Common Instrument Interface (CII) Workshop

ESA Presentation

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East Hyattsville, MD ; 21/04/2011

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Acknowledgment (presentation prepared jointly with):

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- P. Silvestrin (ESA/ESTEC EOP-SF)
- A. Loeschner (ESA/ESTEC EOP-SF)

ESA and CII

ESA and NASA on-going cooperation in the Earth Sciences and climate change areas, with three working groups (WG) established

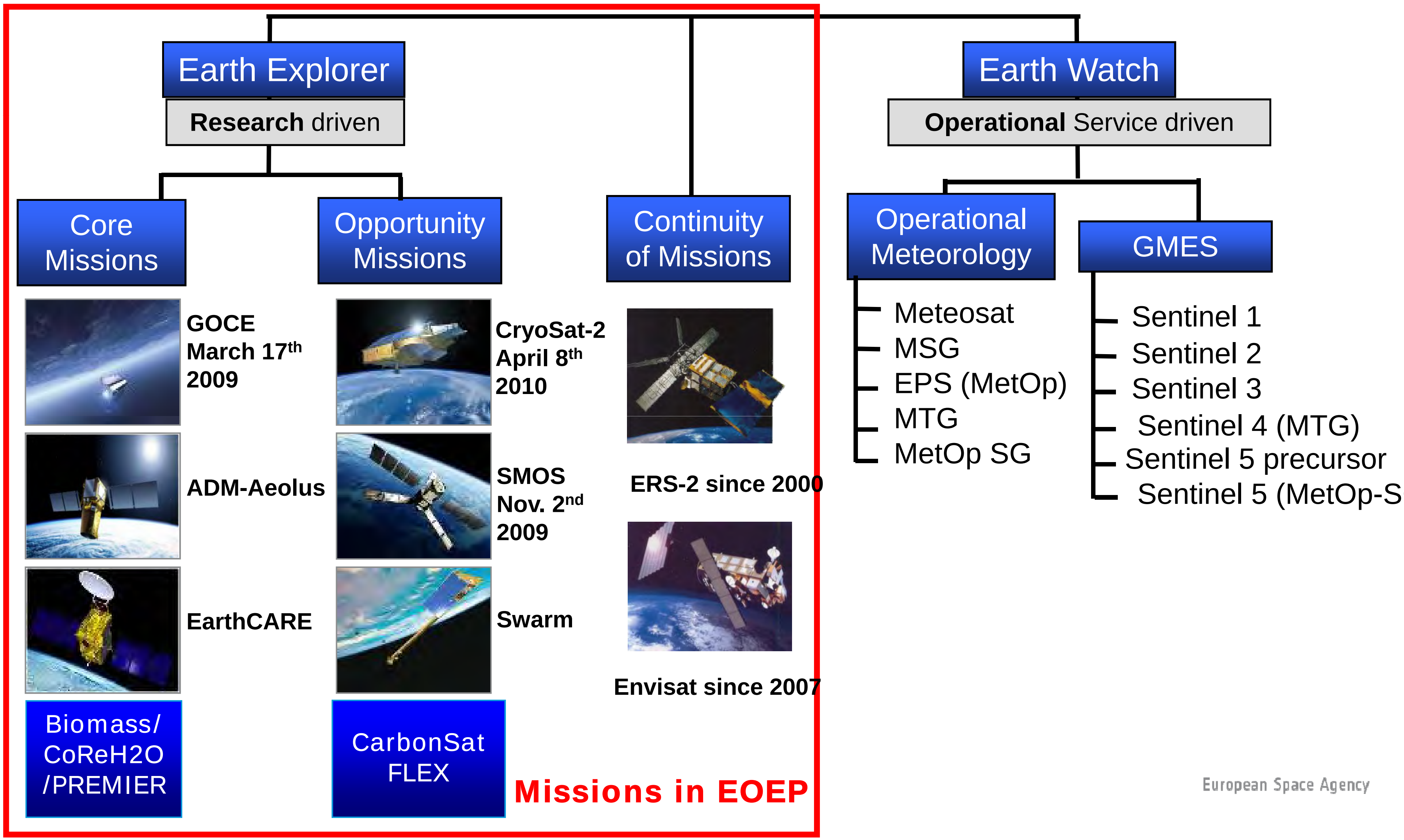
The "Missions and Technology WG", whose global goals are:

- Focus on space mission design, development and operation, considering a broad suite of collaboration opportunities and specific discussions relevant to CII
- Investigate scope for flight opportunities, including exchange of instruments of opportunity
- Possibility of future joint AO on coordinated ESA's Earth Explorer Call and NASA Venture class

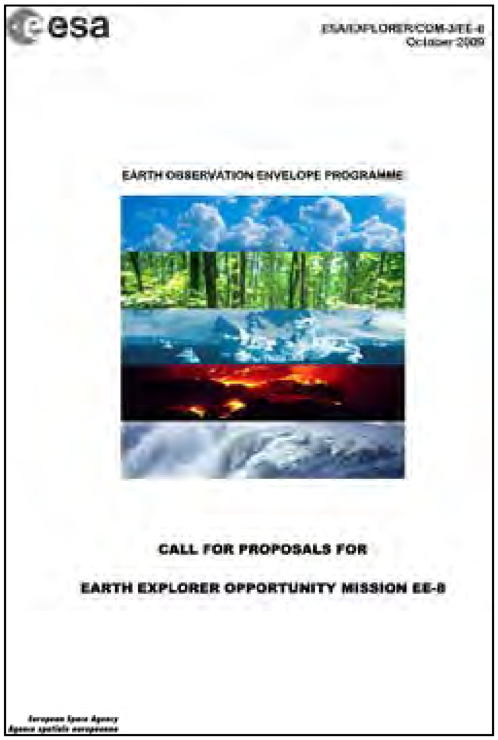
ESA interest:

- CII is fundamental to reduce integration risk/time and cost.
- definition of CII for possible use in Earth Explorers 8 (Carbonsat, FLEX) Phase A/B1
- CII for possible use in NASA mission with a European payload

ESA's Earth Observation Missions



Earth Explorer Opportunity mission EE-8


ESA/EXPLORER/COM-3/EE-8
October 2009

EARTH OBSERVATION ENVELOPE PROGRAMME

CALL FOR PROPOSALS FOR

EARTH EXPLORER OPPORTUNITY MISSION EE-8

European Space Agency
Agence spatiale européenne

- Call for proposals issued on 2 October 2009 to scientists
  - Proposals could be made for a full satellite or a guest payload on a non-ESA mission
  - Budget ceiling of **100 MEURO** industrial cost for the space segment and mission specific ground segment (i.e. excluding launcher, operations, generic ground segment, level 2 processor and ESA internal costs)
  - Compatible with VEGA launcher
- Letters of intent (LoI) were submitted by 1 Dec. 2009 and 31 full proposals by 1 June 2010.
- ITT for phase A/B1 expected by May 2011 for two candidate missions:
  - CarbonSat
  - FLEX
- One EE-8 mission to be launched in 2019

