ENERGISTICS

ADOPT > ADVANCE > ACCELERATE

DISTRIBUTED ACOUSTICS SENSING
PRODML DAS TECHNICAL WEBINAR

For Webinar 2019-04-24

Presenters

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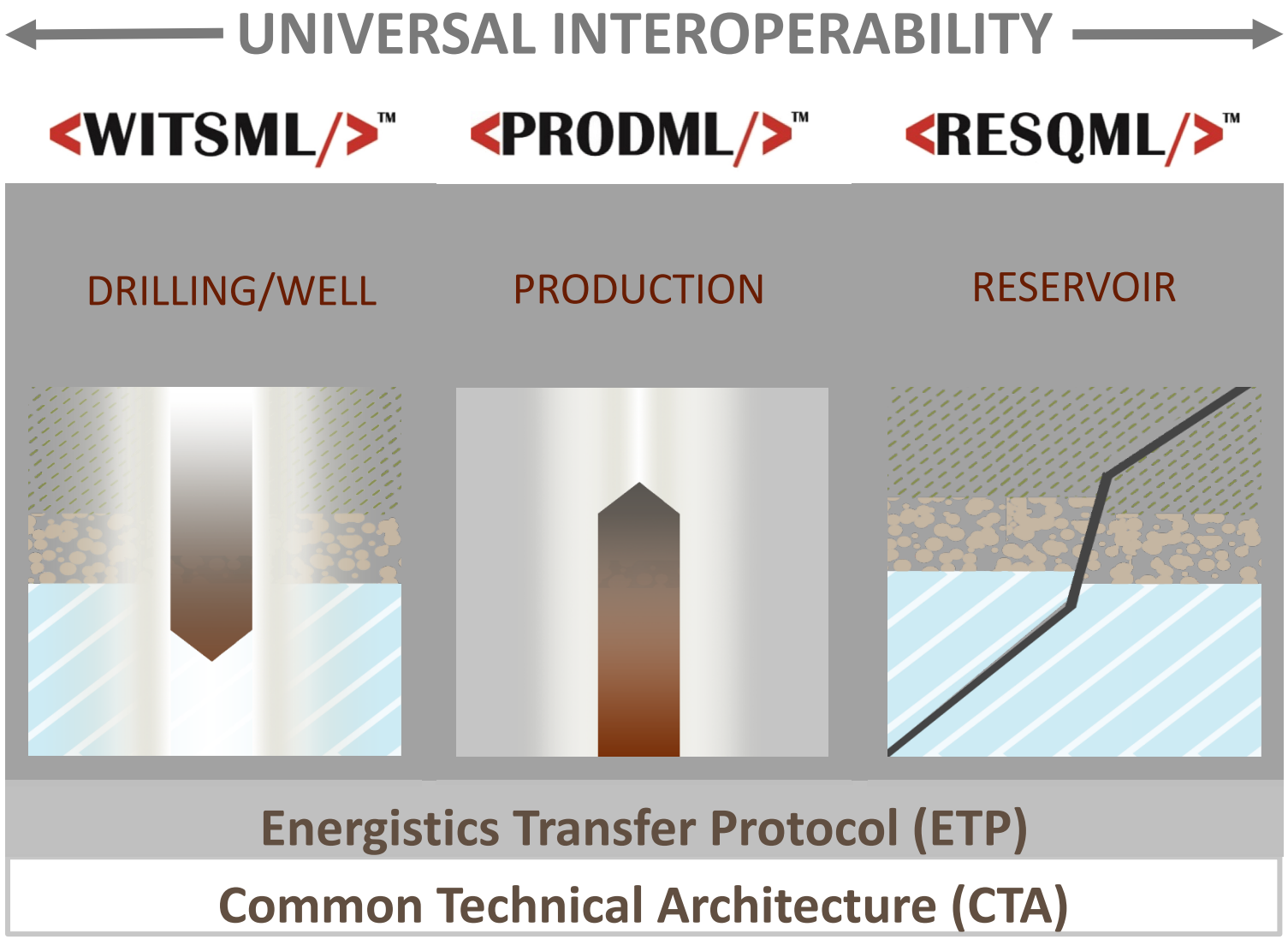
Consultant to Energistics

Energistics' Spectrum of Standards

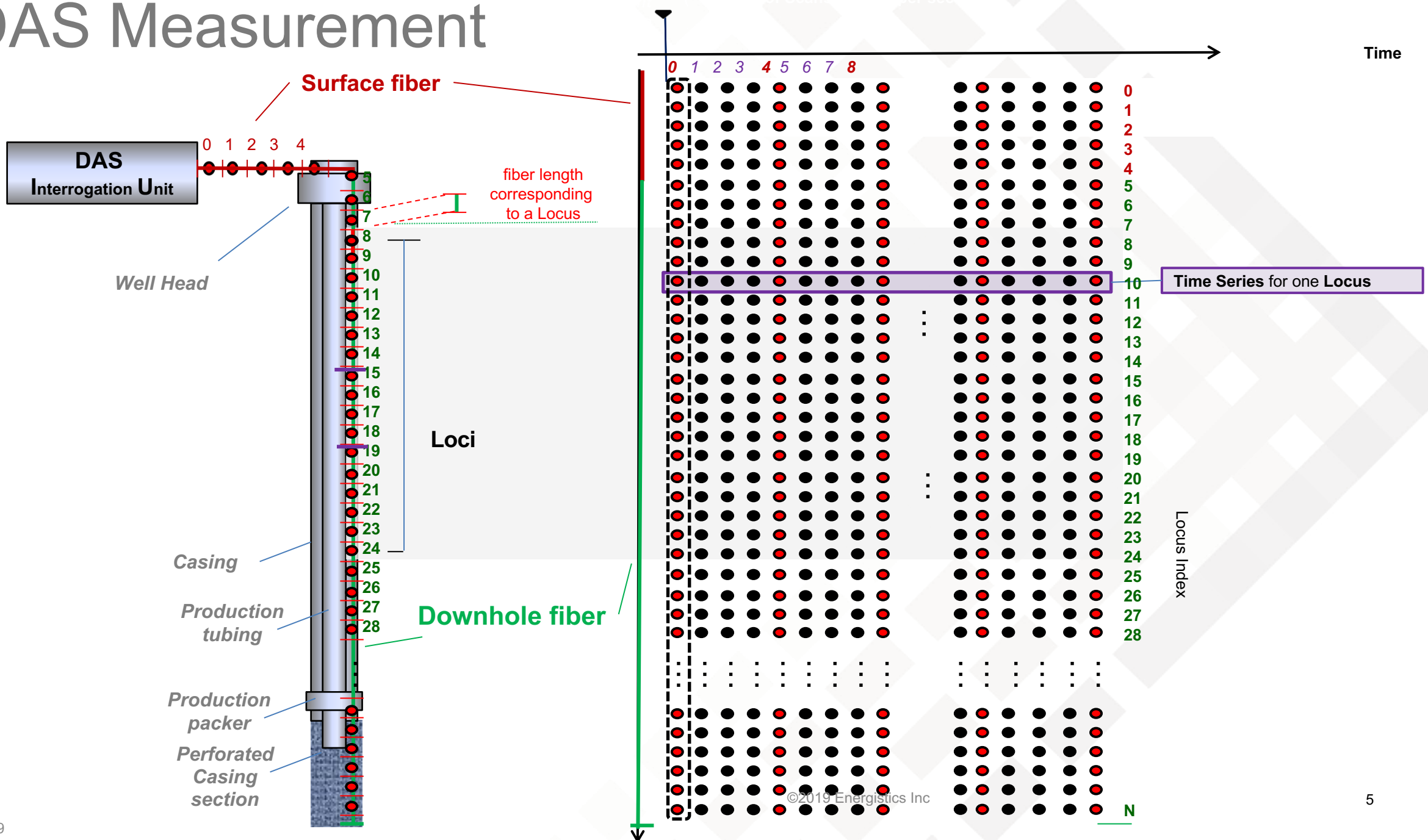


Production Standards: PRODML™

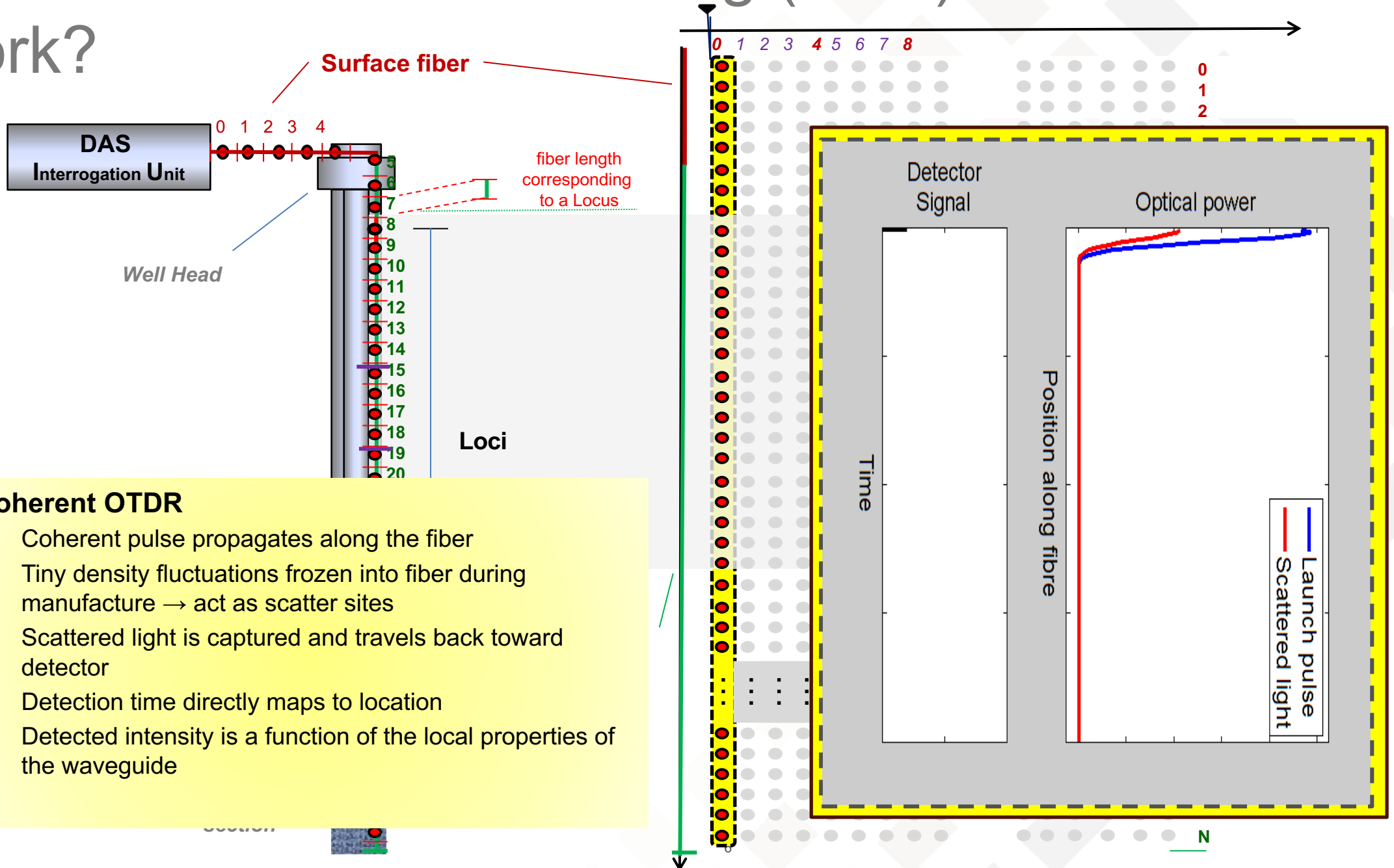
- Consistent, high-quality transfer of production-related data
  - Volumes reporting (intra company, partner to partner, company to regulator)
  - PVT fluid properties (acquisition, samples, lab analysis, fluid characterization)
  - Flow tests (production, pressure transient, formation testing)
  - Flow networks

➢ DTS and DAS exchange standards

DAS Measurement



Distributed Acoustic Sensing (DAS): how does it work?



