Sensor & Actuator Functional Interface

ADCSS workshop 25-10-2011
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Contents

SAFI - Context

- Sensor and Actuators play a major role in the avionics

SAVOIR
space avionics open interface architecture

SAVOIR FAIRE	SAVOIR SAFI	SAVOIR SAIF
Software reference architecture	Sensor/Actuator Functional Interface	Electrical interface (Data & Power)

CCSDS

SPACECRAFT ONBOARD INTERFACE SERVICES

- SAIF, Electrical interface (incl. power): identified one new requirement, the need to standardize the RS422 protocol
- SAFI, Functional interface: from the software control loop to the equipment at functional level – Work in progress

SAFI - Scope

- Sharing knowledge:
  - Bring together the Control and the Software community
  - Reach a common level of knowledge both on Software Reference Architecture principle (COrDeT) and on Control interface functional needs.
  - Introduce SOIS communication concepts to Software and Control engineers and get feedback.

SAVOIR SAFI
space avionics open interface architecture

- The current focus is to investigate existing sensors and actuators from the **functional interface** standpoint in order to identify commonality for future standardised i/f, and extend it for the future.
  - Inventory of the existing interface.
  - Analysis of the functional variability by the working group.

On-going work!...

SAFI - Organization

Phase 1

- Schedule:
  - *15/09/2010* Presentation of TOR to SAG
  - *04/11/2010* Presentation of TOR to Savoir-Faire
  - *17/03/2011* Initiation of the Working Group and Kick-off meeting
  - 12/05/; 31/05/; 23/06;12/07;01/09;22/09;07/10;18/10 Webex meetings
  - *15/09/2011* Part 1 report to SAG for review
  - *25/10/2011* Presentation to ADCSS workshop
  - *30/11/2011* Report on the interface standardisation concept

- SAFI Working Group:
  - SAVOIR FAIRE members and Roger Llorca-Cejudo (Cnes)
  - ESA Control representatives (Fabio v. Hattem, Guillermo Ortega)
  - ESA Data Handling representative (from SOIS WG) (Chris Taylor)
  - CNES Control representative (Jean Mignot)
  - Astrium (Jérôme Lemaire), Thales (Yvan Roche) Control representatives

