MERC 2023 - Session 3

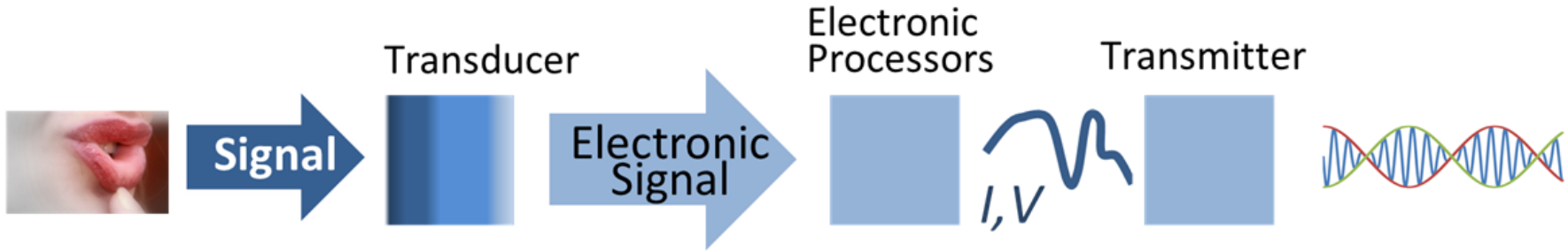
SURVEY DESIGN AND DATA MANAGEMENT

Outline

- Signal Processing
- Data Sampling
- Calibration
- Data Formats
- Software

Signal Processing

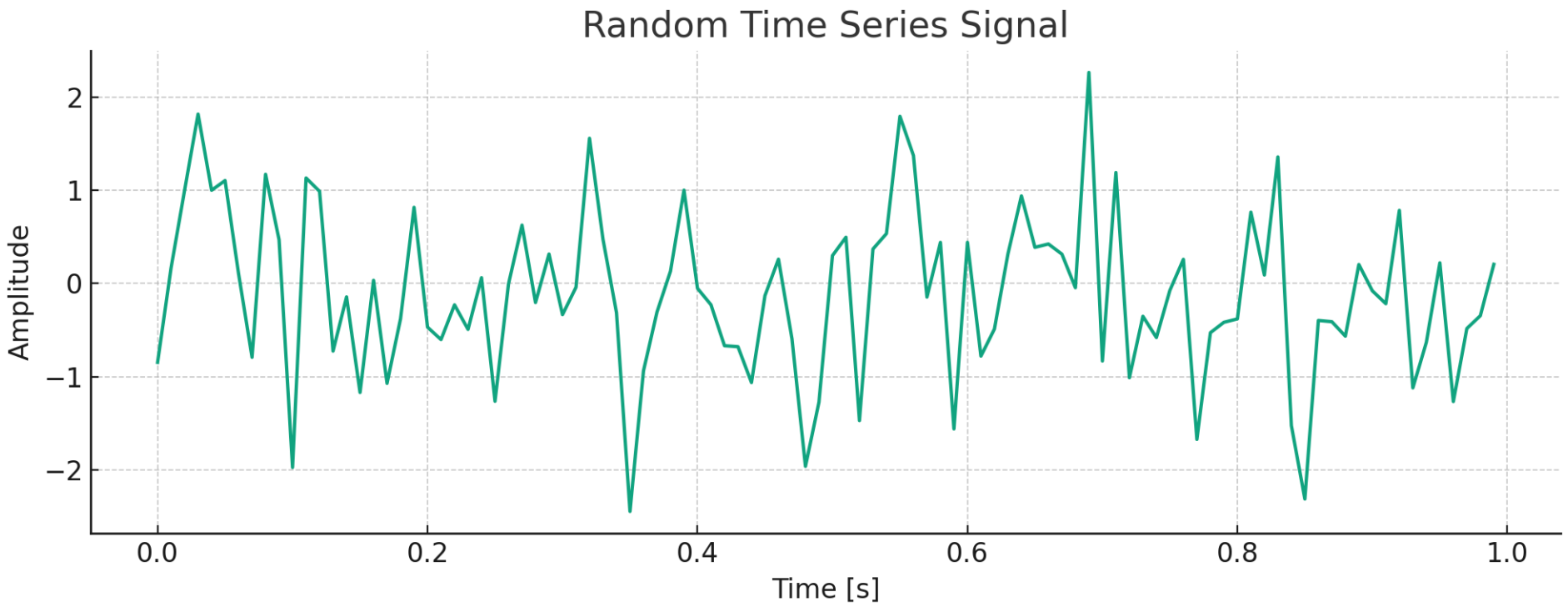
- Signal Processing is the science of receiving, analyzing and manipulating physical measurements to extract useful information.
  - Measurements are usually a function of time or position in space.



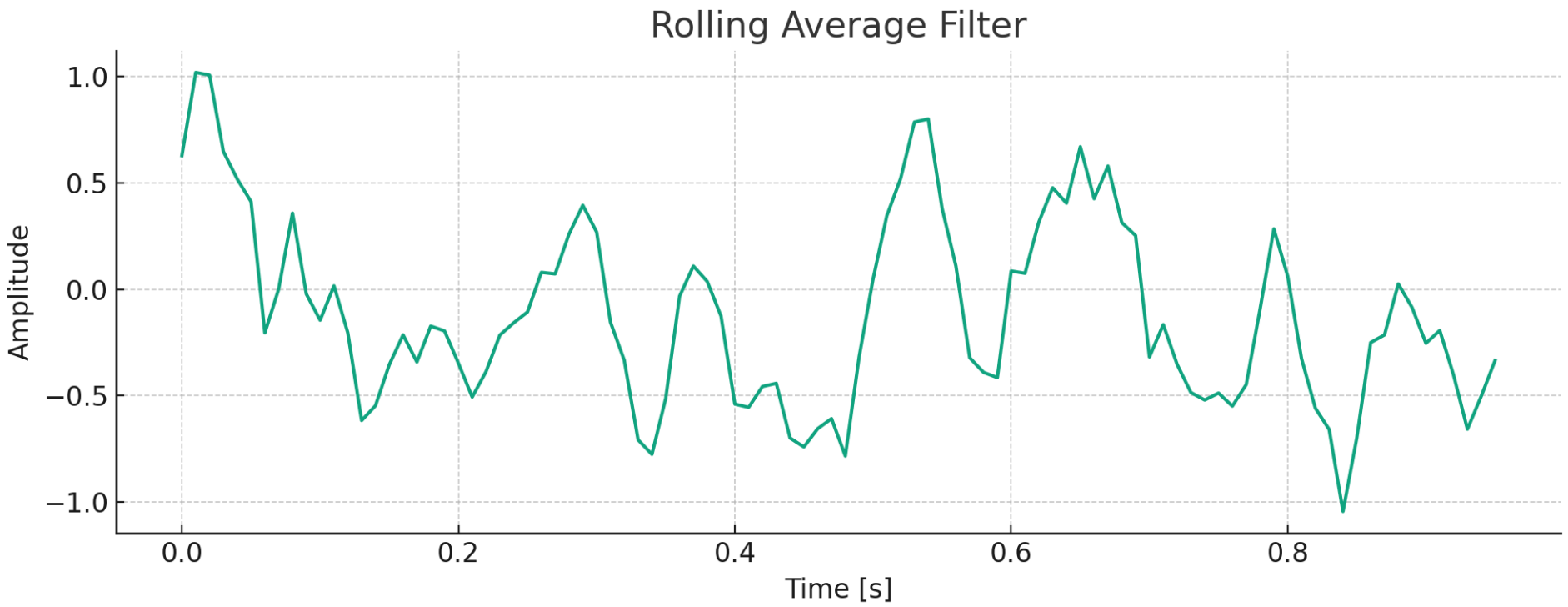
Signal Processing in Borehole Geophysics

- Instruments will poll for a measurement at a pre-defined sampling rate.
- These measurements are reported as voltages (potential differences) or **counts per second (CPS).**
- Through calibration, **CPS** and/or voltages are then converted into physical measurements (more on this later).

