CGI

CCSDS EDS Pink Sheet Interoperability and Tooling

Final Presentation
2024

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04/06/24

Outline

01

CCSDS SOIS Overview and Justification

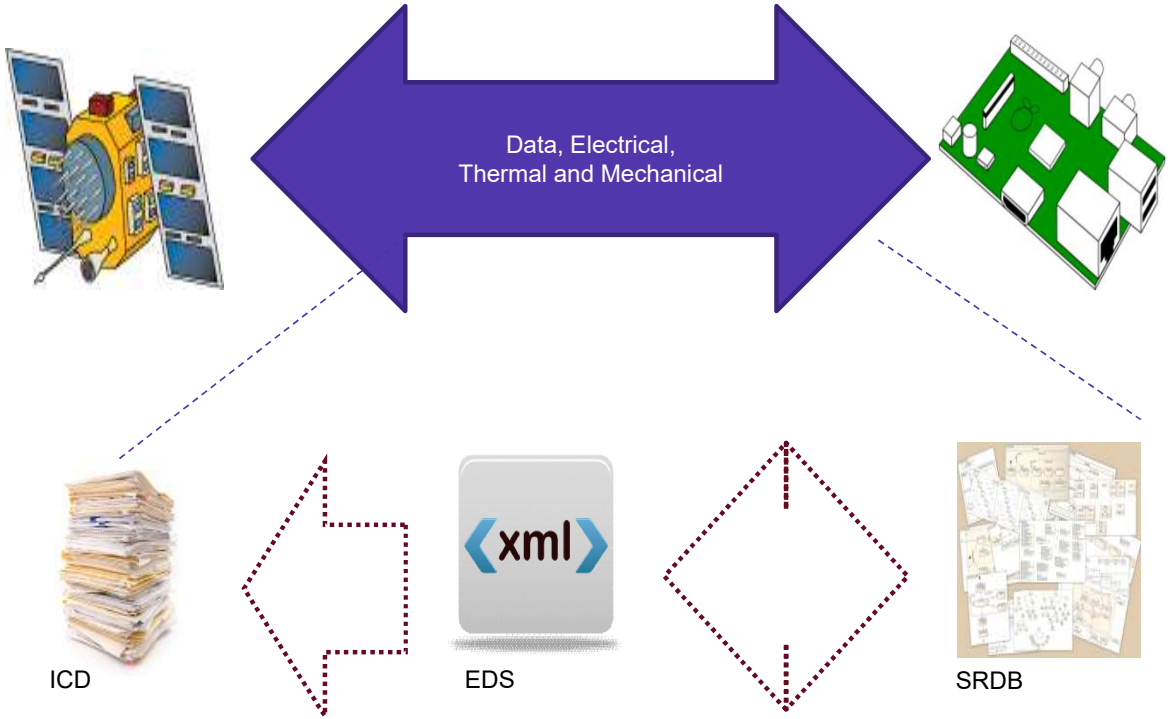
02

2023 Standard Revision

03

Project Result and Conclusions

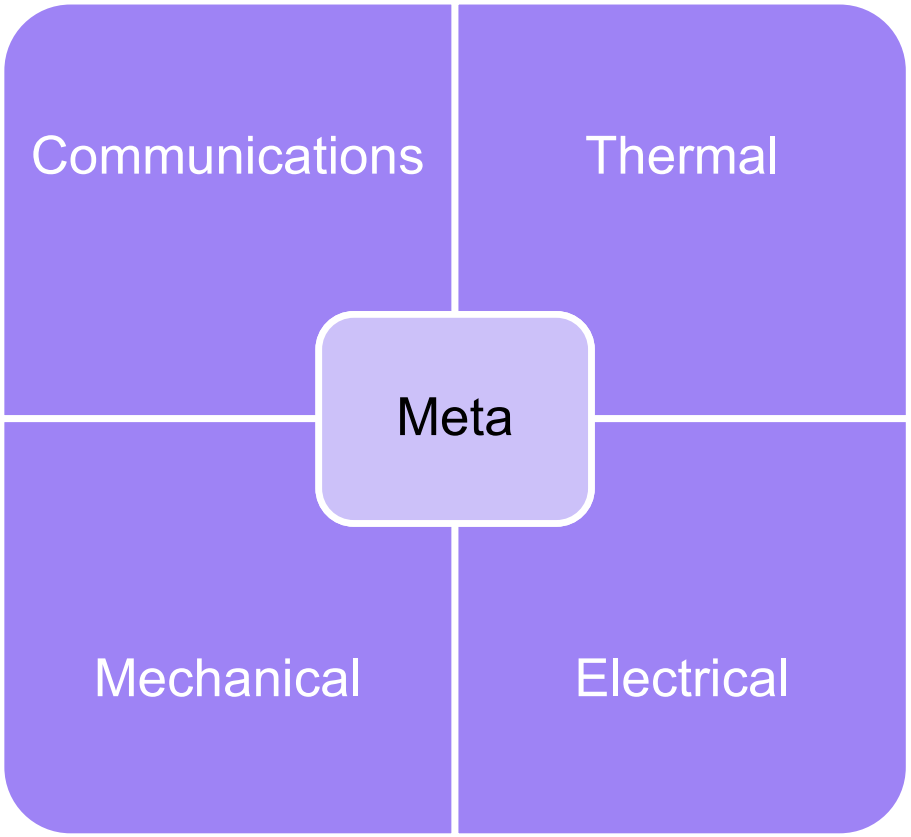
What is an Electronic Data Sheet?



