XTCE Tutorial

- January 23, 2004

- *Agenda*
  - OMG and SDTF Background
  - XTCE Background
  - XTCE Tutorial
  - XTCE Resources

XTCE

XML Telemetry & Command Exchange

An International (OMG) Standard Language for the Description of Mission Operations Databases

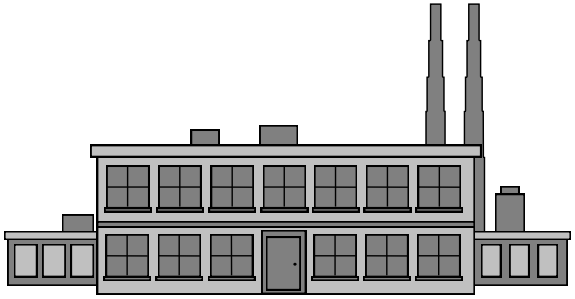
Credits

- Key Design Team
  - European Space Agency
    - Science Systems – Sam Cooper, Roger Thompson
    - ESOC – Mario Merri
  - US Air force/Mission Operations
    - USAF SMC Det 12/VO (Lockheed Martin) – Gerry Simon
  - Boeing Communications & Satellites
    - Janice Champion
  - NASA
    - GSFC – Mike Rackley
    - GST – Kevin Rice
    - Raytheon TSC / UMD – Ed Shaya

More Credits

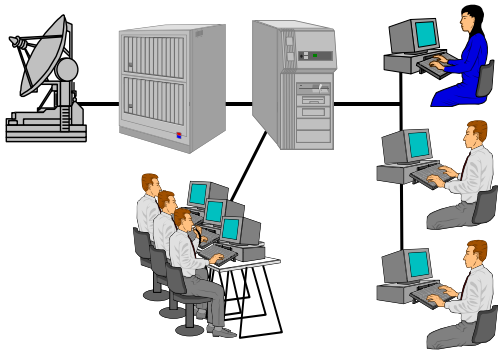
- OMG Space Domain Task Force
  - Joan Dunham (CSC)(OMG Co-chair)
  - Mark Brucks (J3S)
  - Jeff Condron (GSFC/Raytheon)
  - Greg Greer (GSFC/Hammers)
  - Priscilla McKerracher (APL)
  - Peter Shames (JPL)
  - Brad Kizzort (Harris)

Vision

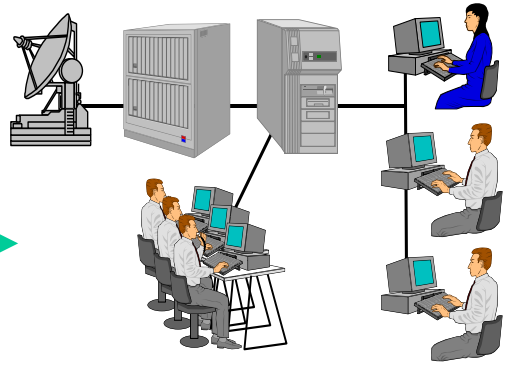


Satellite Factory

Common Formats Facilitate Transition to Operations and Data Exchange



Mission Ground System



Mission Ground System

Basic Concepts

- **What**: Non-proprietary standard description language of T&C parameters and commands for exchange between manufacturers, vendors, testers and operators.
- **Why**: Common format reduces human error, ambiguities, confusion, and lost time in difficult, sometimes lossy, conversions between systems.
  - Save money per mission
  - Reduce mission readiness schedule
  - Better, Faster, Cheaper
- **How**:
  - Common usage of XML to tag information.
  - Greater machine understanding and automation.

Background - Object Management Group (OMG)

- Consortium of ~600 international software companies (Lockheed Martin, IBM, Sun, MS, Borland, etc)
- Standards Organization for CORBA and UML among others. Developed XSI, the XML standard for UML modeling.
- Subdivided by Technology/Industries into platform/domain task forces.
- Meets 5 times per year.
- Tasks Forces
  - Issue Request for Information/Proposal (RFI, RFP) for specifications.
  - Receives responses, then creates a candidate specification.
  - Ultimately OMG Architecture Board (votes) recommends specification.

Background - Space Domain Task Force (SDTF)

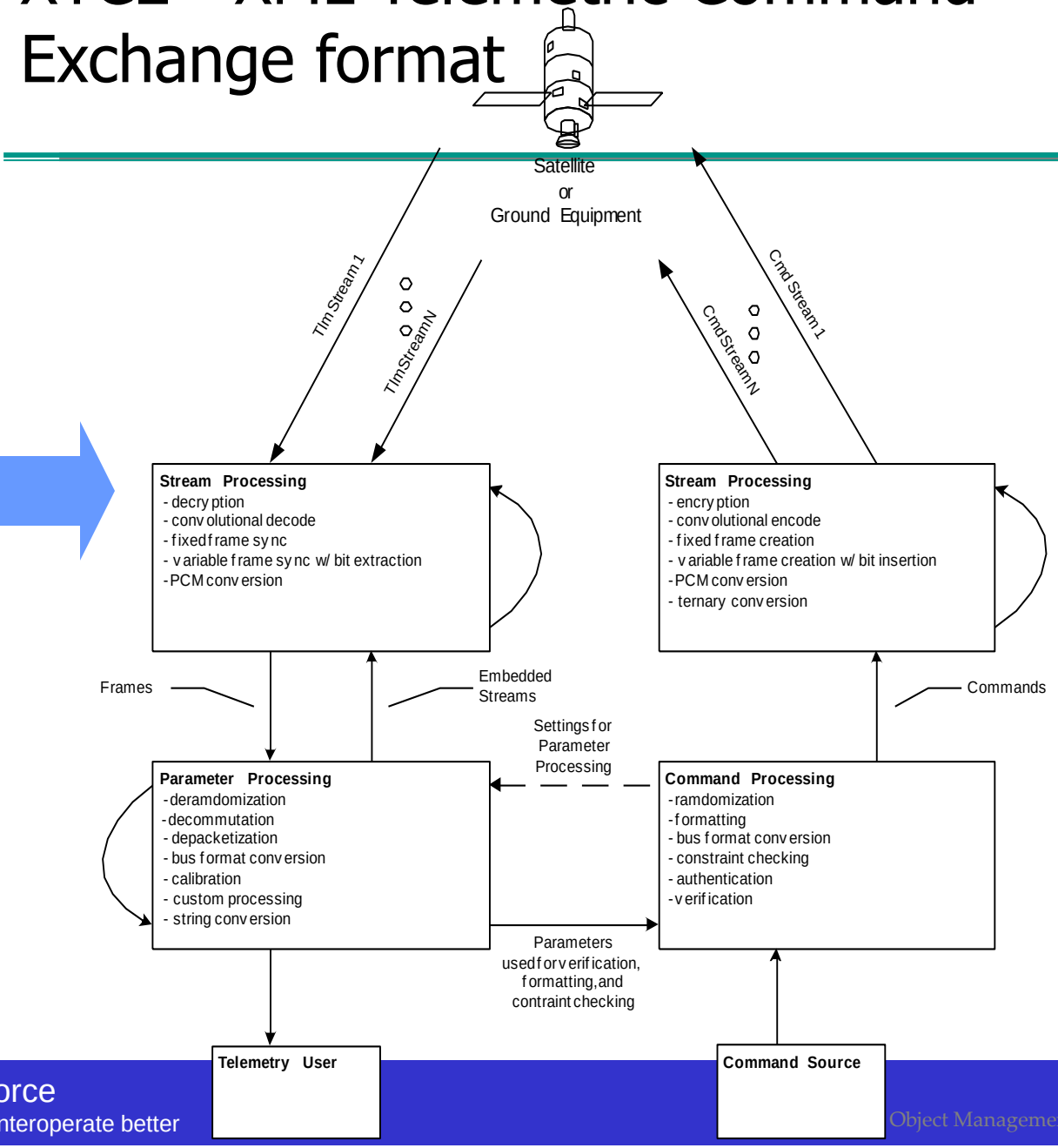
- The Space Domain Task Force (STDF) is an OMG vertical Domain Task Force (DTF) specifically chartered to foster the development of space related standards because:

space applications ***MUST*** interoperate better

- Space professionals committed to greater interoperability, reduction in costs, schedule, and risk for space applications through increased standardization
- The SDTF has been working cooperatively with the CCSDS to ensure consistent space standards development.

XTCE - XML Telemetric Command Exchange format

XTCE Encapsulates the data required to perform all this processing



A Little About XML

- XML is simply:

  <TAG>*data*<\TAG>, where *data* is:

  <TAG>*more data*<\TAG>, etc…

- XML is designed to *carry data – W3C*
- *Example:*

```
<note>
<to>Tove</to>
<from>Jani</from>
<heading>Reminder</heading>
<body>Don't forget me this weekend!</body>
 </note>
```


From XML to XML Schema

- XML Schema is a LANGUAGE builder for building an information model in XML – a meta-model
- Once you define YOUR Schema, you can build a parser to ingest XMLs. If it accepts the XML, the XML in YOUR Schema… (it's valid)
- If the XML is in your language, you can then get data into or out of it, after parsing

A Schema for the Last XML Example

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
targetNamespace=http://www.w3schools.com
 xmlns="http://www.w3schools.com"
elementFormDefault="qualified">

  <xs:element name="note">
    <xs:complexType>
      <xs:sequence>
            <xs:element name="to" type="xs:string"/>
            <xs:element name="from" type="xs:string"/>
            <xs:element name="heading" type="xs:string"/>
            <xs:element name="body" type="xs:string"/>
       </xs:sequence>
     </xs:complexType>
   </xs:element>
</xs:schema>
```

What Does XTCE Do? Data … MetaData

Data	Description	
W3C - Schema	Meta Meta Meta Data – An XML Documents (W3C Schema Language) that describes the format of itself	*Created by the W3C*
XTCE – Schema	Meta Meta Data – An XML Document (W3C Schema Language) that describes the XTCE format	*Created by the SDTF*
XML in XTCE format	Meta Data – An XML Document (XTCE format) that describes the Data	*Created for a S/C program*
Streams, Containers, Parameters & Commands	Data – Actual streams of bits containing packages of parameters or commands	*Created by the S/C, Ground System or Simulator*

TrivalSat Example

Telemetry

	0	8	16	24	32
Minor Frame 0	ASM=fa	MFCtr=0	Bat1V	BeaconStatus	
Minor Frame 1	ASM=fa	MFCtr=1	BeaconStatus	Bat1V	

Bat1V – Battery one voltage, encoded as an 8 bit unsigned integer, MSB first, calibrated to a linear 0 to 32 volt curve

BeaconStatus – Beacon Status, encoded as an 8 bit unsigned integer, MSB first where only the first bit is used, that is treated as a enumerated type where a 1=On and 0=Off.

Command

	0	8	16
Command Format	OpCode	Argument(s)	
BeaconPwr	OpCode=170	On/Off	
BeaconPwrOn	OpCode=170	On/Off=On	

Steps to Building the XML

1. Define a TrivialSat SpaceSystem

TelemetryMetaData

2. Define TelemetryParameterTypes
3. Instantiate Parameters using ParameterTypes
4. Build Sequence Containers

CommandMetaData

5. Define ArgumentTypes
6. Define MetaCommands
7. Define CommandContainers

Quick Notes to help understand the XML

- 'Meta' – means description. Example MetaCommand is a description of a Command.
- 'Set' – is an unordered collection
- 'List' – is an ordered collection
- 'Ref' – is a reference (by name) to an object defined elsewhere in the XML document

Step 1: TrivialSat - SpaceSystem

XML Standard

Default namespace

```
<?xml version="1.0" encoding="UTF-8"?>
<SpaceSystem xmlns="http://www.omg.org/space/xtce" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
    instance" xsi:schemaLocation="http://www.omg.org/space/xtce SpaceSystemV1.0.xsd"
    name="TrivialSat">
    <TelemetryMetaData>
        <ParameterTypeSet></ParameterTypeSet>
        <ParameterSet></ParameterSet>
        <ContainerSet></ContainerSet>
    </TelemetryMetaData>
    <CommandMetaData>
        <ArgumentTypeSet></ArgumentTypeSet>
        <ParameterMetaCommandSet></MetaCommandSet>
        <CommandContainerSet></CommandContainerSet>
    </CommandMetaData>
</SpaceSystem>
```

Schema location

SpaceSystem name

Telemetry description goes here

Command description goes here

Step 2: TrivialSat – ParameterTypeSet

```
<ParameterTypeSet>
    <FloatParameterType name="Battery1VoltageType">
        <UnitSet/>
        <IntegerDataEncoding/>
        <DefaultCalibrator>
            <PolynomialCalibrator>
                <Term coefficient="0.125" exponent="1"/>
            </PolynomialCalibrator>
        </DefaultCalibrator>
    </FloatParameterType>
    <EnumeratedParameterType name="BeaconStatusType">
        <UnitSet/>
        <IntegerDataEncoding/>
        <EnumerationList>
            <Enumeration value="128" label="On"/>
            <Enumeration value="0" label="Off"/>
        </EnumerationList>
    </EnumeratedParameterType>
    <BinaryParameterType name="minorFrameCtrType">
        <UnitSet/>
    </BinaryParameterType>
</ParameterTypeSet>
```

Floating Point Parameter

Is encoded as an integer. Default Integer Encoding is unsigned 8 bit MS Bit and byte first

Linear calibration

Enumeration Parameter

Encoded as an 8 bit unsigned measurand

8 Bit Binary Parameter

Step 3: TrivialSat - ParameterSet