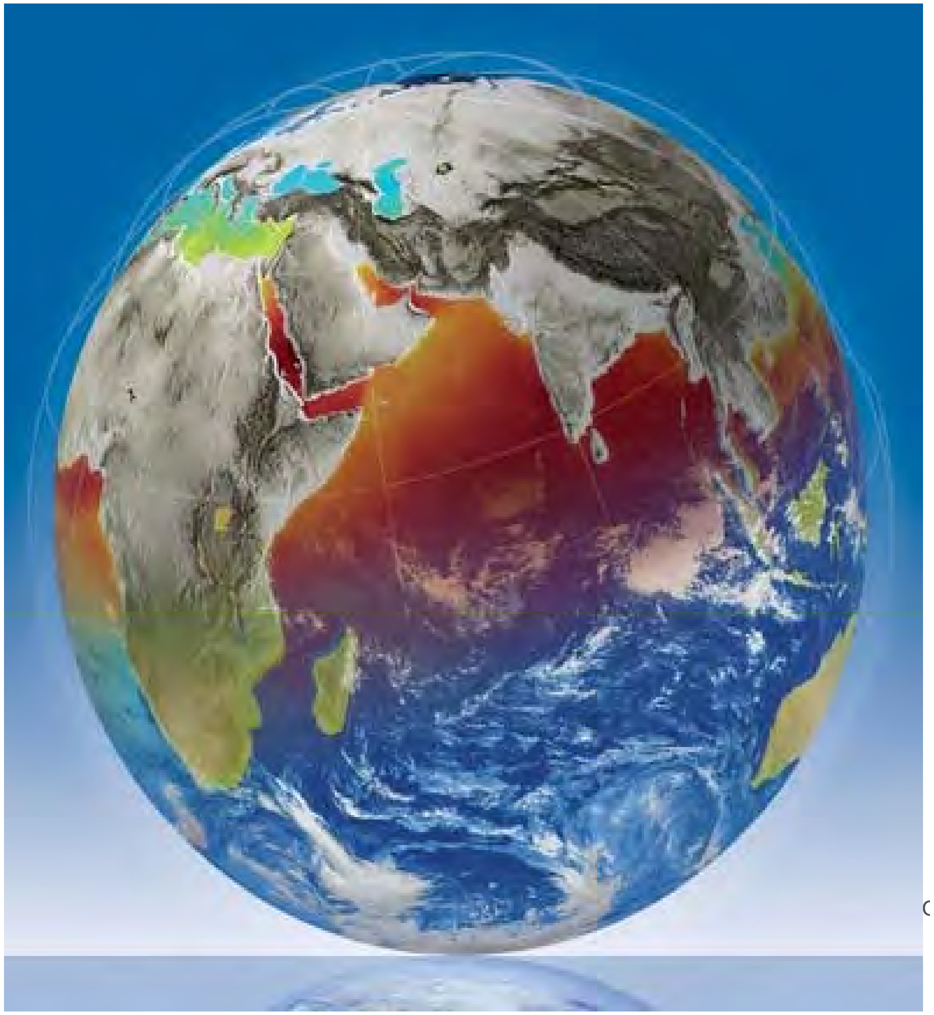
Earth Explorer 8

esa

EE OPPORTUNITY MISSIONS

Smaller Research & Demonstration Missions providing means for rapid response to new ideas.

ESA or Third Party led.



- **Status:** ***The procurement process for the Phase A/B1 activities for both mission candidates has started.***

- **CarbonSat:** **to quantify and monitor the distribution of carbon dioxide and methane**
  => for a better understanding of the sources and sinks of these two gases and how they are linked to climate change.

- **FLEX:** **to provide global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity**
  => to improve our understanding of how much carbon is stored in plants and their role in the carbon and water cycles

Carbonsat (1)
(details to be consolidated during Phase A/B1)

Building up from SCIAMACHY (ESA) and GOSAT (Japan) mission, and future OCO-2 (US)

Initial technical concept is:

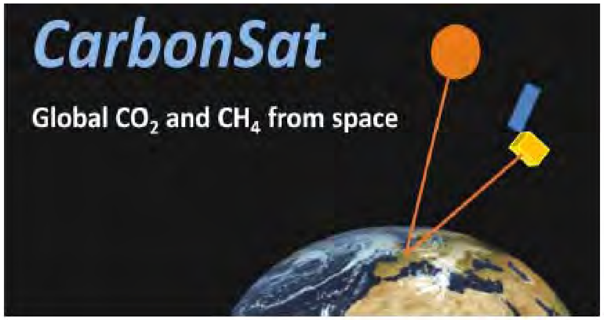
- 3-axis stabilized nadir-pointing satellite
- polar sun-synch. orbit (mean altitude of 828 km ; 13:30 LTAN)
- > 3 year lifetime (consumables for > 5 year)

Preliminary satellite / platform information (assuming only ESA instrument)

- Mass: ~ 800 kg
- Total S/C: ~ 500 W (peak) // 400 W (stand-by) ; One sun pointing /A wing: 3.5 m^2

Payload: **Green House Gases Imaging Spectrometer (GHGIS)**

- High resolution 3-band NIR/SWIR spectrometer for CO2 and CH4
- Budgets
  - mass < 150 Kgr ;
  - Power ~ 250 W (peak) // 150 W (stand-by)
  - Downlink TM data rate < 300 Mbit



Carbonsat (2)
(details to be consolidated during Phase A/B1)

Initially, a Cloud and Aerosol Imager (CAI, GOSAT concept) was proposed.

Due to programmatic constraints, CAI is discarded

CarbonSat has to fly in loose formation with a satellite providing the CAI equivalent instrument

=> many open issues (e.g. Orbit could be adapted to companion satellite)

As said, CarbonSat will be further defined in Phase A/B1 (duration of 20 months)

FLEX

(details to be consolidated during Phase A/B1)

- Submitted as mission proposal to the Earth Explorer (core) 7
  - Studied but not selected in 2009, however strong recommendation for detailed investigations on an in-orbit demonstrator
- Submitted as mission proposal to EE8 call in 2010

- Initial technical concept is:
  - Sun sync. Orbit in **tandem with Sentinel-3** (815 km altitude, 10:00 AM LTDN)
  - > 3 years (target 5 years)

Preliminary satellite / platform information (assuming only ESA instrument)

