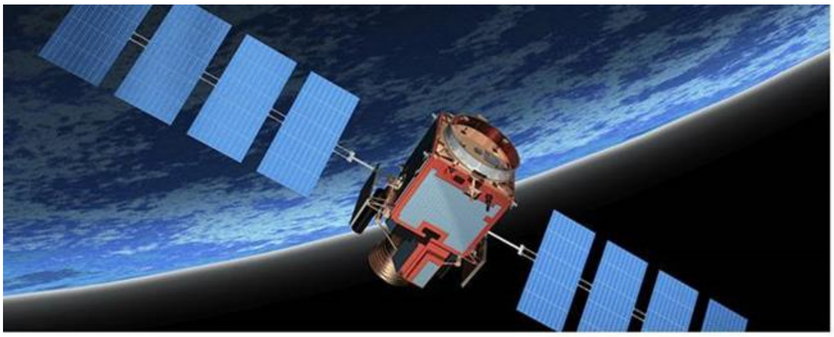
SAVOIR Electronic Data Sheet Definition

SAVOIR EDS Executive Summary



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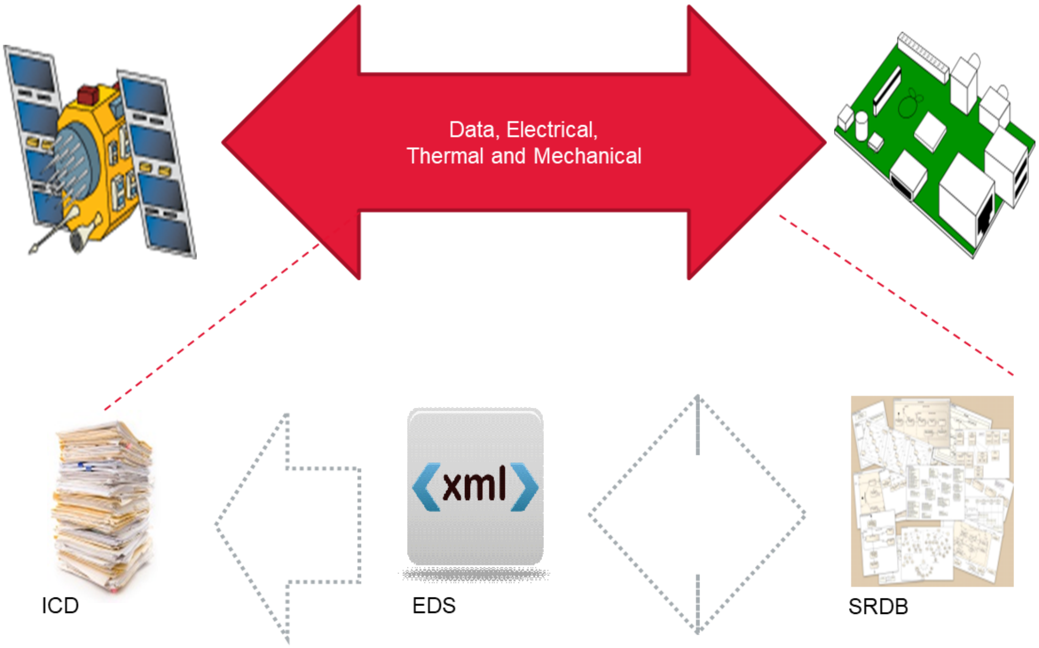
The use of **Electronic Data Sheets** (EDS) to replace the paper ICDs used to exchange information about the custom electronic devices used in space systems has been a long-standing goal, and the subject of several prior studies.



The **SAVOIR EDS** study built on those by:

- focusing on the process of EDS production and use from the point of view of a **Large Systems Integrator** (LSI).
- extending the domains covered from **communications** to **electrical**, **mechanical**, and **thermal**.
- building a **wider consensus** on how to standardise and use EDS, covering all major European LSI.

The concepts developed and elaborated during the initial project phases were validated by producing:

- six **datasheets** based on existing hardware devices
- four **proof of concept prototypes**, one from each consortium member, based on using those datasheets to perform a variety of real-world use cases.
- a single **common validation tool** to help ensure that all datasheets and prototypes share a common interpretation of EDS concepts.

These succeeded in demonstrating the potential for standards-based data exchange by applying those concepts alongside, and integrated into, existing LSI tools and working practises. Based on the experience of doing that work, the concepts were further iterated and developed.

