Command & Control Interfaces: Status quo and medium/long term evolution (Earth Observation views)

Avionics, Data, Control and Software Systems (ADCSS)

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(17-Oct-2018)

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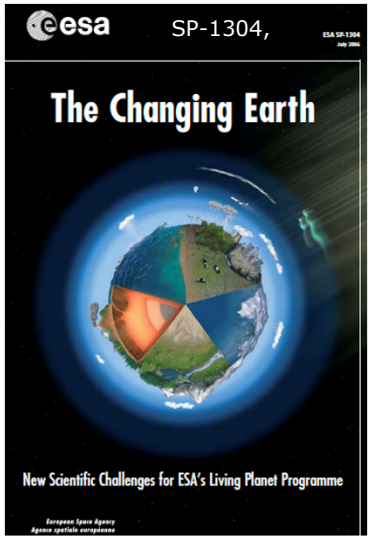
Living Planet Programme



ESA develops world-class EO systems to address

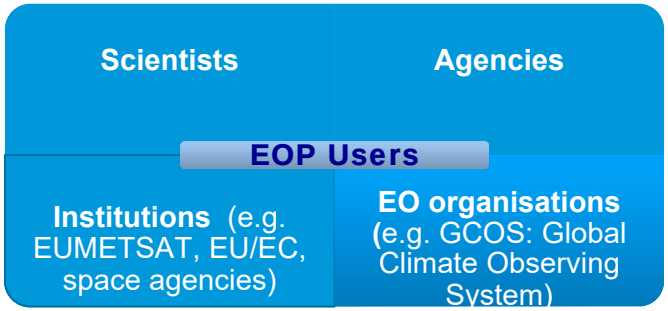
- the **scientific challenges** identified in the **Living Planet Programme** (SP-1304)
- other societal challenges, particularly with European + global partners.

LIVING PLANET: **user driven** + with wide-ranging innovations. Two broad lines:

- **Research missions** :research driven + demonstrate new EO techniques. Its main part: Earth Explorers (EE)
- **Earth Watch missions** driven by operational services + developed with/for partners
  - EUMETSAT for meteorology
  - EU for the Copernicus programme.

Successful paradigm of **end-to-end** mission-orientated innovation

i.e. : science + mission concept +technology



ESA EO: the initial view..

Living Planet
(SP-1304)

Colour Code:
Launched
To be launched

Earth Explorer

Research driven

Core Missions


GOCE
2009-2013


Aeolus
Aug-2018


EarthCARE
2021


Biomass
(EE7) 2022

Opportunity


CryoSat-2
8 April 10


SMOS
2 Nov 09


Swarm
22 Nov 13

Fast Track


FLEX (EE8)
2022

Call EE9 –
Selected for Ph. A
FORUM
SKIM

Call EE10 –
Phase 0
STEREOID
Daedalus
G-Class:H2O

Initiating discussion
with NASA's
(Decadal Survey)

NGGM

Earth Watch

Operational Service driven
In partnership

Meteorology


Meteosat


MSG - GEO
(1 s/c x 4)

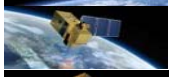

MetOp
(1 s/c x 3)


MTG - GEO
(2 s/c x 3)


MetOp SG
(2 s/c x 3)

Copernicus


Sentinel 1 A/B/C/D


Sentinel 2 A/B/C/D


Sentinel 3 A/B/C/D


Sentinel 4 (on MTG)


Sentinel 5 precursor


Sentinel 5 (on MetOp SG)


Sentinel 6 (Jason)

Copernicus Space Component Evolution:
CO2M, LSTM, PICE, CIMR, CHIME, ROSE-L
Sentinel-1/2/3 NG

EO Technology needs

- **Higher performance / cost ratio**
  - Higher spatial and temporal resolution
  - Higher lifetime (7 yrs → 10 yrs or more)
  - **Increased flexibility** (advanced manufacturing, **re-programmable onboard, COTS**)
  - Long-term continuity of data → BIG DATA
  - **Platform**
    - Stronger performance than Telecom (e.g. AOCS, OB data storage, multi-Gb/s comms)
    - **Lower recurring cost → support standardisation + modular approach + digitisation**
- **Miniaturisation and constellations** (incl. convoys and formations)
  - More autonomous operations (like Telecom and NAV)
  - Distributed Ground Segment
  - Synchronisation (with ISL beacon and/or with GNSS)
  - Launcher techno for efficient access to space
  - lower cost, fast-to-market ability, adaptability and flexibility.

Mainly, but NOT LIMITED to LEO: also High-Elliptic (HEO) and GSO (e.g. G-Class EE-10).