A computer-readable replacement (or supplement) to the current printable documents used to manage the interfaces to and from onboard electronic devices.

This should be capable of both generating a comparable human-readable document, and being automatically imported into, or generated from, relevant system databases.

What does an EDS cover?



- Communications
  Data, TM/TC, packets, parameters, units, calibrations
- Thermal
  Heat-related properties and models
- Mechanical
  Physical properties and models
- Electrical
  Electrical properties and modles, connectors, power
- Meta
  Datasheet-related information, e.g. version and maturity.

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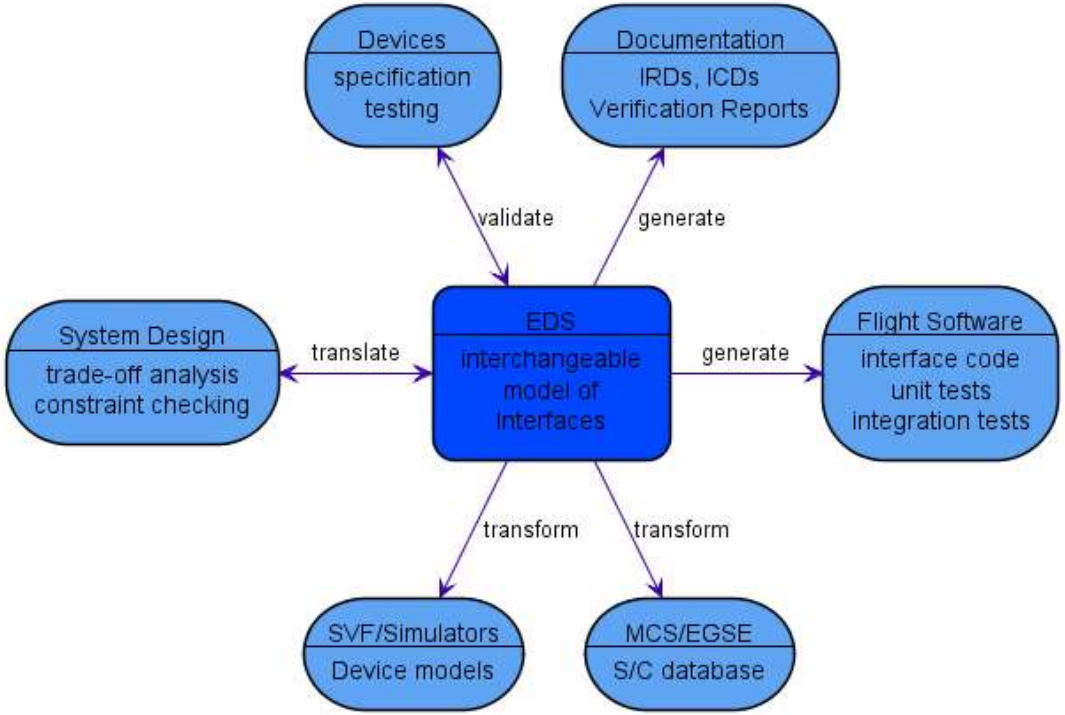
What can you do with an EDS?