```
<ParameterSet>
    <Parameter name="BatteryVoltage" parameterTypeRef="BatteryVoltageType"/>
    <Parameter name="BeaconStatus" parameterTypeRef="BeaconStatusType"/>
    <Parameter name="minorFrameCtr" parameterTypeRef="minorFrameCtrType"/>
</ParameterSet>
```

Parameter will be of this type

Declare a Parameter with this name

Step 4: TrivialSat – ContainerSet

```
<ContainerSet>
    <SequenceContainer name="MinorFrame">
        <EntryList>
            <ParameterRefEntry parameterRef="minorFrameCtr"/>
        </EntryList>
    </SequenceContainer>
    <SequenceContainer name="MinorFrame0">
        <EntryList>
            <ParameterRefEntry parameterRef="Battery1Voltage"/>
            <ParameterRefEntry parameterRef="BeaconStatus"/>
        </EntryList>
        <Base containerRef="MinorFrame">
            <RestrictionCriteria>
                <Comparison parameterRef="minorFrameCtr" value="0x00"/>
            </RestrictionCriteria>
        </Base>
    </SequenceContainer>
    <SequenceContainer name="MinorFrame1">
    ….
    </SequenceContainer>
</ContainerSet>
```

Abstract MinorFrame

MinorFrame0

IS A MinorFrame

Where the minorFrameCtr =0

Step 5: TrivialSat - ArgumentTypes

```
<ArgumentTypeSet>
    <BinaryArgumentType name="opCodeType">
        <UnitSet/>
    </BinaryArgumentType>
    <EnumeratedArgumentType name="onOffType">
        <UnitSet/>
        <EnumerationList>
            <Enumeration value="1" label="on"/>
            <Enumeration value="0" label="off"/>
        </EnumerationList>
    </EnumeratedArgumentType>
</ArgumentTypeSet>
```


Step 6: TrivialSat – MetaCommand: Top level MetaCommand

Abstract TrivialSatCmd – only has an opCode

```
<MetaCommand name="TrivialSatCmdType" abstract="true">
    <ArgumentList>
        <Argument name="opCode" argumentTypeRef="opCodeType"/>
    </ArgumentList>
    <CommandContainer name="TrivialSatCommandContainerType">
        <EntryList>
            <ArgumentRefEntry argumentRef="opCode"/>
        </EntryList>
    </CommandContainer>
</MetaCommand>
```

TrivialSat – MetaCommand: BeaconPwr

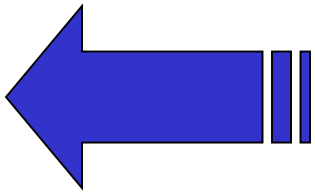
```
<MetaCommand name="BeaconPwr">
    <LongDescription>Turn Beacon Power on or off</LongDescription>
    <BaseMetaCommand metaCommandRef="TrivialSatCmdType">
        <ArgumentAssignmentList>
            <ArgumentAssignment argumentName="opCode" argumentValue="170"/>
        </ArgumentAssignmentList>
    </BaseMetaCommand>
    <ArgumentList>
        <Argument name="powerValue" argumentTypeRef="onOffType"/>
    </ArgumentList>
    <CommandContainer name="BeaconPwr">
        <EntryList>
            <ArgumentRefEntry argumentRef="powerValue"/>
        </EntryList>
        <BaseContainer containerRef="TrivialSatCmdContianerType">
        </BaseContainer>
    </CommandContainer>
</MetaCommand>
```

Value of opCode is fixed for this MetaCommand type

New argument introduced

MetaCommand container – the powerValue argument is added to the container

TrivialSat – Complete XML



The entire XML document for TrivialSat

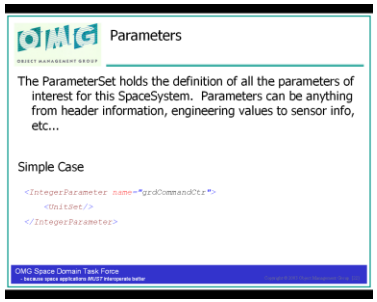
```
<?xml version="1.0" encoding="UTF-8"?>
<SpaceSystem xmlns="http://www.omg.org/space/xtce" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.omg.org/space/xtce ../SpaceSystemV1.0.xsd" name="TrivialSat">
    <TelemetryMetaData>
        <ParameterTypeSet>
            <FloatParameterType name="BatteryVoltageType">
                <UnitSet/>
                <IntegerDataEncoding/>
                <DefaultCalibrator>
                    <PolynomialCalibrator>
                        <Term coefficient="8" exponent="1"/>
                    </PolynomialCalibrator>
                </DefaultCalibrator>
            </FloatParameterType>
            <EnumeratedParameterType name="BeaconStatusType">
                <UnitSet/>
                <IntegerDataEncoding/>
                <EnumerationList>
                    <Enumeration value="128" label="On"/>
                    <Enumeration value="0" label="Off"/>
                </EnumerationList>
            </EnumeratedParameterType>
            <BinaryParameterType name="minorFrameCtrType">
                <UnitSet/>
            </BinaryParameterType>
        </ParameterTypeSet>
        <ParameterSet>
            <Parameter name="BatteryVoltage" parameterTypeRef="BatteryVoltageType"/>
            <Parameter name="BeaconStatus" parameterTypeRef="BeaconStatusType"/>
            <Parameter name="minorFrameCtr" parameterTypeRef="minorFrameCtrType"/>
        </ParameterSet>
        <ContainerSet>
            <SequenceContainer name="MinorFrame">
                <EntryList>
                    <ParameterRefEntry parameterRef="minorFrameCtr"/>
                </EntryList>
            </SequenceContainer>
            <SequenceContainer name="MinorFrame0">
                <EntryList>
                    <ParameterRefEntry parameterRef="BatteryVoltage"/>
                    <ParameterRefEntry parameterRef="BeaconStatus"/>
                </EntryList>
                <BaseContainer containerRef="MinorFrame">
                    <RestrictionCriteria>
                        <Comparison parameterRef="minorFrameCtr" value="0x00"/>
                    </RestrictionCriteria>
                </BaseContainer>
            </SequenceContainer>
            <SequenceContainer name="MinorFrame1">
                <EntryList>
                    <ParameterRefEntry parameterRef="BeaconStatus"/>
                    <ParameterRefEntry parameterRef="BatteryVoltage"/>
                </EntryList>
                <BaseContainer containerRef="MinorFrame">
                    <RestrictionCriteria>
                        <Comparison parameterRef="minorFrameCtr" value="0x01"/>
                    </RestrictionCriteria>
                </BaseContainer>
            </SequenceContainer>
        </ContainerSet>
    </TelemetryMetaData>
    <CommandMetaData>
        <ArgumentTypeSet>
            <BinaryArgumentType name="opCodeType">
                <UnitSet/>
            </BinaryArgumentType>
            <EnumeratedArgumentType name="onOffType">
                <UnitSet/>
                <EnumerationList>
                    <Enumeration value="1" label="on"/>
                    <Enumeration value="0" label="off"/>
                </EnumerationList>
            </EnumeratedArgumentType>
        </ArgumentTypeSet>
        <MetaCommandSet>
            <MetaCommand name="TrivialSatCmdType" abstract="true">
                <ArgumentList>
                    <Argument name="opCode" argumentTypeRef="opCodeType"/>
                </ArgumentList>
                <CommandContainer name="TrivialSatCommandContainerType">
                    <EntryList>
                        <ArgumentRefEntry argumentRef="opCode"/>
                    </EntryList>
                </CommandContainer>
            </MetaCommand>
            <MetaCommand name="BeaconPwr">
                <LongDescription>Turn Beacon Power on or off</LongDescription>
                <BaseMetaCommand metaCommandRef="TrivialSatCmdType">
                    <ArgumentAssignmentList>
                        <ArgumentAssignment argumentName="opCode" argumentValue="170"/>
                    </ArgumentAssignmentList>
                </BaseMetaCommand>
                <ArgumentList>
                    <Argument name="powerValue" argumentTypeRef="onOffType"/>
                </ArgumentList>
                <CommandContainer name="BeaconPwr">
                    <EntryList>
                        <ArgumentRefEntry argumentRef="powerValue"/>
                    </EntryList>
                    <BaseContainer containerRef="TrivialSatCmdContainerType">
                    </BaseContainer>
                </CommandContainer>
            </MetaCommand>
            <MetaCommand name="BeaconPwrOn">
                <LongDescription/>
                <BaseMetaCommand metaCommandRef="BeaconPwr">
                    <ArgumentAssignmentList>
                        <ArgumentAssignment argumentName="powerValue" argumentValue="on"/>
                    </ArgumentAssignmentList>
                </BaseMetaCommand>
            </MetaCommand>
        </MetaCommandSet>
    </CommandMetaData>
</SpaceSystem>
```

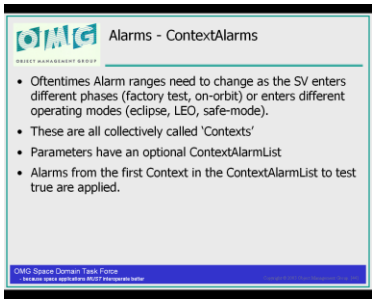

Details

- The remainder of this presentation covers details of the XTCE specification

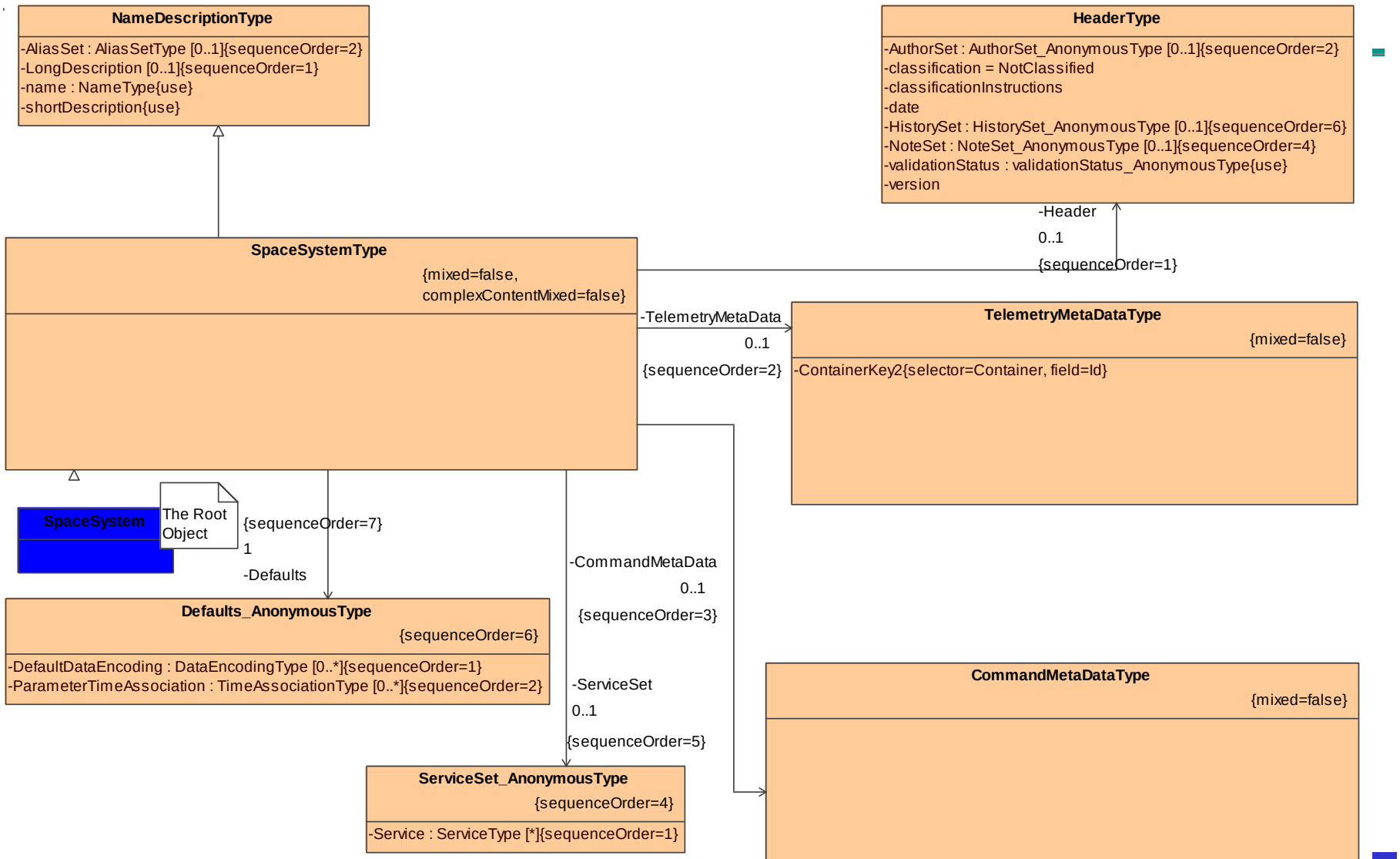
XTCE: Simple to Complex

- XTCE is designed to describe 90% of the data required for 95% of spacecraft missions
- XTCE for simple data formats is simple
- XTCE for esoteric data formats is not simple
- Pages in this presentation that discuss some of the more esoteric concepts have darker backgrounds



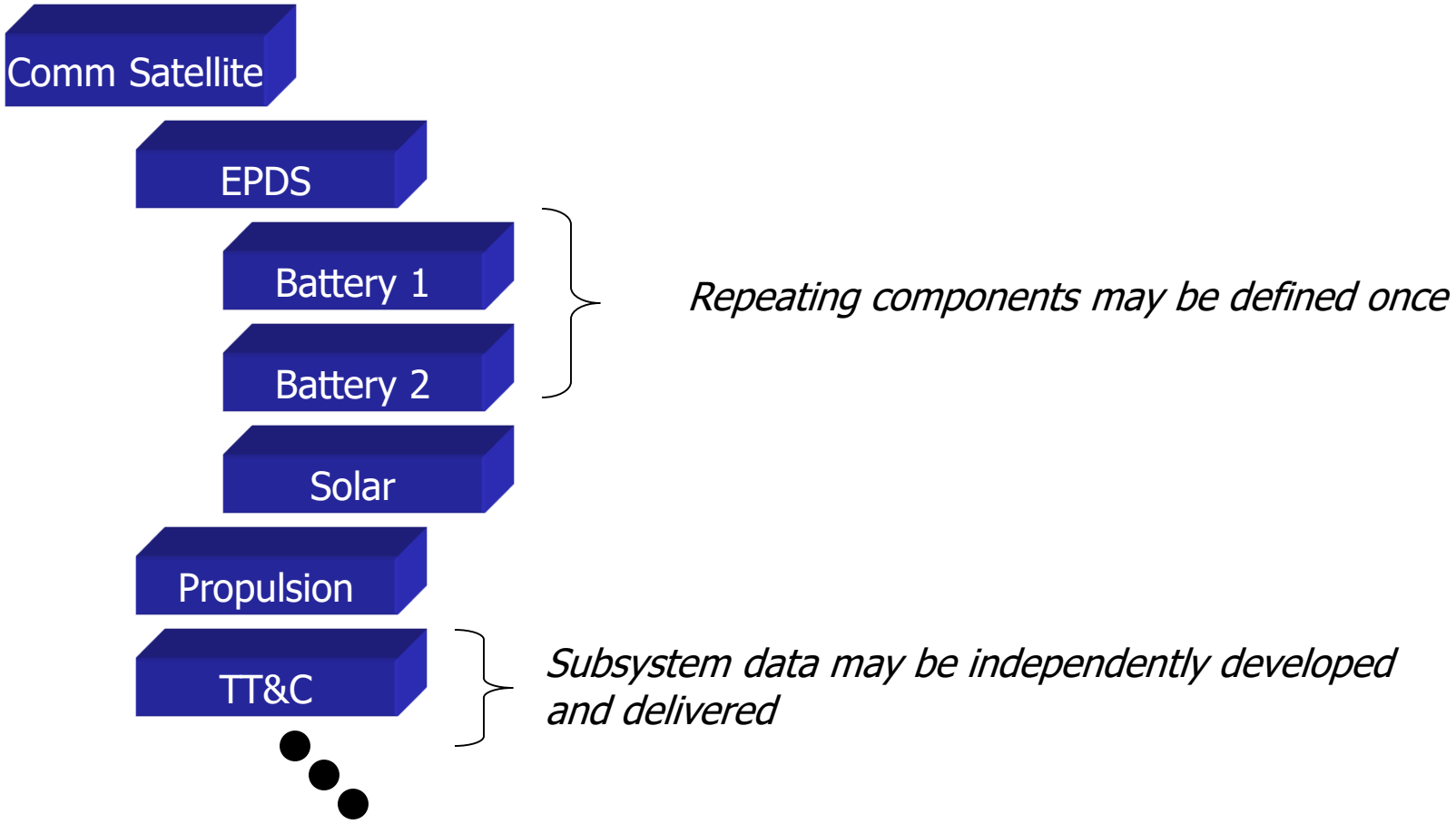


XTCE Top Level UML



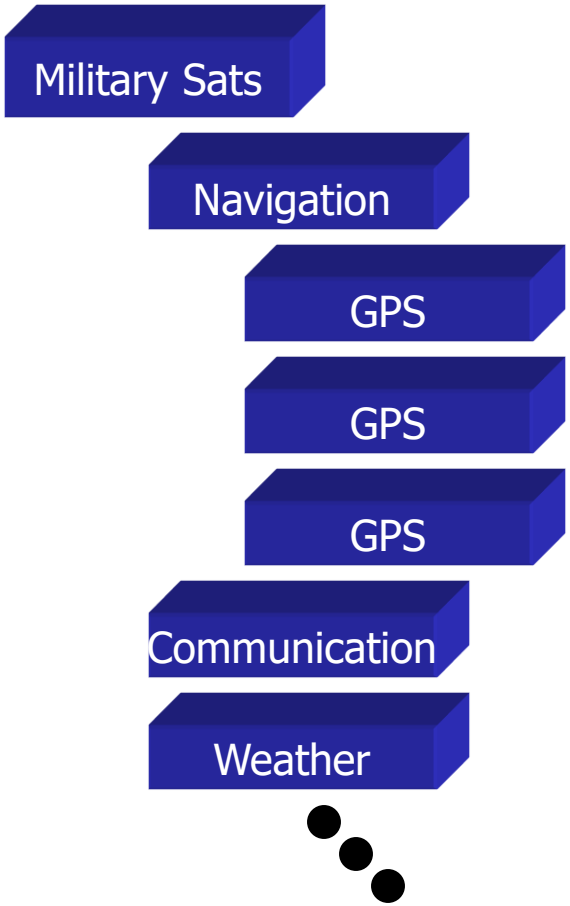
What's With this Systems-of-Systems Thing?

- XTCE's hierarchical structure looks like a real spacecraft



More on the hierarchy

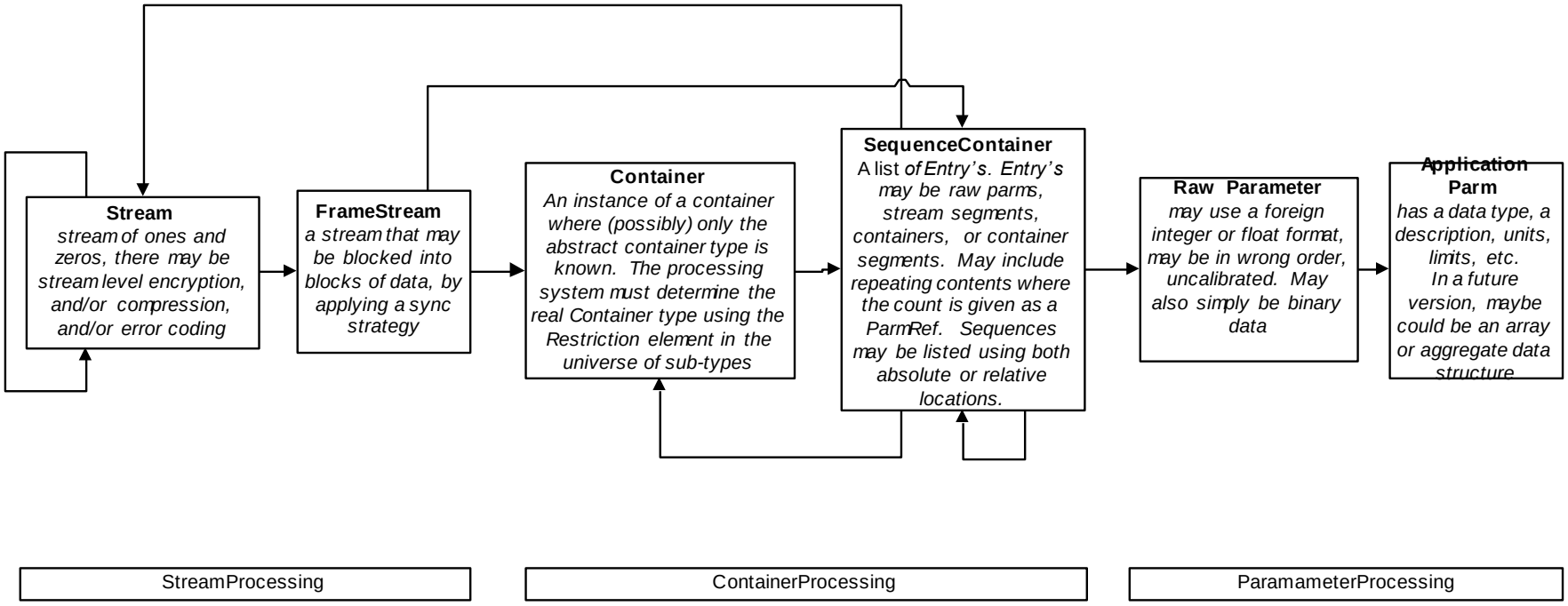
- Hierarchy may start at any level



XTCE Top Level in XML

