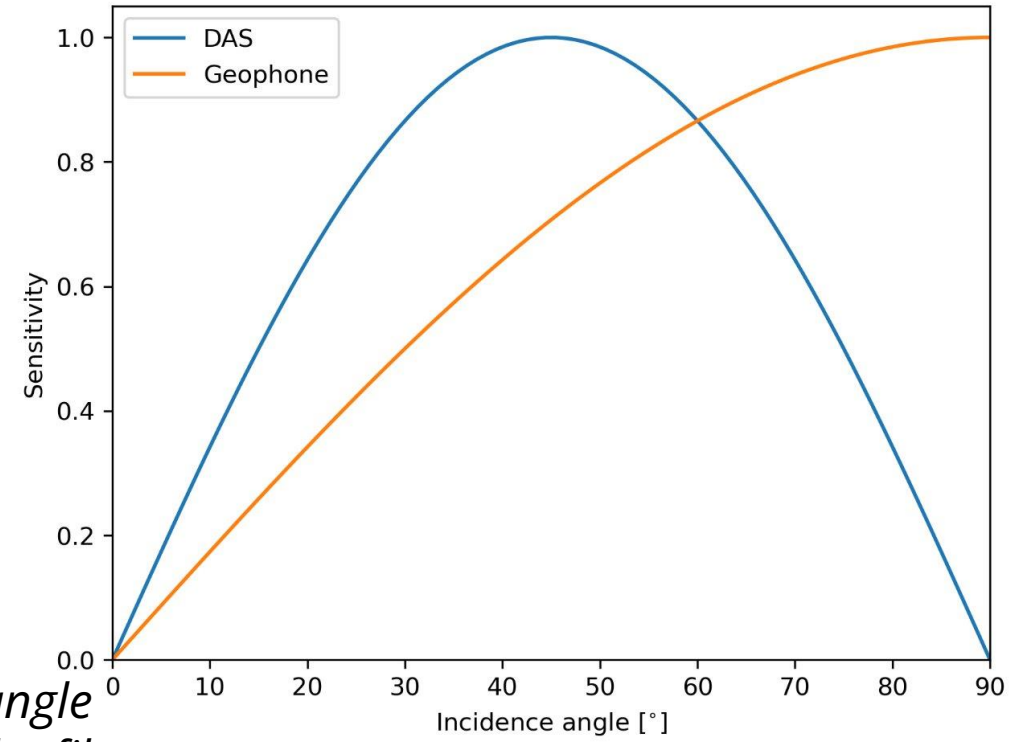


S-wave

(vertical fibre = S_v, horizontal fibre = S_h)