Test that a device conforms to it

Generate human-readable documentation

Generate parts of the FSW handling that device

Generate parts of the databases used by MCS and EGSE to control the device

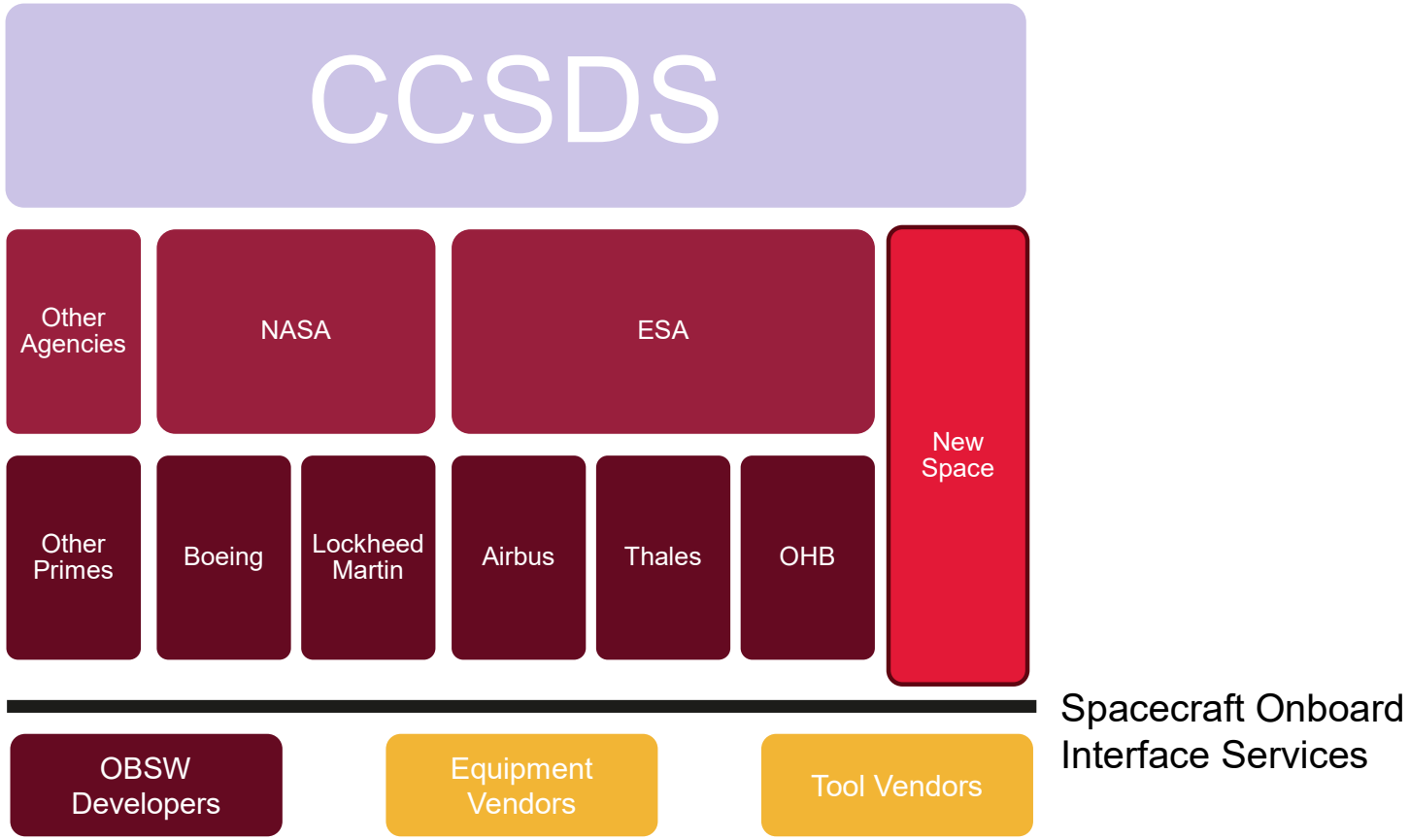
Generate parts of the SVF and simulator models for that device

Import information provided into other system design tools

And more…

C

Big Picture



Standardisation techniques

Application Programming Interface

Define an interface specification in a particular programming language or tool.
Not usable in CCSDS scope due to the variety of platforms, architectures, languages, …

Service Specification

Define a standards document specifying the exchange of data across a particular interface.
Usable when the data exchange **is** adequately known at standardisation time.

Electronic Datasheet

Define a standards document specifying a mechanism that allows specifying the exchange of data across interfaces.
Use when the data exchange **is not** known at standardisation time.

What that means

Widely applicable

Minimal dependency on choice of other standards, infrastructure or architecture

Descriptive, Not Prescriptive

Describes what *has* been done, rather that imposing rules about what *should* be done. Consequently, works with existing hardware.

Space Domain

Covers all things demonstrated to have been used in space domain, and nothing that isn’t.

Concrete Example

iADCS Communications View Access Interface Extract

setSunPointingControllerParameters	ASYNC	Set parameters of sun pointing controller:.			
kp	FLOAT32		[-3.4028234663852886E+38..3.4028234663852886E+38]	IN	Controller feedback gain affecting the behaviour of the control error.
kv	ThreeByThreeMatrix			IN	kv is an [3x3] symmetric damping matrix affecting the behaviour of the angular velocity.
maxTorque	FLOAT32[3]		[-3.4028234663852886E+38..3.4028234663852886E+38]	IN	Maximum available torques on 3 axes in body frame. This values are usually related to the maximum available torquers of the actuators
cmdType	ControllerActuatorCommand		[0..6]	IN	Controller - actuator command interface
tupdate	INT64		[-9223372036854775808..9223372036854775807]	IN	Update interval
setSunVector	ASYNC	Set Sun Vector as unit vector in satellite frame			
sunVector	SunVector			IN	
epochTime	INT64		[-9223372036854775808..9223372036854775807]	IN	
setTemperatureUpdateInterval	ASYNC	Set update interval of temperature reading			
data	INT64		[-9223372036854775808..9223372036854775807]	IN	the actual data field, always fixed-length given C1/C2
setTorquerParameters	ASYNC	Set sensor Parameters for Magnetorquer			
m2c	FLOAT32[3]		[-3.4028234663852886E+38..3.4028234663852886E+38]	IN	Conversion factor from dipole moment to current
maxMoment	FLOAT32[3]		[-3.4028234663852886E+38..3.4028234663852886E+38]	IN	Maximum dipole moment of the torquers on 3 axes
n3d	ThreeByThreeMatrix			IN	Orientation of the torquers with respect to satellite body frame
relaxTime	INT64[3]		[-9223372036854775808..9223372036854775807]	IN	Relax time of the torquers. The residual magnetic field of the torquers will be reduced during this time.

```
<Command mode="async" name="setSunVector">
  <LongDescription>Set Sun Vector as unit vector in satellite frame</LongDescription>
  <Argument dataUnit="false" mode="in" name="sunVector" type="SunVector"/>
  <Argument dataUnit="false" mode="in" name="epochTime" type="CCSDS/SOIS/SEDS/INT64"/>
</Command>
```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Example continued