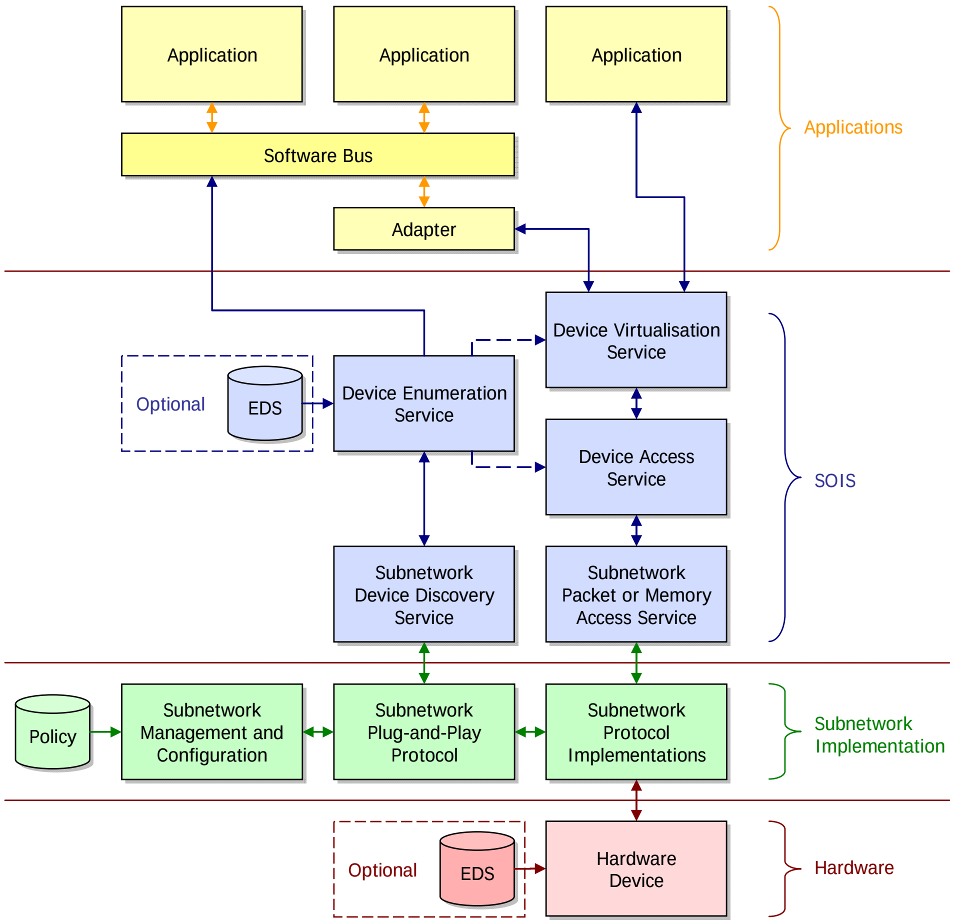
Phase 2

- Deployment with S/A suppliers as defined by SAG

Interaction with SOIS

- The CCSDS SOIS WG has defined a communications architecture which identifies services for accessing onboard devices, including AOCS related sensors and actuators
- Specifically, the command and Acquisition services provide two important subservices:
  - The Device Virtualisation Service (DVS)
  - The Device access service (DAS)
- These services provide a framework that may be used to harmonise the suppliers specific interfaces in use today
- The SAFI group has taken on the task of specifying a set of DVS and DAS based services for all common AOCS devices
- These services will be used as input to the CCSDS WG for the definition of electronic data sheets