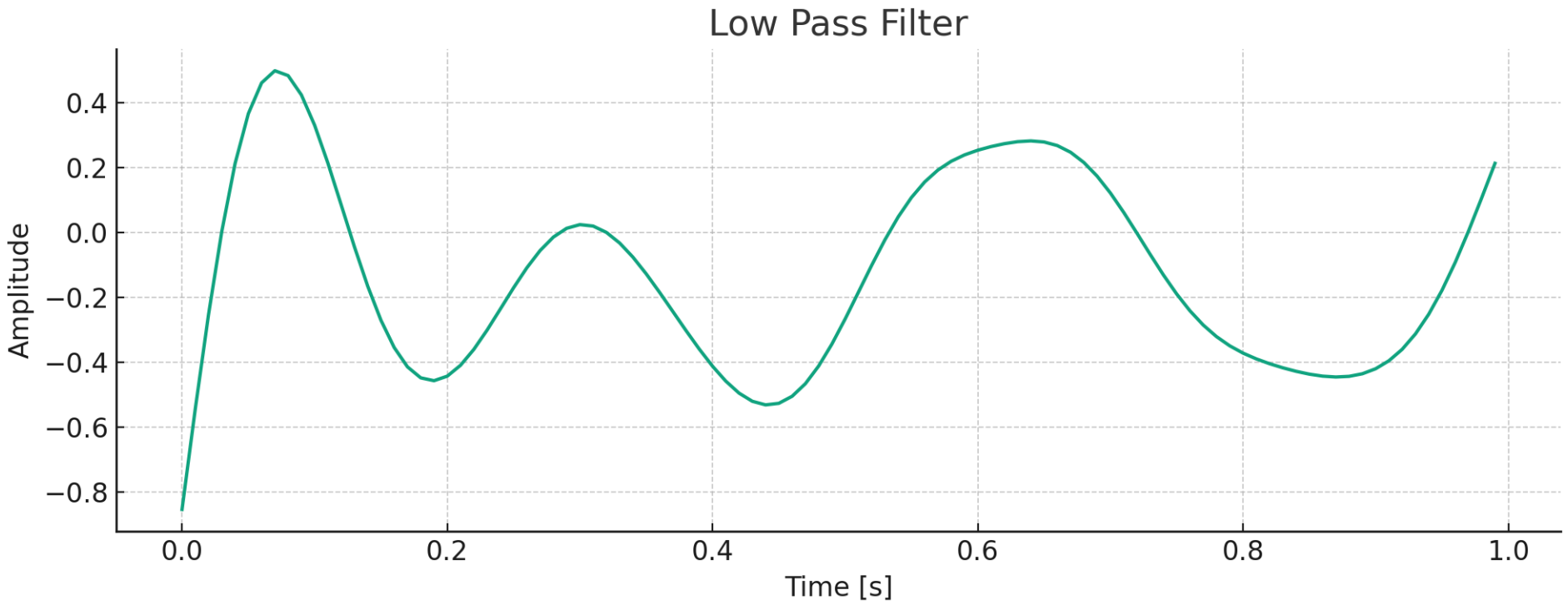
Signal Processing - Filtering



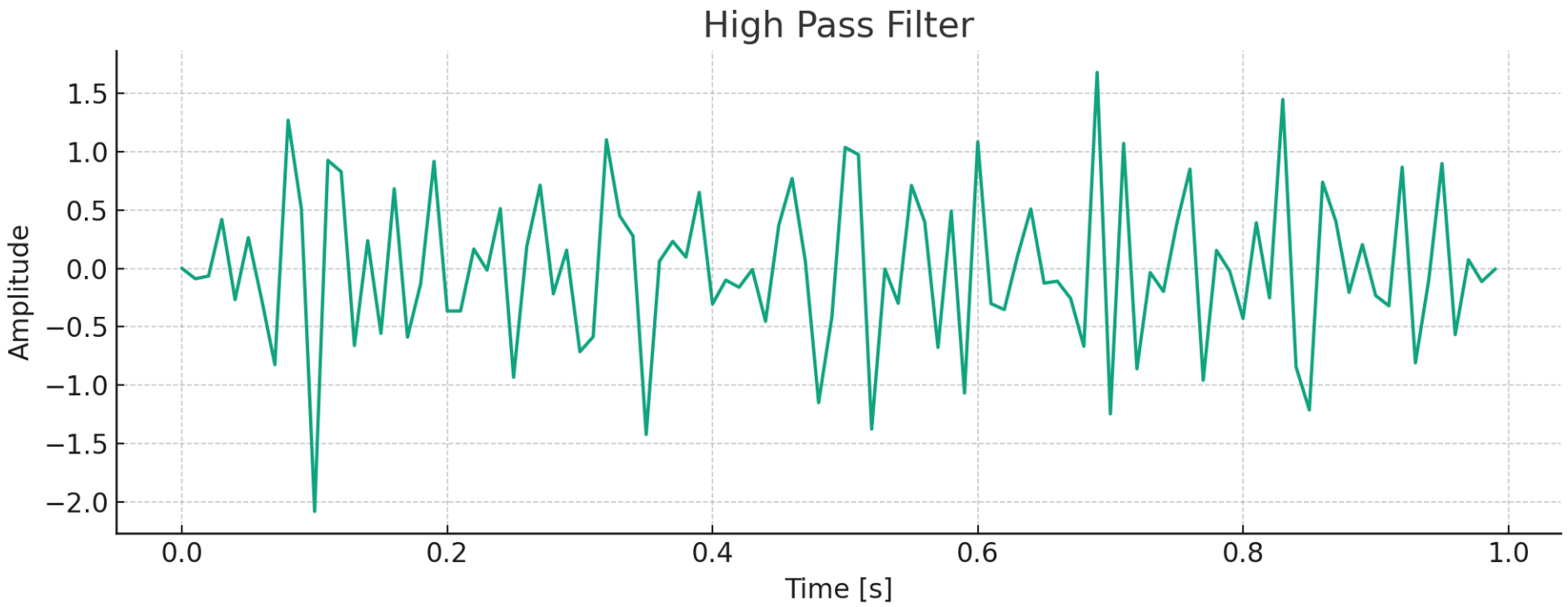
Signal Processing - Filtering



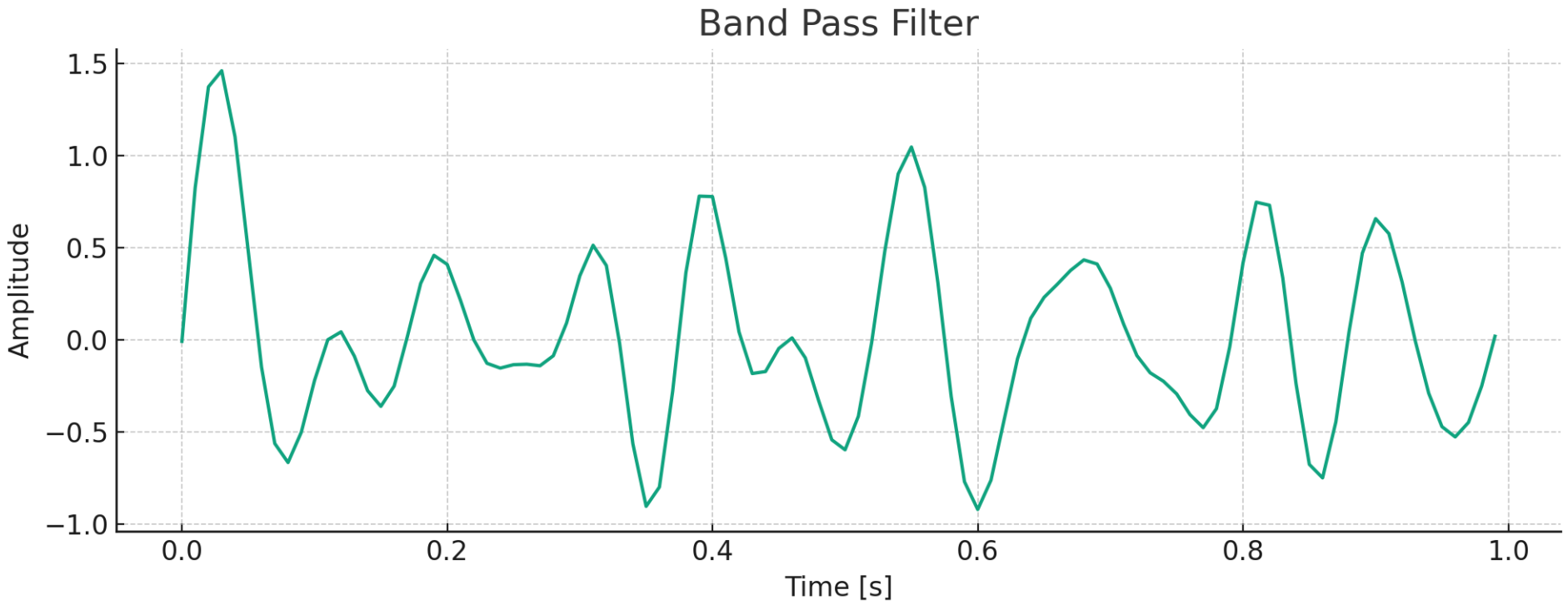
Signal Processing - Filtering



Signal Processing - Filtering

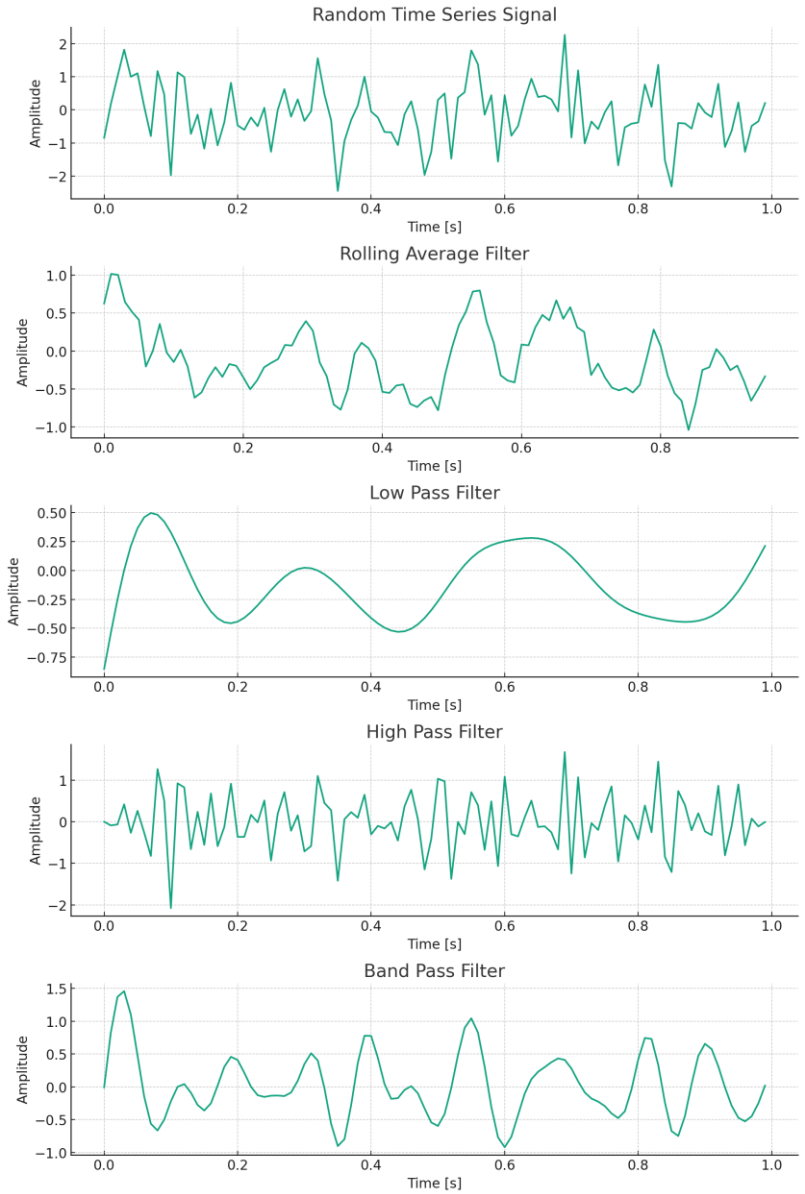


Signal Processing - Filtering



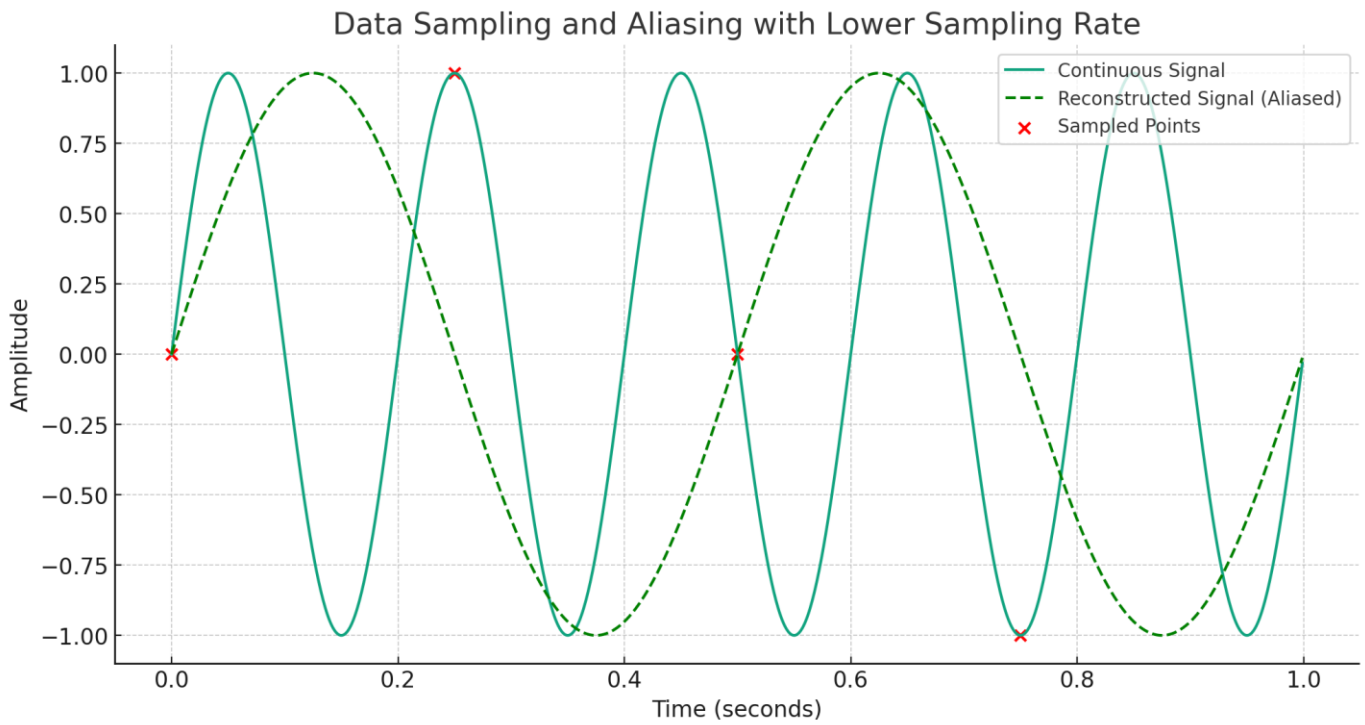
Signal Processing - Filtering

- It is up to the data analyst to determine what the best filter or filters to apply to the raw data.
- Depends on the goals data acquisition.
  - What is more important?
    - Large overall trends.