iADCS Communications View Physical Interface Extract

PDU Binary Encoding for setSunPointingControllerParameters

2.0.2.133 PDU: setSunVector

Set Sun Vector as unit vector in satellite frame

Byte Offset	Bit Range	Field Name	Type	Encoding	Fixed Value	Description
0	[0..7]	C1	UINT8	UNSIGNED	163	primary command id
1	[0..7]	C2	UINT8	UNSIGNED	48	secondary command id
2	[0..15]	NMO	UINT16	UNSIGNED	20	length of data field
4	[0..31]	sunVector	FLOAT32	REAL		Measured sun vector [svx, svy, svz] of 6 sunsensors. Values of not available sensor are set to zero.
Repeat previous 1 entries a total of 3 times						
16	[0..63]	epochTime	INT64	SIGNED		
24	[0..7]	crc	UINT8	UNSIGNED		the crc
Fixed byte length is 25						

PDU Binary Encoding for setSunVector

```
<ContainerDataType baseType="sunSensorCommand" name="setSunVector">
  <LongDescription>Set Sun Vector as unit vector in satellite frame</Long
  <ConstraintSet>
    <ValueConstraint entry="C1" value="163"/>
    <ValueConstraint entry="C2" value="48"/>
    <ValueConstraint entry="NMO" value="20"/>
  </ConstraintSet>
  <EntryList>
    <Entry name="sunVector" type="SunVector"/>
    <Entry name="epochTime" type="CCSDS/SOIS/SEDS/INT64" unit="second"/>
  </EntryList>
</ContainerDataType>
```


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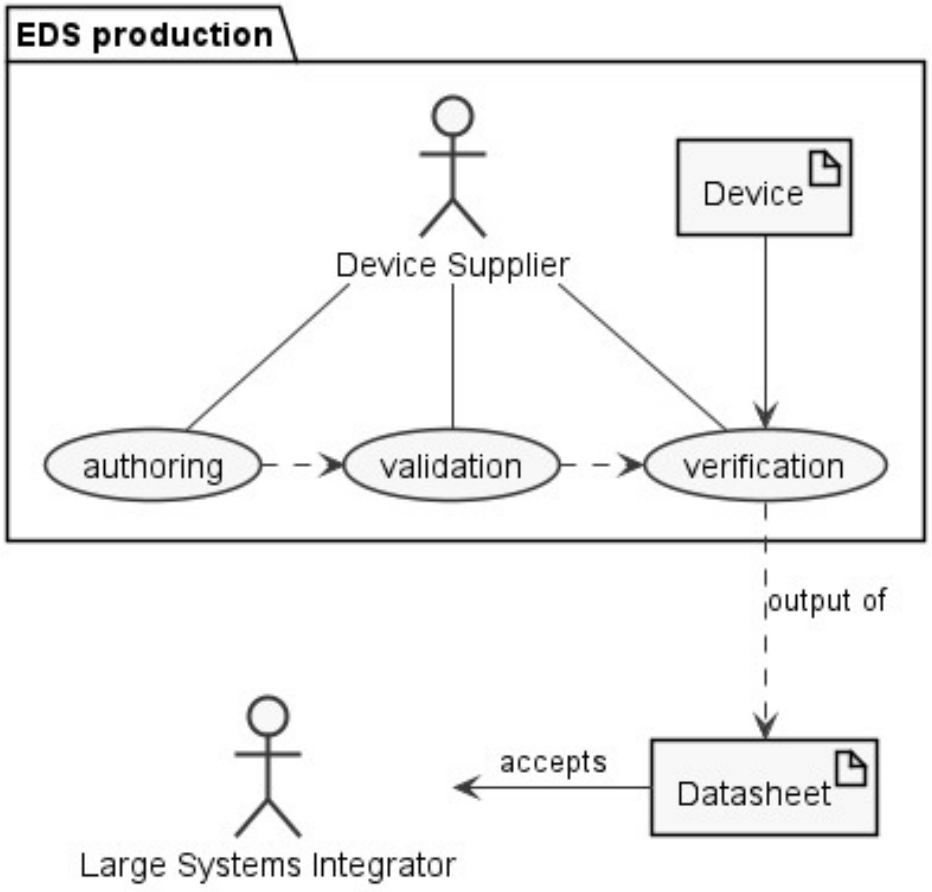
EDS Production Process Model