Coherent OTDR

- Coherent pulse propagates along the fiber
- Tiny density fluctuations frozen into fiber during manufacture → act as scatter sites
- Scattered light is captured and travels back toward detector
- Detection time directly maps to location
- Detected intensity is a function of the local properties of the waveguide

DAS Conceptual Model for Raw & Processed Arrays

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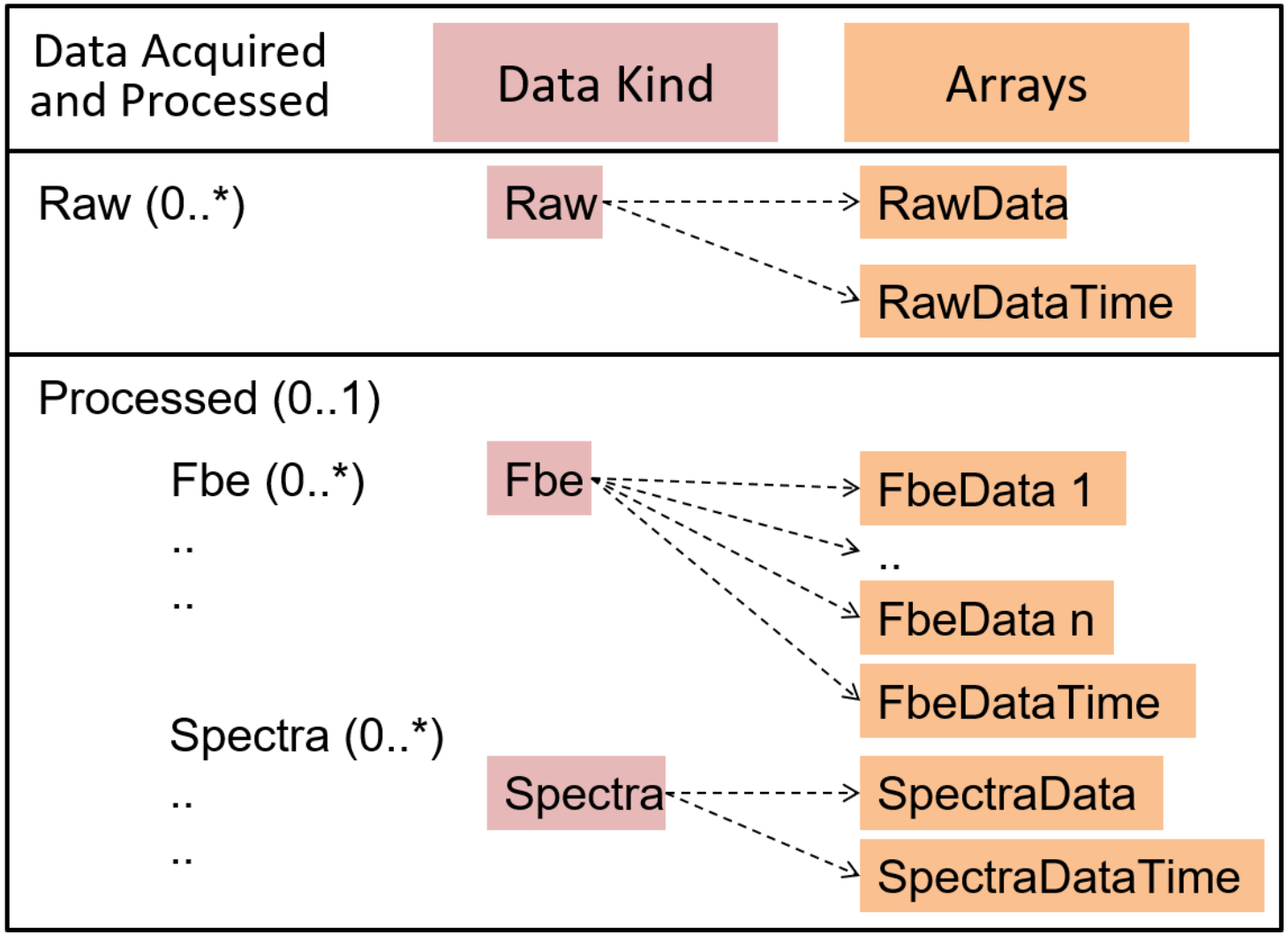
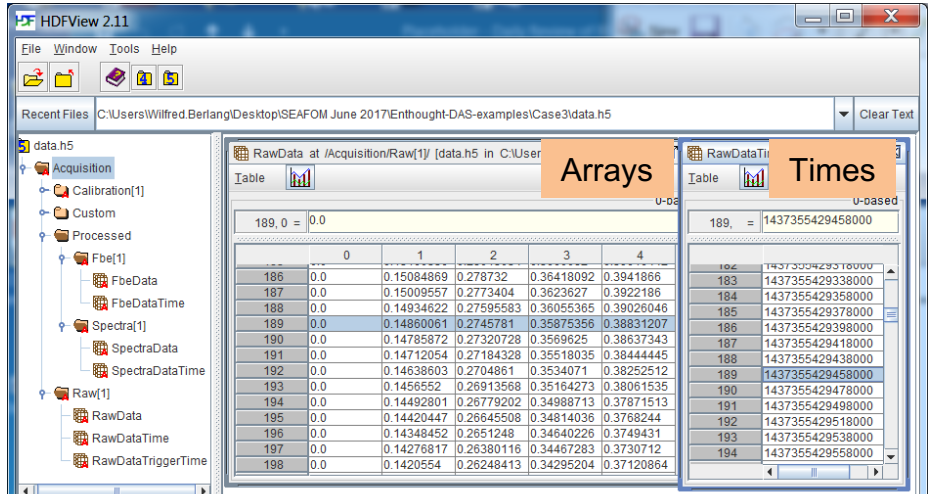
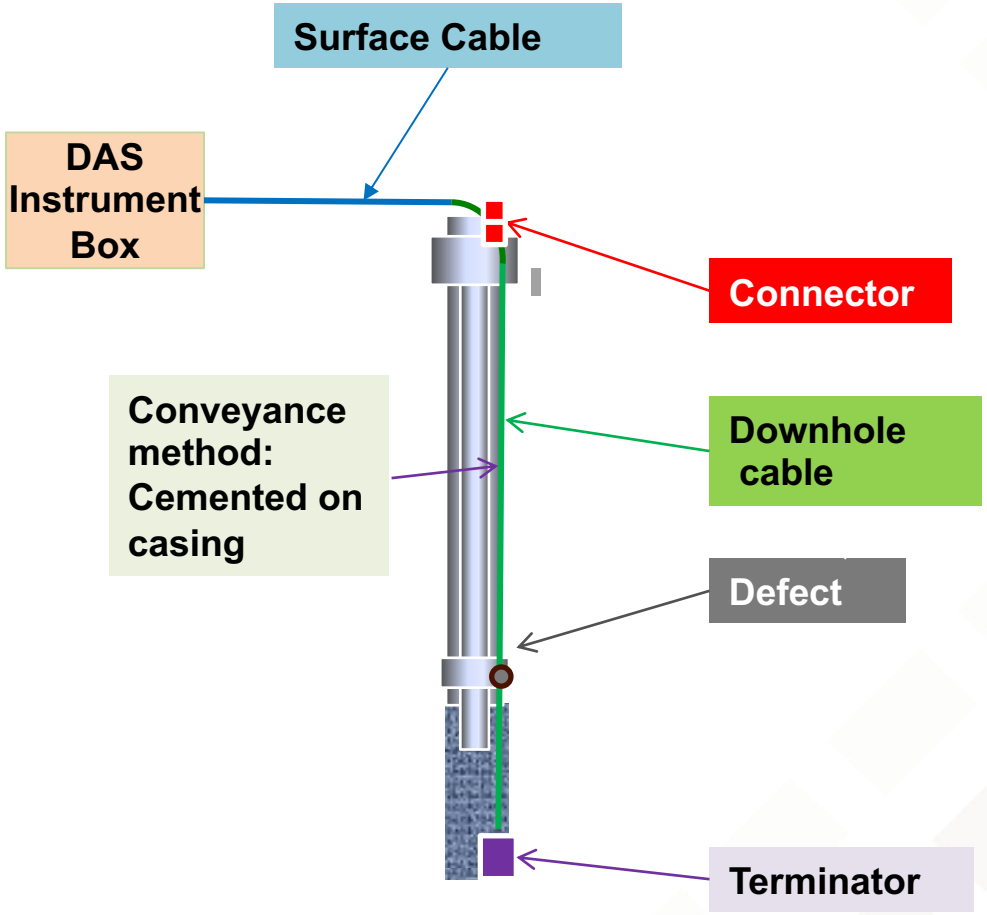




The data and times arrays are very large and are stored in HDF files

Optical Path Components



Equipment Meta Data

Metadata Equipment

DAS Instrument Box

```
<?xml version='1.0' encoding='UTF-8' standalone='yes'?>
<prodml:DasInstrumentBox xmlns:prodml="http://www.energistics.org/energy
http://www.energistics.org/energyml/data/commonv2" xmlns="http://www.ene
http://www.w3.org/2001/XMLSchema-instance" uuid="df9447a1-8c6b-4634-88eb
http://www.energistics.org/energyml/data/prodmlv2 ../../../../xsd_schema
    <eml:Citation>
        <eml:Title>Instrument Box</eml:Title>
        <eml:Originator>Fred Mertz, Field Tech</eml:Originator>
        <eml:Creation>2015-07-20T01:00:00.000000Z</eml:Creation>
        <eml:Format>Vendor:ApplicationName</eml:Format>
    </eml:Citation>
    <prodml:SerialNumber>12645A</prodml:SerialNumber>
    <prodml:Parameter>
        <eml:Name>Parameter1</eml:Name>
        <eml:Value>10.0s</eml:Value>
        <eml:MeasureClass>time</eml:MeasureClass>
```