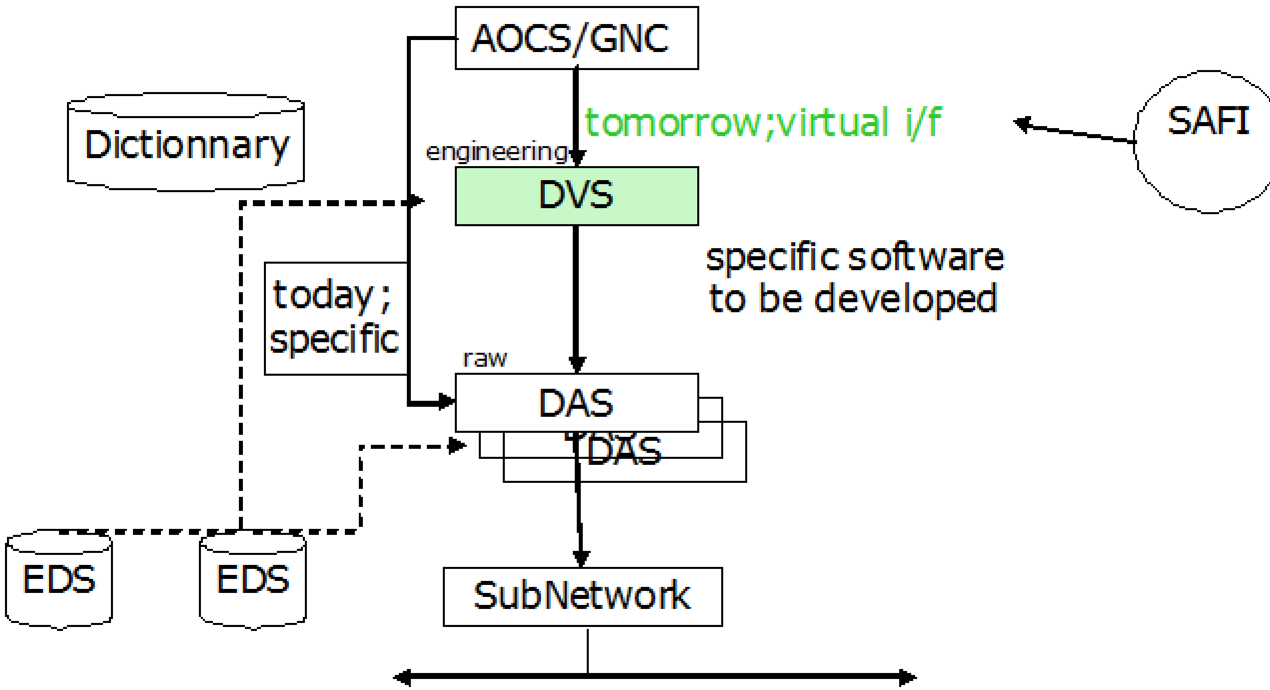
The SOIS P&P model



The SOIS DAS and DVS services and the use of EDS

- Today, direct access to drivers is expensive sw adhoc development
- ➔ make it more systematic
- ➔ use a higher level interface
- ➔ DVS offers the mechanism
- ➔ SAFI to define the i/f

- EDS host the information needed to configure the DAS and DVS software layers.
- EDS includes the semantic types of each S/A type, e.g. a single angular rate for all gyros. This becomes the virtual i/f of the DVS, and is described in the dictionary and the EDS which configures the DVS.
- EDS for DAS too



Software architecture principles

- Identify the variability factors from one project to another
- Localize the impact of variation in identified points of the architecture
- Separate concerns: control system to control engineers and suitable infrastructure to software engineers
- The software infrastructure is a *generic software factory* based on code generators and configurators (concept of software bus)

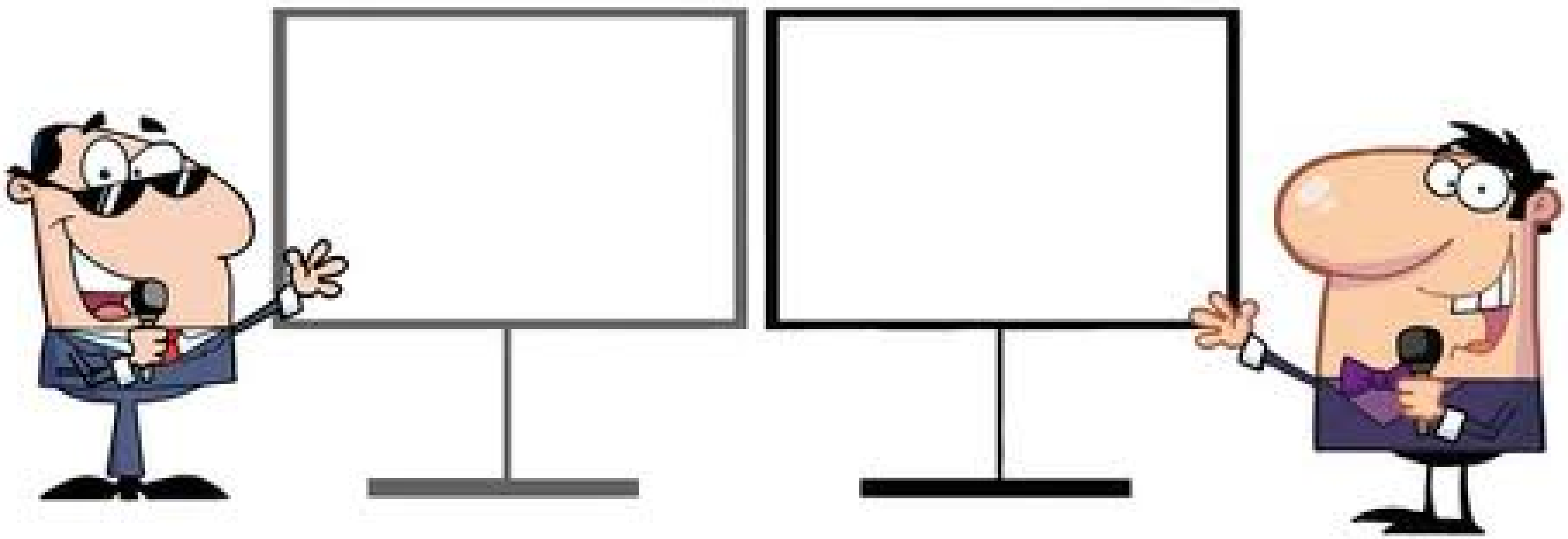
Use case: reduce risk and schedule at software and avionics integration

- The concept extend to the spacecraft data base that host all the parameters. The EDS is likely to be used to configure the spacecraft database and flight software (instead of being embedded).