This resulted in a refined **conceptual framework** which serves as a guide to how EDS standards should be to be adopted, developed, and refined to meet the needs of the European space industry.

2. INTRODUCTION

2.1 Purpose and Scope

The SAVOIR EDS project explored the use of EDS in the European Space Industry. This document is the **Final Report** of that project.

Following the executive summary and this introduction, it is split into the following sections:

- **Overview of the Study**, briefly describing the study itself
- **Project Achievements and Results**, describing the results achieved.
- **Conclusions**, outlining the conclusions reached, and scope for future work.

2.2 Document References

2.2.1 Applicable Documents

ID	Applicable Document	Reference	Version	Date
[D14]	EDS Use Cases Implementation Report	SEDS-SSL-D14-A1	1.2	November 2020
		SEDS-SSL-D14-A2	2.0	September 2020
		SEDS-SSL-D14-A3	1.1	November 2020
		SEDS-SSL-D14-A4	1.1	September 2020
[FR]	EDS Final Report	SEDS-SSL-FR	1.1	November 2020

2.2.2 Reference Documents

ID	Reference Document	Reference	Version	Date
none				

2.3 Definitions

2.3.1 Acronyms

Acronym	Definition
ADCS	Attitude Determination and Control Subsystem
AIT	Assembly, Integration and Testing
ASN.1	Abstract Syntax Notation One
CAT	CATalogue
CBOR	Concise Binary Object Representation
CCSDS	Consultative Committee for Space Data Systems
CDF	Concurrent Design Facility
CSW	Central Software
DoT	Dictionary of Terms
DSAP	Device Specific Access Protocol
DSL	Domain Specific Language
ECSS	European Cooperation for Space Standardization
EDS	Electronic Data Sheet(s)
EGOS	ESA Ground Operation System
EGSE	Electrical Ground Support Equipment
FSW	Flight Software
ICD	Interface Control Document
I/O	Input/Output
IMU	Inertial Measurement Unit
KOM	Kick-off Meeting
IDE	Integrated Development Enviroment
LSI	Large System Integrators
MBSE	Model-Based Software Engineering
MISRA	Motor Industry Software Reliability Association
MTR	Mid-term Review
OCDT	Open Concurrent Design Tool
OCL	Object Constraint Language
OHB	OHB System AG
ORM	Object Role Modelling
PCDU	Power Control and Distribution Unit
PoC	Proof of Concept
POJO	Plain Old Java Object
PUS	Packet Utilization Standard
QUDV	Quantities, Units, Dimensions, Values
RIU	Remote Interface Unit
RTU	Remote Terminal Unit
SAVOIR	Space AVionics Open Interface aRchitecture
SDL	Specification and Description Language
SECT	SAVOIR EDS Common Toolset
SEDS	SAVOIR Electronic Data Sheet(s)
SEDSRT	SOIS EDS Reference Tooling
SMP2	Simulation Model Portability version 2
SOIS	Spacecraft Onboard Interface Services
SoW	Statement of Work
SRDB	System Reference Database
SRR	System Requirements Review
SRS	Software Requirements Specification
SSMM	Solid State Mass Memory
SysML	System Modelling Language
TC	Telecommand
TM	Telemetry
TTR	Telemetry, Telecommand, and Reconfiguration
UML	Unified Modelling Language
UC	Use Case
XMI	XML Metadata Interchange