Fiber Optical Path & OTDR

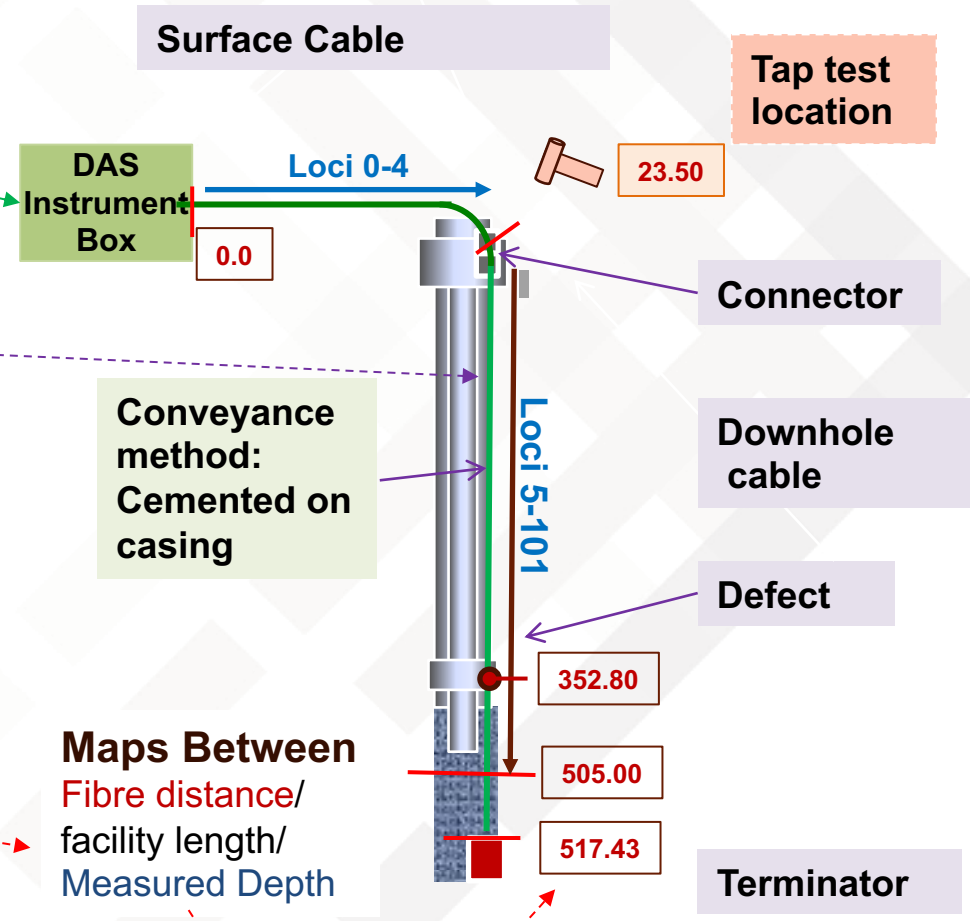
```
<?xml version='1.0' encoding='UTF-8' standalone='yes'?>
<prodml:FiberOpticalPath xmlns:eml="http://www.energistics.org/energyml/data/commonv2" xmlns:pr
http://www.energistics.org/energyml/data/prodmlv2" xmlns:xs="http://www.w3.org/2001/XMLSchema"
http://www.w3.org/2001/XMLSchema-instance" schemaVersion="2.1" uuid="bfd164f4-f9e3-41c0-a74e-37
http://www.energistics.org/energyml/data/prodmlv2 ../../../../xsd_schemas/DasAcquisition.xsd">
  <eml:Citation>...</eml:Citation>
  <prodml:Inventory>...</prodml:Inventory>
  <prodml:OpticalPathNetwork uid="OPN1">...</prodml:OpticalPathNetwork>
  <prodml:FacilityMapping uid="FM1">...</prodml:FacilityMapping>
  <prodml:Defect defectID="OPTDEFECT1">...</prodml:Defect>
  <prodml:Otdr>...</prodml:Otdr>
  <prodml:InstallingVendor>...</prodml:InstallingVendor>
</prodml:FiberOpticalPath>
```

```
<prodml:Inventory>...</prodml:Inventor
<prodml:OpticalPathNetwork uid="OPN1">.
<prodml:FacilityMapping uid="FM1">...<
<prodml:Defect defectID="OPTDEFECT1">..
<prodml:Otdr>...</prodml:Otdr>
```

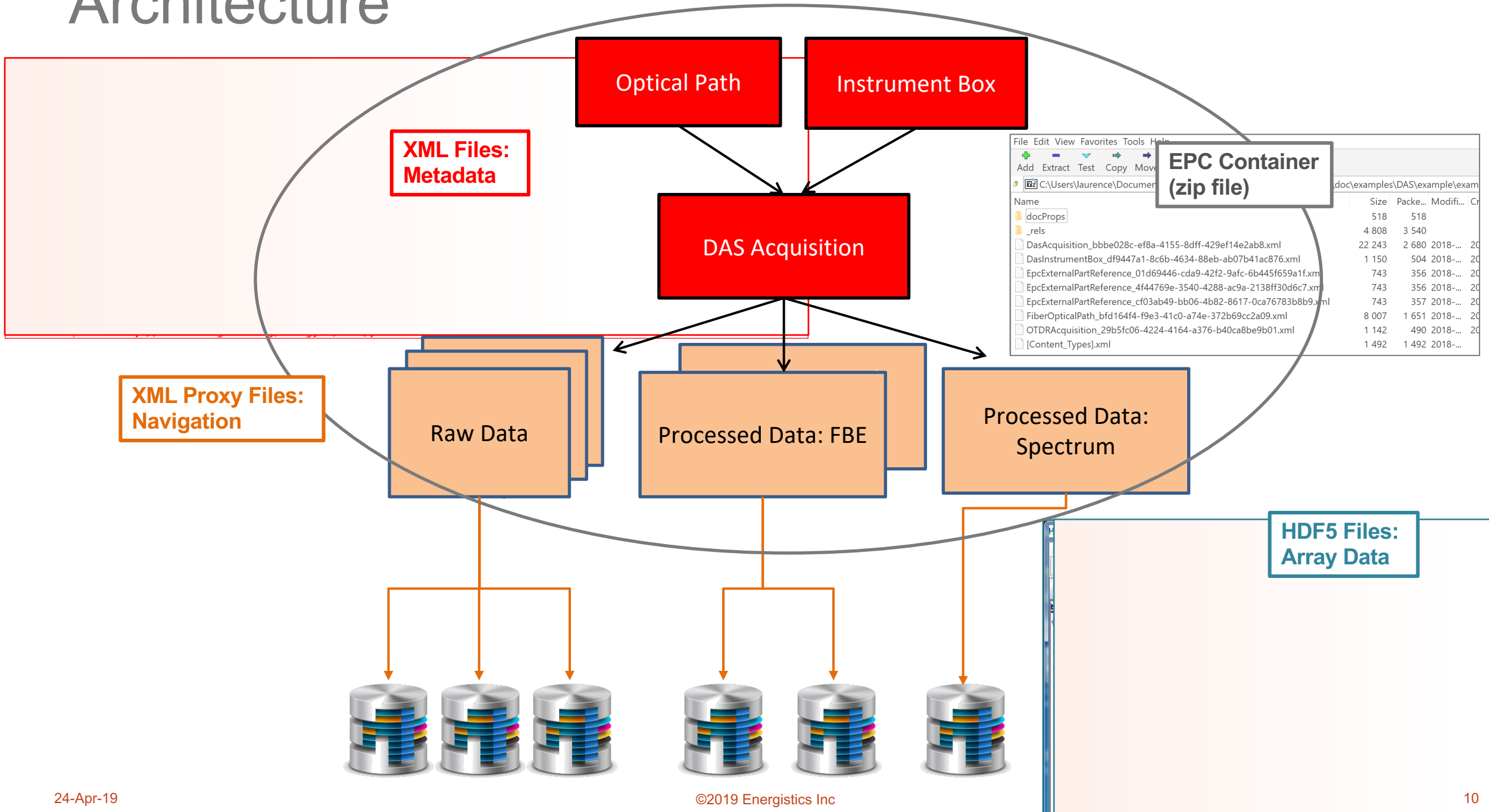
```
<prodml:FacilityCalibration>
  <prodml:FacilityName>ABC Well 1 Surface Cable</prodml:FacilityName>
  <prodml:FacilityKind>generic</prodml:FacilityKind>
  <prodml:OpticalPathDistanceUnit>m</prodml:OpticalPathDistanceUnit>
  <prodml:FacilityLengthUnit>m</prodml:FacilityLengthUnit>
  <prodml:Calibration>
    <prodml:Remark>ABC well 1</prodml:Remark>
    <prodml:LastLocusToEndOfFiber uom="m">12.43</prodml:LastLocusToEndOfFiber>
    <prodml:PipelineDatum>:</prodml:PipelineDatum>
    <prodml:LocusDepthPoint xsi:type="prodml:CompoundExternalArray">
      <prodml:Columns>LocusIndex</prodml:Columns>
      <prodml:Columns>OpticalPathDistance</prodml:Columns>
      <prodml:Columns>FacilityLength</prodml:Columns>
      <prodml:Values>
        <eml:ExternalFileProxy xsi:type="eml:ExternalDatasetPart">
          <eml:Count>5</eml:Count>
```