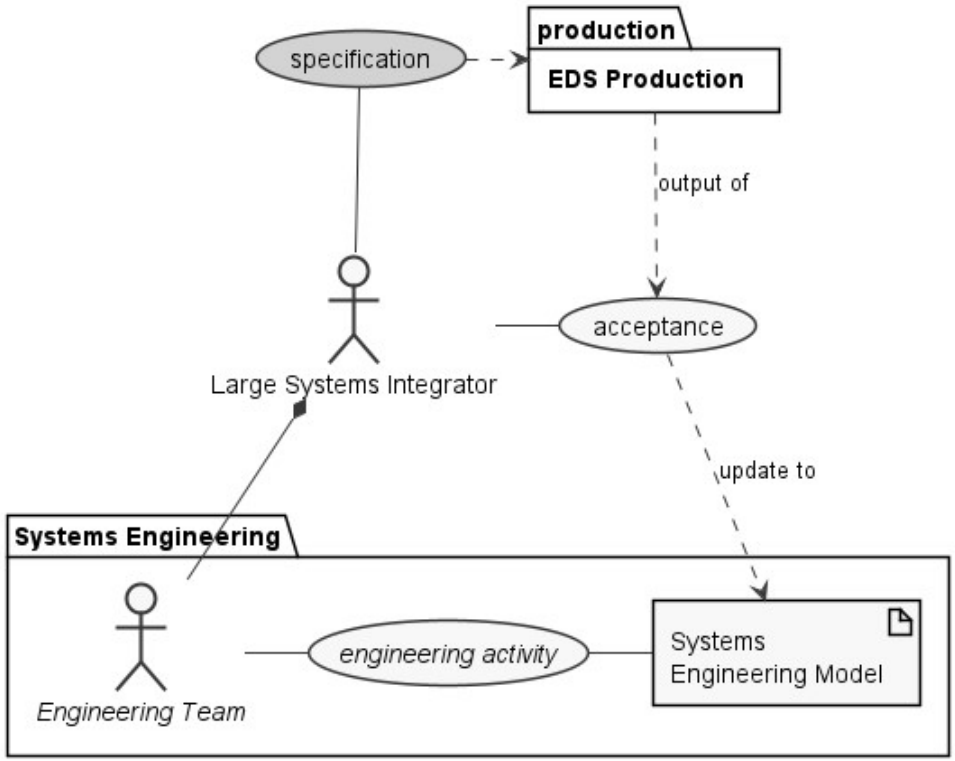
A Device Supplier produces a Datasheet by:

- Authoring: creation or import
- Validation: internal consistency checking
- Verification: checking the correctness of the datasheet against the device

The resulting validated datasheet is delivered to the Large System Integrator (i.e. prime) who accepts it.

Successful completion of the validation and verification process removes most or all errors and ambiguities from the delivered datasheet, speeding acceptance and reducing the risk of downstream problems and rework.

Extended Process Model



The acceptance process, as performed by LSI involves import into a Systems Engineering Model.

This system model is used by a large number of different engineering teams to perform a range of diverse engineering activities.

Acceptance will only succeed if the datasheet conforms to the expectations of the system model:

- contains everything it needs to
- in a form that can be understood

This means there is an additional specification process that is an optional input to EDS production.

iADCS Electrical Model
Device Model Specification

Name	Type	Unit	Ranges	Details	Description
ESD_Protection	ESD_Protection			READ ONLY SYNC	
Isolation	Isolation			READ ONLY SYNC	
PowerMode	PowerMode		Inherent:[0..2]	READ ONLY SYNC	
ReferenceVoltage	ReferenceVoltage	V	Inherent:[-1.7976931348623157E+308..1.7976931348623157E+308]	READ ONLY SYNC	
ShortCircuitTolerance	ShortCircuitTolerance	A	Inherent:[-1.7976931348623157E+308..1.7976931348623157E+308]	READ ONLY SYNC	

Interface Parameters for IADCS

Command	Argument	Type	Unit	Range		Description
PowerConsumption		SYNC		Defined for standard configuration with 3 internal reaction wheels and star tracker @ 5V power supply		
	PowerMode	PowerOptions		[0..2]	IN	Input mode #1
	PowerConsumption	PowerConsumption	A	[-1.7976931348623157E+308..1.7976931348623157E+308]	OUT	Property value

```
<Interface abstract="true" level="environment" name="IADCS">
  <GenericTypeSet>
    <GenericType baseType="CCSDS/SOIS/SEDS/STRING" name="ESD_Protection"/>
    <GenericType baseType="CCSDS/SOIS/SEDS/STRING" name="Isolation"/>
    <GenericType baseType="CCSDS/SOIS/SEDS/FLOAT64" name="PowerConsumption"/>
    <GenericType baseType="PowerOptions" name="PowerMode"/>
    <GenericType baseType="CCSDS/SOIS/SEDS/FLOAT64" name="ReferenceVoltage"/>
    <GenericType baseType="CCSDS/SOIS/SEDS/FLOAT64" name="ShortCircuitTolerance"/>
  </GenericTypeSet>
  <ParameterSet>
    <Parameter mode="sync" name="ESD_Protection" readOnly="true" type="ESD_Protection"/>
    <Parameter mode="sync" name="Isolation" readOnly="true" type="Isolation"/>
    <Parameter mode="sync" name="PowerMode" readOnly="true" type="PowerMode"/>
    <Parameter mode="sync" name="ReferenceVoltage" readOnly="true" type="ReferenceVoltage" unit="volt"/>
    <Parameter mode="sync" name="ShortCircuitTolerance" readOnly="true" type="ShortCircuitTolerance" unit="ampere"/>
  </ParameterSet>
  <CommandSet>
    <Command mode="sync" name="PowerConsumption" shortDescription="Defined for standard configuration with 3 internal reaction wheels and star
    tracker @ 5V power supply">
      <Argument dataUnit="false" mode="in" name="PowerMode" shortDescription="Input mode #1" type="PowerOptions"/>
      <Argument dataUnit="false" mode="out" name="PowerConsumption" shortDescription="Property value" type="PowerConsumption" unit="ampere"/>
    </Command>
  </CommandSet>
```