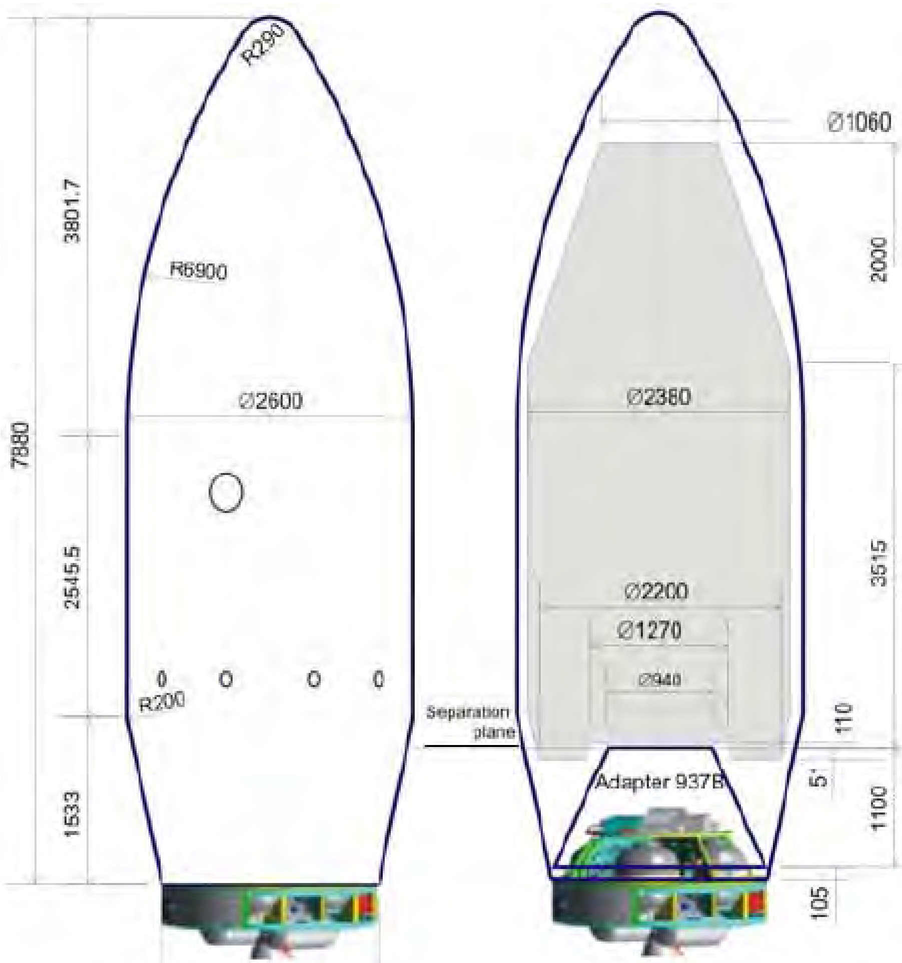
- Mass < 250 kg
- Power : ~ 200 W (peak)

Payload: **<u>Fluorescent IMAaging Spectrometer (FIMAS)</u>** -

- grating spectrometer (spectral range 530 nm to 800 nm)
- Two concepts to be investigated. For one of them
  - mass < 100 kg ;
  - Power ~ 60 W (peak) // 150 W (stand-by)
  - Output data rate: 70 Mbit/s
  - Volume ~ 60 x 60 x 45 cm3

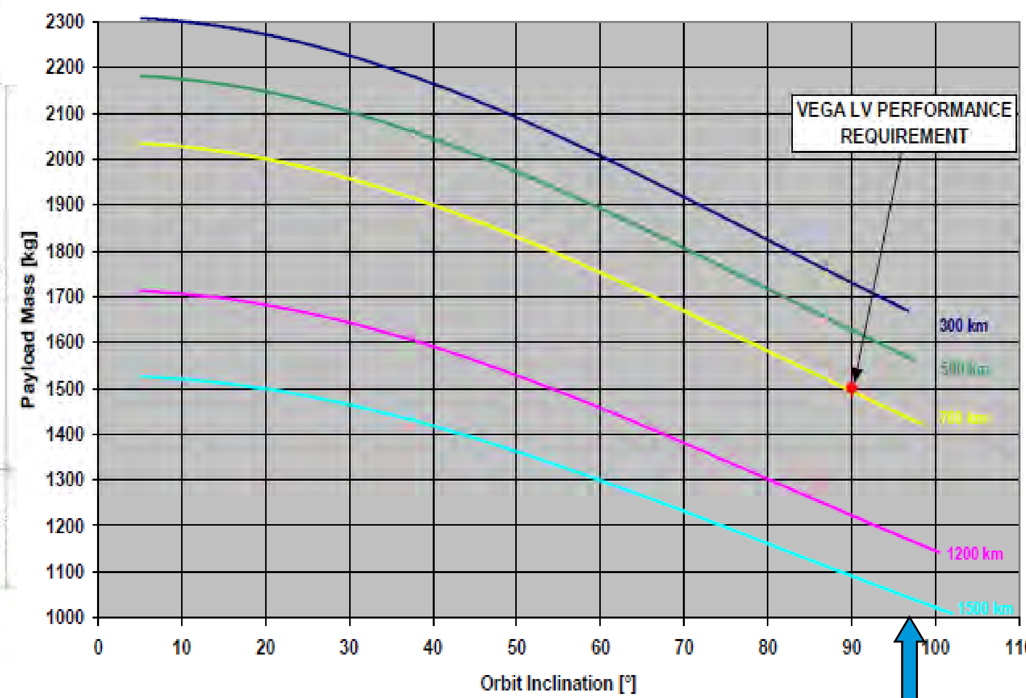
VEGA rocket (User Manual , March 2006)

(http://www.arianespace.com/launch-services-vega/VEGAUsersManual.pdf)



New Space Vehicle Manual under preparation

Payload fairing:
-2.6 m. diameter
-7.88 m. length



98 deg.

Well over 1 tone launch capacity
=> Potential for add-on payload

Power Interfaces

ESA and CII

Earth Explorer 8 missions

Power Interfaces

Data Handling interfaces

Conclusions

Understanding of CII power requirements

The power interface shall be defined according to:

- mission assumptions
- and system needs

The instrument power interface shall be **adaptable** to meet the relevant **system** requirements

LEO reference mission assumptions (Earth Explorer 8)

- Unregulated, battery bus with 7 or 8 Li-Ion cells in series
- Bus power 500W-1kW
- Non pulsed bus application (no LIDAR, no RADAR)
- ~ 1.5 hours orbit typical, cover any Local Time
- for CII application:
  - Solar Array (SA) illumination and temperature not critical
  - the bus quality is anyhow dominated by battery performance
- Assumed lifetime: 7 years

CII – Battery sizing (example of assumptions)

Based on previous reference missions data **(Note: No margins added !!!)**

Voltage range

- **Max** 4.2V * 8 cells = **33.6V**
- **Min (operative*) TYP** 2.8V * 7 cells = **19.6V @ 30% DOD, EOL**
- **Min (absolute**)** 2.5V*7 cells = **17.5V @ 100% DOD**