```
<?xml version="1.0" encoding="UTF-8"?>
<SpaceSystem xmlns="http://www.omg.org/space/xtce" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
    instance" xsi:schemaLocation="http://www.omg.org/space/xtce SpaceSystem.xsd" name="Camera">
  <TelemetryMetaData>
    <ParameterSet>
      <BinaryParameter name="colorImage">
        <UnitSet/>
        <BinaryDataEncoding>
          <SizeInBits>
            <FixedDecimalValue>1000000</FixedDecimalValue>
          </SizeInBits>
        </BinaryDataEncoding>
      </BinaryParameter>
    </ParameterSet>
  </TelemetryMetaData>
</SpaceSystem>
```


Telemetry Processing Flow



ParameterTypeSet

- The ParameterTypeSet holds the definition of all the parameters of interest for this SpaceSystem. ParameterTypes can be anything from header information, engineering values to sensor info, etc...
- Parameter types: Integer, Float, String, Enumeration, Binary, Absolute Time, Relative Time, Array and Boolean
- Simple Case

```
<IntegerParameterType name="grdCommandCtr_t">
   <UnitSet/>
</IntegerParameterType>
```

ParameterTypes and Parameters

- ParameterTypes are instantiated as Parameters. Parameters can have a value; it is not the value itself
- Parameters types indicate how the parameter is to be handled on the ground
- Integer (32, 64 or 128 bit)
- Float (32, 64 or 128 bit)
- Binary (any size)
- String (any size)
- Enumerated – has a list of numerical values each with a matching strings
- RelativeTime – an elapsed time value (precision is not currently specified)
- AbsoluteTime – time referenced to a fixed epoch

ParameterType – Example XML

```
<BinaryParameterType name="frameSyncType" shortDescription="Frame Synchronization Field"
initialValue="0934">
    <LongDescription><![CDATA[This long description for frame sync contains an <b>HTML</b>markup
description]]></LongDescription>
    <UnitSet/>
    <BinaryDataEncoding bitOrder="mostSignificantBitFirst">
        <SizeInBits>
            <FixedDecimalValue>13</FixedDecimalValue>
        </SizeInBits>
    </BinaryDataEncoding>
</BinaryParameterType>
```

Parameter – Example XML