Specifically to Data Handling and Next Generation EO

HIGHER DATA RATES

- **X-band uplink** (7.190 - 7250 GHz) ➔ **2 Mb/s TT&C** (> 10x than in S-band)
  - Needed for Copernicus convoy / fleet ➔ less G/S to command them
  - Affects all O/B comms from SMU (OBC + TTC) to the rest of the satellite
    - 1553 / CAN (1 Mb/s) - SpW (multi Gb/s, but not deterministic)
- **K-band downlink** (25.5 to 27 GHz) ➔ **3 Gb/s** (one channel) ➔ **up to > 10 Gb/s** (dual pol, 2 channels x pol.)
  - Needed for example in:
    - Copernicus (e.g. CO2M spectrometer, Hyperspectral CHIME, ROSE-L band SAR, S1-NG, S2-NG)
    - EE-10 (e.g. Bi-static SAR – passive companions of Sent.1)
  - Variable Coding + Modulation (VCM) → variable rates (constant within the CCSDS frame)
    - from QPSK to 64-APSK → allows flexibility wrt atmospheric conditions
    - Extension to ACM (A=Adaptive) → real-time TC uplink needed to close the loop
    - Details at Appendix-G of https://www.ioag.org/Public%20Documents/2016-11-18_LEO26SG_Final.pdf
  - Affects Solid State Mass Memories

HIGHER FUNCTIONALITY / RELIABILITY

- PUS + CFDP → and perhaps CCSDS DTN (due to K-band sensitivity to atmospheric conditions and use of multiple G/S)

LOWER COST (per platform → opening to constellations) :

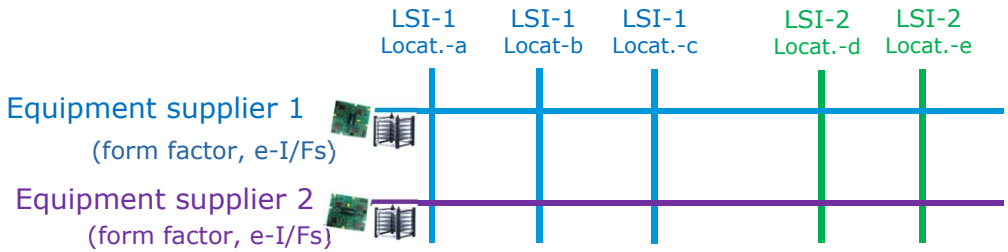
- **standardisation + modular approach + digitisation**
- fast-to-market ability, adaptability and flexibility (re-programmable OB , COTS)

Optimise Standard Platform → more resources for the Payload

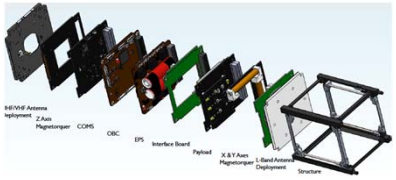
Platform Needs:

- Architecture evolution
  - Miniaturisation (units→ boards → components)
  - more Integration (AIT) → potential savings
  - Digital Interfaces : shifting intelligence-location & less cables
  - Higher performance (2 Mb/s) + functionality (e.g. CFDP)

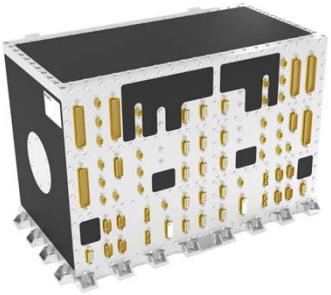
- Standardisation:
  - Common interfaces (electrical & mechanical form-factor)
  - Multi-source suppliers :
    - ✓ interchangeable modules
    - ✓ newcomers (incl. COTS)