Intended use cases

- Early definition of AOCS. Aim at using the same functional interface at model level and at on-board software level
    - The functional interface in AOCS functional simulator is reused all along the development up to the on-board software: the functional interface is automatically put in a specific on-board software envelop
- Improve schedule software by minimizing changes of S/A interface when the actual equipment is selected
- Streamline the development of the on-board software element that link the control loop to the specific equipment access layers: manual ad hoc glue software replaced by configurable architectural blocs
- In the S/A interface, separate the functional aspects from the format of data that may be handled by e.g. the EDS
- Expose a more common interface to the users
- Suppliers need to know, understand and practice the concept of Electronic Data Sheet. However, it is just a formalization of what exists today

Speaker change



Sensors & Actuators overview

- Existing S/A landscape shows a large variety of practices in interface.
- Digital:
  - Some Sensors can provide a large amount of data, the largest part is used only on-ground for diagnostic.
  - Each company uses a different subset to implement different functionality for the same type of equipment.
  - There can be differences in the datation of the measure/command, in the use of reference frame, etc.
- Analog:
  - S/A may provide/require voltage (or currents) with different range/scale-factor and functional implication.
- SAFI aims at a solution for most of the cases, but might exclude very specific cases.
- The view of the Suppliers will be given in next phase.

SAFI - S/A investigations

- SAFI WG focused initially on 5 selected equipments which are considered to be the most commonly used by AOCS:

- Sensors
  - Star tracker: investigated → preliminary funct. I/F standardization proposal
  - Gyro: under investigation
  - Sun sensor: under investigation

- Actuators
  - Reaction wheel: investigated → preliminary funct. I/F standardization proposal
  - Magneto torquer: under investigation

- Other equipments (ex. Thrusters, Magnetometers, GNSS receivers etc.) will be investigated in a second phase.

SAFI – Approach for S/A standardised i/f

- **S/A functional I/F standardization is performed only for core data/command parameters which are directly used on board (by AOCS and FDIR). Parameters which are not used onboard but just exchanged with ground are not standardized.**

- Standardized functional I/F includes mandatory and optional parameters.

- In particular:
  - Parameter Number Name: a common Id
  - Name: to be defined according to common agreed naming conventions
  - Mandatory or Optional
  - Description: what represents this data or command parameter
  - Format: data organisation, reference frame, coordinate, etc…
  - Unit: SI unit
  - Range: expected [min , max] values
  - Type: real, natural number, enumerated
  - Interaction with Electronic Data Sheet (EDS) from SOIS

S/A examples of standardised i/f – STR (1/3)

Galileo AASTR

Number of tracker windows
Number of SEU filtered
Covariance_X
Covariance_Y
Covariance_Z
Optic temperature
TEC current
Tracking loss counter
…

Sodern Hydra

Number of expected stars
Number of coherent stars
Quality index X
Quality index Y
Quality index Z
Peltier temperature flag
…

Final Attitude Quaternion
Time associated to STR measure for quaternion
STR mode
Quality Index of the Attitude
STR Health status
Final Angular Rate vector
Time associated to STR measure for angular rate
Number of stars used for attitude determination
Counter since last Reset
ON command for TEC number n
Target temperature for TEC number n
Reset Command
STR Mode
Uploaded Date
Attitude initialisation (Optional)
Angular rate vector initialisation

Number of trackable stars
Number of identified stars
Number of acquired objects
Detector temperature
Optics temperature
Housing temperature
TEC mode
…

Jenoptik Astro APS

Core data/commands package for any STR

(This core should contain all data/commands used directly on-board by AOCS & FDIR)

S/A examples of standardised i/f – STR (2/3)