    - Small changes.
    - Somewhere in between?



Signal Processing - Aliasing

- When sampling from a higher frequency signal, it is important to consider the sampling rate, otherwise **aliasing** may occur.
- **Aliasing** is when a high frequency signal can get mapped to a lower frequency signal.
- The minimum sampling rate must be at least twice the rate of the source frequency you want to resolve.
  - i.e. Source frequency is 40 Hz – Sampled frequency must be at least 80 Hz.



Data Sampling

- Instruments are continuously sampling at regular time intervals.
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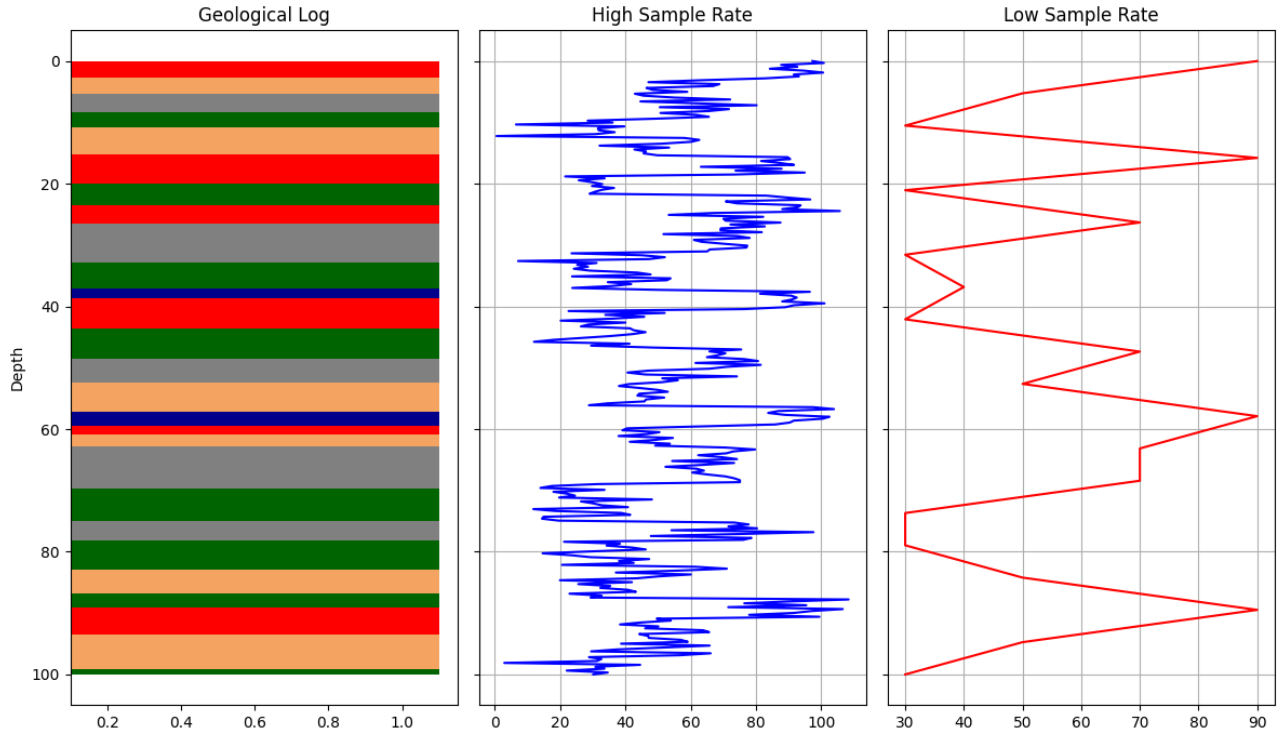
- Based on the specifications of the survey the **counts** are averaged over a period of distance traveled by the probe.

- The number of measurements during this period is a function of the winch speed.
  - Higher Speed → Fewer measurements
  - Lower Speed →More measurements.
  - Time is money.

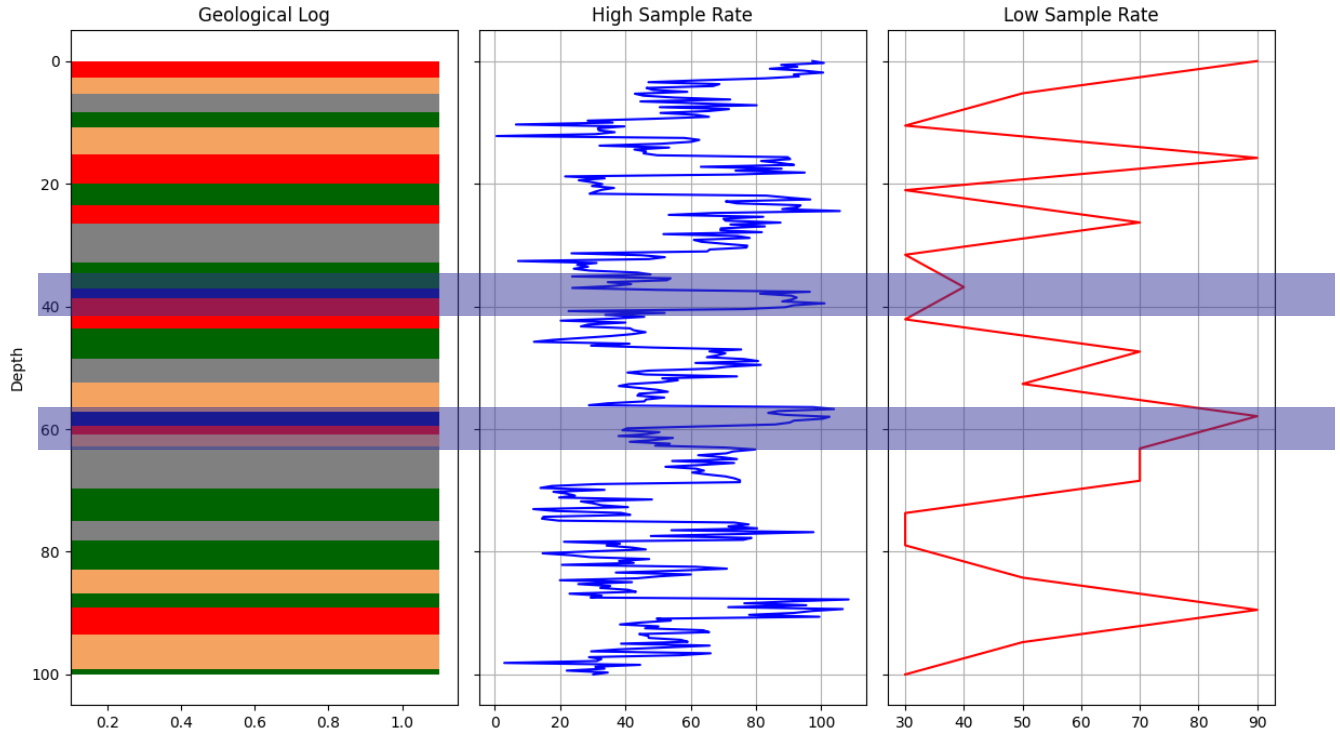
Depth Sampling and Aliasing

- Choosing the correct sampling rate is important.
- The smallest interval you can reliably map would be twice the sampling rate.
  - i.e. Sample Rate is 0.2 m, smallest unit is 0.4 m.