```
<Parameter name="frameSyncType" parameterTypeRef="frameSyncType" shortDescription="Frame
    Synchronization Field">
  <ParameterProperties dataSource="telemetered" readOnly="true"/>
</Parameter>
```


Parameter Properties

- dataSource – telemetered, derived, constant, local
- readOnly
- SystemName

  Optional. Normally used when the database is built in a flat, non-hierarchical format
- ValidityCondition

  Optional condition that must be true for this Parameter to be valid
- PhysicalAddressSet

  Contains the address (e.g., channel information) required to process the spacecraft telemetry streams. May be an onboard id, a mux address, or a physical location.
- TimeAssociation

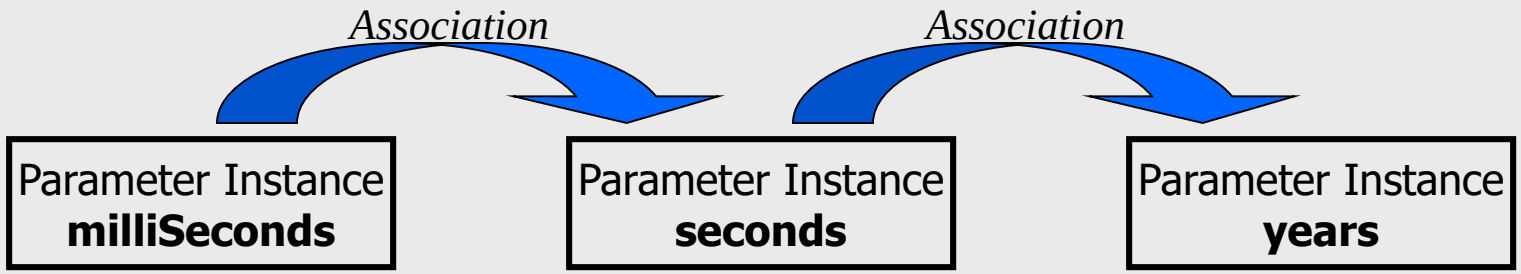
  See discussion on following page

TimeAssociation

- Telemetry parameter instances are oftentimes "time-tagged" with a timing signal either provided on the ground or on the space system. This data element allows one to specify which AbsoluteTimeParameters to use to "time-tag" instances of this Parameter with.
- TimeAssociation is a special case of ParameterInstanceRef that also includes a flag ‘interpolateTime’ that indicates whether the actual value should be used or if the value of the ParameterInstanceRef should be adjusted to reflect the probable time elapsed.

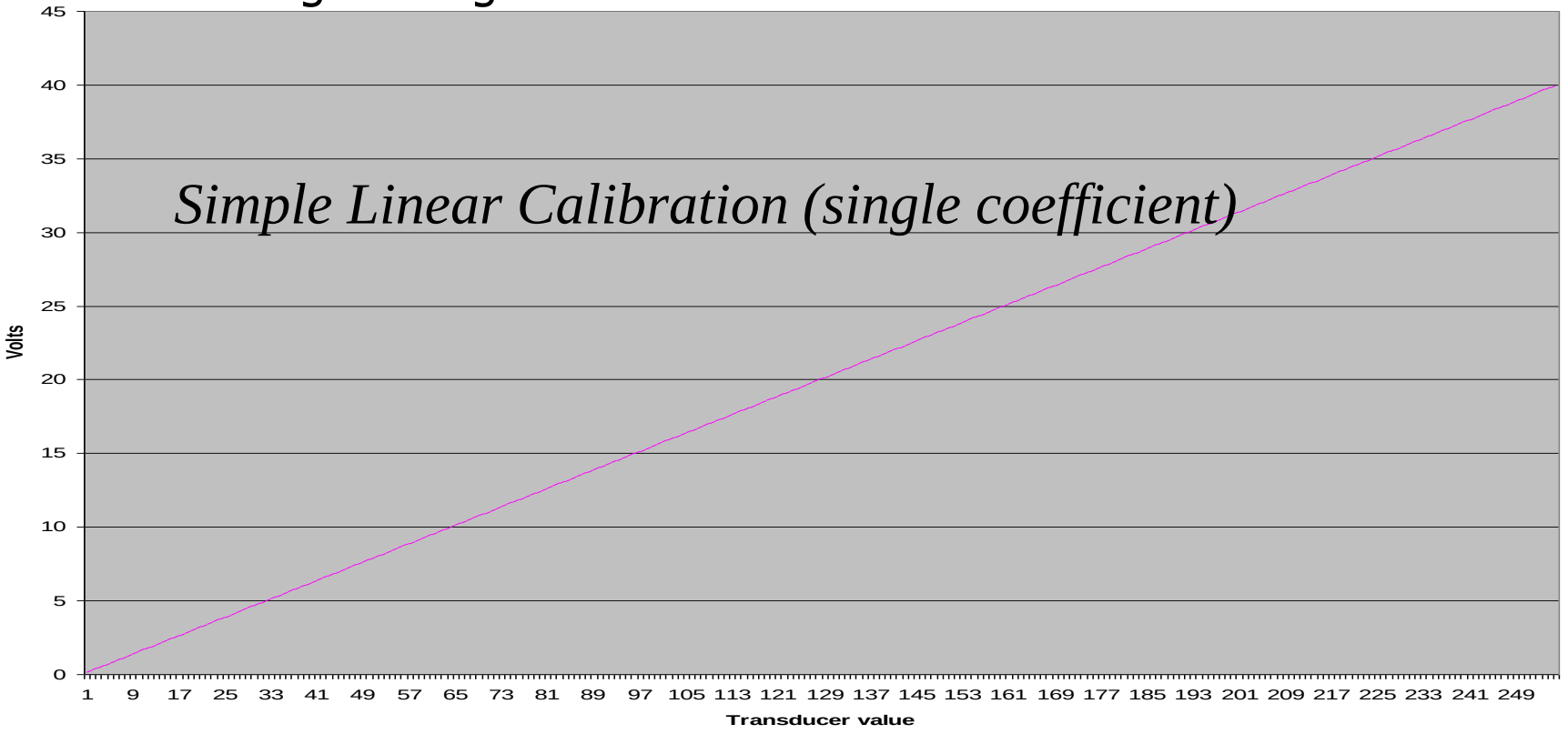
TimeAssociation cont.

- Time values are typically built up from one or more separate Parameter instances starting with least significant and working towards most significant



Calibrators

- Sensors errors on the spacecraft plus the need to 'compress' data for transmission result in a need to 'calibrate' incoming telemetry data into usable engineering data.



Calibrators – Two Types

- Polynomial, any number of coefficients

  $Y = C_0 + C_1x + C_2X^2 \ldots. + C_NX^N$

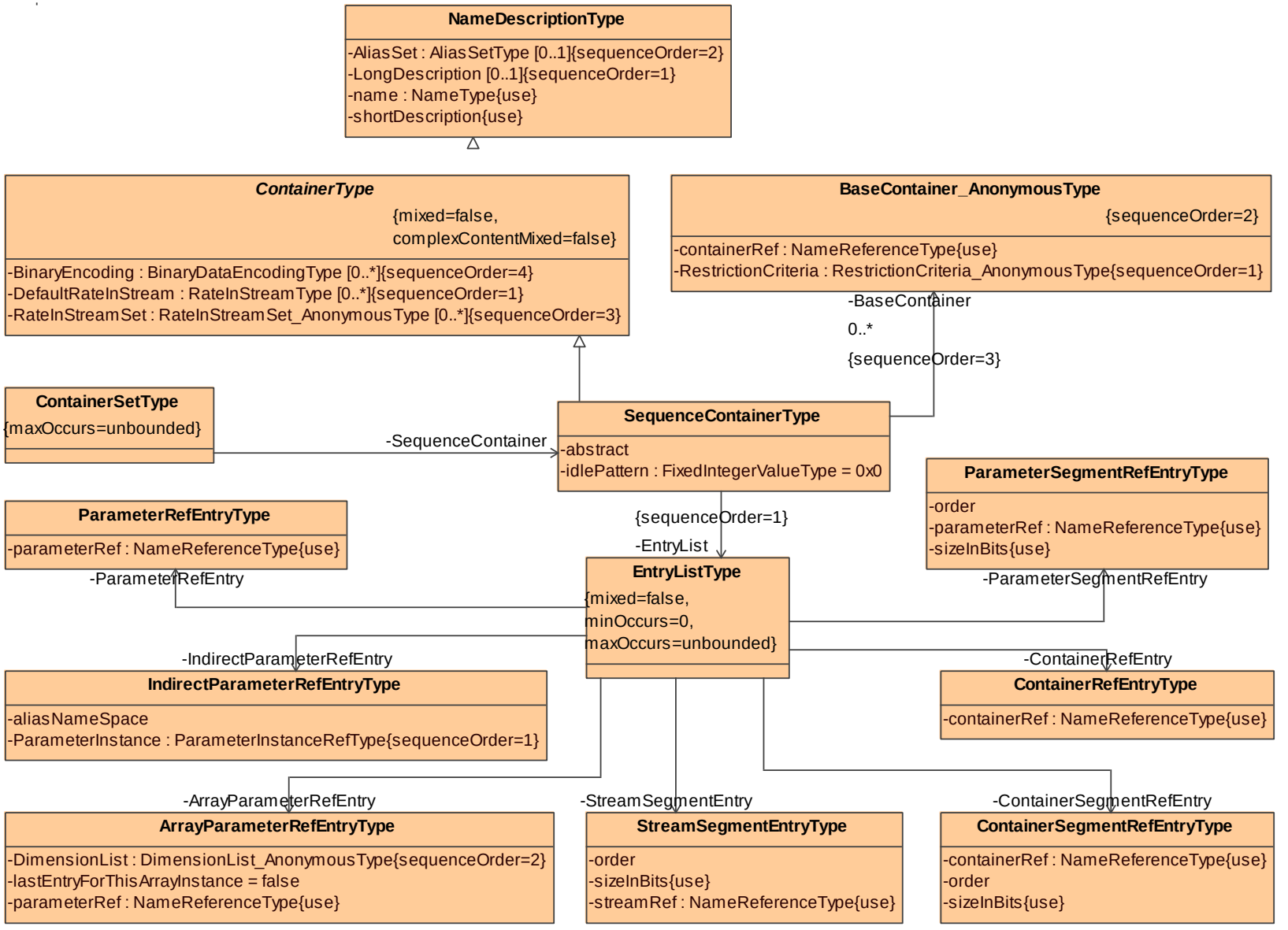
  Where Y is the calibrated value and x is the uncalibrated value

- Spline, segmented curve, arbitrary order
  - 1st Order is a set of line segments
  - 2nd Order is a set of quadratic segments
  - 3rd Order is a set of cubic segments
  - Etc.
  - 1st Order is the default

Calibrators – Default and Context

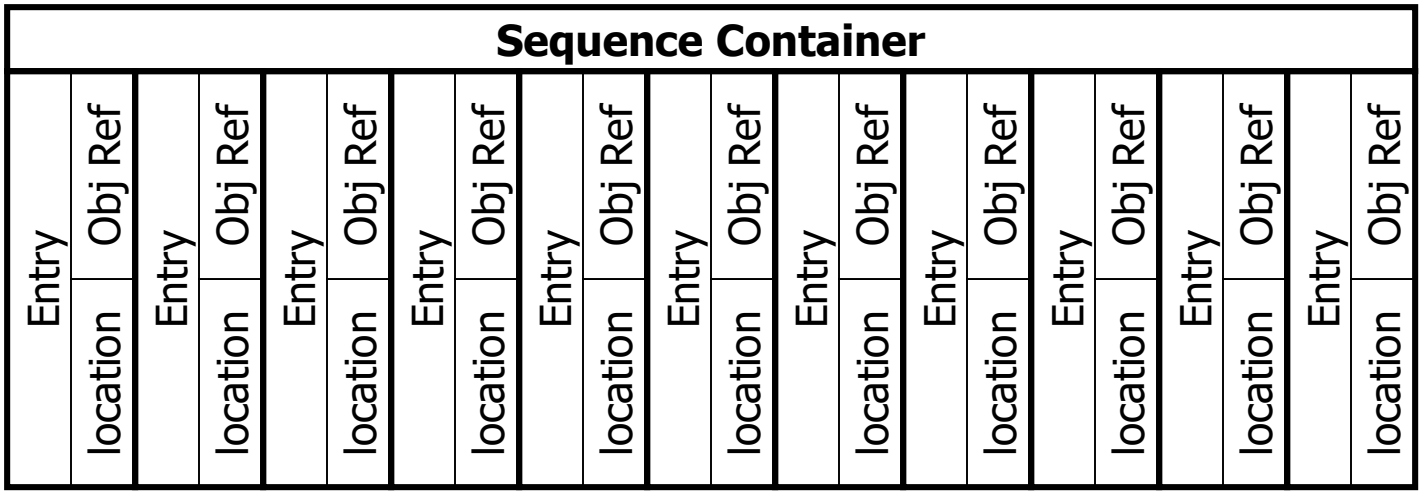
- On rare occasions Calibrations need to change as the SV enters different phases (factory test, on-orbit) or enters different operating modes (eclipse, LEO, safe-mode)
- On other occasions, it may be necessary to apply different Calibration curves depending on the uncalibrated value
- These phases, and operating modes are collectively called 'Contexts'
- ParameterTypes have an optional ContextCalibratorList
- The Calibrator from the first Context in the ContextCalibratorList to test true is applied.

Packaging - Container UML



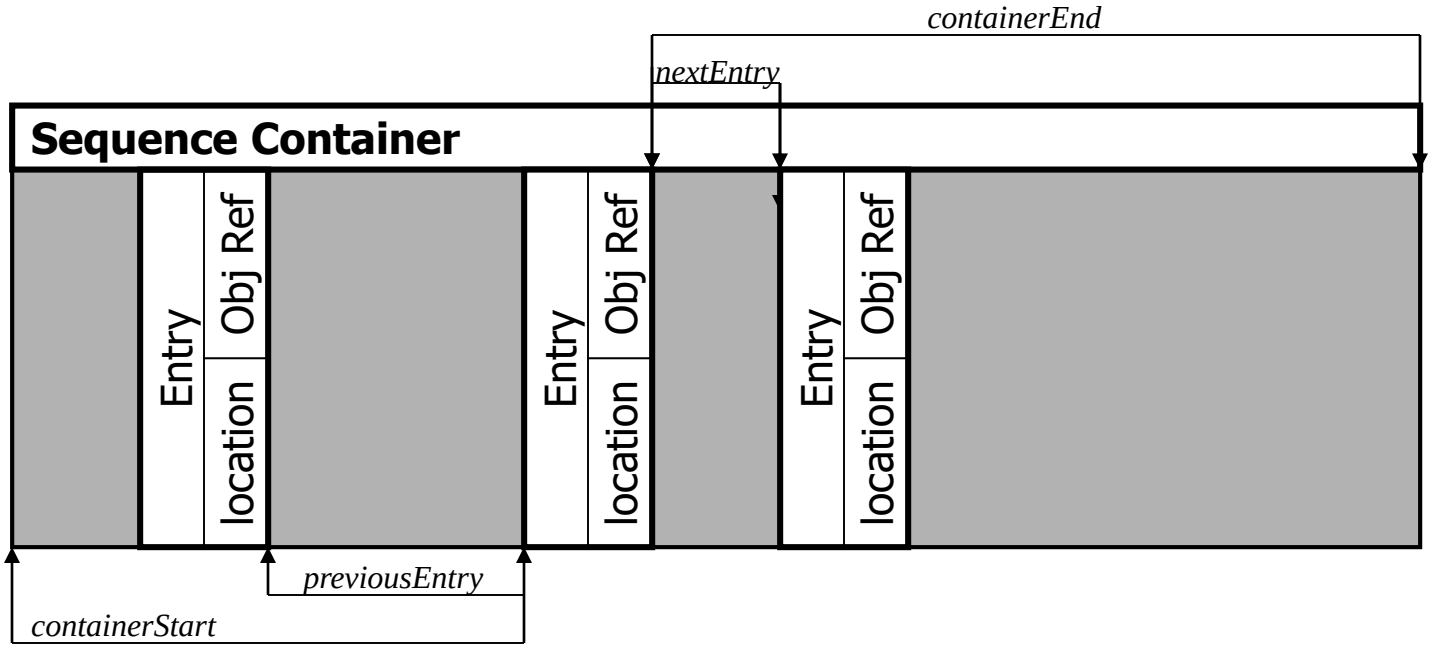
Packaging – Sequence Container

- Has a list of Entry's. Entry's may be a reference to a Parameter (including arrays), a Parameter segment, a Stream segment, a Container, a Container segment, or an indirect reference to a Parameter.



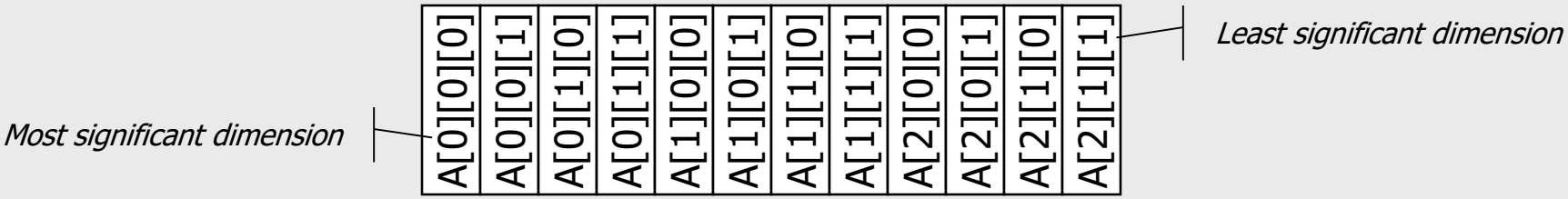
Packaging – Entries

- Location of the entry is an integer value referenced from:
  - The end of the previous entry to the start of this entry (default)
  - The start of the container to the start of this entry
  - The end of the container to the end of this entry



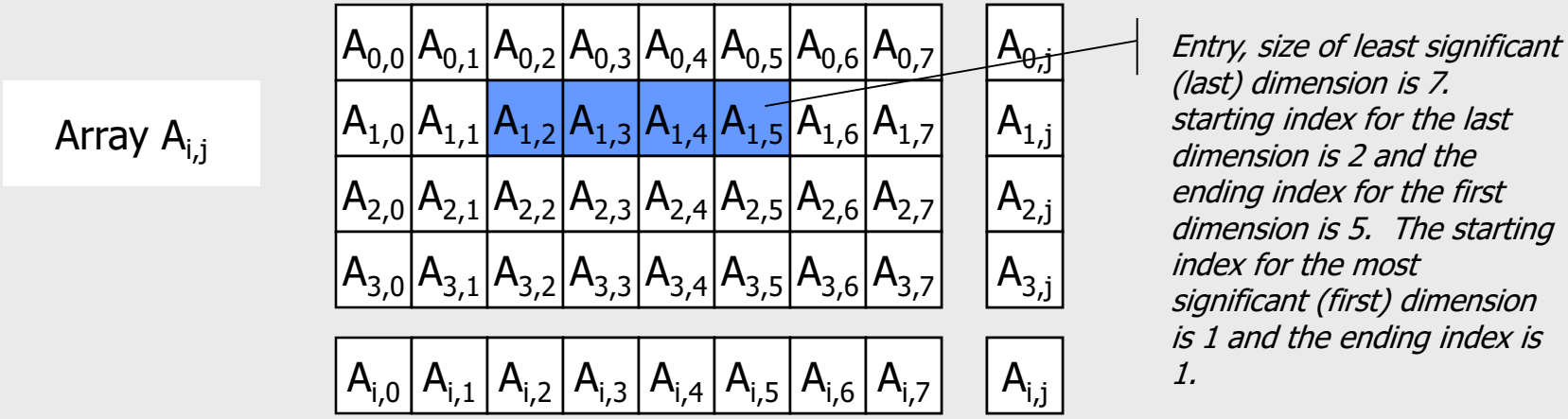
Packaging – Array Entries

- An Array entry may refer to the entire array, a part of the array or a single element of the array.
- Entire Array: must supply the size of every dimension (e.g. A[2][5][3]). Array order is assumed to have a sequence where the 0^{th} elements in the first (most significant) dimension is supplied first.
  - Thus, a three dimensional array whose size is A[3][2][2] will have the sequence order as shown below



Packaging – Array Entries

- Partial Array: Where the entry is only part of the array (e.g. a row) and may simply be a single element of the array.
- Must supply the starting index and ending index for each dimension to be included in the entry.

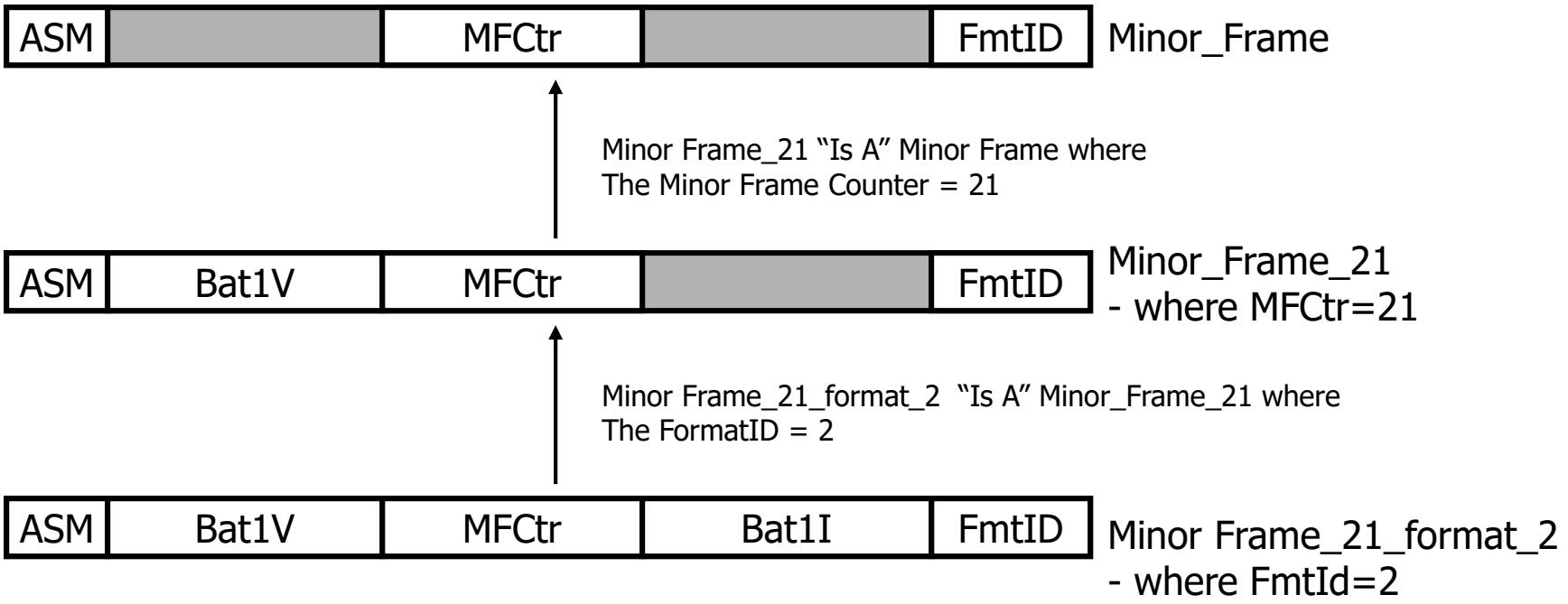


Packaging - Entry Complexities

rarely used

- Location may be provided dynamically, from the value of a Parameter Instance (e.g., the start of a packet from in a CCSDS transfer frame).
- May have an "include" condition – A condition where the entry will not be included in the sequence.
- May include repeating contents where the count is given as a Parameter Instance value.

Packaging – Sequence Container Inheritance Example



Packaging - Inheritance

- The EntryList of the Base container is inherited by the child container and the Child's EntryList is concatenated to that of the Base.
- Doubly defined space is OK, multiple overlapping parameters are assumed.

Packaging - RestrictionCriteria

- Usually a single Parameter that must be equal to some number – a Comparison
- But, the comparison does not have to be ==
- Or, may be a comparison list (logically anded)
- Or, could be a BooleanEquation
- Or, could have a temporal relationship (container B comes after container A)
- Or, could be a reference to an external algorithm

<X>Refs

- ParameterRef, StreamRef, ContainerRef, etc.
- Uses Unix 'like' naming across the SpaceSystem Tree