Capacity range (assumed 1 full orbit survival with no SA support, max 30% DOD)

- **Max** 1000W*1.5hours/30% = 5kWh
  corresponding to about 5KWh/7cells/3.7V/cell = **193 Ah**
- **Min** 500W*1.5hours/30% = 2.5 KWh
  corresponding to about 2.5KWh/8cells/3.7V/cell = **84 Ah**

Derived Impedance at low frequencies (@ 0degC, EOL, 10Hz to 1 KHz)

- **Max 41 mOhm** (84 Ah, 7 cells in series),
  Min 15 mOhm (193 Ah, 8 cells in series)

(assuming small cells of 1.5 Ah each)

Based on this kind of high level assumptions, current CII parameters to be iterated

* Instrument keeps performance
** Instrument is not operative

DOD = Depth of Discharge

Discussion on present CII power requirements

- Definition of mission assumptions and battery interface (including redundancy)
- Current CII parameters to be iterated after agreeing those assumptions .
  - E.g. power feeds characteristics (normal, abnormal, transients, over and undervoltage conditions, etc)

- Capability to interface Latching Current Interface (LCL) to be added
- EMC requirements to be added

Typical ESA power system architecture for LEO

PCDU = Power Control and Distribution Unit

SA = Solar Array

SAR = Solar Array Regulator i (i=1…n)

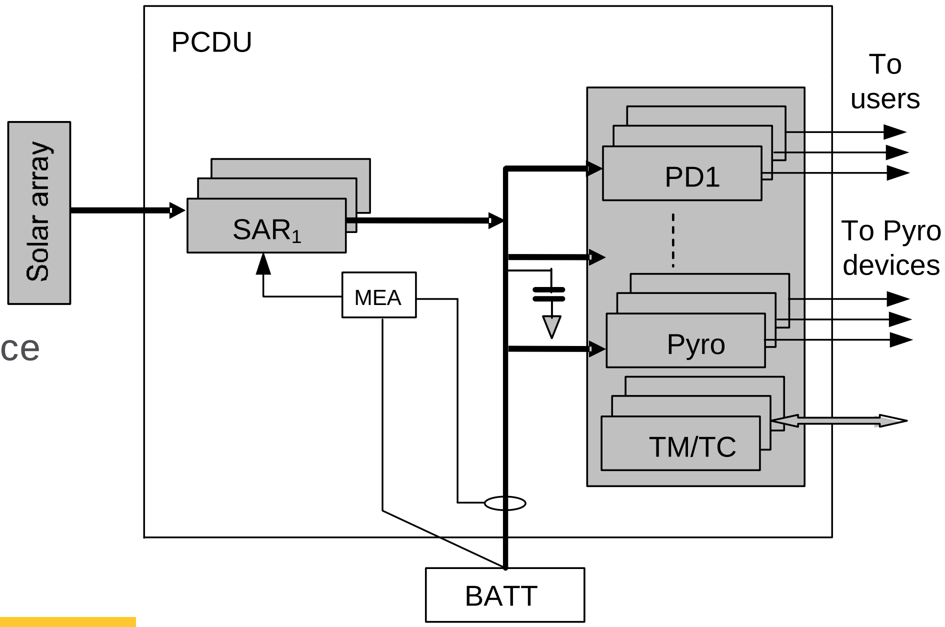
BATT = Battery

PDi = Power Distribution Board i (i=1…n)

Pyro – Pyrotechnic Supply Driver

MEA = Main Error Amplifier

TM/TC = Telemetry / Telecommand Interface



Differences with NASA to be discussed

Data Handling Interfaces

ESA and CII

Earth Explorer 8 missions

Power Interfaces

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Conclusions

ESA appreciates NASA support to SpaceWire

ESA LEO Satellite / Instrument Data Handling Interfaces

Typical ESA architecture based on the following electrical interfaces, **but we also consider**:

Data Handling Interfaces

- **SpaceWire for TM / TC based on ECSS-E-ST-50-12C**
- **Protocols for TM / TC are mission specific,** but we consider for SpW
  - ECSS-E-ST-50-51C (ID)
  - ECSS-E-ST-50-53C & CCSDS 133.0-B-1 (Blue Book)
- **MIL-1553B for TC based on ECSS-E-ST-50-13C**

  (but could be replaced by SpaceWire + protocols for TC)