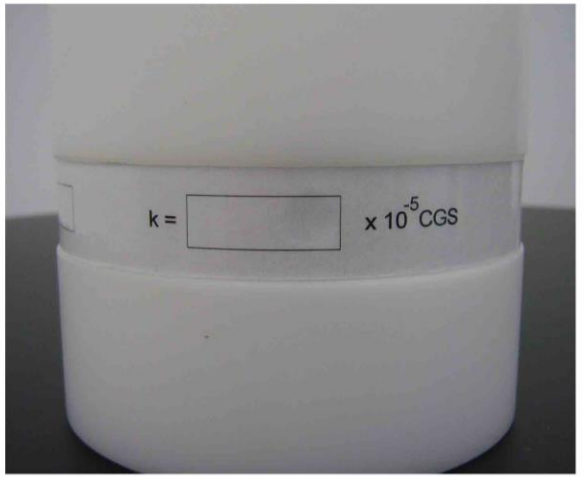
Depth Sampling and Aliasing

- Highlighted areas show the low sample rate log completely missed the response of the blue zone.



Calibrations

- **Importance**
- Standards
  - Auditable Trail
  - Process
- Types of Calibration
  - Factory Calibration
  - Field/jig calibration
  - Calibration holes
    - On site versus established
- Temperature drift
- Hole size
- Fluid conditions
- Measurement Range



Calibrations

- Sign off certificates
- Calibrate and document regularly

Test #1 - Aluminum Block

Aluminum Block (g/cc):	2.6

Test File Name: 446_MSDT_5167_4081CO_Aluminum_011718

Near Density	g/cc	Far Density	g/cc
Min:	2.628	Min:	2.586
Max:	2.766	Max:	2.811
Average:	2.701	Average:	2.699
Difference:	0.101	Difference:	0.099

Total number of sample data points: 1118

Test Results:
- ☑ Passed
- ☐ Needs Re-calibration

Test #2 - Hardy Test Hole 200m-370m

Reference Average (g/cc):	2.942

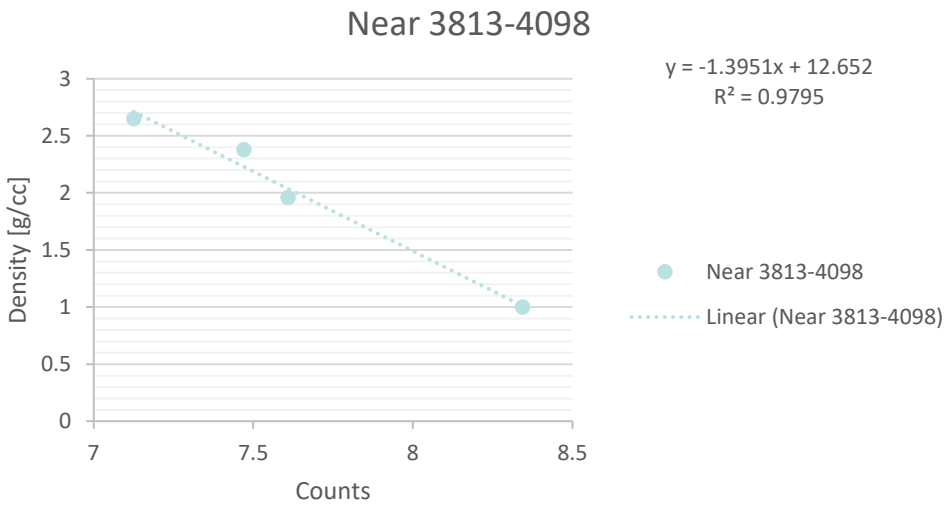
Test File Name: 000_MSDT_5167_4081CO_u1_011818

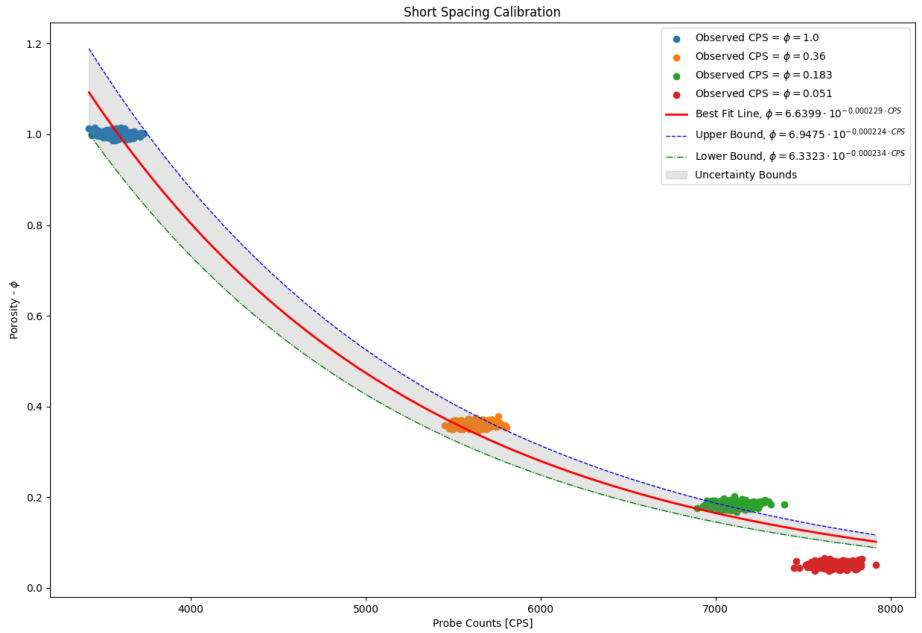
Near Density	g/cc	Far Density	g/cc
Average:	2.942	Average:	2.942
Difference Average Values:	-0.001	Difference Average Values:	0.000