3. Overview of the Study

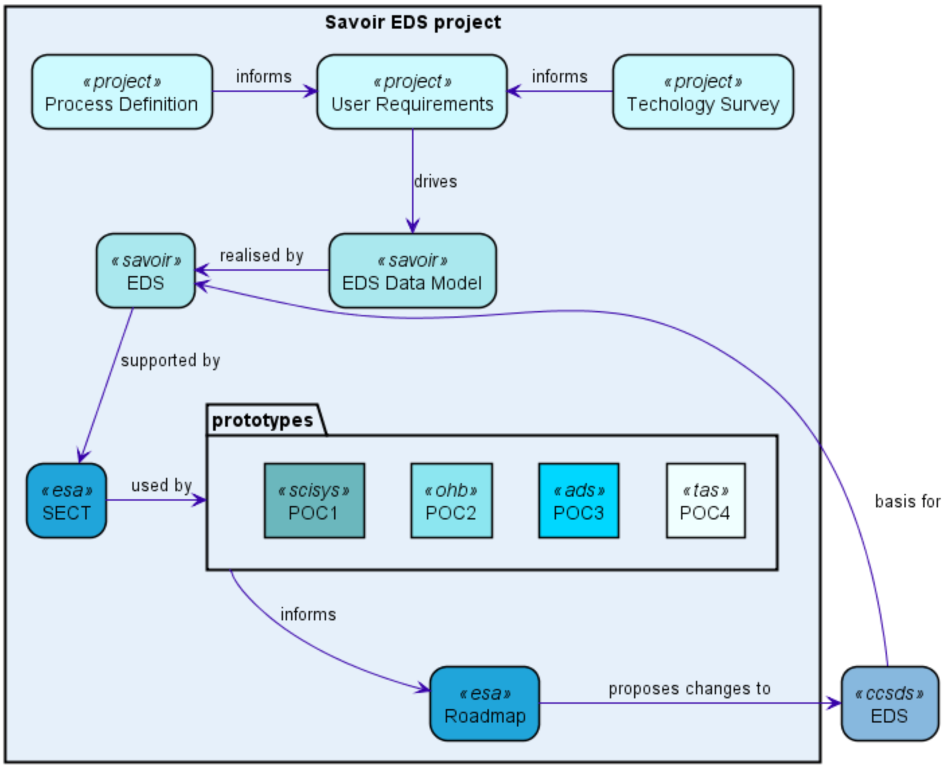


Figure 1: SAVOR EDS Project Overview

In this and subsequent diagrams, the colour coding and secondary labels (e.g.‹‹ savoir››) indicate the scope of the task or artefact.

In order to meet the overall goals, the following approach was adopted for this study:

- Specify **User Requirements** for the EDS concept within the context of SAVOIR and the European Space Industry, informed by two inputs:
    - A **Process Definition** stating how the use of EDS can be used in the process of device specification, procurement and integration performed by a LSI
    - A **Technology Survey** examining existing relevant tools and standards for inspiration and possible reuse.
- Driven by those requirements, define the **SAVOIR EDS Data Model**, an abstract specification of the required contents of EDS.
- Assess the existing **CCSDS EDS** data exchange format standard for use as the basis for a concrete representation of the above model.
- Develop the **SAVOIR EDS Common Toolset (SECT),** supporting the above format.
- Develop a set of **Proof of Concept** prototypes, one for each participating company, covering a wide range of possible use cases for EDS technology.
- Use the experience gained from the prototyping activity to propose a **Roadmap** for the adoption of EDS standards and technology by the European space industry.
- Propose changes or extensions to the existing CCSDS standards as appropriate.

Despite various challenges along the way, the study was ultimately performed successfully, with all project goals met or exceeded.

3.1 Device Datasheets

As described in [D8] and [D14], the device datasheets produced for this project were:

- **aps:** Astro APS
- **astrix:** Astrix 200 fibre optic inertial measurement unit
- **iadcs:** BerlinSpace iADCS
- **juice**: Juice MMS
- **pcdu:** TAS-B PCDU
- **riu**: RUAG RIU

3.2 Proof of Concept Protoypes

4 **proof of concept** prototyping activities were performed, one for each consortium member.

- CGI worked with ESOC to generate C code integrated into the OPSSAT Java-based FSW.
- TAS integrated EDS import into the Capella-based CCM4Space modelling tool
- AIRBUS added EDS import and export to the RangeDB SRDB tool
- OHB added EDS support to the MPS modelling tool and used it to generate code and simulator skeletons for several devices.

Table 1 Prototyping Summary

	UC1 Unit Documentation	UC2 SRDB Generation	UC3 FSW Generation	UC4 Test Generation	UC5 Device I/O Simulation
ASTRO APS Jena Optronik	CGI	ADS			
IMU Astrix 200	CGI		OHB		OHB
iADCS BerlinSpace	CGI		CGI, TAS	CGI	
PCDU TAS-B	CGI		TAS		
RIU RUAG	CGI		TAS		
JUICE MMS	CGI				

4. PROJECT ACHIEVEMENTS AND RESULTS

This section summarises the major deliverable outputs of the project. It focuses on the final status, not the process of getting there.

4.1 SAVOIR EDS Process Definition

The **EDS Process Definition** activity written up in [D01] performed a detailed analysis of the exchange of data between device supplier and prime, identifying a large number of data categories that need to be exchanged in six specific project phase.