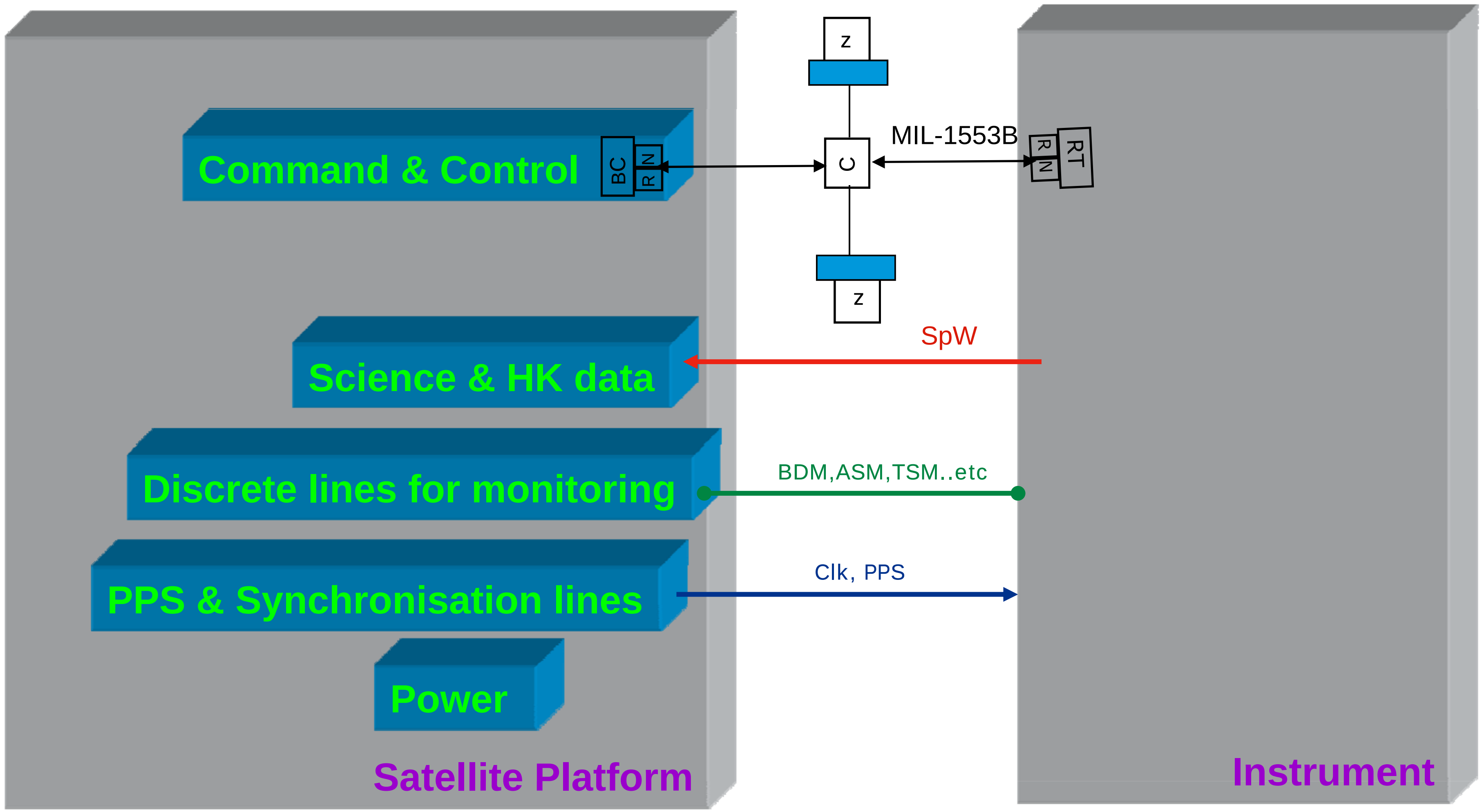
Monitoring Interfaces

- **Discrete lines based on ECSS-E-ST-50-14C** (see next slide)

Synchronisation Interfaces

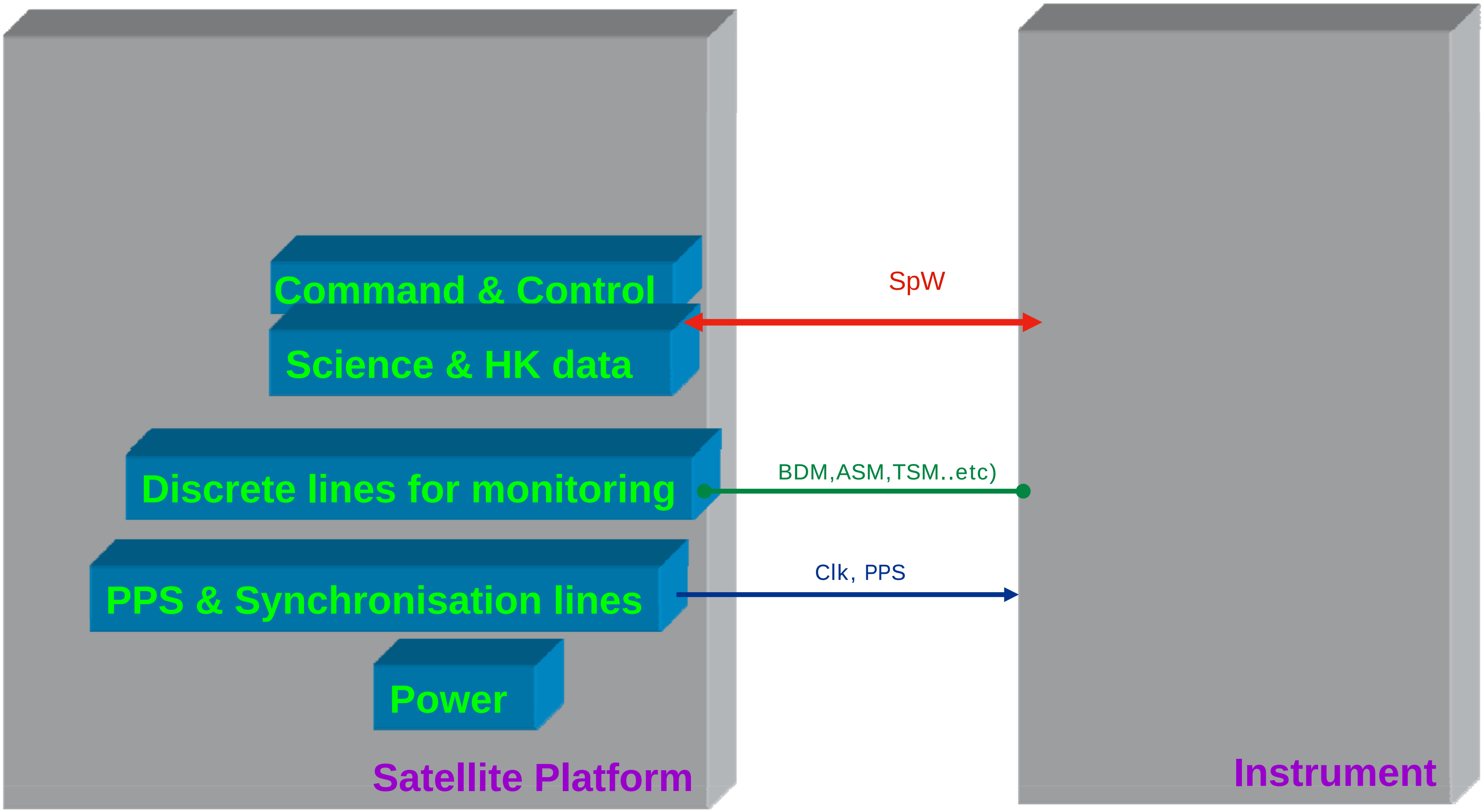
- **PPS based on ECSS-E-ST-50-14C for the electrical signal**
- **Specific Synchronisation Interface based on ECSS-E-ST-50-14C for the electrical signal.** **Frequency** and **precision** requirements are specific to instrument need

ESA LEO Satellite / Instrument Data Handling Interfaces (2)



ASM: Analogue Signal Monitor
BDM: Bi-level Discrete Monitor
TSM: Temperature Sensors Monitor

ESA LEO Satellite / Instrument Data Handling Interfaces (3)



Comments to the CII data handling document

- Assumptions to be added (e.g. redundancy, use of routers)

- Physical layer to be extended
  - e.g. 9-pin connector is one option (but not the only one)

- We assume that codec (ESA – NASA) are compatible (**TBC**)

- Protocol of CII to be extended for FDIR
  - What if commands or ACK do not arrive (on-time)?
  - A simple approach could be to:
    - let platform (master) read on buffers (size TBD) available at instrument side (slave)
    - use time-codes to alert instrument

Conclusions

ESA's interest in collaborating with CII in the frame of "Missions and Technology WG"

Earth Explorer 8 (Carbonsat and FLEX) presented

- ITT for Phase A/B1 to be issued in May 2011 (a lot of parameters to be refined)
- Assumptions to be further defined for CII

Power interfaces

- Assumptions (e.g. battery sizing) to be clarified, and current parameters to be revisited based on the assumptions
- Capability to interface Latching Current Interface (LCL) limiter to be added
- EMC requirements to be added