Translating between the terms in the iADCS ICD (e.g. ReferenceVoltage, ShortCircuitTolerance) and the domain model (TypicalVoltage, MaxCurrent) is a non-trivial process involving expert knowledge. So we simply reproduced what the device model that produced the data documented in the ICD would have been.

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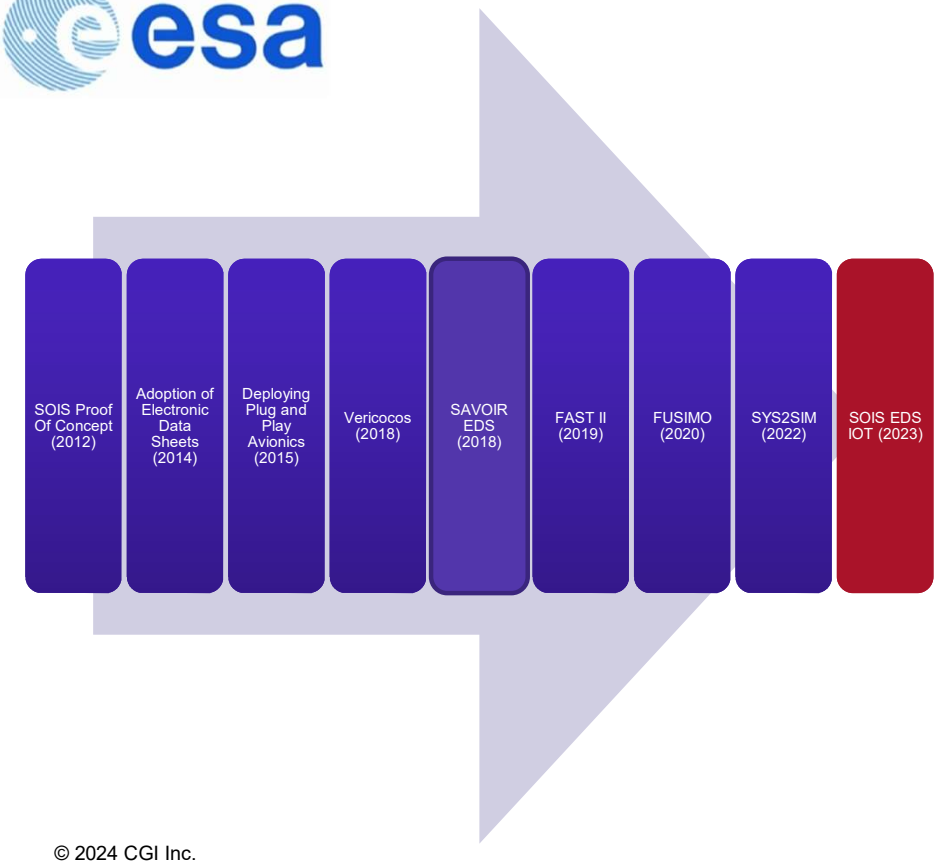
What has been done with EDS?



SOIS PoC
- Originated the idea of a datasheet

Adoption of EDS
- Standardized datasheet as XML schema

Deploying PnP Avionics
- EDS production by device suppliers

Vericocos
- TASTE integration
- SMP2 simulator interface generation

SAVOIR EDS
- EDS adoption by primes.

FAST II
- Static analysis of FSW code

FUSIMO
- Simulator model generation

SYS2SIM
- Simulator architecture generation

SOIS EDS IOT
- CCSDS standards update

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What documentation is available from CCSDS?

876x0b2	• XML Specification for Electronic Data Sheets • 2023 update to standard.
876x1r1	• Specification for Dictionary of Terms for Electronic Data Sheets
870x0g1	• EDS and DoT for Onboard Devices
876x0y1	• SOIS XML EDS Prototyping Test Plan & Report

Sources of Feedback on 2019 Standard

ESA Studies	• SAVOIR EDS (feedback and recommendations in Final Report) • FUSIMO and SYS2SIM (correspondence)
Standard Updates	• XTCE 1.2 Update
Operational Use	• Gateway/Artemis
Working Group Prototyping	• CCSDS DTN Bundle Protocol • CCSDS CFDP Protocol • Deployment schema

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Areas changed

Containers	• Encoding Rules • Field Presence and Validity Conditions
Constraints	• Negated Constraints • Alternative Constraints
State Machines	• OnTransition trigger • Removal of transactions
Types	• Alias Types • Binary Data Encoding • Extensible limit sets • Enumeration subranges