Following that analysis, the process model shown below is suggested.

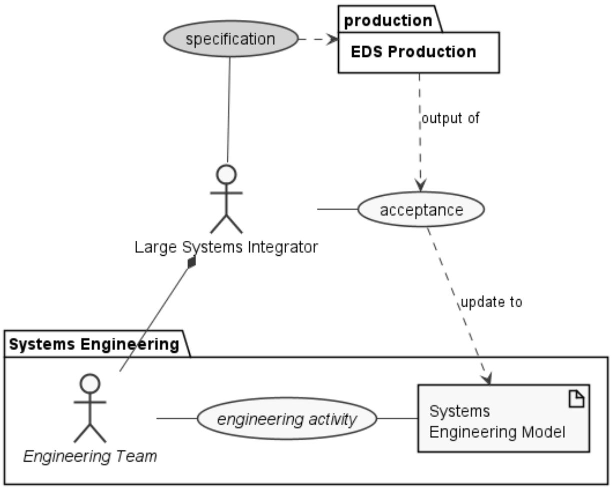


Figure 2: Extended Process Model

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 **acceptance** process, as performed by the 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.

4.2 SAVOIR EDS Domain Model

[D06] describes a domain model [DM01] derived from the data categories required by the process model. As a result of that analysis, the full domain model context expands to that shown in the diagram below.

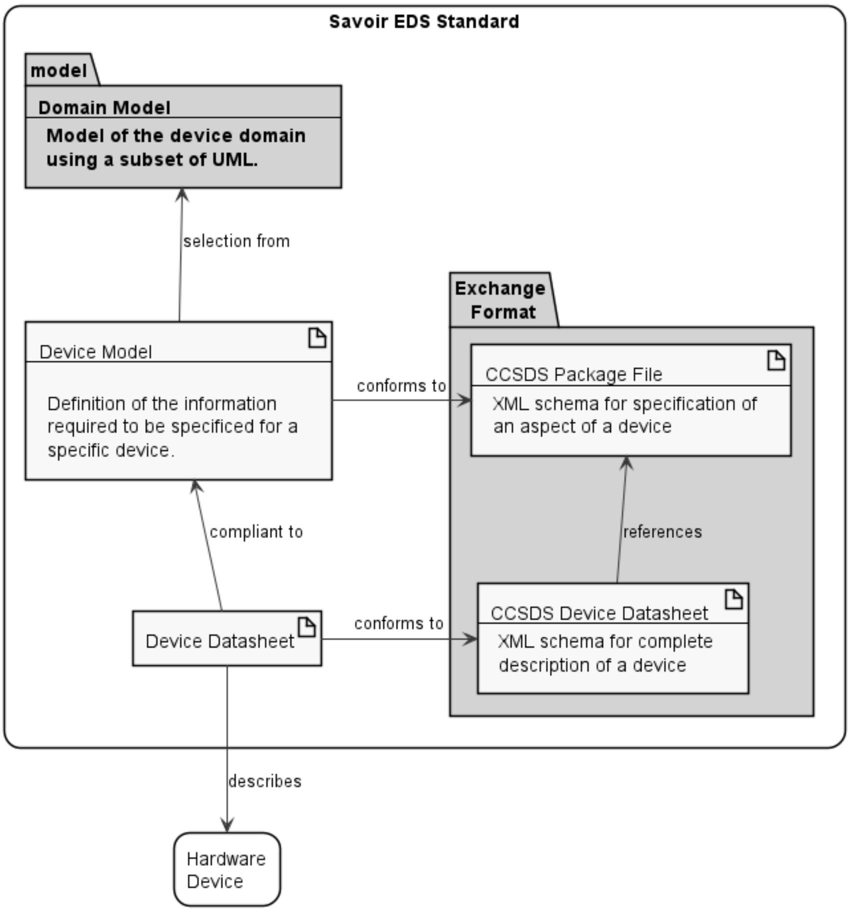


Figure 3: Extended Domain Model Context

A **Device Datasheet** describes a particular hardware device (or class of devices).

- It has a concrete, checkable format, the **Exchange Format**.
- The domain concepts in that format are implicitly taken from the **Domain Model**. This consists of the subset of the overall Systems Engineering Model relevant to hardware devices in general.