- Core data for any STR

Standard TM Parameter Number	Name	mandatory / optional	Description	Format	Unit	Range	Real / usigned integer number / enumerated	Interaction with Electroinc Data Sheet (SOIS)
TM 01		mandatory	Final Attitude Quaternion provided by STR	q = [scalar; vector(3)] Reference frame: J2000 frame --> STR frame	-	[-1 1]	real	accuracy provided in electronic data sheet (32 / F64)
TM 02		mandatory	Time associated to STR measure for quaternion	Time elapsed between the last synchronisation signal and measurement	ms	[-inf inf]	real	
TM 03		optional	Final Angular Rate vector provided by STR	w = vector(3) Reference frame: STR frame vs Inertial Frame	rad/s	[-inf inf]	real	accuracy provided in electronic data sheet (32 / F64)
TM04		optional	Time associated to STR measure for angular rate	Time between the last synchronisation signal and the datation of the angular rate	ms	[-inf inf]	real	
TM 05		mandatory	STR mode (typically a number)	enumerated Mandatory modes: tracking, acquisition, non-operational mode Other STR states shall be sub-modes (optional): stand-by, software mode, rate mode Further sub-states defined by supplier?	-	-	enumerated	Modes number shall be defined either in the electronic data sheet either in functional TM/TC Standard
TM 06		mandatory	Quality Index of the Attitude provided by STR (typically a number)	Real value from 0 to 1. 1 being good quality. This value is not used directly in the attitude estimation This convention shall be addressed with STR suppliers.	-	[0 1]	real	Quality index shall be defined in the electronic data sheet and in the STR ICD
TM 07		optional	Number of stars used for Attitude determination	In case of fused measure, TBD by suppliers	-	[0 inf]	unsigned integer	
TM 08			Counter since last Reset		s	[0 inf]		
TM 09		mandatory	STR Health status (typically a number)	enumerated Mandatory states: OK / STR Severe warning (Restart is needed) / STR warning (Restart not necessary) Optional sub-states can indicate the hardware involved (Electronic Unit, OH_n)	-	-	enumerated	Health Status enumeration shall be defined in the electronic data sheet
TM 10		TBD	Current date as used by STR	CCSDS CCSDS Unsegmented Code (CUC) time code format TBC by suppliers	-	-	-	

S/A examples of standardised i/f – STR (3/3)

- Core commands for any STR

Standard TC Packet Name	Standard TC Parameter Number	mandatory / optional	Description	Format	Unit	Range	Real / usigned integer number / enumerated	Interaction with Electroinc Data Sheet (SOIS)
TC RESET	TC 01	Mandatory	Reset Command (Tipiclly a nuber in order to give the possibility to perform different type of reset)	Reset command of the complete STR mandatory. Other reset command optionals.	-	-	enumerated	enumeration shall be defined in the electronic data sheet
TC THERMAL CONTROL	TC 02	Mandatory	ON command for TEC number n	n = TEC nuber	-	-	enumerated	enumeration of the TEC shall be defined in electronic data sheet
	TC 03	Mandatory	Target temperature for TEC number n	Target temperatures for the detector in °C: if T > Tmax: peltier cooler operates at maximum power if T < Tmin: peltier cooler is switched off	deg	[-inf inf]	real	Tmin and Tmax shall be described in ICD (Typical values [-30; +40]°C)
TC UPLOAD DATE	TC 04	TBD	Uploaded Date	CCSDS Unsegmented Code (CUC) time code format TBC by suppliers	TBD	TBD	TBD	
TC SET STR MODE	TC 05	Mandatory	STR Mode	-	-	-	enumerated	enumeration shall be defined in the electronic data sheet
	TC 06	Optional	Attitude initialisation (quaternion) (Optional)	q = [scalar; vector(3)] Reference frame: J2000 frame --> STR frame	-	[-1 1]	real	accuracy provided in electronic data sheet (32 / F64)
	TC 07	Optional	Angular rate vector initialisation (Optional)	w = vector(3) Reference frame: STR frame vs Inertial Frame	rad/s	[-inf inf]	real	accuracy provided in electronic data sheet (32 / F64)
	TC 08	Optional	Validity time for the initialised attitude (TBC by STR Suppliers)	-	sec	[-inf inf]	unsigned integer	
TC LINEAR VELOCITY UPDATE	TC 09	Optional	Enable aberration correction (To Be discussed with STR suppliers)	No Aberration correction/ Enable Aberration correction based on velocity/ Enable aberration correction based on orbital parameters	-	-	enumerated	
	TC 10	Optional	Velocity vector (To Be discussed with STR suppliers)	S/C velocity vector = vector (3) in J2000 frame	m/s	[-inf inf]	real	
	TC 11	Optional	Orbital Parameters (To Be discussed with STR suppliers)	TBD	TBD	TBD	TDB	
	TC 12	Optional	Validity time for the velocity/Orbital Parameters (To Be discussed with STR suppliers)		sec	[-inf inf]	real	