Data Handling interfaces

- Assumptions (e.g. Physical layer, assumptions on redundancy – e.g. routers) to be added
- SpaceWire (bi-directional) has great potential, but could impose important complexity/cost on spacecraft if it is the only I/F to be used. Caution on
  - Synchronization easier done with discrete lines
  - Command and control (protocols not consolidated)
    - possible buffering approach at instrument side to handle transmissions to S/C and related FDIR
    - other options (e.g. Mil-Std-1553) not to be discarded too quickly

Backup slides

Earth Explorer 7

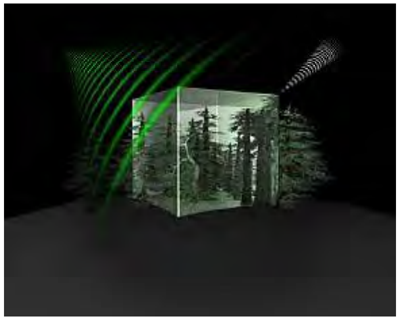
EE CORE MISSIONS

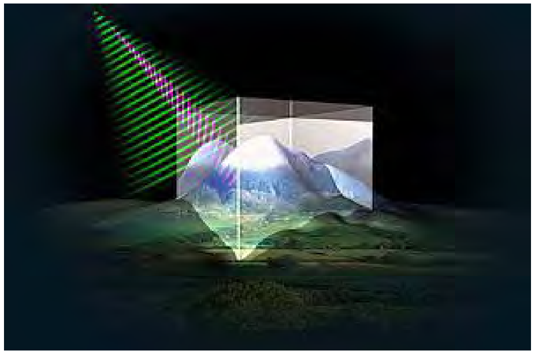
Larger Research & Demonstration Missions, ESA led.

Selection through extensive consultation with European/Canadian scientific community

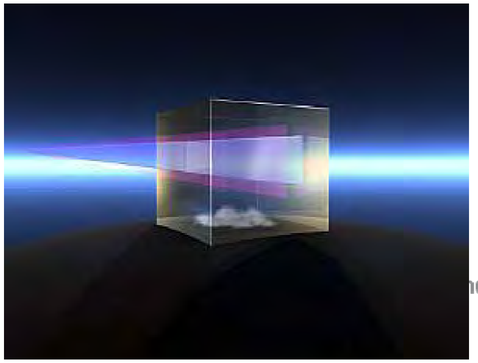
- **Status: Industrial Phase A system studies for the 3 missions are progressing well and have passed the stage of the Prel. Concept Review**

BIOMASS: single satellite carrying a P-band SAR **to provide continuous global interferometric and polarimetric radar observations of forested areas.**





- **CoReH2O / Snow mission:** single satellite with dual frequency (X, Ku), dual-polarisation SAR **to observe snow / ice at high spatial resolution**



- **PREMIER: 3D fields of atmospheric composition in upper troposphere and lower stratosphere with** an infrared limb-imaging spectrometer and a mm-wave limb-sounder.

Discussion on present CII power requirements

All power feeds characteristics (normal, abnormal, transients, over and undervoltage conditions, etc) need to be harmonised (enveloped?) after agreements on reference mission assumptions and battery interface definition.

Power feeds and redundancies:

- The present understanding after the telecon held on March 11th, 2011 is that:
  - There are two power feeds to the instrument (main and redundant) plus another power feed for instrument heaters
  - There is a common power feed return according to Distributed Single Point Grounding scheme

Additional ESA requirements to CII document

Capability to interface a Latching Current Limiter (LCL), in addition to a fuse

- More specifically, require that the instrument input filter can be charged completely at power up when connected to a current limited source (the LCL) well within the relevant trip off time (usually 50% margin is applied)

EMC requirements (CE, CS, RE, RS, time and frequency domain) to meet usual platform specification

- Driven by platform needs
- CII to comply with it
- To be specified by ESA and NASA
- To be discussed to get a common baseline

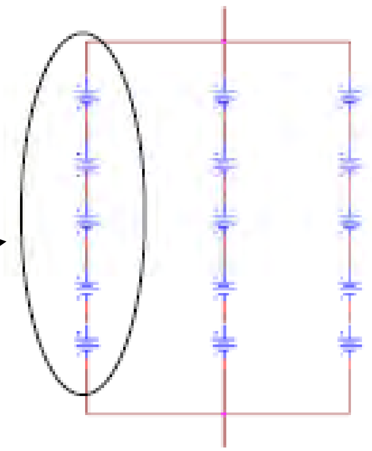
Reference standard is ECSS-E-ST-20-C (Electrical and Electronic, 31-July-2008).

CE: Conducted Emission
CS: Conducted Susceptibility
RE: Radiated Emission
RS: Radiate Susceptibility

Battery, detail on cell assembly

Cells mounted in series to build up voltage output.

Cells/strings mounted in parallel to fit the energy/capacity requireme



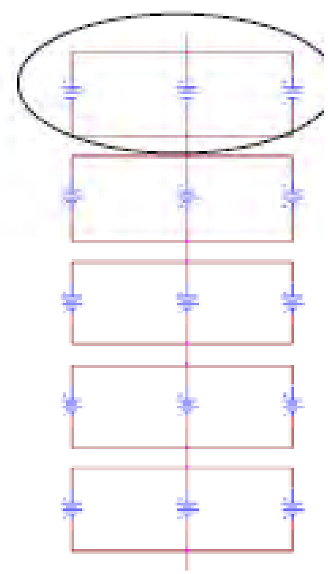
Redundancy Approach: A cell might fail open or short

Small cells approach:

- Individual cell overcurrent/overcharge protections
- Strings in parallel without interconnections.
- Cells matched & battery charge management done at battery level
- One additional spare string for tolerance to the failure of any cell

Large cells approach:

- Cells in parallel interconnected
- Individual charge management/balancing capability for each group of cells in parallel
- By-pass protection for each group of parallel cells
- One additional group of cells in series for tolerance to the failure of any cell



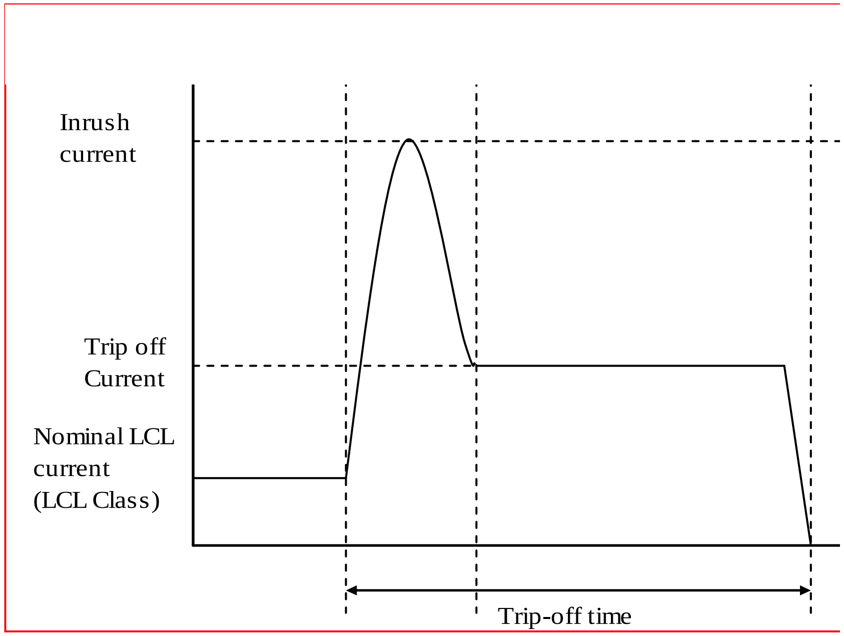
Distribution by Latching Current Limiters (LCLs)

➢**Latching Current Limiters**

The **LCL** is a solid state switch provided with **current limitation** (from a fraction of an Amp to several Amps).