Total number of sample data points: 1669

Test Results:
- ☑ Passed
- ☐ Needs Re-calibration

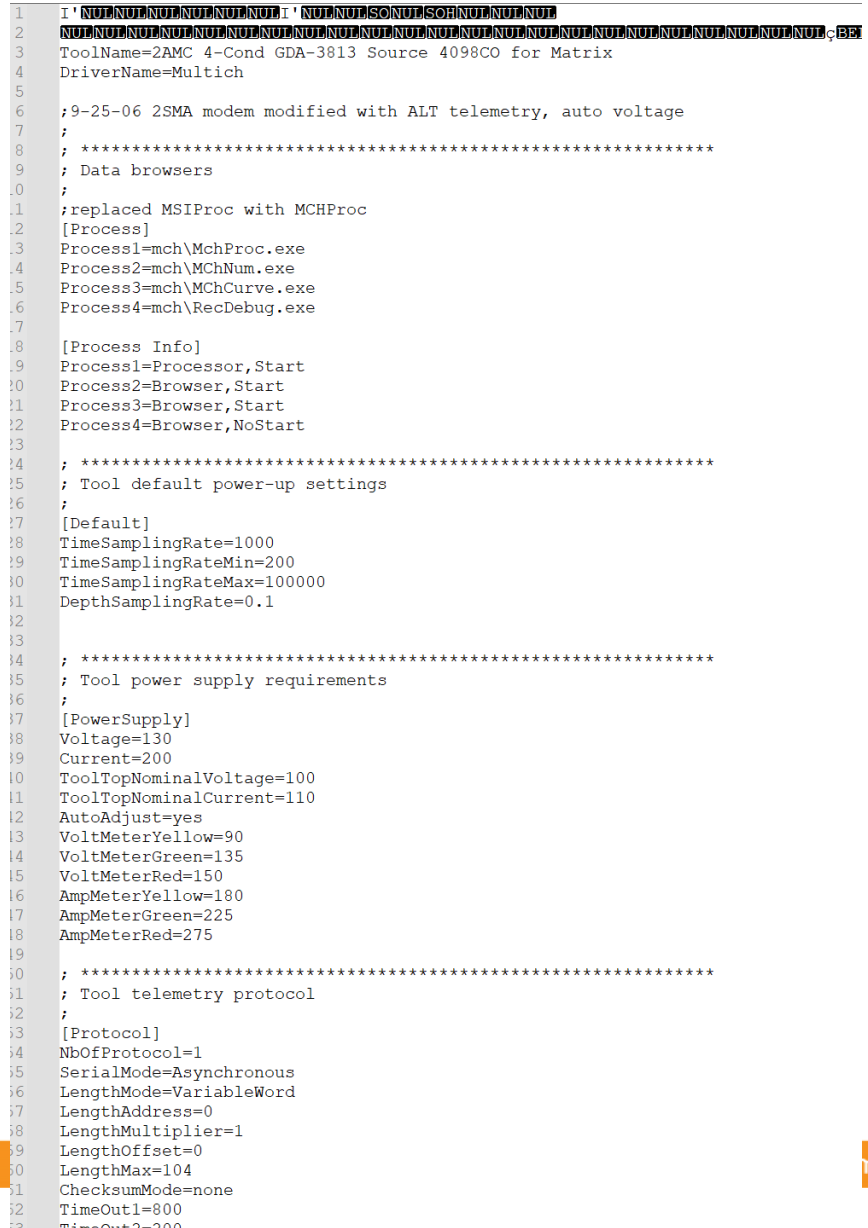
Calibration





Data Formats - TFD

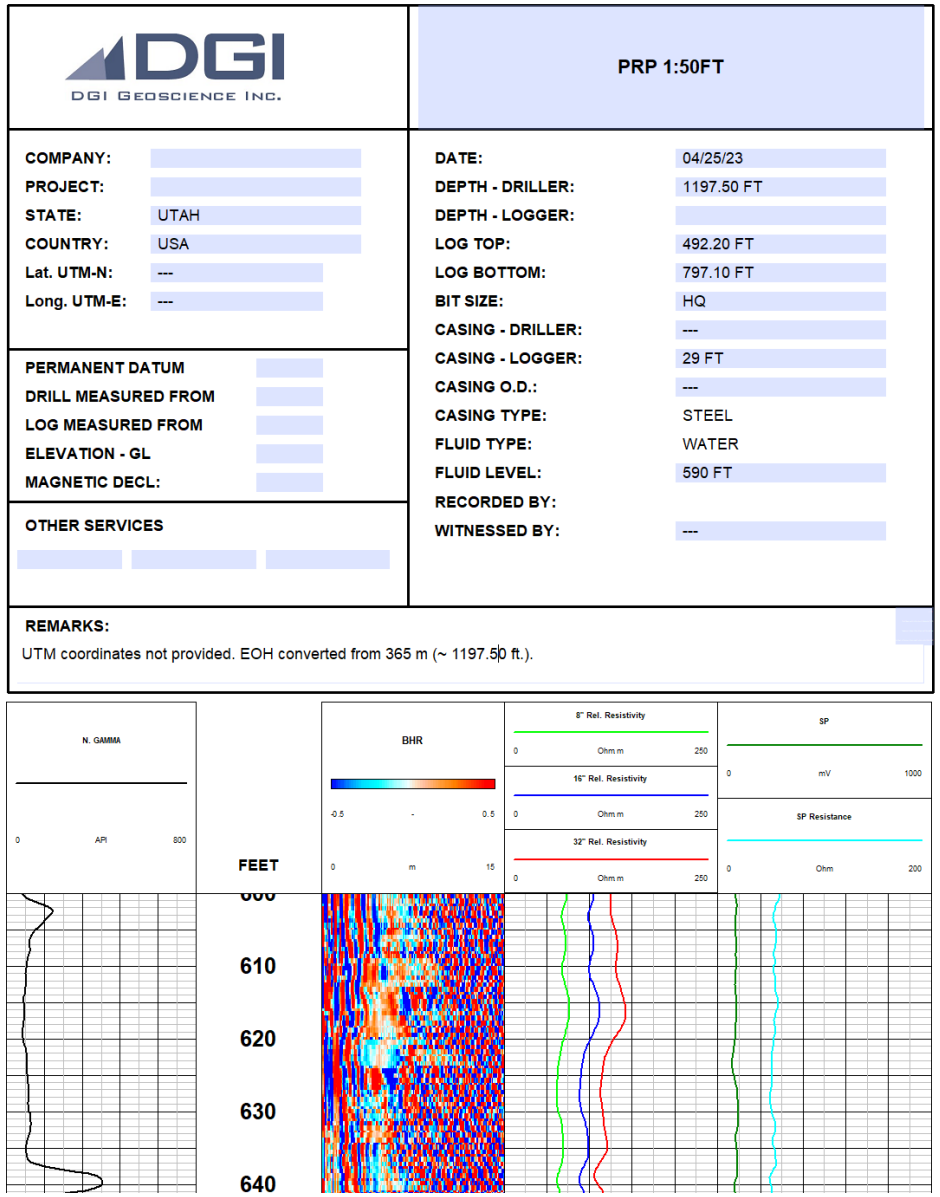
- Most slim-line probes will create a **TFD** file.
  - This file format is the primary format for Advanced Logic Technology (ALT) and Mont Sopris Instruments (MSI).
  - ALT is the developer of WellCAD and Logger Suite software.
    - They also perform research and development of acquisition systems and new probes.
  - MSI is a popular manufacturer of probes, winches and logging consoles.
    - They work in partner with several development firms (includes ALT) to manufacture probes.
  - **TFD** is a proprietary binary file format, that can only be read by WellCAD software.
  - The header information of the file can be viewed in plaintext in a text editor.
- Only used for **RAW** data, processed data is never stored in this format.



```
I'NULNULNULNULNULNULI'NULNULSONULSOHNULNULNUL
NULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULçBE
ToolName=2AMC 4-Cond GDA-3813 Source 4098CO for Matrix
DriverName=Multich

;9-25-06 2SMA modem modified with ALT telemetry, auto voltage
;
; ****************************************************************
; Data browsers
;
;replaced MSIProc with MCHProc
[Process]
Process1=mch\MchProc.exe
Process2=mch\MChNum.exe
Process3=mch\MChCurve.exe
Process4=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,NoStart

; ****************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=1000
TimeSamplingRateMin=200
TimeSamplingRateMax=100000
DepthSamplingRate=0.1


; ****************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=130
Current=200
ToolTopNominalVoltage=100
ToolTopNominalCurrent=110
AutoAdjust=yes
VoltMeterYellow=90
VoltMeterGreen=135
VoltMeterRed=150
AmpMeterYellow=180
AmpMeterGreen=225
AmpMeterRed=275

; ****************************************************************
; Tool telemetry protocol
;
[Protocol]
NbOfProtocol=1
SerialMode=Asynchronous
LengthMode=VariableWord
LengthAddress=0
LengthMultiplier=1
LengthOffset=0
LengthMax=104
ChecksumMode=none
TimeOut1=800
```