DAS Acquisition Tables of locus locations

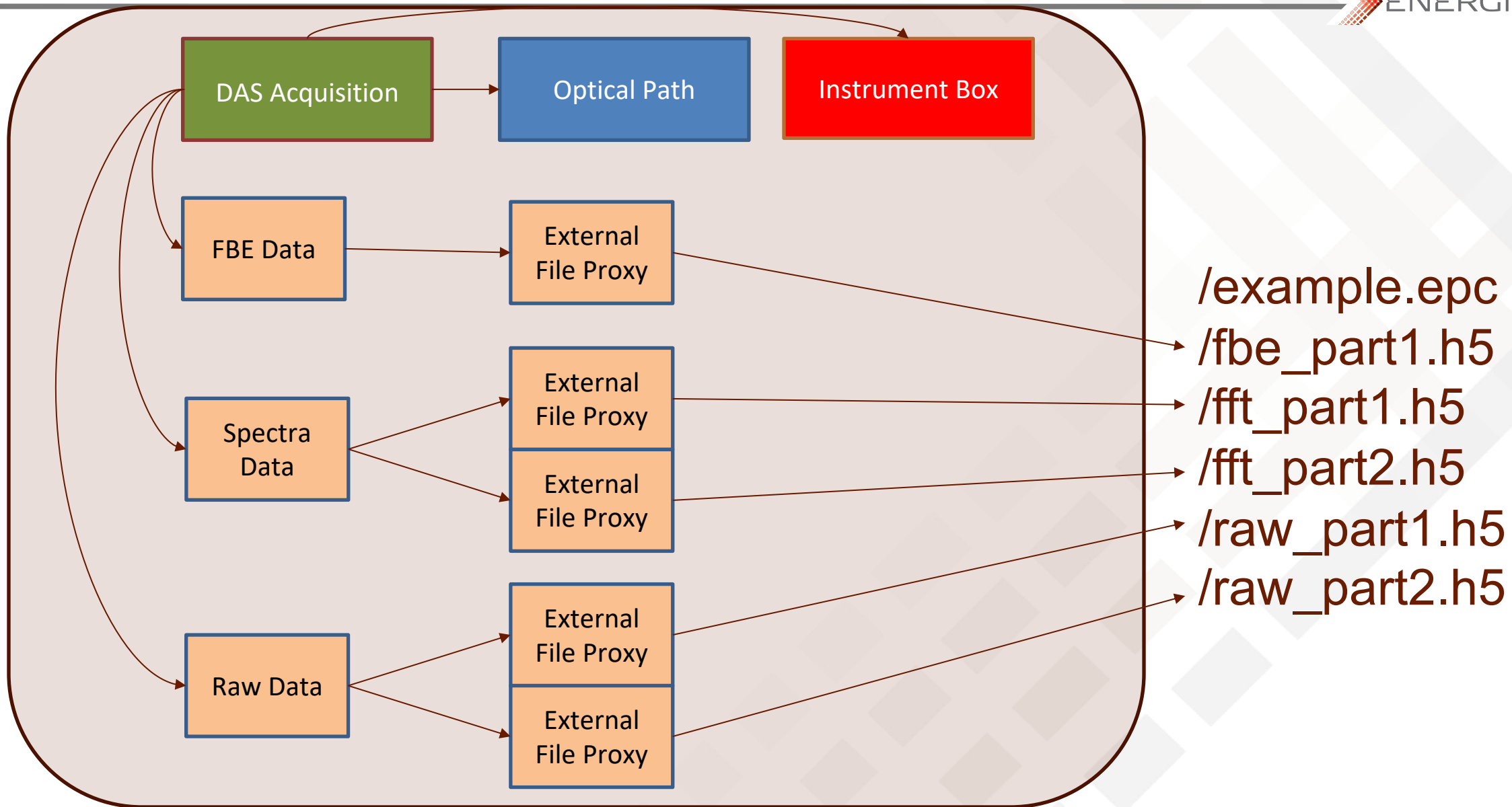
Maps Between Fibre distance/ facility length/ Measured Depth



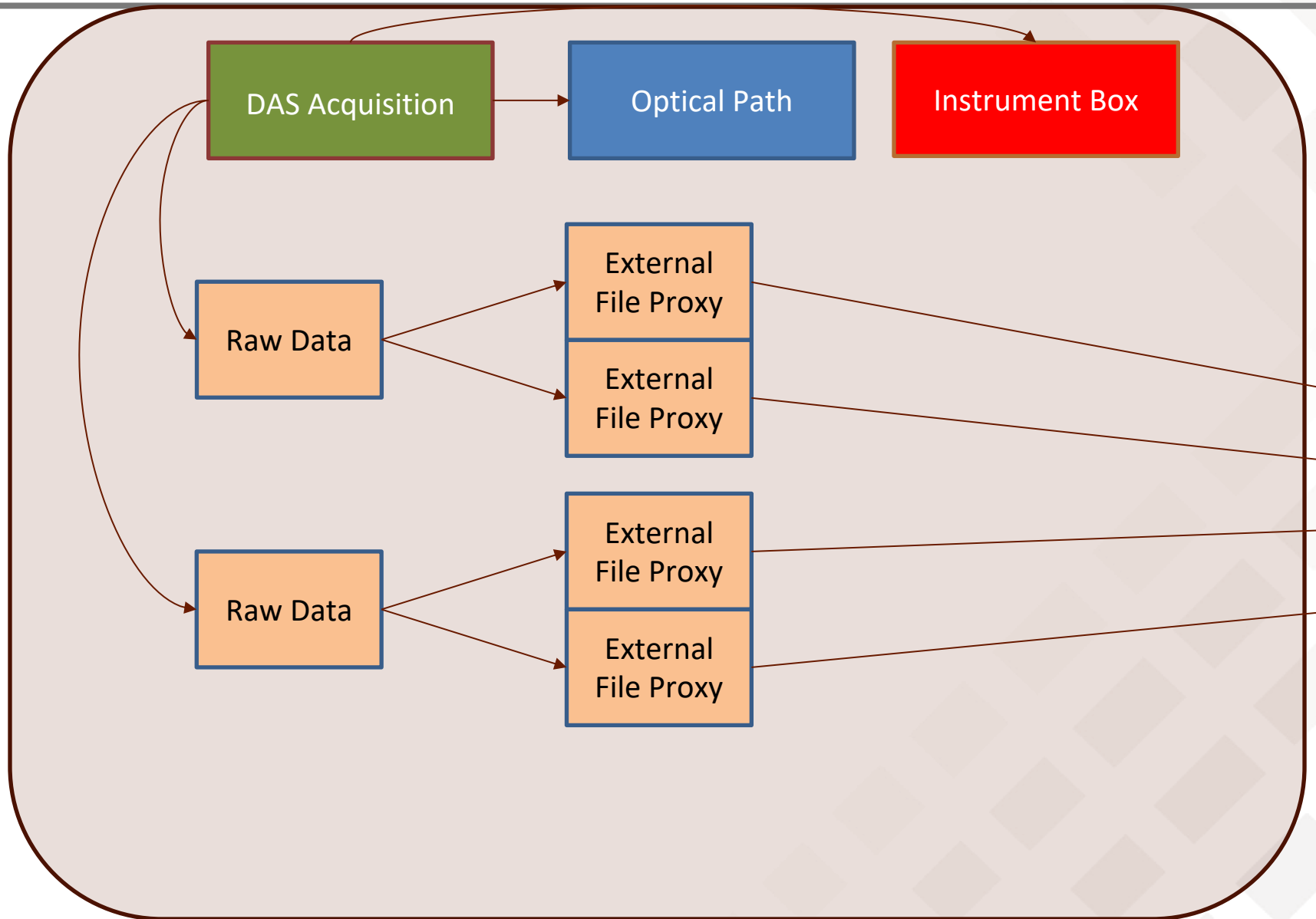
Architecture



The HDF5 files are typically outside of the EPC file

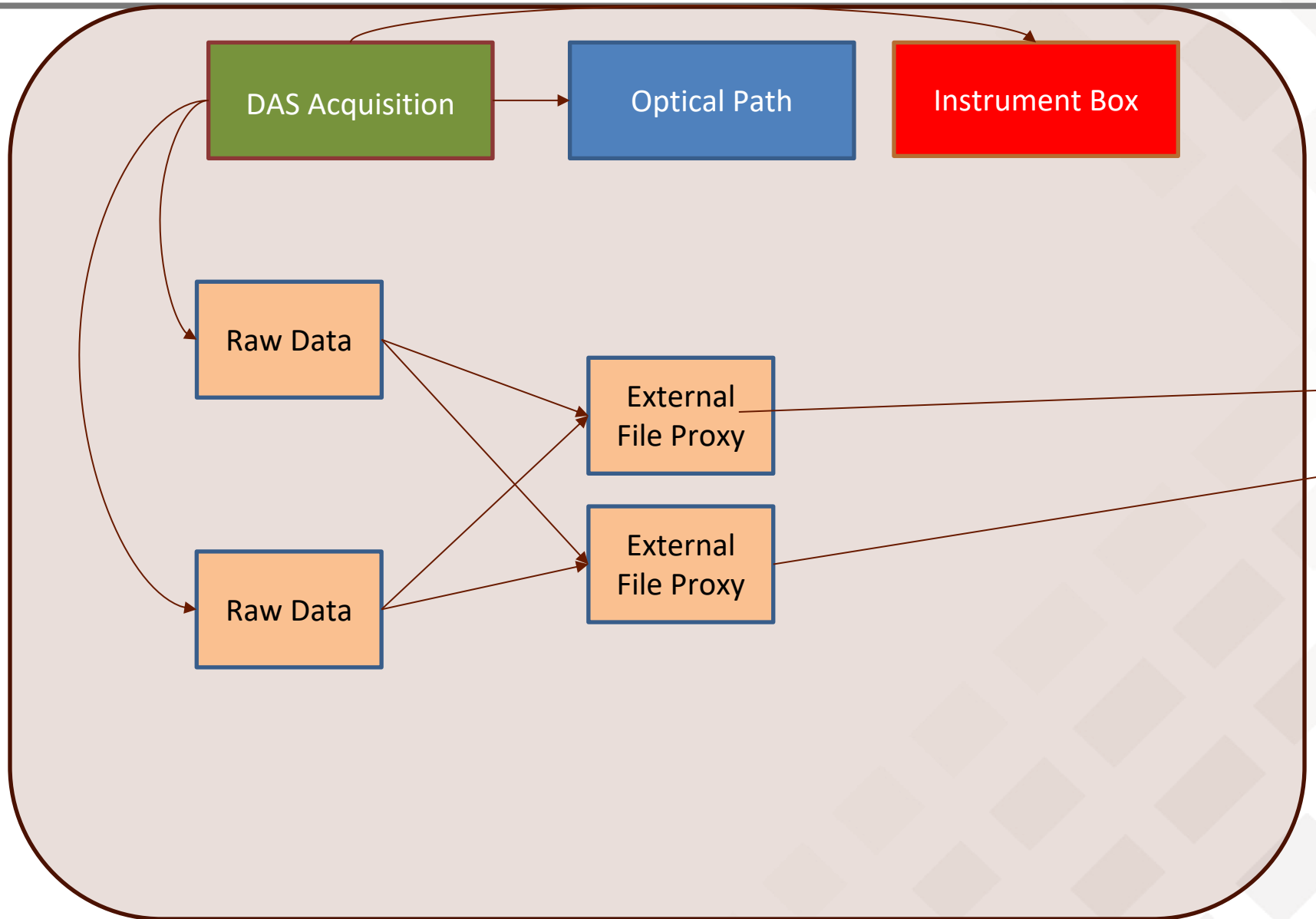


Different layouts are allowed...