  e.g. /SimpleSat/Bus/EPDS/BatteryOne/Voltage

- The use of an unqualified name will search for a item in the current SpaceSystem first, then if none is found, in progressively higher space systems

  e.g. a parameter reference "VCC" within a Container in the /SimpleSat/Bus sub-system will result first in a search of the Bus sub-system for "VCC" then in /SimpleSat.

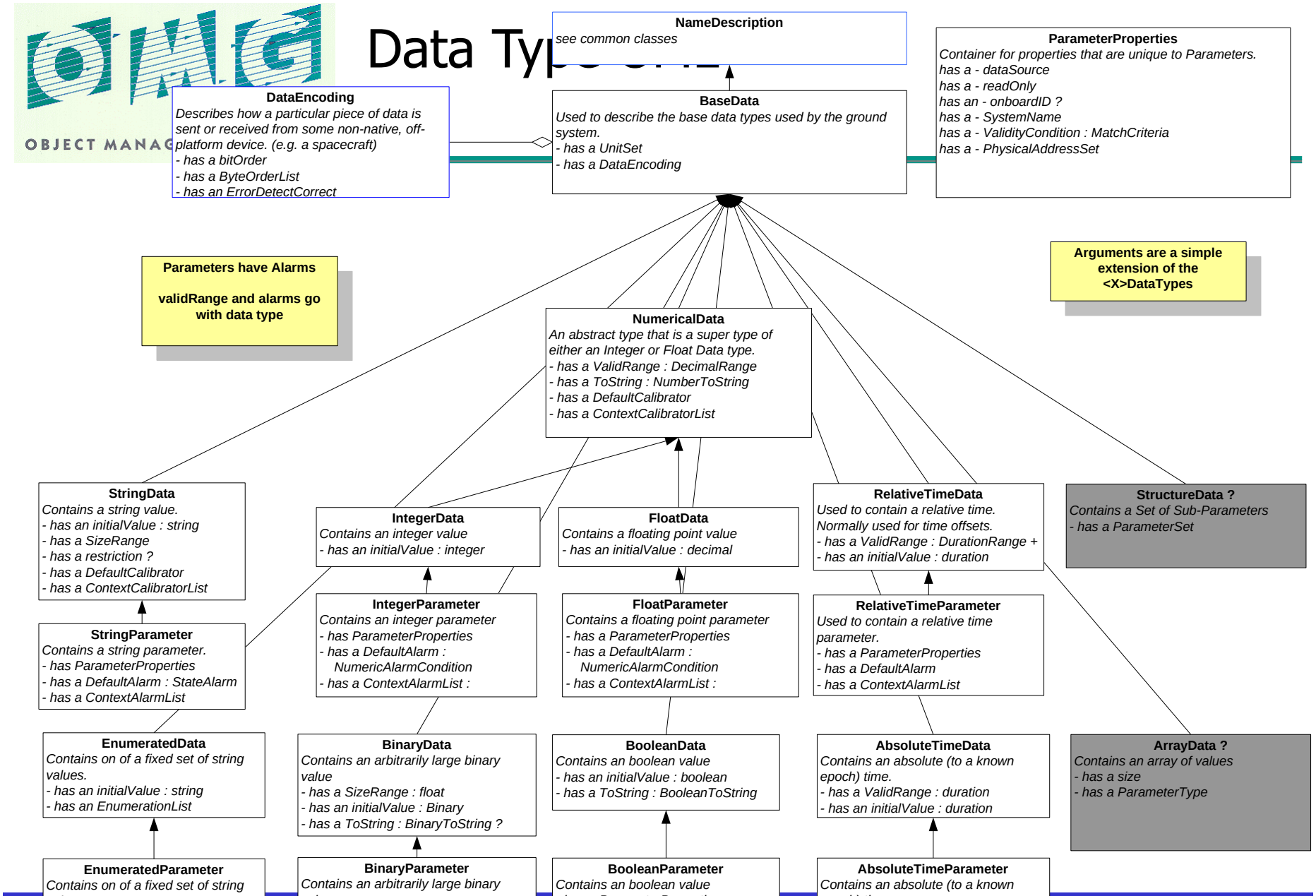
- For arrays, use the zero based bracket notation

  e.g. Voltage[3][6];

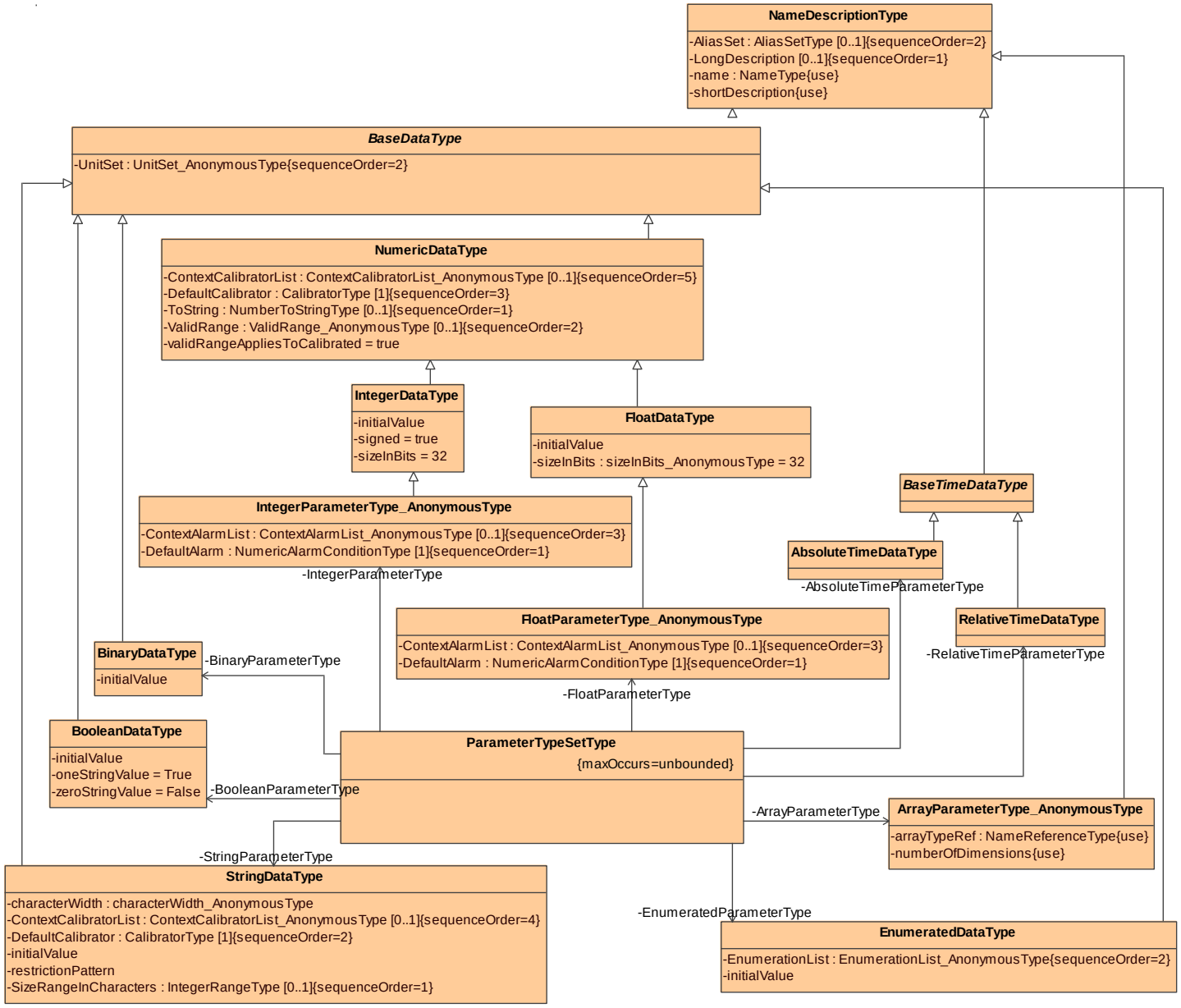
ParameterInstanceRefs

- Used when it's necessary to refer to a specific instance of a Parameter.
- Used when the value of the Parameter is used for a calculation or a reference
- The reference is either positive for forward or negative for backward in time, 0 is the current value or the very first instance of the Parameter within a container of concern.

Data Types


NameDescription
see common classes
ParameterProperties
Container for properties that are unique to Parameters.
has a - dataSource
has a - readOnly
has an - onboardID ?
has a - SystemName
has a - ValidityCondition : MatchCriteria
has a - PhysicalAddressSet
DataEncoding
Describes how a particular piece of data is sent or received from some non-native, off-platform device. (e.g. a spacecraft)
- has a bitOrder
- has a ByteOrderList
- has an ErrorDetectCorrect
BaseData
Used to describe the base data types used by the ground system.
- has a UnitSet
- has a DataEncoding
Parameters have Alarms
validRange and alarms go with data type
Arguments are a simple extension of the <X>DataTypes
NumericalData
An abstract type that is a super type of either an Integer or Float Data type.
- has a ValidRange : DecimalRange
- has a ToString : NumberToString
- has a DefaultCalibrator
- has a ContextCalibratorList
StringData
Contains a string value.
- has an initialValue : string
- has a SizeRange
- has a restriction ?
- has a DefaultCalibrator
- has a ContextCalibratorList
IntegerData
Contains an integer value
- has an initialValue : integer
FloatData
Contains a floating point value
- has an initialValue : decimal
RelativeTimeData
Used to contain a relative time. Normally used for time offsets.
- has a ValidRange : DurationRange +
- has an initialValue : duration
StructureData ?
Contains a Set of Sub-Parameters
- has a ParameterSet
StringParameter
Contains a string parameter.
- has ParameterProperties
- has a DefaultAlarm : StateAlarm
- has a ContextAlarmList
IntegerParameter
Contains an integer parameter
- has ParameterProperties
- has a DefaultAlarm : NumericAlarmCondition
- has a ContextAlarmList :
FloatParameter
Contains a floating point parameter
- has a ParameterProperties
- has a DefaultAlarm : NumericAlarmCondition
- has a ContextAlarmList :
RelativeTimeParameter
Used to contain a relative time parameter.
- has a ParameterProperties
- has a DefaultAlarm
- has a ContextAlarmList
EnumeratedData
Contains on of a fixed set of string values.
- has an initialValue : string
- has an EnumerationList
BinaryData
Contains an arbitrarily large binary value
- has a SizeRange : float
- has an initialValue : Binary
- has a ToString : BinaryToString ?
BooleanData
Contains an boolean value
- has an initialValue : boolean
- has a ToString : BooleanToString
AbsoluteTimeData
Contains an absolute (to a known epoch) time.
- has a ValidRange : duration
- has an initialValue : duration
ArrayData ?
Contains an array of values
- has a size
- has a ParameterType
EnumeratedParameter
Contains on of a fixed set of string values.
- has a ParameterProperties
- has a DefaultAlarm : StateAlarm
- has a ContextAlarmList
BinaryParameter
Contains an arbitrarily large binary value
- has a ParameterProperties
- has a DefaultAlarm
- has a ContextAlarmList
BooleanParameter
Contains an boolean value
- has a ParameterProperties
- has a DefaultAlarm
- has a ContextAlarmList
AbsoluteTimeParameter
Contains an absolute (to a known epoch) time.
- has a ParameterProperties
- has a DefaultAlarm
- has a ContextAlarmList

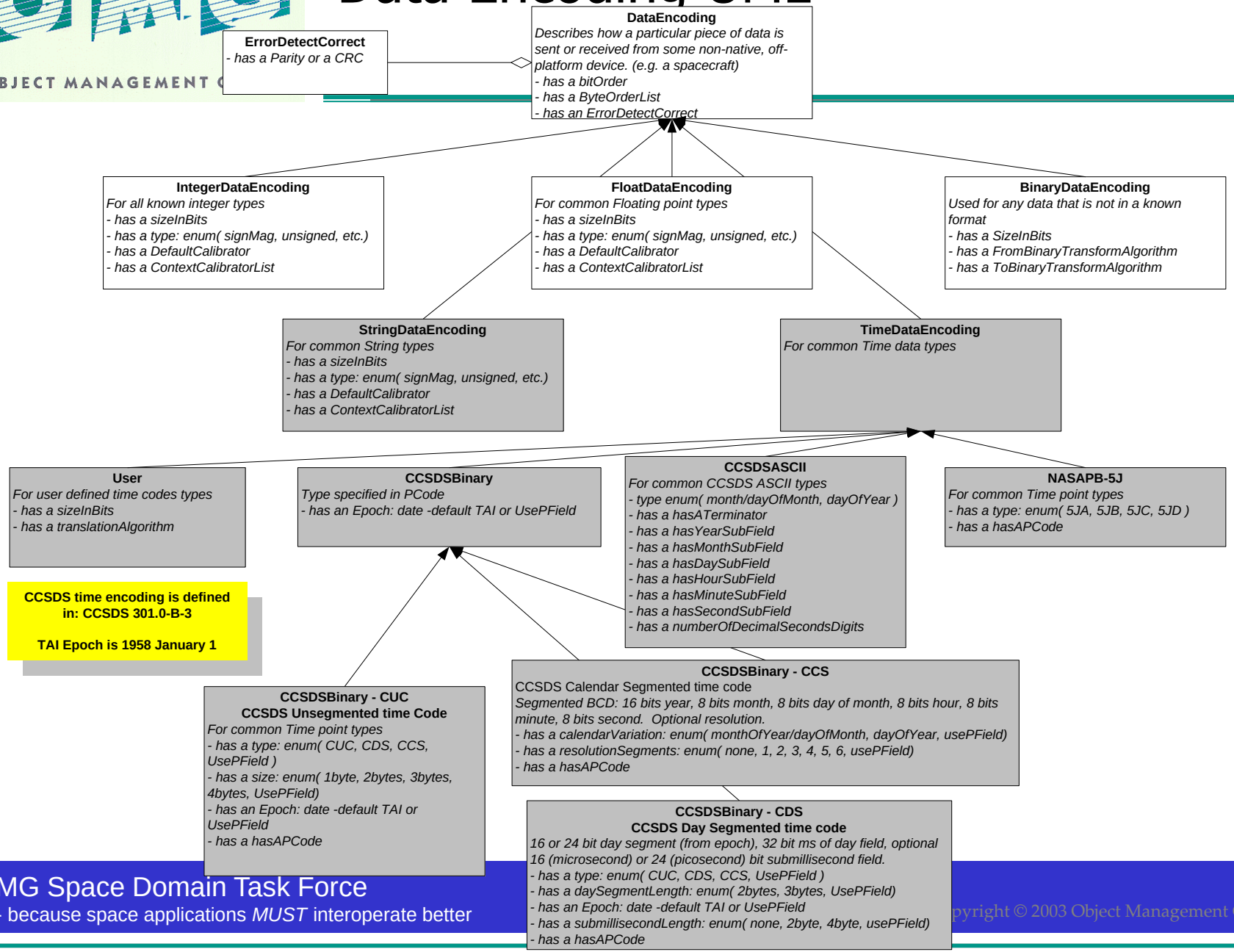
Parameter Type UML



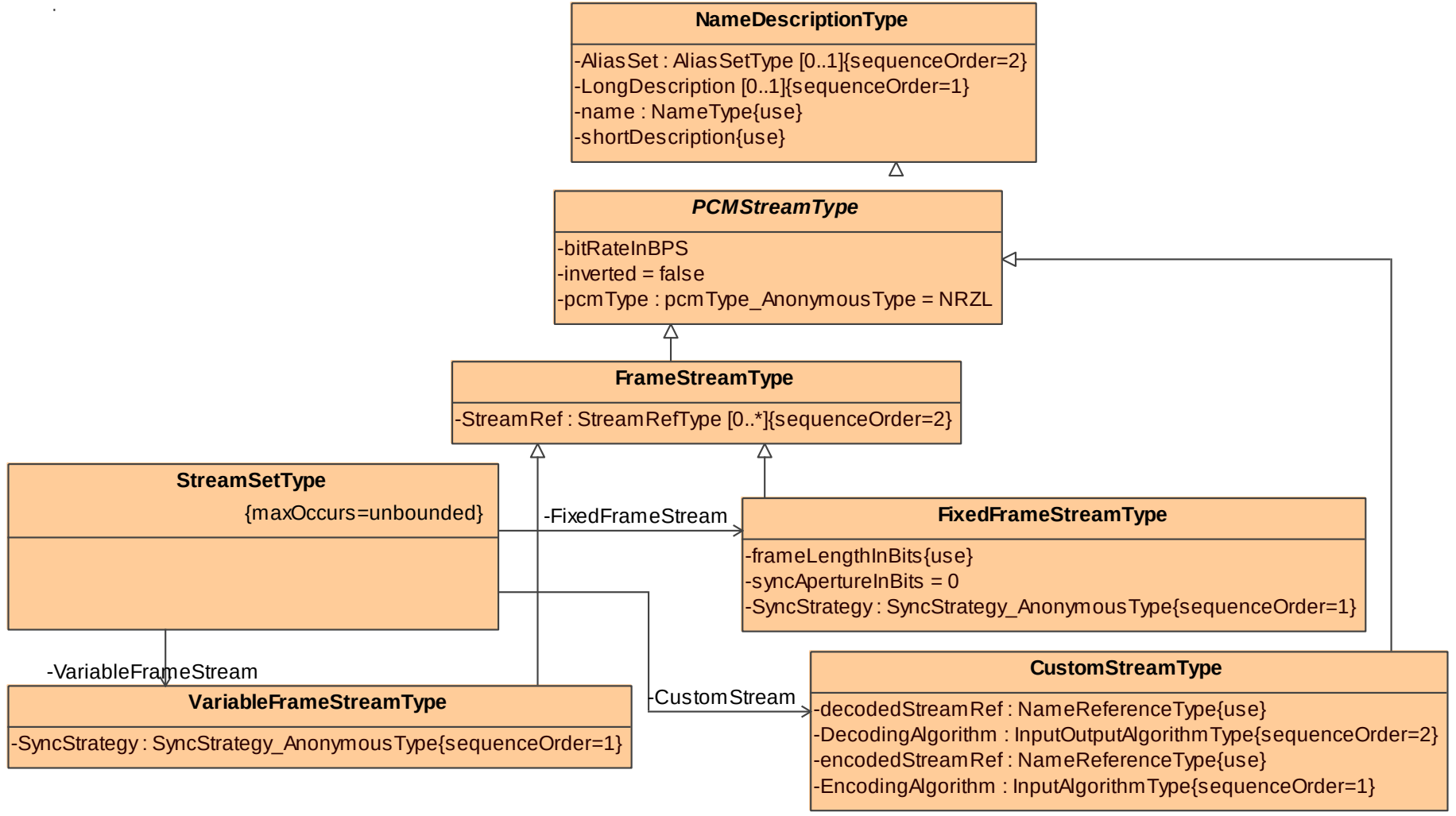
Data Types

- Parameters and Command Arguments are sub-types of Data
- All data types may have an initial value

Data Encoding UML



Stream UML



Algorithms

- XTCE does not have it's own algorithm languages, but the database format must still refer to external algorithms from time to time
- The basic algorithm type simply refers to some external algorithm
  - External algorithm may be a script, a shared library name, a Java Object file, etc.
  - Multiple references may be included so that a single XTCE file may be used across multiple ground systems.

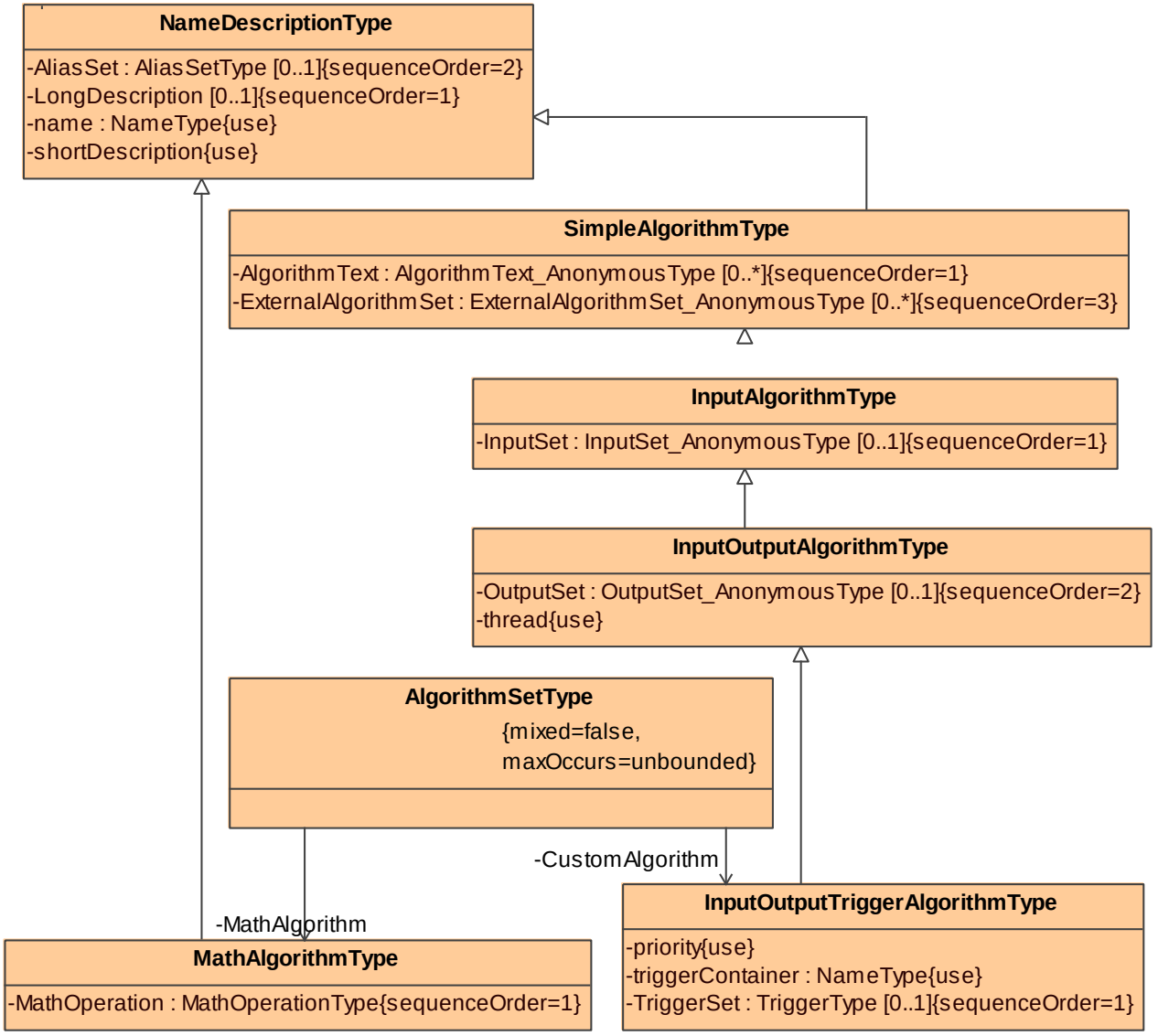
Algorithm Inputs and Outputs

- Some Algorithms allow a set of inputs
  - Inputs are named ParameterInstanceRefs or
  - Named Constants
- Some Algorithms also allow a set of outputs
  - Outputs are named ParametersRefs

Algorithm Triggers

- Triggers are used to initiate the processing of some algorithms. A trigger may be based on an update of a Parameter or on a time (periodic) basis.
- Triggers may also have a rate that limits their firing to a 1/rate basis.

Algorithm UML



Alarms – Simple to Complex

- Simple (Default Limits):
  - warning, critical