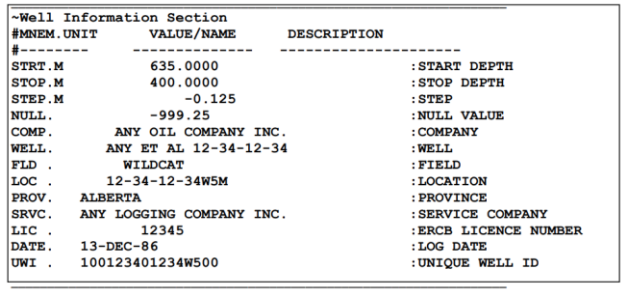
Data Formats - WCL

- WellCAD is by far the most common software to view and process data acquired from borehole logging for slimline logging.
- WCL is proprietary binary file format that can be only opened in the fully licensed and reader versions of WellCAD.
- Support for almost any type of data that can be acquired within a borehole.
  - Point, Interval and Array data.
  - Categorical
  - Images.
  - Annotations and Text.
- Commonly used to format logs into plots for printing to PDF or paper.

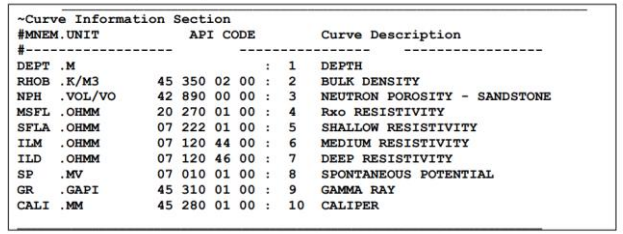


Data Formats - LAS

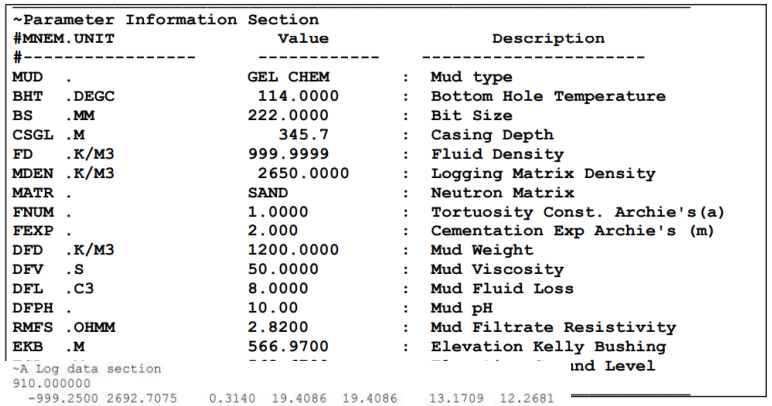
- Has existed as a file format for several decades.
  - Some say was originally based on punch cards.
- Developed by the Canadian Well Logging Society.
  - The current version is 3.0
  - The most supported version is 2.0.
  - Version 2.0 only supports regularly sampled numeric data.
  - Version 3.0 has support for irregularly sampled data, as well as categorical and array data.
- Includes a header section for metadata.
- Supported in most geologic software packages.



```
~Well Information Section
#MNEM.UNIT       VALUE/NAME      DESCRIPTION
#--------     --------------   -----------------------
STRT.M            635.0000                :START DEPTH
STOP.M            400.0000                :STOP DEPTH
STEP.M              -0.125                :STEP
NULL.             -999.25                 :NULL VALUE
COMP.        ANY OIL COMPANY INC.         :COMPANY
WELL.       ANY ET AL 12-34-12-34         :WELL
FLD .         WILDCAT                     :FIELD
LOC .       12-34-12-34W5M                :LOCATION
PROV.    ALBERTA                          :PROVINCE
SRVC.    ANY LOGGING COMPANY INC.         :SERVICE COMPANY
LIC .           12345                     :ERCB LICENCE NUMBER
DATE.    13-DEC-86                        :LOG DATE
UWI .    100123401234W500                 :UNIQUE WELL ID
```



```
~Curve Information Section
#MNEM.UNIT            API CODE         Curve Description
#------------------  ------------  ------------------
DEPT .M                          :  1   DEPTH
RHOB .K/M3        45 350 02 00 :  2   BULK DENSITY
NPH  .VOL/VO      42 890 00 00 :  3   NEUTRON POROSITY - SANDSTONE
MSFL .OHMM        20 270 01 00 :  4   Rxo RESISTIVITY
SFLA .OHMM        07 222 01 00 :  5   SHALLOW RESISTIVITY
ILM  .OHMM        07 120 44 00 :  6   MEDIUM RESISTIVITY
ILD  .OHMM        07 120 46 00 :  7   DEEP RESISTIVITY
SP   .MV          07 010 01 00 :  8   SPONTANEOUS POTENTIAL
GR   .GAPI        45 310 01 00 :  9   GAMMA RAY
CALI .MM          45 280 01 00 : 10   CALIPER
```



```
~Parameter Information Section
#MNEM.UNIT                Value                 Description
#------------------   -------------   ----------------------
MUD   .                GEL CHEM      :  Mud type
BHT   .DEGC             114.0000     :  Bottom Hole Temperature
BS    .MM               222.0000     :  Bit Size
CSGL  .M                  345.7      :  Casing Depth
FD    .K/M3             999.9999     :  Fluid Density
MDEN  .K/M3              2650.0000   :  Logging Matrix Density
MATR  .                 SAND          :  Neutron Matrix
FNUM  .                 1.0000        :  Tortuosity Const. Archie's(a)
FEXP  .                 2.000         :  Cementation Exp Archie's (m)
DFD   .K/M3             1200.0000     :  Mud Weight
DFV   .S                50.0000       :  Mud Viscosity
DFL   .C3               8.0000        :  Mud Fluid Loss
DFPH  .                 10.00         :  Mud pH
RMFS  .OHMM             2.8200        :  Mud Filtrate Resistivity
EKB   .M                566.9700      :  Elevation Kelly Bushing
                                          nd Level
```

```
~A Log data section
910.000000
  -999.2500 2692.7075    0.3140  19.4086  19.4086    13.1709  12.2681
    -1.5010   96.5306  204.7177  30.5822 -999.2500 -999.2500   3.2515
  -999.2500    4.7177 3025.0264 3025.0264  -1.5010   93.1378   0.1641
     0.0101    0.1641    0.3140   0.1641  11.1397    0.3304   0.9529
     0.0000    0.1564    0.0000  11.1397   0.0000    0.0000   0.0000
909.875000
  -999.2500 2712.6460    0.2886  23.3987  23.3987    13.6129  12.4744
    -1.4720   90.2803  203.1093  18.7566 -999.2500  999.2500   3.7058
  -999.2500    3.1093 3004.6050 3004.6050  -1.4720   86.9078   0.1456
    -0.0015    0.1456    0.2886   0.1456  14.1428    0.2646   1.0000
     0.0000    0.1456    0.0000  14.1428   0.0000    0.0000   0.0000
909.750000
  -999.2500 2692.8137    0.2730  22.5909  22.5909    13.6821  12.6146
    -1.4804   89.8492  201.9287   3.1551 -999.2500 -999.2502   4.3124
  -999.2500    1.9287 2976.4451 2976.4451  -1.4804   86.3465   0.1435
     0.0101    0.1435    0.2730   0.1435  14.5674    0.2598   1.0000
     0.0000    0.1435    0.0000  14.5674   0.0000    0.0000   0.0000

909.625000
  -999.2500 2644.3650    0.2765  18.4831  18.4831    13.4159  12.6900
    -1.5010   93.3999  201.5826  -6.5861 -999.2500 -999.2500   4.3822
  -999.2500    1.5826 2955.3528 2955.3528  -1.5010   89.7142   0.1590
     0.0384    0.1590    0.2765   0.1590  11.8600    0.3210   0.9667
     0.0000    0.1538    0.0000  11.8600   0.0000    0.0000   0.0000
909.500000
```