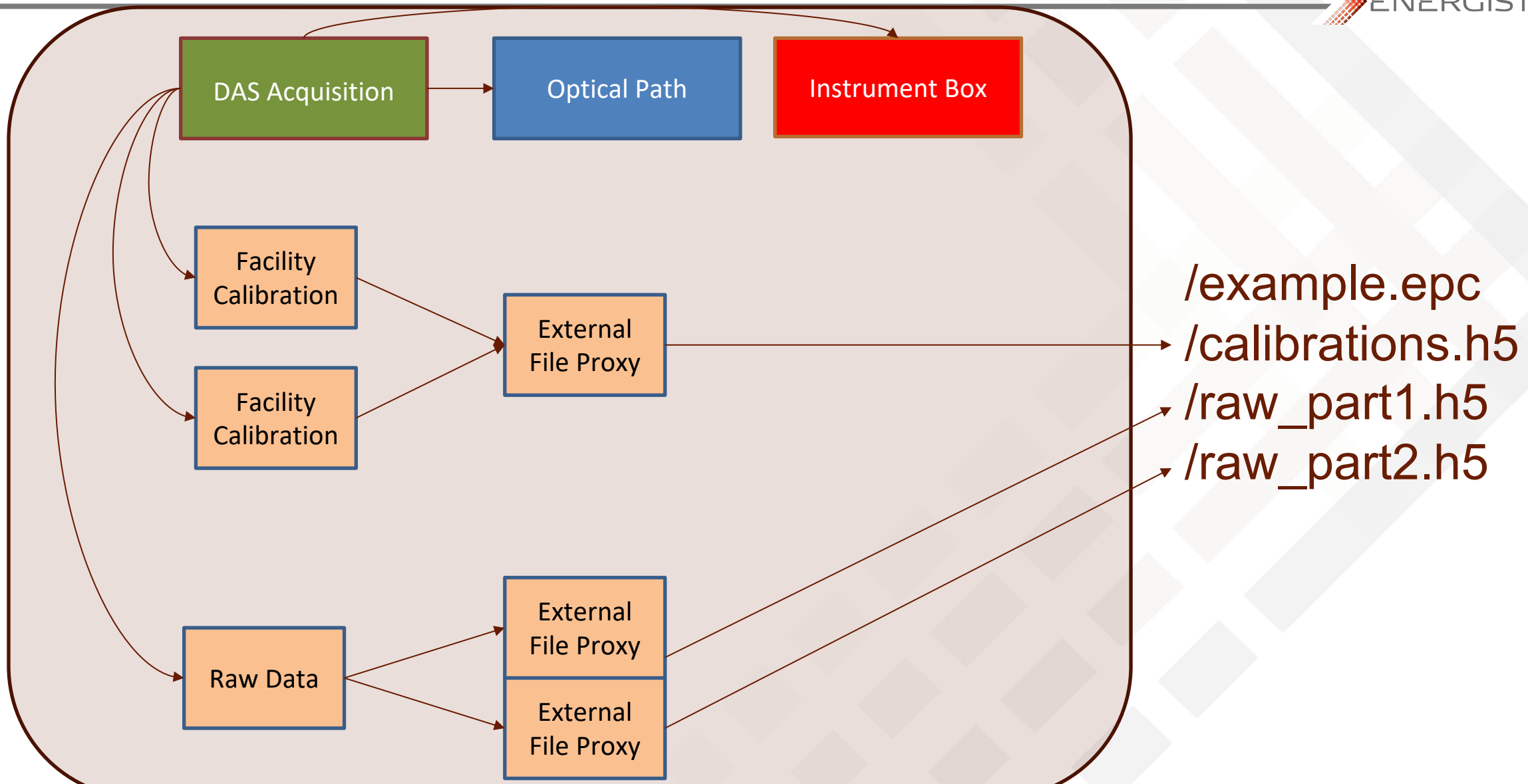
/example.epc
/raw_1_part1.h5
/raw_1_part2.h5
/raw_2_part1.h5
/raw_2_part2.h5

Different layouts are allowed...



/example.epc
/raw_part1.h5
/raw_part2.h5

Calibration data arrays are treated in the same way



Adoption: EPC first or HDF5 first

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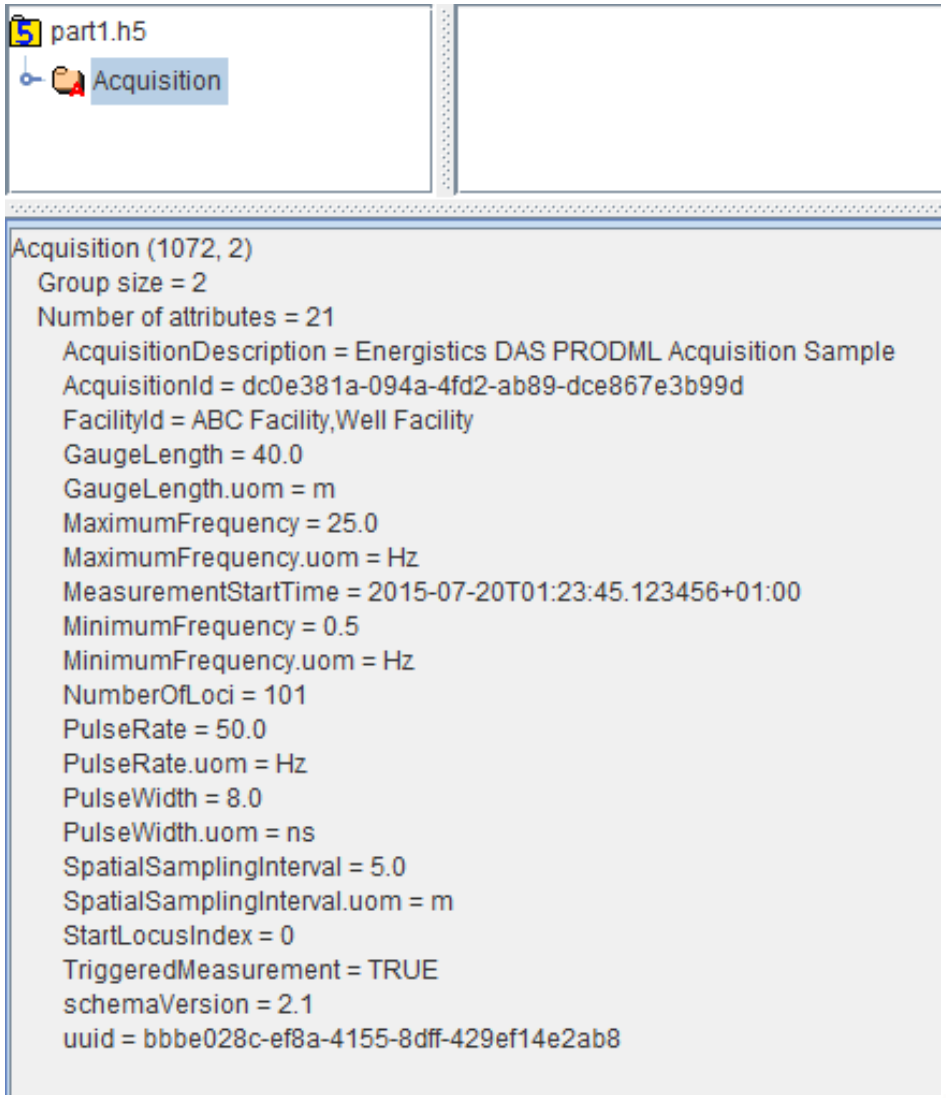
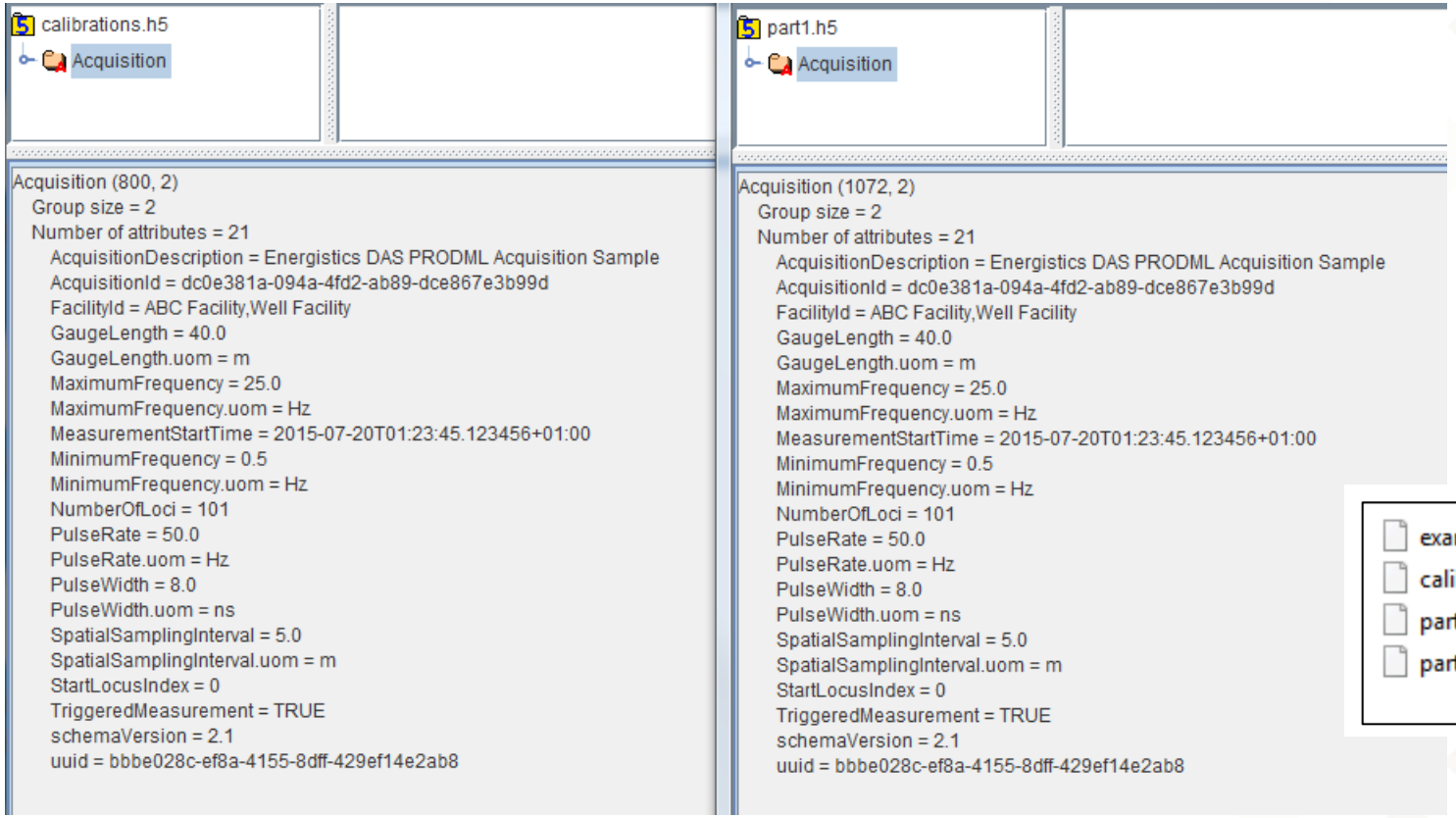
- Starting from EPC is a better way to get familiar with how datasets are linked and organized.
- In practice, businesses tend to approach the adoption by implementing the HDF5 files first.
  - Pros: This allows quick deployment of software writing DAS data arrays.
  - Cons: Indexing requires reading attributes in every HDF5 file as well as applying some assumptions on the directory structure; it is not as scalable.
- Consequently, some metadata in the EPC are repeated in the HDF5 files to support the most common use cases. These HDF5 attributes become part of the standard.