DAS = $\sin(2\theta)$

Geophone = $\sin(\theta)$



θ = incidence angle

0° = in-line with the fibre

90° = perpendicular to the fibre

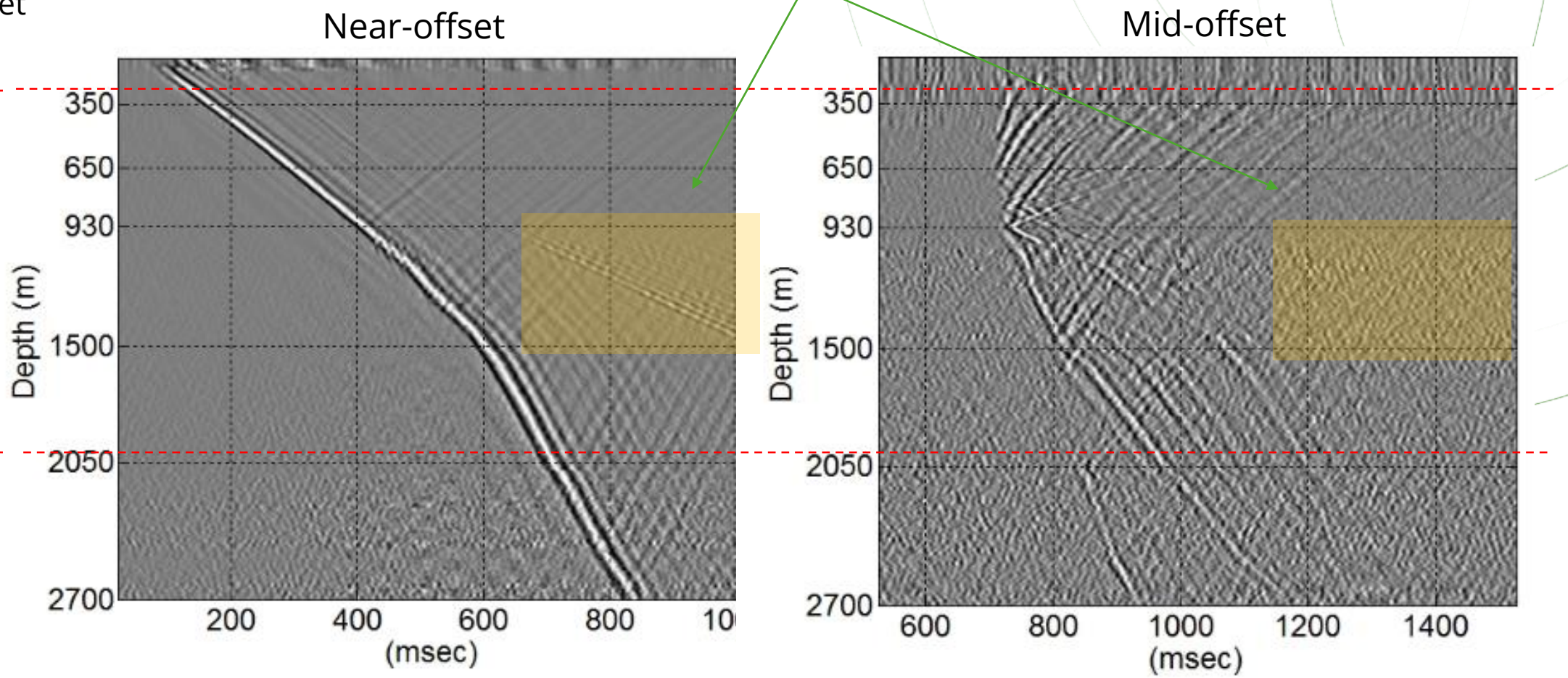
Data QC

Signal QC

- Effect of offset

Tube waves
Near offset: Tube waves generated
Mid-offset: Tube waves not generated