```
<DefaultAlarm>
   <StaticAlarmRanges>
      <WarningRange minInclusive="-22" maxExclusive="12"/>
      <CriticalRange minExclusive="-40" maxInclusive="13.7"/>
   </StaticAlarmRanges>
</DefaultAlarm>
```

Alarms – A Little More Complex

- Actually 6 ranges are available in increasing severity:
  - normal -> watch -> warning -> distress -> critical -> severe
- All of the ranges are optional
- The normal range is implied to be inside the least severest range

Alarms – ChangePerSecond

- Parameters have an optional ChangePerSecond (Dynamic/rate-of-change) set of alarm ranges
- Both have static limits and rate-of-change limits

```
<DefaultAlarm>
   <ChangePerSecondAlarmRanges>
            <WarningRange minInclusive="5" maxExclusive="5"/>
            <SevereRange minExclusive="-8" maxInclusive="8"/>
   </ChangePerSecondAlarmRanges>
</DefaultAlarm
```


Alarms - ContextAlarms

- Oftentimes Alarm ranges need to change as the SV enters different phases (factory test, on-orbit) or enters different operating modes (eclipse, LEO, safe-mode).
- These are all collectively called 'Contexts'
- Parameters have an optional ContextAlarmList
- Alarms from the first Context in the ContextAlarmList to test true are applied.

Alarms – Context Alarm Example