HDF5 duplicates **some** attributes in the EPC



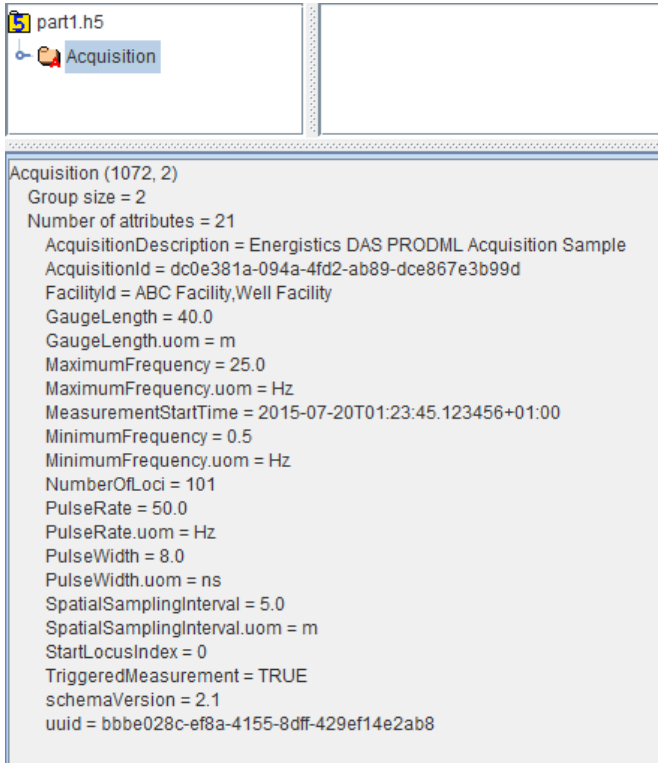

```
<?xml version='1.0' encoding='UTF-8' standalone='yes'?>
<prodml:DasAcquisition
    xmlns:eml="http://www.energistics.org/energyml/data/commonv2"
    xmlns:prodml="http://www.energistics.org/energyml/data/prodmlv2"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    schemaVersion="2.1"
    uuid="bbbe028c-ef8a-4155-8dff-429ef14e2ab8"
    xsi:schemaLocation="http://www.energistics.org/energyml/data/prodmlv2 ../../../../xsd_schemas/DasAcquisi
  <eml:Citation>…
  </eml:Citation>
  <prodml:AcquisitionId>dc0e381a-094a-4fd2-ab89-dce867e3b99d</prodml:AcquisitionId>
  <prodml:AcquisitionDescription>Energistics DAS PRODML Acquisition Sample</prodml:AcquisitionDescription>
  <prodml:OpticalPath>…
  </prodml:OpticalPath>
  <prodml:DasInstrumentBox>…
  </prodml:DasInstrumentBox>
  <prodml:FacilityId>ABC Facility</prodml:FacilityId>
  <prodml:FacilityId>Well Facility</prodml:FacilityId>
  <prodml:VendorCode>…
  </prodml:VendorCode>
  <prodml:PulseRate uom="Hz">50.0</prodml:PulseRate>
  <prodml:PulseWidth uom="ns">8.0</prodml:PulseWidth>
  <prodml:GaugeLength uom="m">40.0</prodml:GaugeLength>
  <prodml:SpatialSamplingInterval uom="m">5.0</prodml:SpatialSamplingInterval>
  <prodml:MinimumFrequency uom="Hz">0.5</prodml:MinimumFrequency>
  <prodml:MaximumFrequency uom="Hz">25.0</prodml:MaximumFrequency>
  <prodml:NumberOfLoci>101</prodml:NumberOfLoci>
  <prodml:StartLocusIndex>0</prodml:StartLocusIndex>
  <prodml:MeasurementStartTime>2015-07-20T01:23:45.123456+01:00</prodml:MeasurementStartTime>
  <prodml:TriggeredMeasurement>true</prodml:TriggeredMeasurement>
  <prodml:Raw uuid="dadd1266-3ce9-43e4-a1d6-a1fecb00e295">…
  </prodml:Raw>
  <prodml:FacilityCalibration>…
  </prodml:FacilityCalibration>
  <prodml:FacilityCalibration>…
  </prodml:FacilityCalibration>
  <prodml:Processed>…
  </prodml:Processed>
</prodml:DasAcquisition>
```

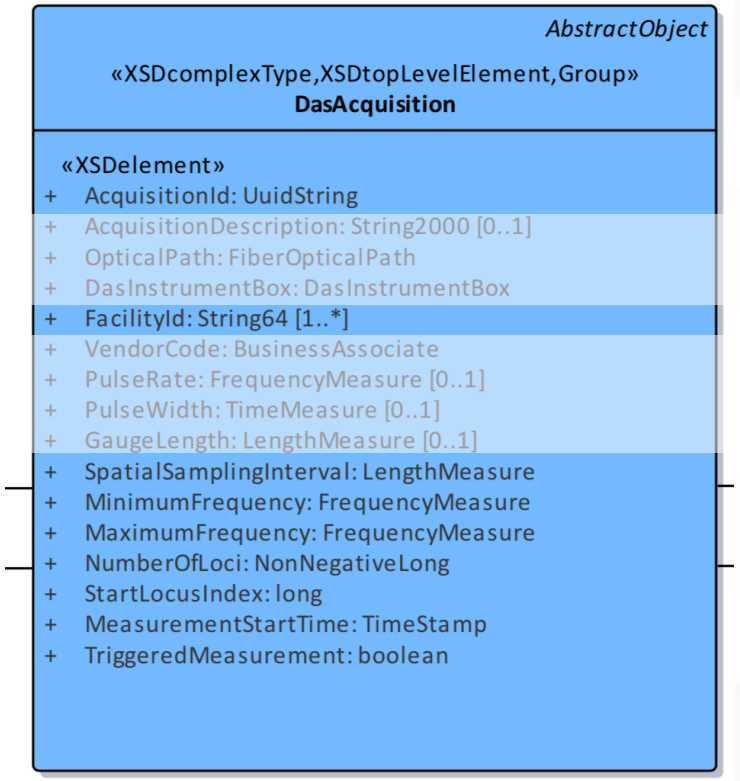
HDF5: The Acquisition attributes are the same for HDF5 files in the same package



- In the EPC, these values occur only once. For the HDF5 first adoption approach, these attributes are repeated in every HDF5 file.

HDF5: What are the required attributes?





Energistics common Technical Reference Guide

1.3 AbstractObject

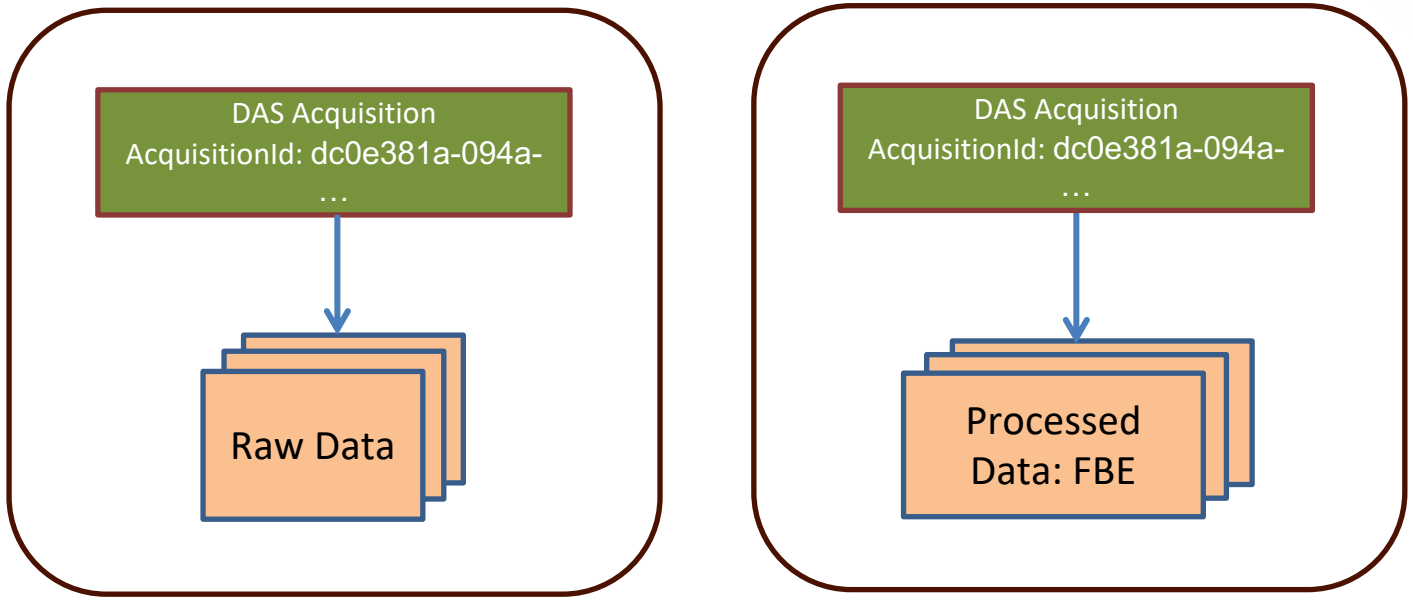
Type: Class *Stereotype:* «XSDcomplexType»
Detail: *Created:* 5/25/2014 *Last modified:* 11/10/2016
Notes: The Mother Class for all Top Level Elements across the MLs.

Attributes

Name	Type
Aliases	ObjectAlias
Citation	Citation
CustomData	CustomData
existenceKind	ExistenceKind
ExtensionNameValue	ExtensionNameValue
objectVersion	String64
schemaVersion	String64
uuid	UuidString

- Attributes are defined in the XSD either locally or are inherited from more abstract objects.
- Rule 1: If the attribute is required in the XSD and is a basic type or a Measure type, it is required in the HDF5.
- Rule 2: Measure type attributes have units represented as “X.uom”
- There are a few more rules. Refer to PRODML DAS Technical Usage Guide v2.1 Chapter 24.6.5

HDF5 / EPC: AcquisitionId and uuid are different!