CCSDS EDS Pink Sheet: InterOperability and Tooling (IOT) project

MP0

ESA Contract No. 4000141831/23/NL/AS

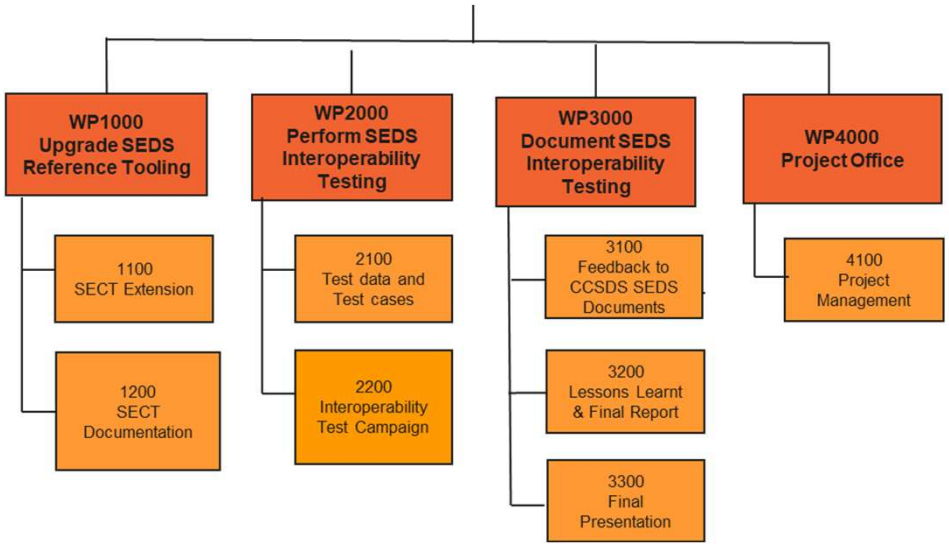
- Update SECT to support updated schema
- Custom encoding rules extension interface
- Interoperability testing with NASA

cgi.com

Slide 18

MP0 The name is CCSDS EDS Pink Sheet...
Marek Prochazka, 2024-01-19T15:47:33.708

Work Packages



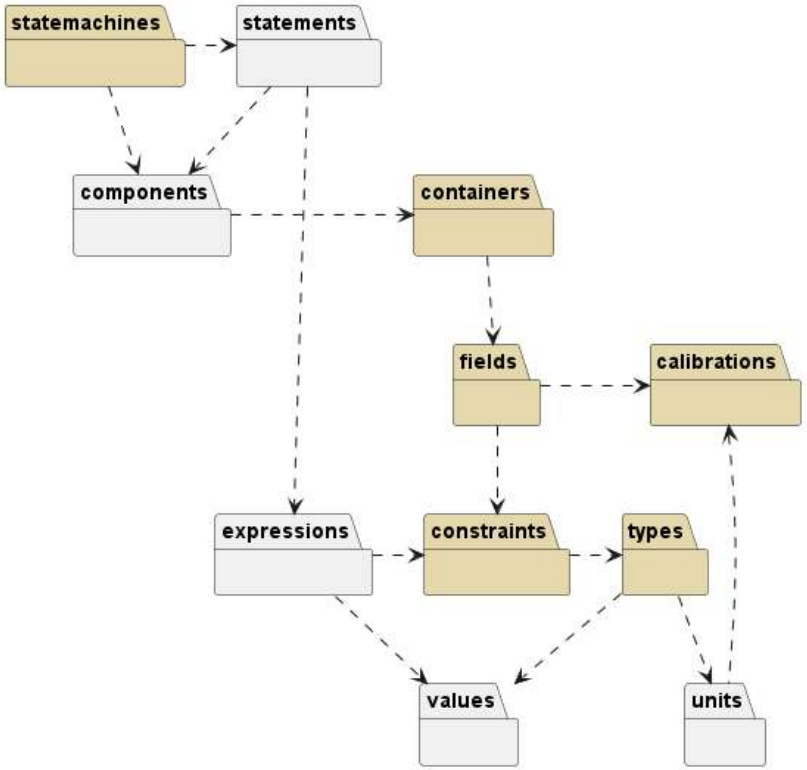
MP0

Slide 19

MP0 The name wrong again
Marek Prochazka, 2024-01-19T15:47:50.937

RM0 0 Hard to update this diagram, and name is close
Melvin, Richard A, 2024-01-29T15:47:40.180