It normally works in saturated mode (e.g. it presents a **small resistance in series** with the load current). The voltage drop is kept typically within 0.2-0.3V maximum.

In case of an overload on the line, the current limitation feature enters quickly into action, and the line is opened if the **overload duration** exceeds the **trip off time** (some ms to tens of ms). The LCLs are usually protecting the ***non essential loads*** (CII case).



➢ Bus (battery) protection by LCLs is very different from protection by fuses:

- on overload or load failures,
  - LCLs can be reset by telecommand, fuses shall be replaced;
  - There is no main bus voltage "hole" due to fuse clearance.

Available SpaceWire technology in ESA (1)

Standards

ECSS-E-ST-50-12C: SpaceWire – Links, nodes, routers and networks
ECSS-E-ST-50-51C: SpaceWire protocol identification
ECSS-E-ST-50-52C: SpaceWire - Remote memory access protocol (RMAP)
ECSS-E-ST-50-53C: SpaceWire - CCSDS packet transfer protocol

IP Cores

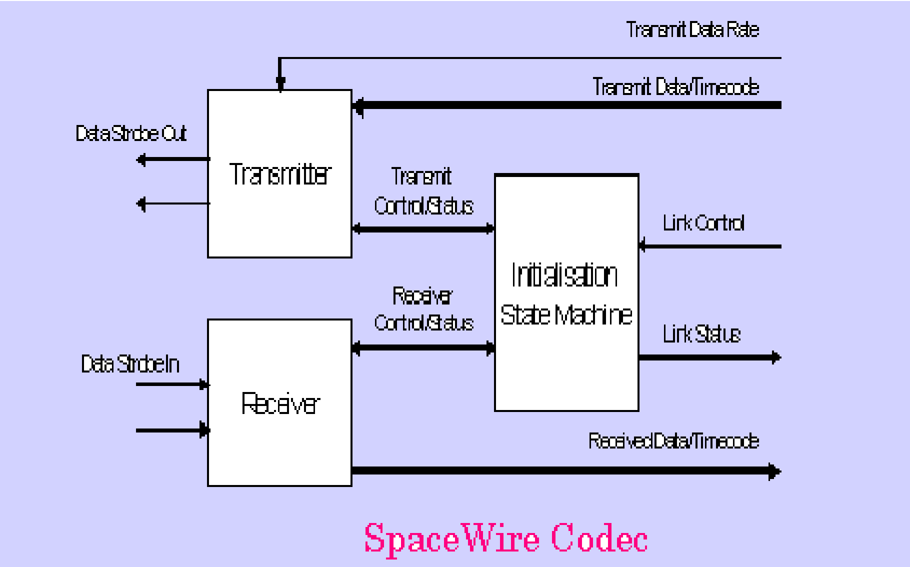
SpW Codec IP Core – available to ESA projects
RMAP IP Core

Components

AT910E: SpW-10X SpaceWire Router
AT911E: SpW-SMCS332 Triple SpaceWire Links High Speed Controller
AT913E: SpW-RTC SpaceWire Remote Terminal Controller

See ATMEL web site for datasheets and TNs
http://www.atmel.com/dyn/products/devices.asp?category_id=172&family_id=641&subfamily_id=787&source=left_nav

Available SpaceWire technology in ESA (2)



SpW Coder-Decoder (SpW-CoDec)

– Encodes and decodes bit-stream on physical medium, SpaceWire cable.

– Part of the data-link layer for SpaceWire systems to communicate

– Implemented in RTL level VHDL code.

– Compliant with ECSS-50-12A SpaceWire standard

<u>Goals of the IP code development</u>

– Technology independent

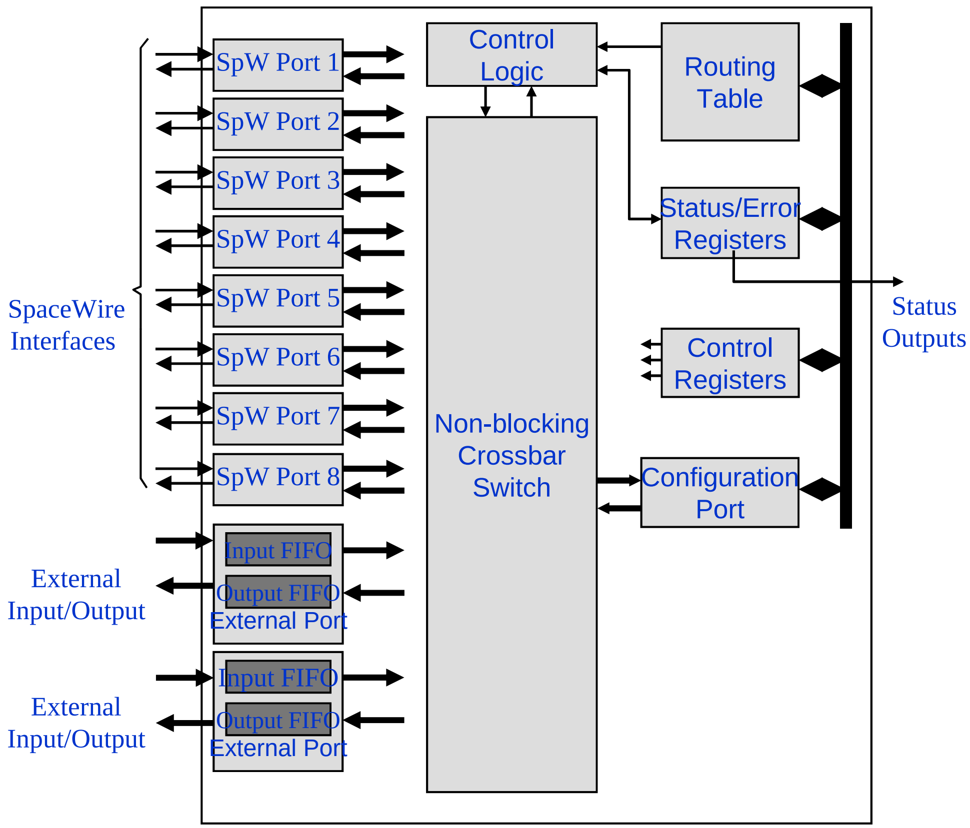
– Configurability to users requirements and target technology