```
<ContextAlarmList>
  <ContextAlarm>
    <StaticAlarmRanges>
      <WarningRange minInclusive="-22.2" maxExclusive="12.2"/>
      <CriticalRange minExclusive="-44" maxInclusive="14"/>
    </StaticAlarmRanges>
    <ContextMatch>
      <ComparisonList>
        <Comparison parameterRef="/sc-operating-environment" value="LEO"/>
      </ComparisonList>
    </ContextMatch>
  </ContextAlarm>
</ContextAlarmList>
```

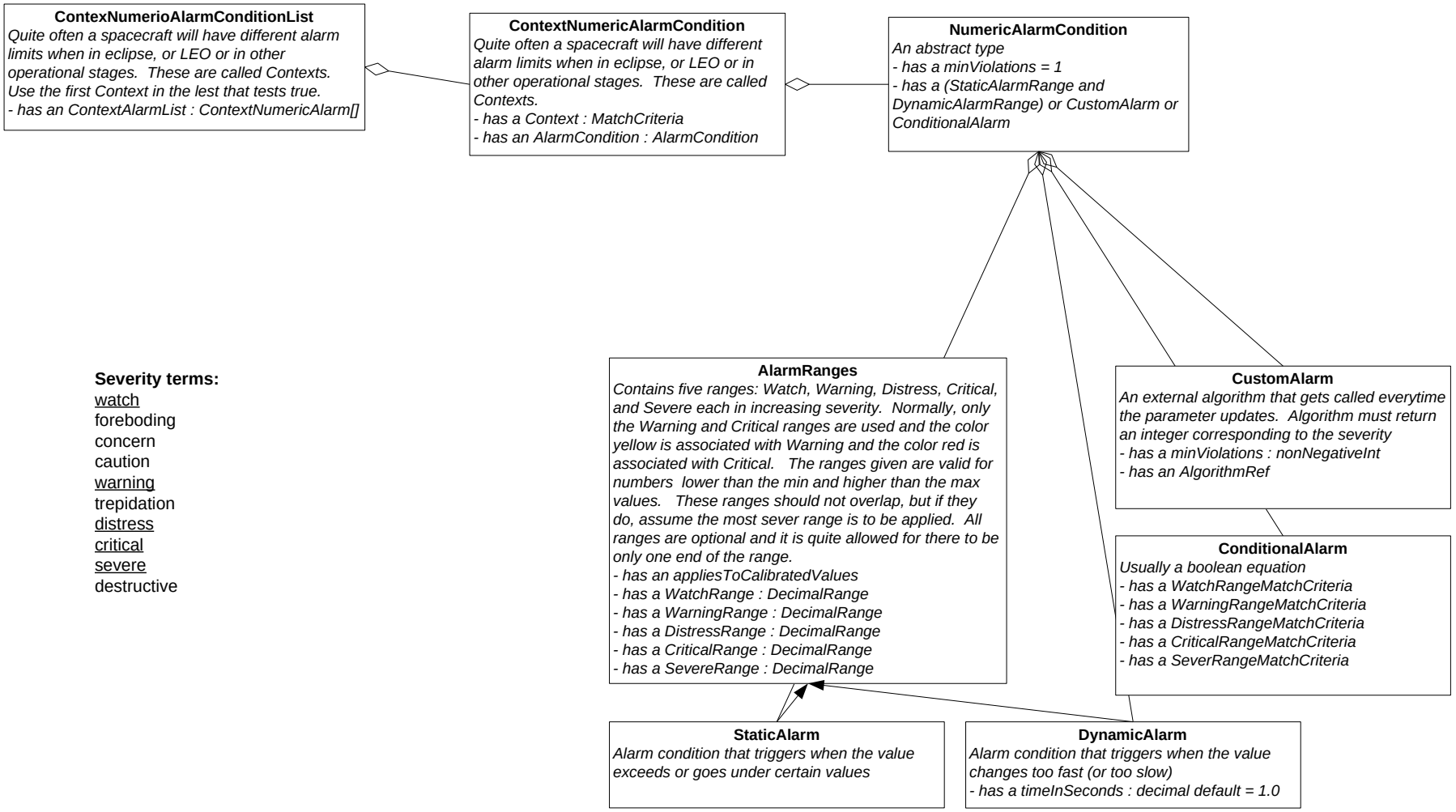
Alarms – ConditionalAlarm

- Used when the Alarm is more then a simple range
- Alarm is set when a Condition is true
- There is a Condition (MatchCriteria) for each Alarm level
- Highest Level to test true will be the Alarm Condition

Alarms – User Algorithm

- Used when the conditions for the Alarm are too complex to otherwise describe in XTCE
- A reference to an external algorithm that will set the Alarm state

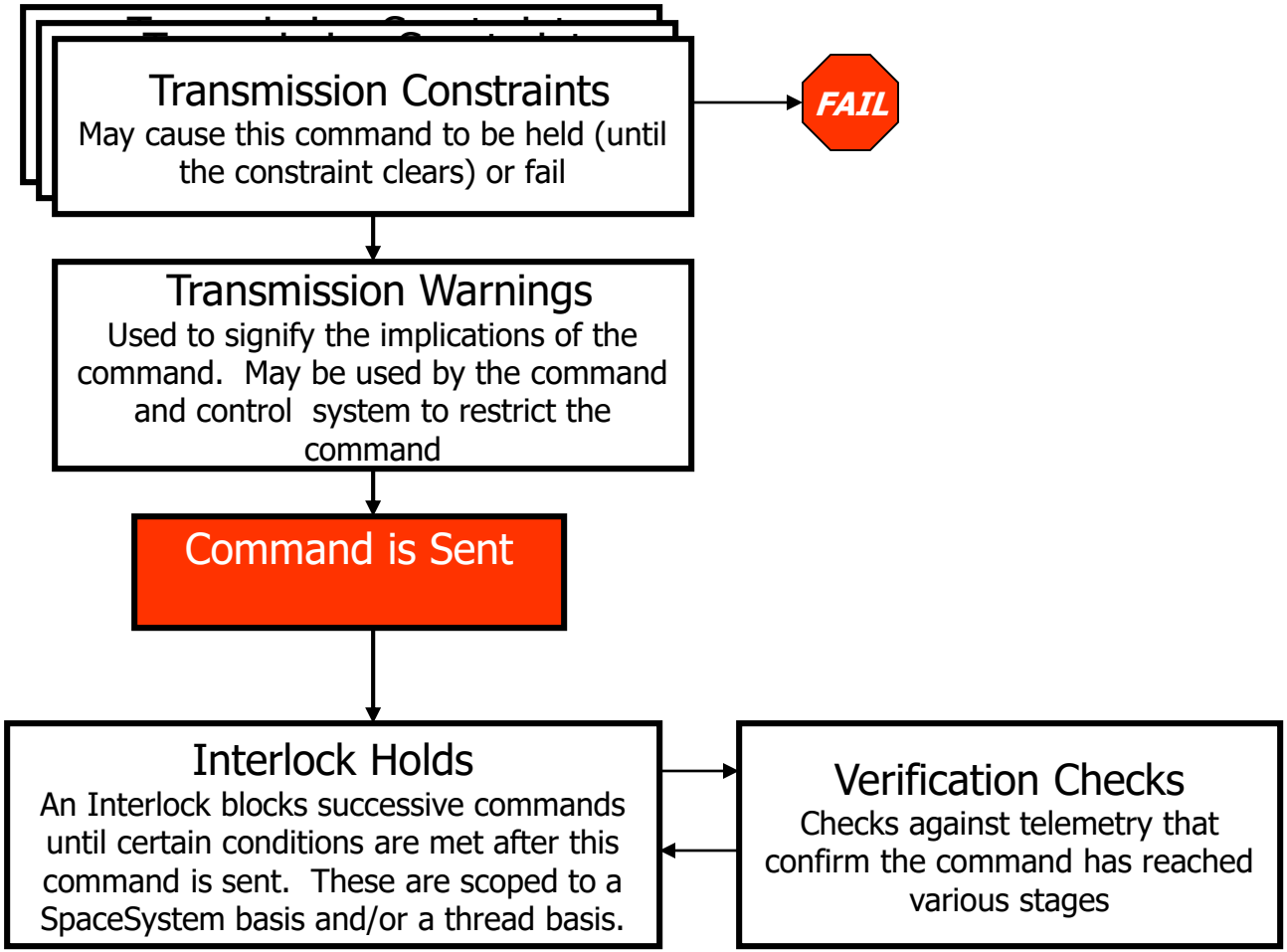
Alarms - Numeric Alarm UML



Command Processing Flow

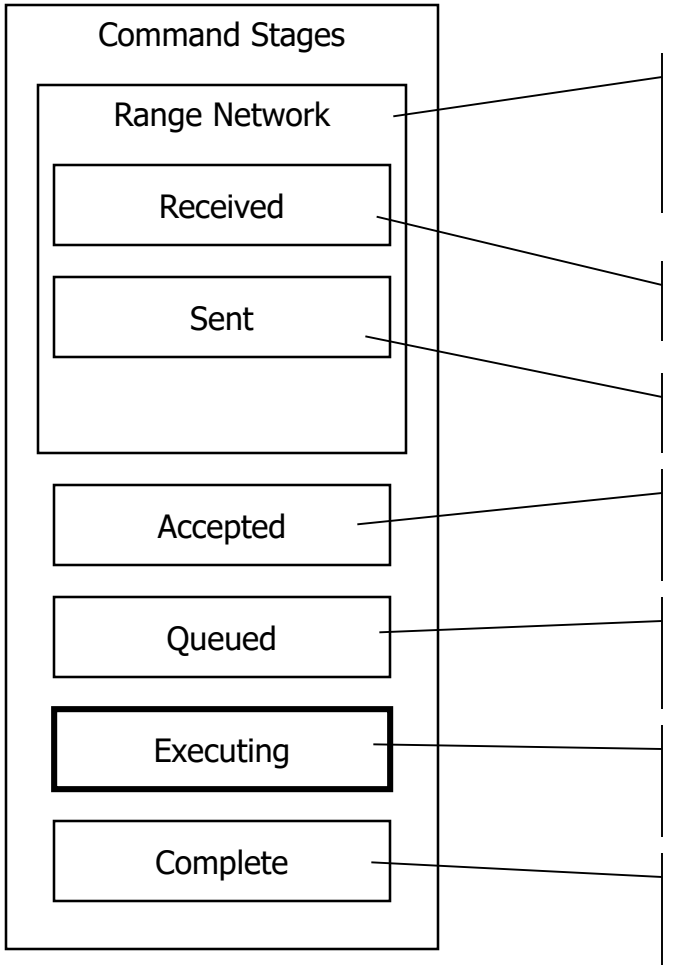
- Similar to Telemetry processing flow

Command Execution Sequence



Command Verification Stages

Failed



The Command link may simply be earth to space, but it may also involve several 'hops' before it reaches the target spacecraft.

The Command has reached the receiving end of this link

The Command has been sent on this link

The command has passed any authentication by the target has been excepted for execution

The command is now queued for execution. It may be queued for execution at a much later time.

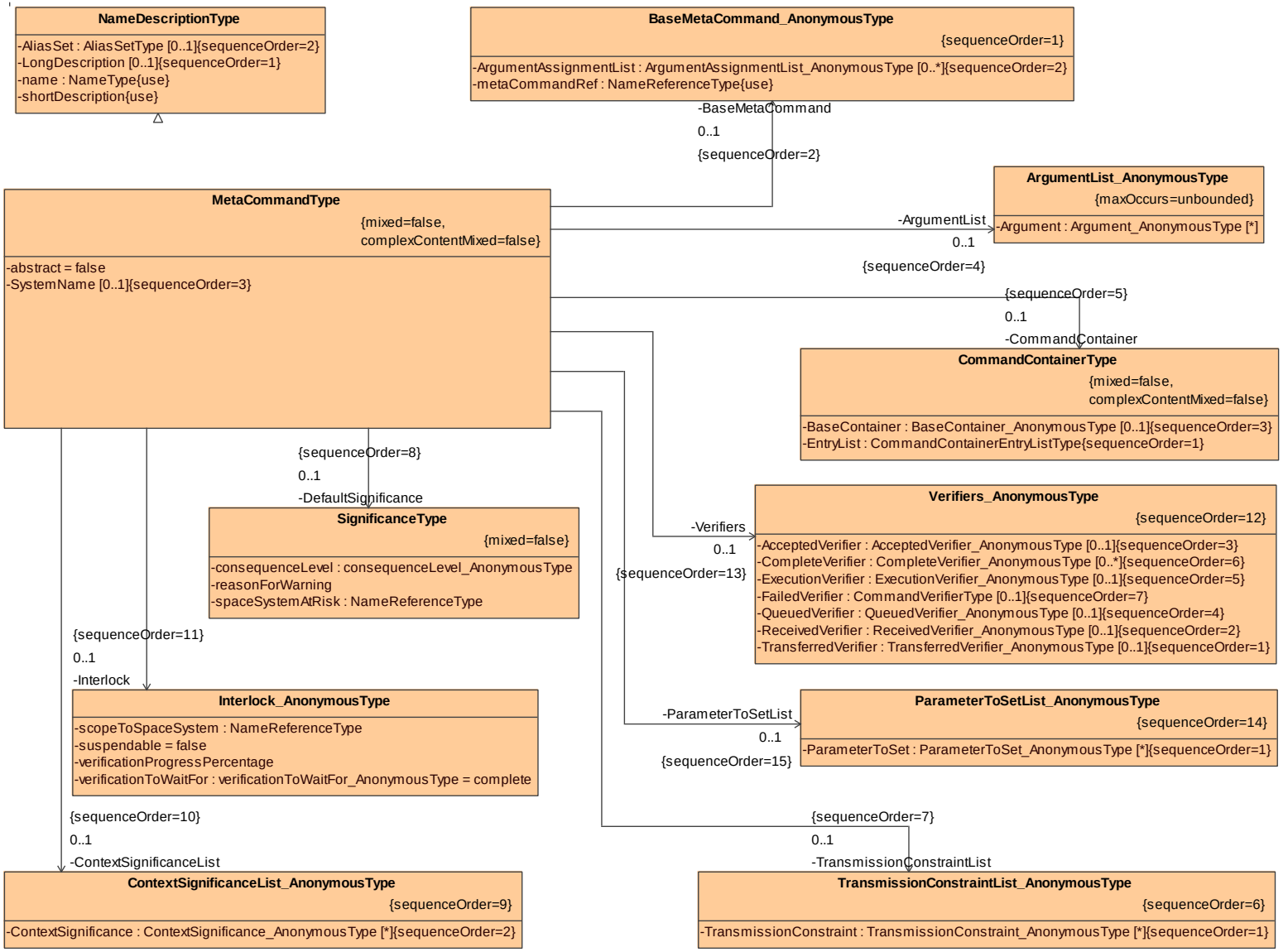
The command is being executed.

The command is complete.

Command Restrictions

- Prohibited - Command should not be sent
- spaceSystemRisk – A warning that the issuance of this command may incur risk to the space system
- missionRisk – A warning that the issuance of this command may disrupt service
- Caution – A general warning

Command Meta Data UML



Nuances - Descriptions

- shortDescription – all major elements have this attribute for short "tool tip" size descriptions (max size of 32 characters)
- LongDescription – all major elements also have this as a sub-element; it is intended for "instructive" type descriptions. HTML markup is allowed in LongDescriptions.

  Neither shortDescription nor LongDescription have size limitations.

Nuances – Aliases

- Aliases –all major Elements may have an unlimited number of aliases. Aliases may be used for ground IDs, Onboard IDs, mnemonics etc.
- An alias has a nameSpace e.g., *OnBoardID* and the alias e.g. *020660*