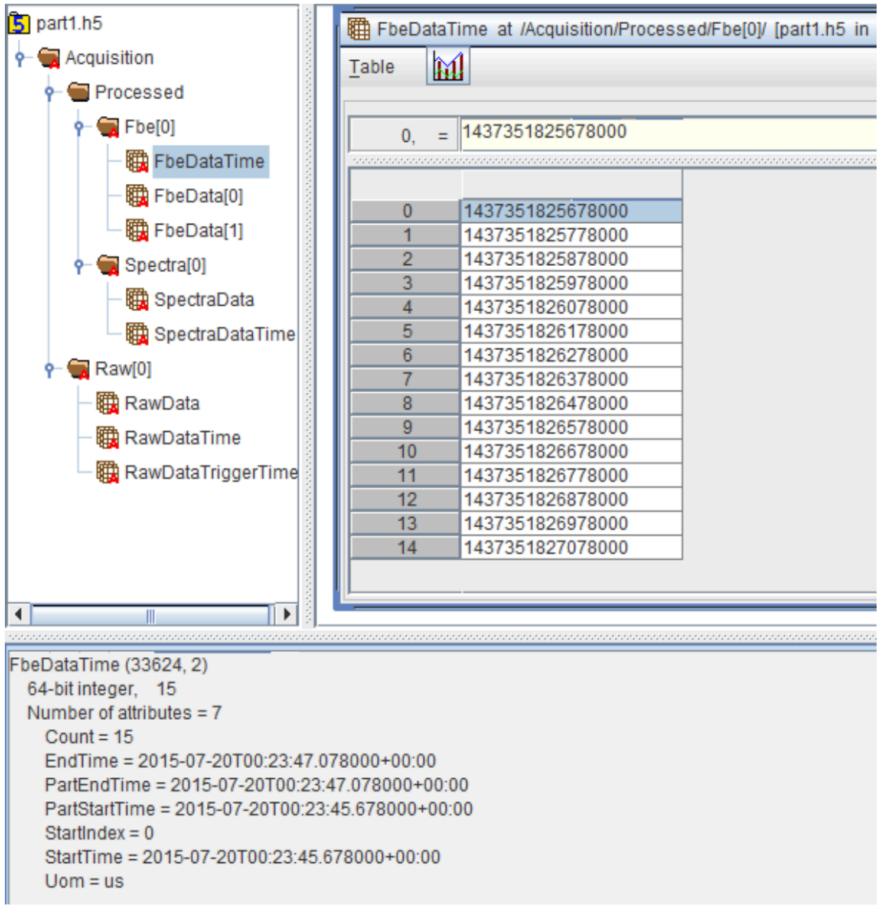
raw.epc
uuid: df9447a1-8c6b-46…

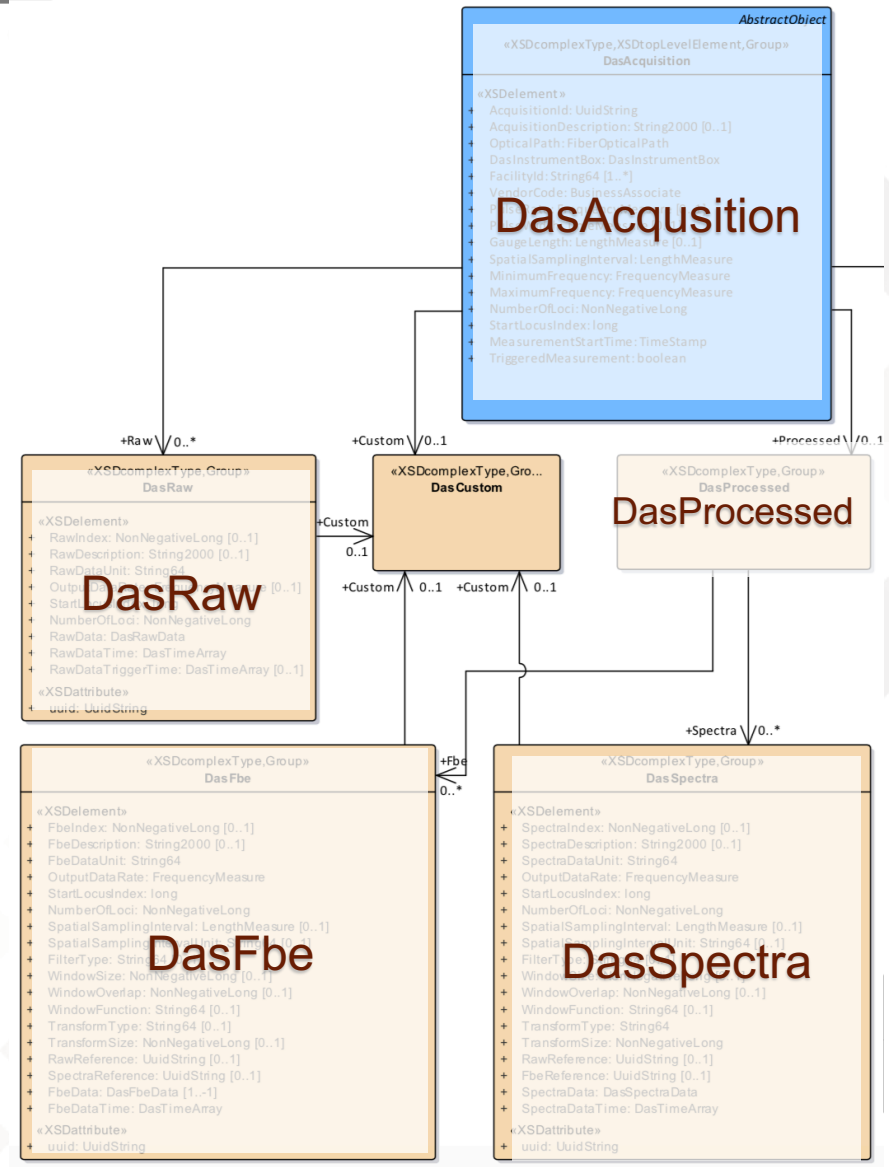
fbe.epc
uuid: bbbe028c-ef8a-41…

```
<prodml:DasAcquisition
    xmlns:eml="http://www.energistics.org/energyml/data/commonv2"
    xmlns:prodml="http://www.energistics.org/energyml/data/prodmlv
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    schemaVersion="2.1"
    uuid="bbbe028c-ef8a-4155-8dff-429ef14e2ab8"
    xsi:schemaLocation="http://www.energistics.org/energyml/data/p
  <eml:Citation>…
  </eml:Citation>
  <prodml:AcquisitionId>dc0e381a-094a-4fd2-ab89-dce867e3b99d</proc
  <prodml:AcquisitionDescription>Energistics DAS PRODML Acquisitic
  <prodml:OpticalPath>…
  </prodml:OpticalPath>
```

- “uuid” is the unique identifier for the DAS data package (represented by DasAcquisition).
- The AcquisitionId refers to the DAS Acquisition job.
- Multiple data packages can share the same AcquisitionId if they refer to the same Acquisition job. But they must have different uuid.

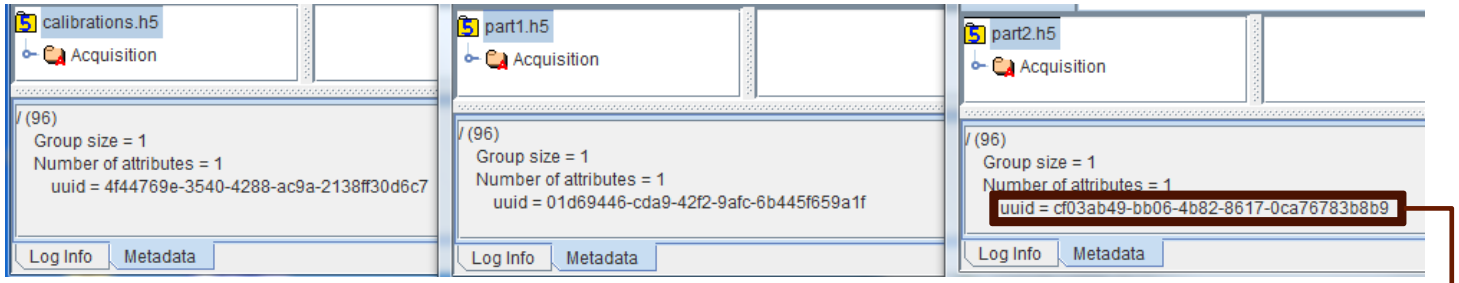
HDF5: The organization imitates the structure in the XML





» Refer to PRODML DAS Technical Usage Guide v2.1 Chapter 24.6.4 for details.

HDF5: Each file has a uuid to identify itself



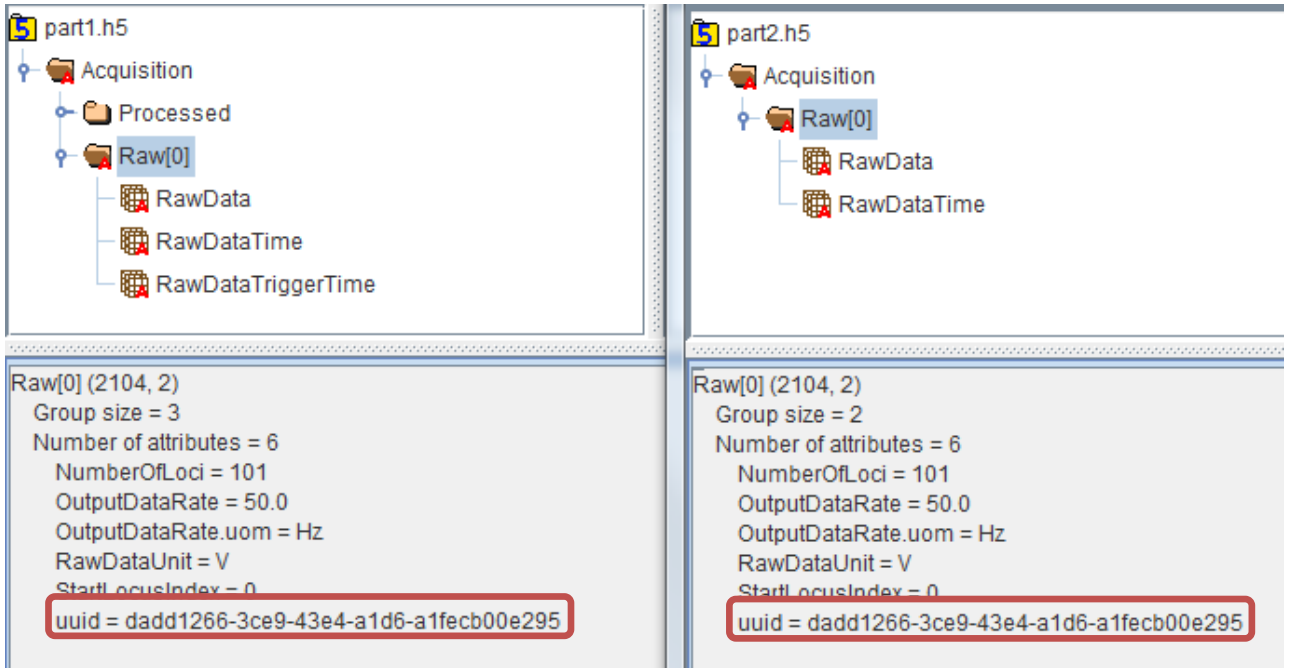
HDF files

One of the relationship files in example.epc

```
<?xml version='1.0' encoding='UTF-8' standalone='yes'?>
<Relationships xmlns="http://schemas.openxmlformats.org/package/2006/relationships">
  <Relationship Id="bbbe028c-ef8a-4155-8dff-429ef14e2ab8" Target=
  "DasAcquisition_bbbe028c-ef8a-4155-8dff-429ef14e2ab8.xml" TargetMode="Internal" Type="
  http://schemas.energistics.org/package/2012/relationships/externalPartProxyToML"/>
  <Relationship Id="cf03ab49-bb06-4b82-8617-0ca76783b8b9" Target="part2.h5" TargetMode=
  "External" Type="http://schemas.energistics.org/package/2012/relationships/externalResource"/>
</Relationships>
```

- For the HDF5-only approach, this uuid is not used as there are no EPC.
- This is a required attribute in the standard, however.