P-wave Angle of incidence
Near offset = ~0°
Mid-offset = ~90°



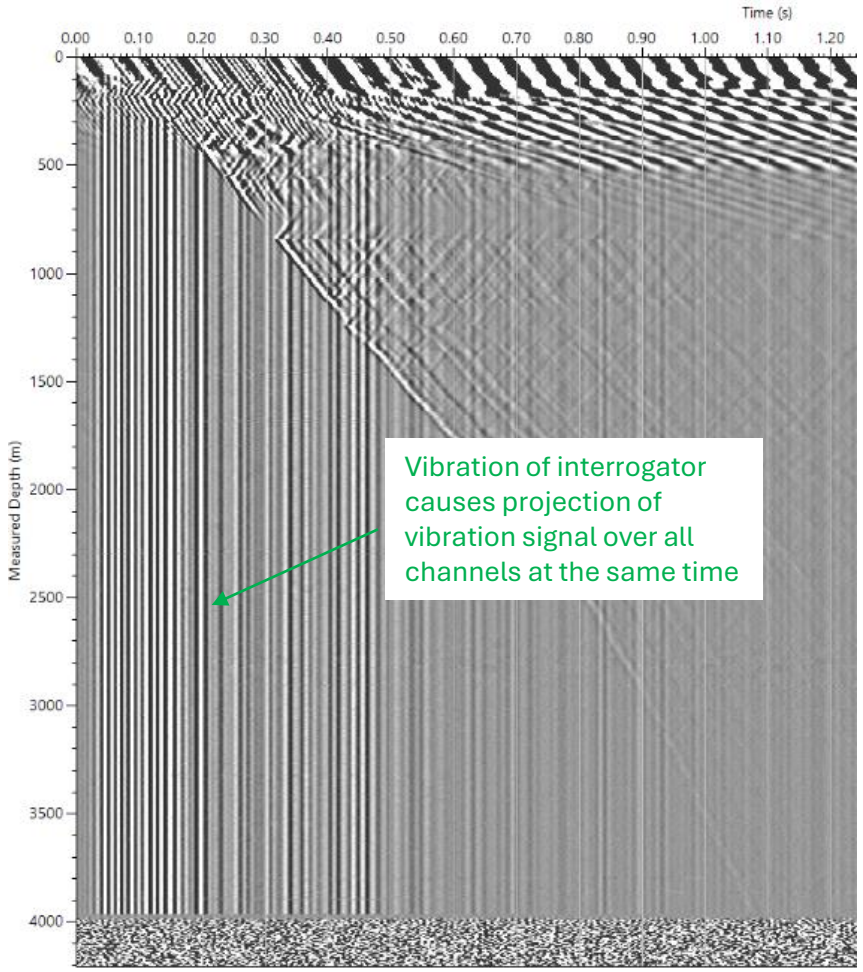
Common Issues

Signal QC

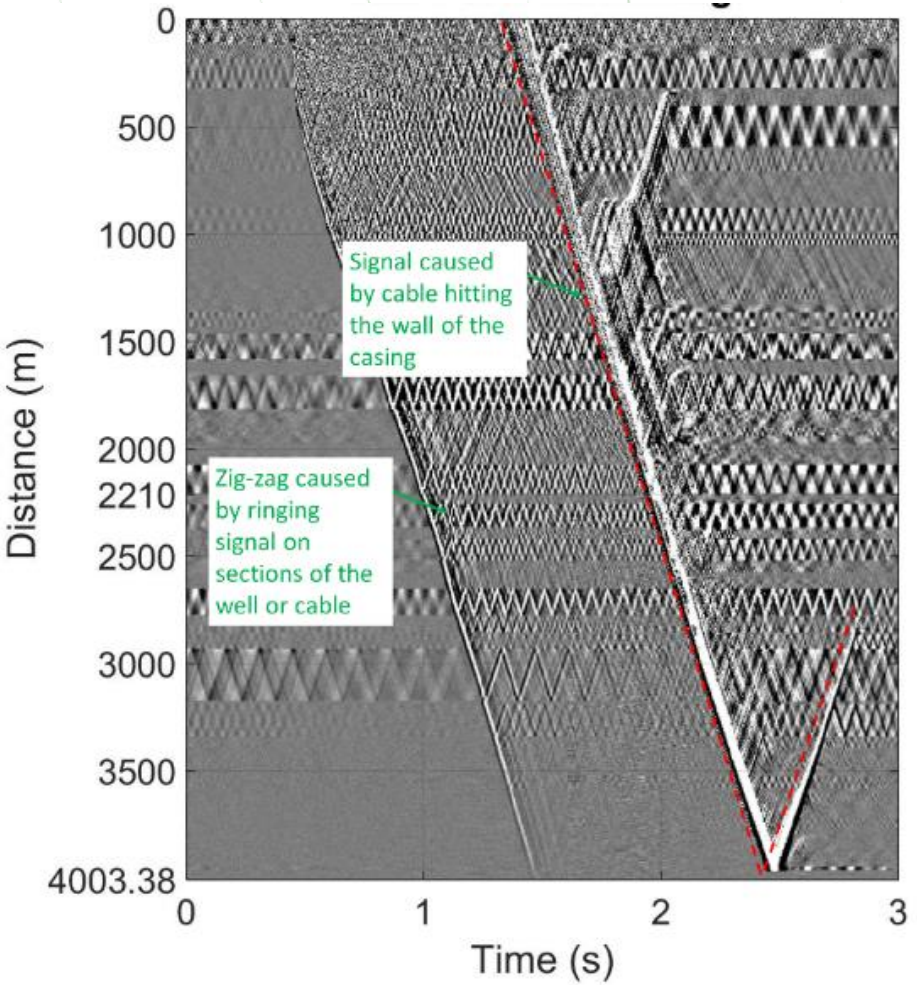
Common mode noise
- Caused by vibration of the DAS unit
- Seen as stripes at same time over all depths
- Vertical stripes if depth is on Y-axis

Intervention cable “ringing”
- Poor coupling between cable and wellbore means the cable acts like guitar string
- Ringing is zig-zag pattern seen in data

Common-Mode Noise



Intervention cable “ringing”