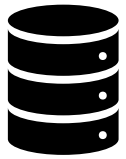
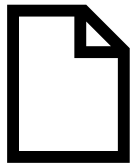
Data Formats - ASCII

- ASCII formats such as CSV and TXT formats are also common.
- These file formats are supported in many software packages.
  - Can easily view data in Excel.
- Lack support for metadata.
- Flexible formatting and can include data from multiple holes for compilation.
- Support for Categorical type data.

```
Depth_m,natural_gamma,near_density,far_density,compensated_density,neutron_ss_counts,neutron_ls_cou
0.059,126.606,NaN,NaN,NaN,51.786,39.116,NaN,NaN,NaN,NaN,151.142,24.389,NaN,NaN,NaN
0.259,143.729,NaN,NaN,NaN,58.347,36.345,NaN,NaN,NaN,NaN,85.622,26.953,NaN,NaN,NaN
0.459,158.569,NaN,NaN,NaN,96.876,34.967,NaN,NaN,NaN,NaN,56.644,23.129,NaN,NaN,NaN
0.659,172.925,NaN,NaN,NaN,167.026,34.111,NaN,NaN,NaN,NaN,47.189,36.509,NaN,NaN,NaN
0.859,186.833,NaN,NaN,NaN,262.922,34.339,NaN,NaN,NaN,NaN,47.335,47.977,NaN,NaN,NaN
1.059,186.49,NaN,NaN,NaN,423.449,45.399,NaN,NaN,NaN,NaN,45.876,37.042,NaN,NaN,NaN
1.259,189.525,NaN,NaN,NaN,586.135,54.828,NaN,NaN,NaN,NaN,58.865,35.989,NaN,NaN,NaN
1.459,209.426,2.983,NaN,2.062,737.533,62.132,NaN,NaN,NaN,NaN,94.615,42.94,NaN,NaN,NaN
1.659,223.085,2.959,215.142,2.021,837.233,108.123,NaN,NaN,NaN,NaN,135.069,42.896,NaN,NaN,NaN
1.859,232.573,2.954,228.068,1.937,906.557,158.56,NaN,NaN,NaN,NaN,197.179,46.039,NaN,NaN,NaN
2.059,220.226,2.98,238.23,1.931,910.724,178.135,NaN,NaN,NaN,NaN,425.874,59.538,NaN,NaN,NaN
2.259,209.432,2.98,243.488,2.068,935.954,198.242,NaN,NaN,NaN,NaN,607.021,73.966,NaN,NaN,NaN
2.459,203.966,2.971,231.838,2.154,1001.743,218.852,NaN,NaN,NaN,NaN,733.928,88.938,NaN,NaN,NaN
2.659,230.307,2.947,214.853,2.21,998.563,NaN,NaN,NaN,NaN,NaN,846.41,134.074,NaN,NaN,NaN
2.859,268.9,2.921,212.32,2.159,972.515,NaN,NaN,NaN,NaN,NaN,937.466,178.659,NaN,NaN,NaN
3.059,234.672,2.892,217.863,2.033,1021.586,NaN,NaN,NaN,NaN,NaN,948.108,221.705,NaN,NaN,NaN
3.259,210.989,2.916,233.728,1.805,NaN,260.674,NaN,NaN,NaN,NaN,942.788,234.667,NaN,NaN,NaN
3.459,203.308,2.945,258.336,1.843,NaN,222.58,NaN,NaN,NaN,NaN,924.188,235.409,NaN,NaN,NaN
3.659,213.665,2.947,277.811,1.938,NaN,230.617,NaN,NaN,NaN,NaN,947.318,237.067,NaN,NaN,NaN
3.859,229.65,2.938,258.253,1.948,1004.542,232.457,NaN,NaN,NaN,NaN,958.514,243.555,NaN,NaN,NaN
4.059,244.336,2.921,250.859,1.955,989.786,215.338,NaN,NaN,NaN,NaN,924.527,256.469,NaN,NaN,NaN
4.259,265.394,2.917,254.798,1.957,978.525,NaN,NaN,NaN,NaN,NaN,917.977,266.069,NaN,NaN,NaN
4.459,293.467,2.918,255.603,1.841,970.669,NaN,NaN,NaN,NaN,NaN,927.924,271.061,NaN,NaN,NaN
4.659,279.198,2.931,260.54,1.754,976.663,NaN,NaN,NaN,NaN,NaN,916.05,254.681,NaN,NaN,NaN
4.859,259.5,2.941,280.195,1.836,NaN,276.34,NaN,NaN,NaN,NaN,918.861,237.504,NaN,NaN,NaN
5.059,251.778,2.95,277.624,1.884,NaN,251.793,NaN,NaN,NaN,NaN,950.38,219.552,NaN,NaN,NaN
5.259,252.619,2.943,260.022,1.909,NaN,248.878,NaN,NaN,NaN,NaN,957.442,242.047,NaN,NaN,NaN
5.459,260.338,2.95,257.52,1.818,NaN,253.754,NaN,NaN,NaN,NaN,953.3,258.534,NaN,NaN,NaN
5.659,278.407,2.988,257.523,1.769,872.397,263.138,NaN,141.119,NaN,7086.203,935.948,233.512,NaN,NaN,
5.859,282.657,2.997,261.457,1.834,854.936,259.587,83.831,140.941,11928.753,7094.498,911.843,228.301
```

Data Management and Metadata

- For every single ‘run’ up and down a hole, a file is produced.
- It’s critical to be consistent with file naming conventions and keep track of various metadata about the hole run.
  - Probe and equipment serial numbers.
  - Start and End Record Depths
  - Start and End Zero’s
  - Probe Velocity and Depth Increments.
  - Probe Telemetry
    - Different parameters may require unique settings to keep track of.
  - Hole and Location


Software

- Logger Suite
  - Data Acquisition Software
- WellCAD
  - Processing and Interpretation
- Excel
  - Everyone's favourite spreadsheet
- Python
  - This has been a game changer the last 10 years.

Software - Python

- IDE's and Platforms
  - PyCharm
    - Python IDE
  - DataSpell
    - IDE with more focus on data analysis.
    - Integration of Jupyter Notebooks
  - DataLore
    - Cloud or hosted data analysis environment with emphasis on collaboration.
  - VSCode
    - Lightweight code editor with a huge eco system of plug-ins and extensions.

- Python Modules
  - PyWellCAD
    - Official Python library for automating WellCAD.
  - Welly
    - Extensive library for visualizing and analyzing well logs.
  - Pandas and/or Polars
    - Both are used for handling and transforming tabular data.
    - Polars is fairly new and gaining a lot of traction.
  - SciPy
    - Giant library of advanced numerical analysis.