– Facilitates <u>**compatibility**</u> between components

– Availability: The CoDec VHDL core is freely available for ESA Projects.

http://www.atmel.com/dyn/products/devices.asp?category_id=172&family_id=641&subfamily_id=787&source=left_nav

Available SpaceWire technology in ESA (3)



SpW-10X
(available from ATMEL)

ASIC
Implementation in Atmel MH1RT gate array
Max gate count 519 kgates (typical)
0.35 µm CMOS process

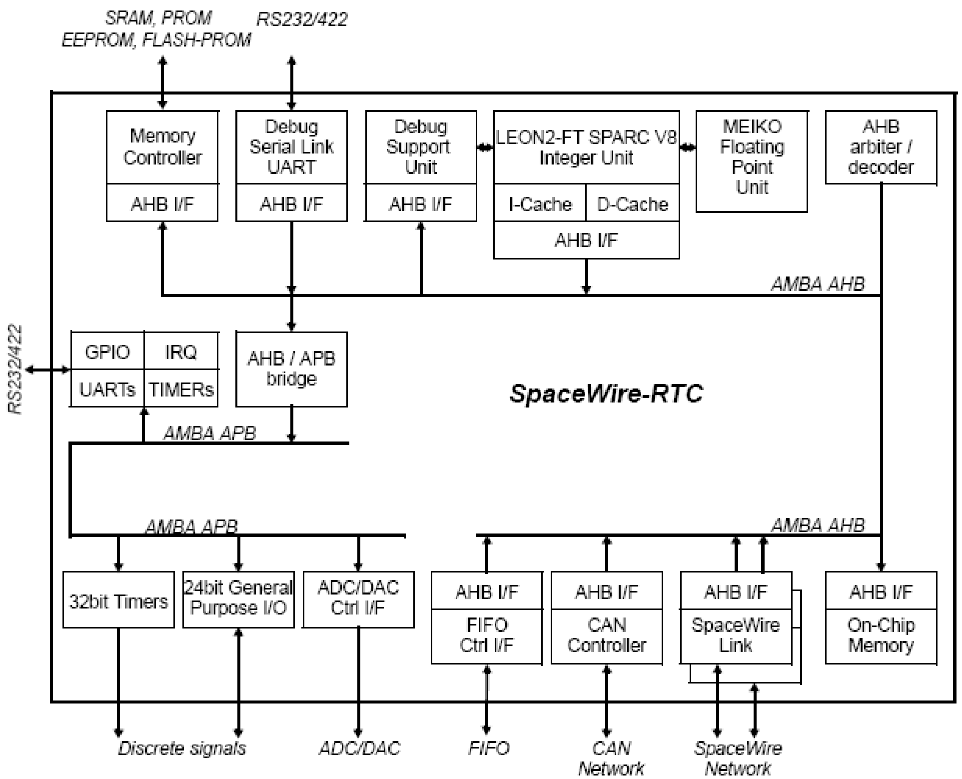
Radiation tolerance
Up to 300 krad
SEU free cells to 100 MeV
Used for all critical memory cells
Latch-up immunity to 100 Mev

Performance
SpaceWire interface baud-rate 200 Mbits/s
LVDS drivers/receivers integrated on-chip

Power
4 W power with all links at maximum data rate
Single 3.3 V supply voltage

Package
196 pin ceramic Quad Flat Pack 25 mil pin spacing

Available SpaceWire technology in ESA (4)



SpaceWire Remote Terminal Controller (RTC) block diagram

SpW-RTC
(available from ATMEL)

ASIC
- Implementation in Atmel MG2RT gate array
- Max gate count 480 kgates (max technology)
- 0.5 µm CMOS process

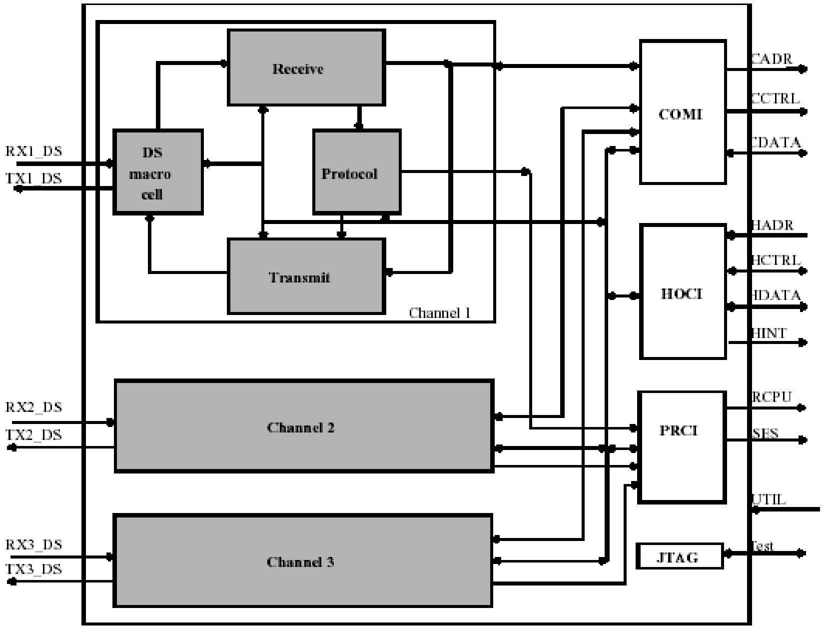
Radiation tolerance
- Up to 100 kRad
- SEU free cells to 100 MeV
- Used for all memory cells
- Latch-up immunity to 70 Mev

Performance
- SpaceWire interface baud-rate 200 Mbits/s

Power
- max 190mA at 5.5V at maximum data rate
- 5 V and 3.3 V supply voltage

Package
- 196 pin ceramic Quad Flat Pack 25 mil pin spacing

Available SpaceWire technology in ESA (5)



SpW-SMCS332

(available from ATMEL)

ASIC
- Implementation in Atmel MG2RT gate array
- Max gate count 480 kgates (max technology)
- 0.5 µm CMOS process

Radiation tolerance
- Up to 100 kRad
- SEU free cells to 100 MeV
- Used for all memory cells
- Latch-up immunity to 70 Mev

Performance
- SpaceWire interface baud-rate 200 Mbits/s

Power
- max 190mA at 5.5V at maximum data rate
- 5 V and 3.3 V supply voltage

Package
- 196 pin ceramic Quad Flat Pack 25 mil pin spacing