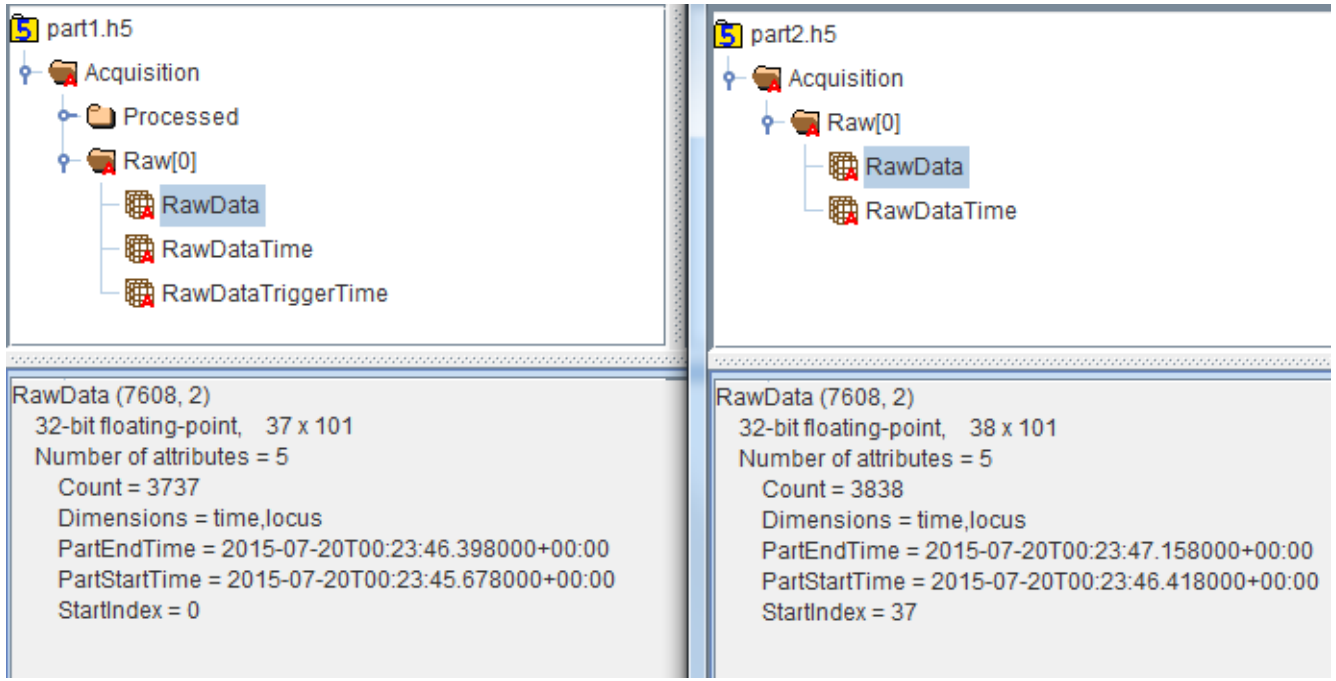
HDF5 / EPC: How are file parts linked?




```
<prodml:Raw uuid="dadd1266-3ce9-43e4-a1d6-a1fecb00e295">
  <prodml:RawDataUnit>V</prodml:RawDataUnit>
  <prodml:OutputDataRate uom="Hz">50.0</prodml:OutputDataRate>
  <prodml:StartLocusIndex>0</prodml:StartLocusIndex>
  <prodml:NumberOfLoci>101</prodml:NumberOfLoci>
  <prodml:RawData>…
  </prodml:RawData>
  <prodml:RawDataTime>…
  </prodml:RawDataTime>
  <prodml:RawDataTriggerTime>…
  </prodml:RawDataTriggerTime>
  <prodml:Custom/>
</prodml:Raw>
```

- A raw data array is split into two files. They are linked by the DasRaw object's uuid.
- Note that the DasRaw's uuid is not the same as the DasAcquisition!
- The metadata for these two files are included in the same Raw object in the XML.

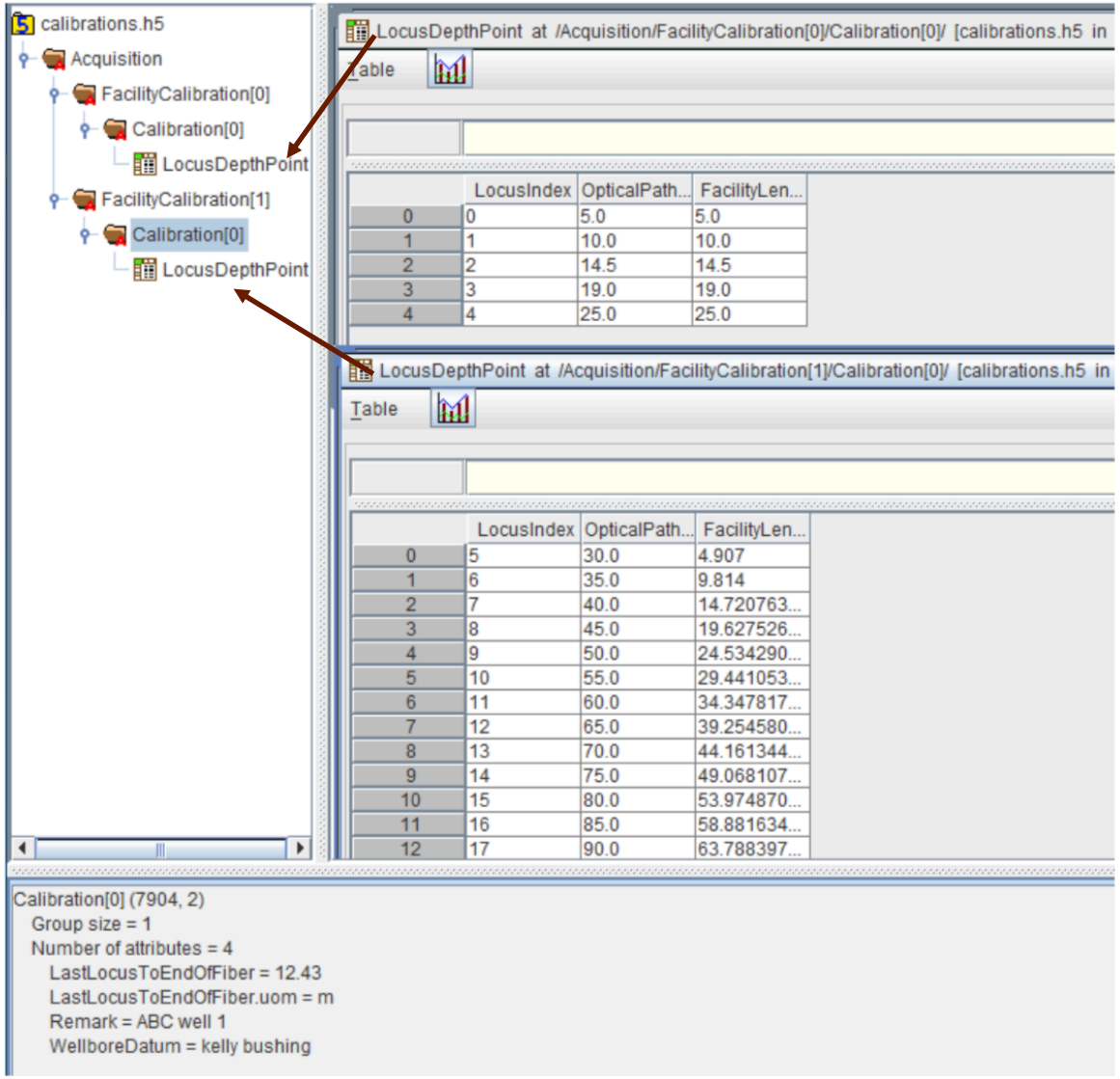
HDF5 / EPC: How are file parts ordered?




```
<prodml:RawData>
  <prodml:Dimensions>time</prodml:Dimensions>
  <prodml:Dimensions>locus</prodml:Dimensions>
  <prodml:RawDataArray xsi:type="eml:FloatExternalArray">
    <eml:Values>
      <eml:ExternalFileProxy xsi:type="prodml:DasExternalDatasetPart">
        <eml:Count>3737</eml:Count>
        <eml:PathInExternalFile>/Acquisition/Raw[0]/RawData</eml:PathInExternalFile>
        <eml:StartIndex>0</eml:StartIndex>
        <eml:EpcExternalPartReference>
          <eml:ContentType>application/x-eml+xml;version=2.2;type=EpcExternalPartReference</eml:ContentType>
          <eml:Title>HDF Proxy</eml:Title>
          <eml:Uuid>01d69446-cda9-42f2-9afc-6b445f659a1f</eml:Uuid>
        </eml:EpcExternalPartReference>
        <prodml:PartStartTime>2015-07-20T00:23:45.678000+00:00</prodml:PartStartTime>
        <prodml:PartEndTime>2015-07-20T00:23:46.398000+00:00</prodml:PartEndTime>
      </eml:ExternalFileProxy>
      <eml:ExternalFileProxy xsi:type="prodml:DasExternalDatasetPart">
        <eml:Count>3838</eml:Count>
        <eml:PathInExternalFile>/Acquisition/Raw[0]/RawData</eml:PathInExternalFile>
        <eml:StartIndex>37</eml:StartIndex>
        <eml:EpcExternalPartReference>
          <eml:ContentType>application/x-eml+xml;version=2.2;type=EpcExternalPartReference</eml:ContentType>
          <eml:Title>HDF Proxy</eml:Title>
          <eml:Uuid>cf03ab49-bb06-4b82-8617-0ca76783b8b9</eml:Uuid>
        </eml:EpcExternalPartReference>
        <prodml:PartStartTime>2015-07-20T00:23:46.418000+00:00</prodml:PartStartTime>
        <prodml:PartEndTime>2015-07-20T00:23:47.158000+00:00</prodml:PartEndTime>
      </eml:ExternalFileProxy>
    </eml:Values>
  </prodml:RawDataArray>
</prodml:RawData>
```

- The StartIndex attribute allows us to order the file parts.
- The references to the HDF files and data paths are stored in the XML.

HDF5: A group only exists if there is a leaf dataset...except for “Custom”



- LocusDepthPoint is a full mapping from locus to optical paths and facility lengths.
- This is an optional array.
- If it is not included, none of its parent groups will be written to the HDF5.

HDF5 seems enough, why do we need EPC?

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- A lot of metadata cannot be presented in the HDF5 files, e.g. the configuration of a fiber optical path network, metadata of a DAS instrument box etc.
- Rules for the HDF5 files are documented in words, not in code (e.g. XSD schema). Misinterpretations are still possible, leading to incompatibility between writers and readers written by different parties.
- HDF5 files cannot be validated without a custom made tool, whereas the XML can be validated with the XSD schema.
- If all writers supply EPC, readers can find all the referenced data arrays from the EPC. The only HDF5 attribute it needs to read is the file uuid, for sanity check.
- If all readers can read EPC, the writers only need to write the file's uuid in the HDF5.

Conclusion

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- The experience from businesses who have adopted PRODML v2.0: It is a little involved but perfectly workable once the standard is understood.
- PRODML v2.1 is built on top of v2.0 experience:
  - Enhanced the documentation targeting the HDF5-first approach, e.g. clarified certain rules on HDF5 attributes and data objects.
  - Calibration data is reorganized.
  - Fixed a number of schema and documentation bugs.
- Version 2.1 is now available for review (but intended as the release shortly) and should be the target version for new adopters
- A previous business usage webinar is available at https://youtu.be/HapbbPQvW5s