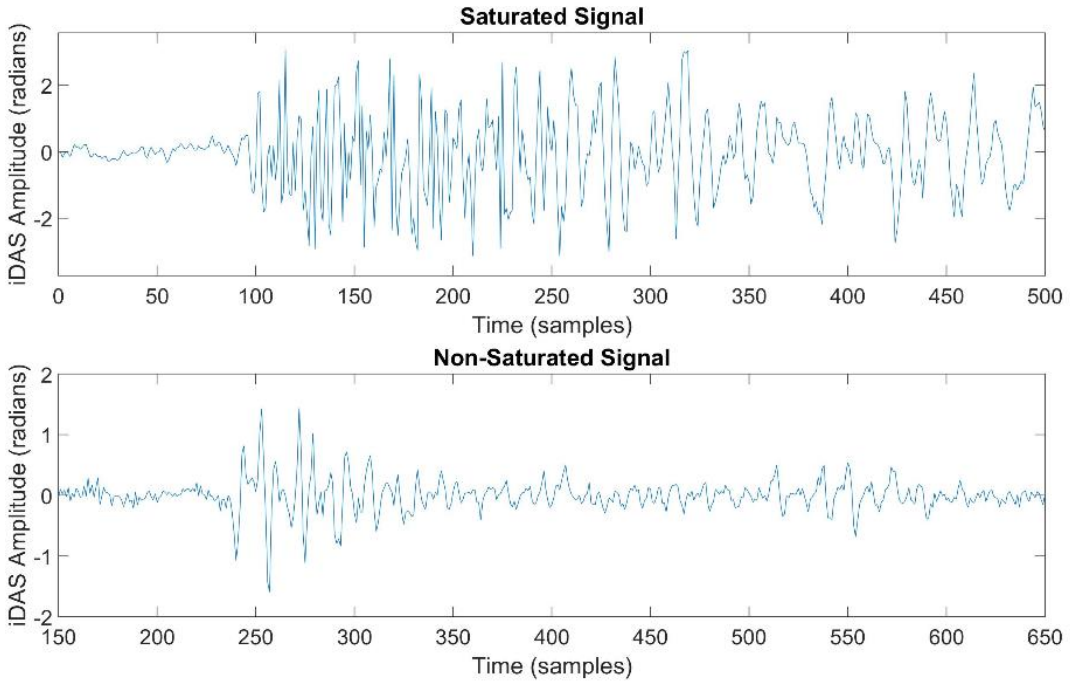


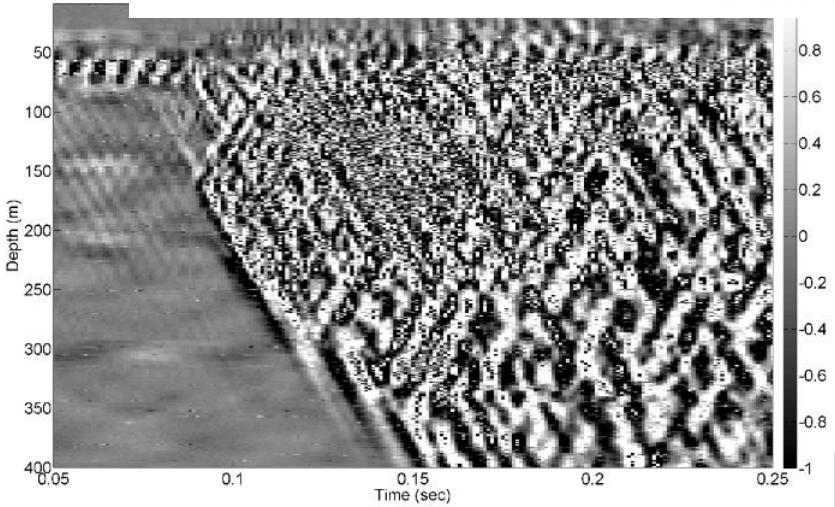
Common Issues

Signal QC

Saturated signal e.g. too loud

- It is possible in rare cases to exceed the maximum signal amplitude that DAS can record
- Seen in waterfall-style plot as “mottled” data rather than clearly defined propagating waves
- Signal saturates in optical domain so does NOT look like “clipping” i.e. signal reaching a maximum value and being limited
- Saturation in optical domain causes signal to “wrap around” which, in acoustic data, looks like many discontinuities (much spikier)