A **Device Model** corresponds to the subset of the overall domain model that applies to a particular device. It:

- Specifies what is required of a datasheet for it to be accepted into the domain model.
- Can be represented as a **CCSDS Package File**, a subunit of the CCSDS Device Datasheet.

4.3 CCSDS EDS Standards

Overall, the study found that the CCSDS standards provided a sound foundation for data exchange.

The major areas where there was felt to be room for improvement were:

- The overall complexity of the standard
  While the subject matter is in some cases unavoidably complex, any artificial complexity should be avoided wherever possible.
- The gap that sometimes exists between what is represented and how it is represented. This tends to hard to understand error messages when validating an incorrect document.
- The strategy of representing complex situations as state machines is sometimes the only available option in cases where a simpler approach might be possible.
- Missing support for:
  - Property-based data such as electrical, mechanical and thermal properties.
  - Topology (i.e. graph-structured) data such as electrical interconnections or software deployments.
  - Timing data such as schedules

As a result of the project activity, 13 detailed technical and editorial points have been raised with the relevant CCSDS committee, for inclusion in the 876c0r1 pink sheet update. In addition, [D15] covers larger-scale changes proposed to the CCSDS standards, under the categories:

- General simplifications
- Replacement of Alternate Type Maps
- Device Model Support

4.4 SAVOIR EDS Core Tooling

The SECT software [D04], [D09], [D10], [D11], [D12], [D13] is a **reference implementation** of the SAVOIR and CCSDS EDS standards. As such, its role in the EDS production process is to ease the development of high-quality tools that can make use of datasheets following those standards.

Its features can be briefly summarised as follows:

- **Check datasheet**
  automated and manual checks on the supplied information for correctness and completeness. Manual checking is supported by transforming the datasheet into a more readable HTML form, with diagrams and tables.
- **Transform datasheet**
  predefined automated transformations on a datasheet.
- **Import datasheet**
  Non resource-constrained **ground applications** can simply read and process SEDS data using the reference tooling as a library
- **Generate source code**
  Where appropriate, e.g. for resource-constrained onboard applications, an appropriate **Code Generator** plugin can generate code from the SEDS data.

5. Conclusions

5.1 Summary of Results

Storing and exchanging information in a tool-readable electronic datasheet has the potential to be a major source of time and cost savings and risk reduction The ability for the device supplier to do **validation**, **verification** and **conformance checking** is the key to unlocking that potential; bad data efficiently imported is still bad data.

XML is an acceptable underlying exchange format to all study participants While some would ideally have preferred something different, there is no consensus on what that different thing would be. Consequently, **CCSDS SEDS** is also an acceptable starting point for representing the communications domain of an EDS. Furthermore, if the recommendations described in Section 4.3 are adopted, then it would be expected to be usable for datasheets covering the whole scope of the domain model.

Representing the **device model** as a set of CCSDS XML Package files works; most of the work of conformance checking is then a straightforward use of the CCSDS EDS type system

Common tooling, in the form of the **SECT**, is very helpful in ensuring compatibility. Even when not used as an implementation library, a universally accessible **reference implementation** that provides an unambiguous answer as to what is and is not allowed is key to successful exchange. For a tool to be universally accessible in that way, it is very helpful for it to be released under an open source license, as the SECT is.

5.2 Future Work

Potential future work on SAVOIR EDS can be split into three distinct categories:

- Raising the **Technology Readiness Level** of the existing core capability, with the goal of operational use on upcoming ESA missions
- Extending the **scope** of that core capability to better address current weak points, including the difficulty of creating complex datasheets, or using datasheets created using a different domain model.
- Exploration of **new ideas** and related technologies, such as a space ontology

While the latter two are important, it should be emphasised that there is a great deal of potential benefit to ESA and the European Space industry from adopting EDS technology in something close to its current form. Novel device datasheets are generally internal to a project, and so naturally use a common domain model. Pre-existing off-the-shelf devices typically correspond to a small set of known categories (i.e. star trackers, gyros, etc), and so would be straightforwardly adapted.

Focusing on the core capability, the main technical prerequisite for wider adoption is further development of the SECT reference implementation,

Given the solid foundation of such a robust and powerful core capability, a large number of potential study topics become possible, covering the full range of mission lifecycle activities. Two such are:

- the development of a full EDS authoring tool
- investigation into the relationship between domain models and space ontologies.