Tooling updates: model packages changed or added



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Extensions to Test Case 0 : Synthetic Data Sheets Validation and XML to model round trip

```
<SubRangeDataType baseType="STRING1" name="STRING1_RANGE6">
  <Range>
    <EnumeratedRange>
      <Label>A</Label>
      <Label>C</Label>
    </EnumeratedRange>
  </Range>
</SubRangeDataType>
```

```
<BinaryDataType fixedSize="false" name="BIN6" sizeInBits="128">
  <BinaryDataEncoding maxSizeInBits="128"/>
</BinaryDataType>
```

```
<ContainerDataType abstract="false" baseType="BASE" name="PACKET9">
  <ConstraintSet>
    <ORedConstraints>
      <RangeConstraint entry="bf1" negate="true">
        <MinMaxRange min="8.0" rangeType="atLeast"/>
      </RangeConstraint>
      <TypeConstraint entry="bf1" negate="true" type="range2"/>
      <ValueConstraint entry="bf1" negate="true" value="10"/>
    </ORedConstraints>
    <ValueConstraint entry="bf2" value="11"/>
  </ConstraintSet>
  <EntryList>
    <Entry name="f1" type="SHORT"/>
    <Entry name="f2" type="SHORT"/>
    <Entry name="f3" type="SHORT"/>
    <Entry name="f4" type="SHORT"/>
  </EntryList>
</ContainerDataType>
```

```
<Parameter mode="async" name="param5" readOnly="true" type="ENUM">
  <RangeSet severity="nominal">
    <EnumeratedRange>
      <Label>A</Label>
    </EnumeratedRange>
  </RangeSet>
  <RangeSet severity="safe">
    <EnumeratedRange>
      <Label>A</Label>
    </EnumeratedRange>
  </RangeSet>
</Parameter>
```


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Extensions to Test Case 3 : Synthetic Data Sheets
Binary to binary round trip

```
<ContainerDataType name="ER_ODD" baseType="BASE2" shortDescription="Enumerated derived Container 1">
  <ConstraintSet>
    <RangeConstraint entry="ident">
          <EnumeratedRange>
                <Label>ONE</Label>
                <Label>THREE</Label>
                <Label>FIVE</Label>
                <Label>SEVEN</Label>
          </EnumeratedRange>
    </RangeConstraint>
  </ConstraintSet>
  <EntryList>
    <Entry name="optional1" type="U8EB" >
      <PresentWhen>
          <ValueConstraint entry="ident" value="ONE"/>
      </PresentWhen>
    </Entry>
    <Entry name="optional2" type="U16EB"  >
      <PresentWhen>
          <ValueConstraint entry="ident" value="THREE"/>
      </PresentWhen>
    </Entry>
    <Entry name="mandatory1" type="U16EB" />
  </EntryList>
</ContainerDataType>
```

PDU: ER_ODD : *Enumerated derived Container 1*

PDU ER_ODD

Byte Offset	Bit Range	Field Name	Encoding	Value	Raw Value
0	[0..16)	fixed	UNSIGNED	21930	55 aa
2	[0..8)	ident	UNSIGNED	THREE	03
3	[0..32)	length	UNSIGNED	104	00 00 00 68
7	[0..16)	optional2	UNSIGNED	8688	21 f0
9	[0..16)	mandatory1	UNSIGNED	55066	d7 1a
11	[0..16)	crc	UNSIGNED	44743	ae c7
13	[0..32)	fixedCheck	UNSIGNED	1234567	00 12 d6 87

Test Case 5 : User-Defined Encoding Rules Binary to Binary Round Trip

```
<ContainerDataType name="Bundle" encodingRules="CBOR_INDEFINITE">
 <LongDescription>
  The overall bundle is a cbor-indefinite array containing the primary block,
  all extension blocks, and the payload block.
</LongDescription>
    <EntryList>
        <Entry name="primary" type="PrimaryBundleBlock"/>
        <ImplicitListEntry name="blocks" type="CanonicalBundleBlock" encodingRules="CBOR_INLINE"/>
    </EntryList>
</ContainerDataType>
```

```
9F                                      # array(*)
   89                                   # array(9)
      07                                # unsigned(7)
      18 40                             # unsigned(64)
      02                                # unsigned(2)
      82                                # array(2)
         02                             # unsigned(2)
         82                             # array(2)
            19 8006                     # unsigned(32774)
            17                          # unsigned(23)
```

```
<ContainerDataType abstract="true" name="CanonicalBundleBlock" encodingRules="CBOR_DEFINITE">
    <EntryList>
        <Entry name="blockType" type="BundleBlockType"/>
        <Entry name="blockNum" type="BlockNumber"/>
        <Entry name="processingControlFlags" type="BlockProcessingControlFlags">
            <IntegerDataEncoding encoding = "unsigned" sizeInBits="64"/>
        </Entry>
        <Entry name="crcType" type="CRCType" subject="crc"/>
    </EntryList>
    <TrailerEntryList>
        <ErrorControlEntry name="crc16" errorControlType="CRC16_CCITT" type="CRC16">
            <PresentWhen>
                <ValueConstraint entry="crcType" value="CRC16"/>
            </PresentWhen>
        </ErrorControlEntry>
        <ErrorControlEntry name="crc32c" errorControlType="CRC32C" type="CRC32">
            <PresentWhen>
                <ValueConstraint entry="crcType" value="CRC32C"/>
            </PresentWhen>
        </ErrorControlEntry>
    </TrailerEntryList>
</ContainerDataType>
```

```
85                                      # array(5)
   18 C1                                # unsigned(193)
   03                                   # unsigned(3)
   01                                   # unsigned(1)
   00                                   # unsigned(0)
   45                                   # bytes(5)
      8400010000                        # "\x84\u0000\u0001\u0000\u0000"
```


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Conclusions

SECT tooling updated to 2023 SEDS standard

- Proposed changes prototyped and refined

ESA end of CCSDS interoperability performed

- Test data and results provided to NASA who plan to complete corresponding tests mid 2024

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