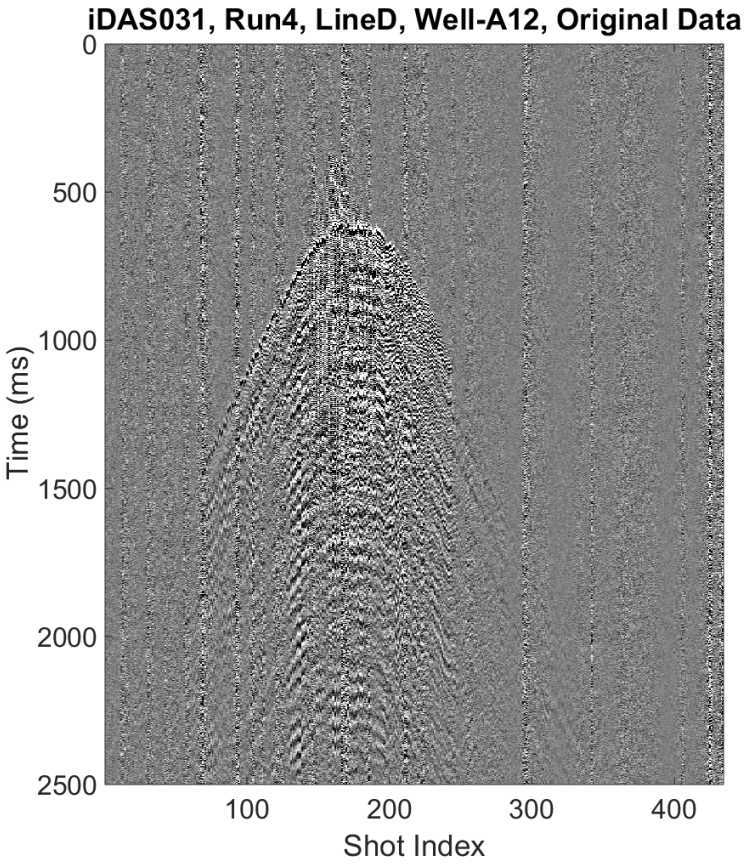


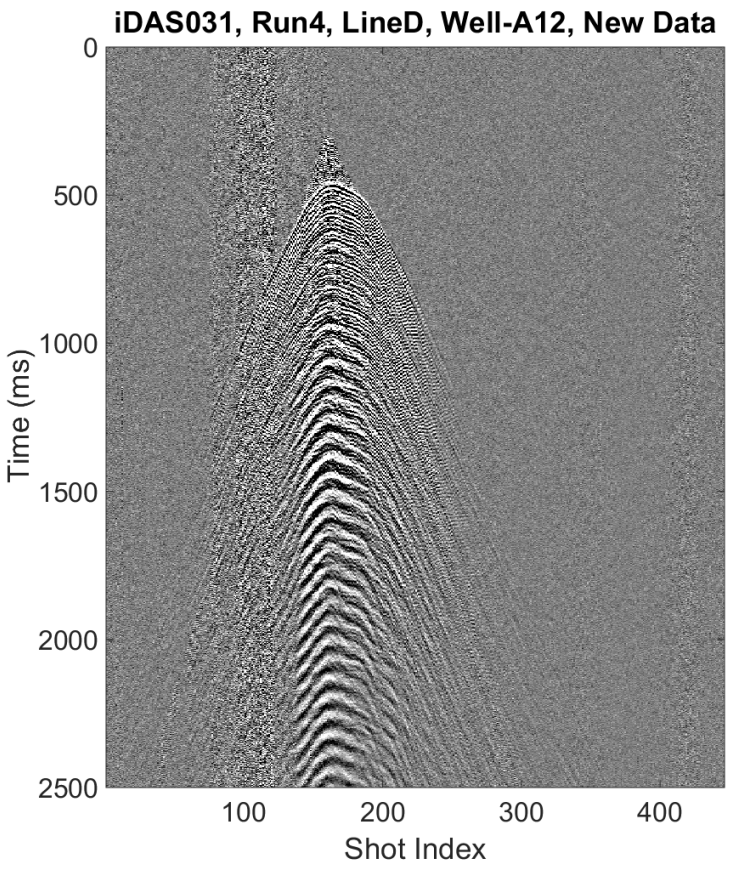


Common Issues

Timing problems

UTC vs GPS Timing
(or bad DAS timing sync with GPS)