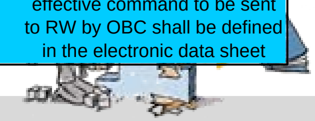
S/A examples of standardised i/f – RW

- Rockwell Collins RSI + Bradford Engineering RWU
- Core data for any RW

Standard TM Parameter Number	Name	mandatory / optional	Description	Format	Unit	Range	Real / Natural number / enumerated	Interaction with Electronic Data Sheet (SOIS)
TM 01	RW Speed	Mandatory	RW angular rate around rotation axis		Rad/s	[-inf; inf]	real	Electronic data sheet shall provide information on how to merge Tachometer pulses and Speed direction information in order to obtain RW speed
TM 02	Motor Current	Mandatory	For monitoring		A	[-inf; inf]	real	Conversion between RW analogue or digital signal and effective motor current shall be defined in the electronic data sheet
TM 03	Bearing temperature	Mandatory	For monitoring		deg	[-inf; inf]	real	Conversion between RW analogue or digital signal and effective Bearing temperature shall be defined in the electronic data sheet
TM 04	On/Off Status	Optional		0 = OFF 1 = ON	-	[0; 1]	Boolean	

- Core commands for any RW

Standard TC Parameter Number	Name	mandatory / optional	Description	Format	Unit	Range	Real / Natural number / enumerated	Interaction with Electronic Data Sheet (SOIS)
TC 01	Torque Command	Mandatory	Torque command around rotation axis		Nm	[-inf; inf]	Real	Conversion between Torque around RW rotation axis and effective command to be sent to RW by OBC shall be defined in the electronic data sheet



SAFI - S/A standardised i/f considerations

- Preliminary investigation is concluded only for STR and RW. In both cases the existing equipments (coming from different European manufacturers) seem to share a similar core of parameters. However, other types of Sensor or Actuators may not have similar communalities.

- An agreement within the WG was found on preliminary STR and RW functional standardised I/F for core data/command parameters. However, there are still some minor open points. These shall be submitted to suppliers in the next phase.

- A functional standardised I/F together with an electrical I/F standard may reduce the impact of S/A equipment change. However, for some units mechanical and thermal compatibility may have a higher impact.

SAFI - S/A standardised i/f recommendations

- Eventual S/A functional standardised interface should target only newly developed H/W.
- Preliminary S/A functional standardised interface is based on existing units. SAFI WG shall ensure that this standardised i/f will not impose major limitations to evolution of future AOCS and units design, as foreseen by primes and suppliers.
- AOCS shall be able to specify Sensor detection maximum delay and Actuators command maximum delay. In general, specification of all real-time performance is needed.
- Functional standardization does not need to affect performance of S/A.
  - As long as suppliers continue to use the proprietary i/f, to be mapped on the standardised i/f → some overhead;
  - When they converge on standardised i/f → no mapping, no overhead

→ Input to SAVOIR FAIRE

Conclusion

- So far no identified inconsistency or impossibility between the software reference architecture (COrDeT) and the Control functional chain
- The concept of standardizing the functional interface to S/A has been investigated and refined considering:
  - Needs of the software architecture.
  - Constraints of the control functional chain.
  - The opportunity offered by the SOIS standardisation.
- The concept of a functional standard for data/command parameters (used on board) seems feasible for investigated S/A.
- Examples of standardised interface have been investigated for selected S/A (STR and RW).

→ **The working group propose to proceed with the next phase by involving representatives of S/A community to discuss further the standardised interface definition.**

Contact

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