```
<AliasSet>
   <Alias nameSpace="Mnemonic" alias="BAT1I"/>
   <Alias nameSpace="OnBoardID" alias="020660"/>
</AliasSet>
```


Nuances – Integer Values

- May be specified as a decimal number: e.g., 1234
- May be specified as a hexadecimal number: e.g., 0xFA or 0Xfa
- May be specified as an octal number: e.g., 0o123 or 0O123
- May be specified as a binary number: e.g., 0b0110 or 0B0110
- If the size is smaller than the number given, the number is truncated from the most significant side

Nuances – Physical Address

- Physical Address's are most often used by the Spacecraft factory
- Contains a sourceName, a sourceAddress, and a SubAddress (arbitrarily deep)
- There many be any number of Physical Address's

```
<PhysicalAddressSet>
  <PhysicalAddress sourceName="TransducerIP" sourceAddress="143.57.15.01">
    <SubAddress sourceAddress="TransducerCard" sourceName="8">
      <SubAddress sourceName="portNumber" sourceAddress="14"/>
    </SubAddress>
  </PhysicalAddress>
</PhysicalAddressSet>
```

Nuances - Units

- Units in XTCE were a compromise between the very complex and overly simple.
- All Data Types (Parameters and Command Arguments) have a mandatory UnitSet – the UnitSet may be empty.
- Unit has a factor and a power. Multiple Units are multiplied.

```
<FloatParameter name="DarkEnergySensor">
   <UnitSet>
      <Unit>Joules</Unit>
      <Unit power="-4">m</Unit>
   </UnitSet>
   <IntegerDataEncoding sizeInBits="7" encoding="unsigned"/>
</FloatParameter>
```

$$= \frac{Joules}{m^4}$$

Schema Style Notes Used By The SDTF

- Element and Type names begin with a capitol letter.
- Type names end with the word "Type".
- Attribute names begin with a lowercase letter.
- Usually, when the UML class diagram references classes, W3C Elements are used, and whenever the UML references simple types (strings, ints), W3C Attributes are used. In general, attributes are preferred over elements because they're easier to deal with in SAX and DOM, but whenever the Element/Attribute may one day carry metadata, elements should be used. One exception, is enumerated classes, because enumerations may be defined for attributes but not for elements.
- Bias toward self-describing names over short, bandwidth conserving ones.
- Use mixed case in names rather than underscores to combine multiple words (camelCase).

Schema Style Notes (cont)

- A documentation annotation is included in every element and type definition. Annotations for a type are included with the type definition, use of the type are annotated in the element definition.
- Hints on units (for values with units) are provided in the names of attributes and elements (e.g. "dataRateInBPS" is preferred over "dataRate" OR "frameLengthInBits" is preferred over "frameLength").
- Major elements or any elements used multiple times are first defined with a complexType definition
- All collections are put inside either a "List" element or a "Set" Element depending on whether the collection is ordered or unordered.
- Simplicity in compliant XML files is favored over simplicity in the schema.

Resources

- OMG Issues Page - http://www.omg.org/technology/agreement.htm
- SDTF - http://www.omg.org/space
- XML Spy - http://www.altova.com/products_ide.html
- Xerces - http://xml.apache.org/#xerces
- Castor - http://www.castor.org/

ServiceList

Similar in concept to "Unix" system services. For example TCP port 80 always has HTTP packets under Unix. So on your spacecraft, APID 1024 might always have memory dump telemetry packets. Separating that out as a "service" could help you organize your telemetry. (blame ESA/PUS for this… but seems like a good idea)

Services

- There is some debate on the necessity of this.