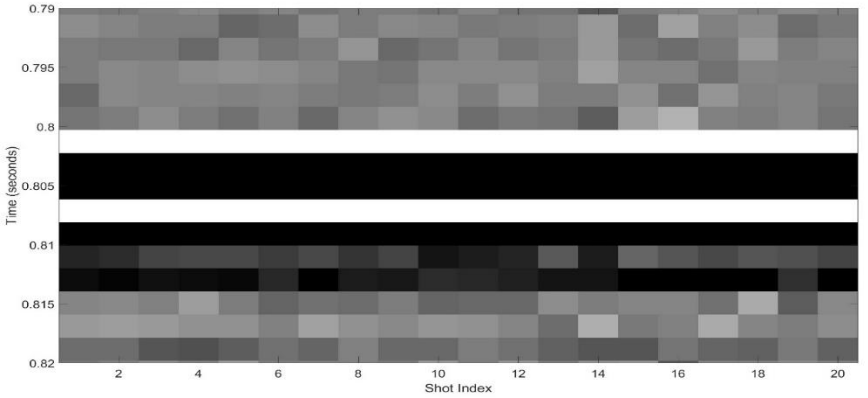




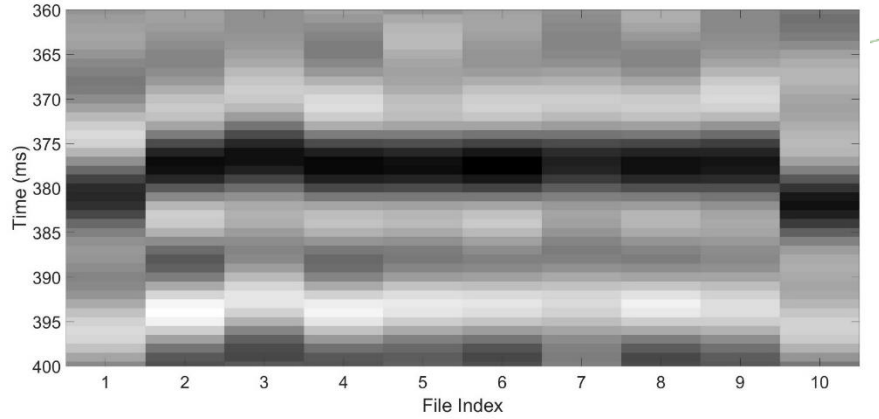
Triggering Issue

Receiver gather, single shot point, triggered

Good



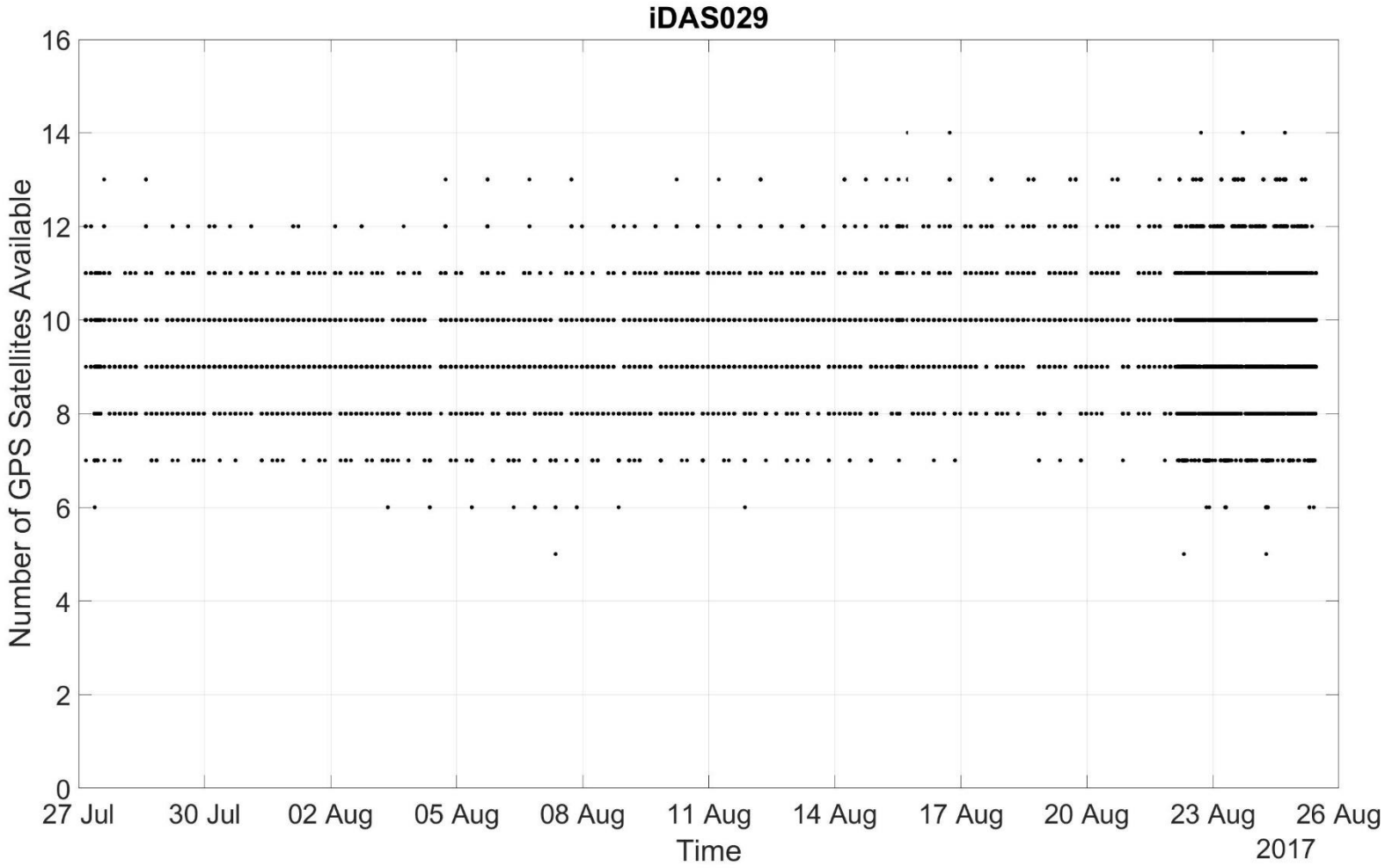
Bad



Common Issues

GPS Satellite Drop-Out

- This is a very rare issue but worth pointing out
- Plot Number of GPS satellites vs time (values stored in TDMS or PRODML headers)



Remote Limitations

Real-time Data visualisation bandwidth

- Waterfall heatmaps plot a lot of data and can often be too resource intensive to use over a slow internet connection
- Waterfall heatmaps are extremely useful in seismic for real-time QC so best practice is to monitor performance on a case-by-case basis
- If it is causing problems switch to a mode that doesn't use a waterfall heatmap and use static data viewers to intermittently check data quality

Comms with source

- It is vital to know what the source is doing at any given time to allow for good QC of the data
- This is harder to achieve on a land job as the source movements can be more random, i.e. not following straight lines
- Radio comms are normally used on site. However, if performing remotely the source company should periodically update source movements by email (or better, a messenger application such as Teams or WhatsApp etc)
- Concentrate on DAS QC and ensuring good data quality when comms is patchy

Observer Notes

- Normal practice is to ensure detailed notes about events throughout the day are recorded. Specifically noting any bad shots or abnormal noise in the area.
- This is impossible when no one is there in person. So important that the source company or a client rep on-site make notes

Remote Limitations

Losing remote access
- If internet or network access drops out it can be impossible to connect to perform any QC. This can throw up a few issues
- No knowledge if DAS is still recording
- No knowledge that the source is still shooting or that data quality is OK
- Notify the client and attempt to regain access as quickly as possible
- Have a plan in place for someone on-site to be able to assist in troubleshooting and restarting machines if necessary

Hardware shut down restart
- Turn it off and turn it back on again is a widely known fix for all problems
- Having someone on site who is aware they may be called on to restart machines (and supplying them with documentation on who to do this safely) is important
    - Note that this person may be busy with other duties so there may be a delay in them doing this. Make the client aware of this in the pre-job meetings
- Having equipment on a managed Power Distribution Unit can allow the power to be cycled remotely

Power failures
- Lots of sites have unreliable power supplies
- Once again, having a plan for how to turn on equipment in the event of a power failure is important
    - It is possible to make the interrogators and some processing machines turn on automatically. Set up and test this in pre-job
    - DAS can auto-restart the CTRL SW after a power failure in some circumstances

THANKS!

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
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