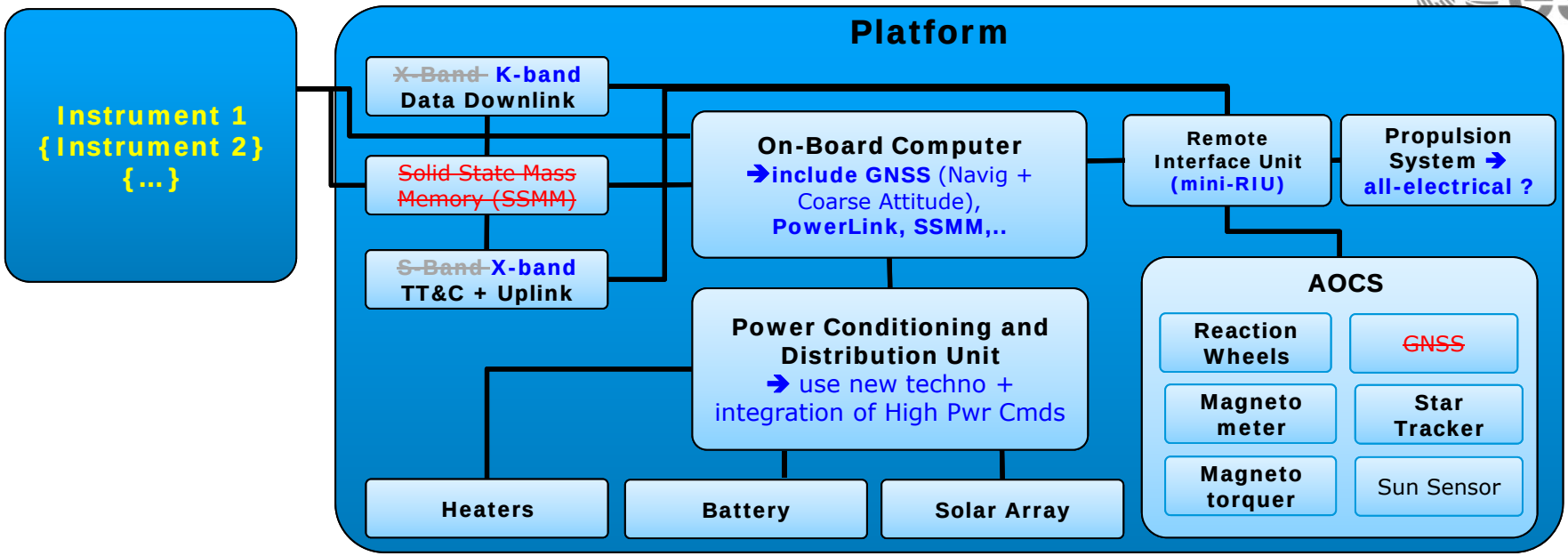
Standardisation done for Cubesats → big success



Multi-board SMU:
OBC, GNSS, SSMM, mini-RIU



Possible Architecture evolution



Avionics architecture evolution:

- Higher frequencies Comms (more BW & data) & higher speed and more digital I/Fs
  - 2 Mb/s TT&C in X-band ➔ useful for convoys like multi-Sentinel(s) : less G/S to command them
- digitize / standardize discrete interfaces ➔ simplify RIU & harness ➔ reduce mass/volume
  - PowerLink could be the solution (also enabler for decentralize intelligence)
- Integrate more (e.g. GNSS and/or Mass Memories in OBC) ➔ less AIT
- Impact of COTS

EO activities

EOEP-5 funding **System studies** → **Roadmap for standardisation :**

- 3 x 2 M€ studies : EO Standard Platform for Copernicus

- 2 x 400 k€ studies : Data Handling Roadmap

but

- **GSTP** should (co-) fund the **Module Developments**
  (e.g. GNSS Rx board)

Standard EO Platform study

- Budget : 2 M€ x 3 parallel contracts (1 Airbus + 1 OHB + 1 TAS)
  - Negotiations in Oct. 2018 - completion in Dec. 2019
  - Includes a provision of 300 k€ in each contract for equipment suppliers

- **Focus only on Copernicus Evolution** (not NewSpace or EarthExplorer)
  - complementing the 6 High Priority Candidate Missions that started Ph. A in 2Q-2018 (i.e. CO, LSMT, CMIR, P-ICE, CHIME, ROSE-L) and will be completed end-2019.
  - Sentinel 1,2,3 Next Generation also considered

- Broader scope than the Data Handling Roadmap (in next slide):
  - Avionics commonalities (only for the above Copernicus Evolut.) – this part complements the DH Roadmap
  - Debris mitigation
  - Standardisation of space to ground interfaces, including
    - X-band TT& @ 2 Mb/s + K-band data downlink @ multi Gb/s
    - Protocols : e.g. PUS, CFDP, questions on DTN, etc.
  - Payloads of opportunity
  - Others

Data Handling RoadMap for EO - activity

Definition / roadmap for an advanced Data Handling architecture for EO satellites -

- 400 k€ funded by EOP – KO in Oct-2018 - Duration 18 months duration
- 2 parallel contracts (to facilitate standardisation in a shared Workshop in Task-4)
  - with TAS : Ctrct 4000124947
  - With RUAG + Airbus : Ctrct 4000124946

- Scope:
  - **Standardise modularity** (boards, including all electrical and mechanical form factor)
  - Special focus on **SMU, RIU and SSMM** (and interfaces)
    - Considering 2 Mb/s TT&C ➔ only SpW seems to sustain it, but what about determinism ?
    - Protocols : PUS / CFDP / questions on DTN ?
    - multi Gb/s data downlink ➔ SSMM, SpFi equivalent Interfaces
    - Central vs decentralised intelligence (with microprocessor in nodes & digitised I/Fs like PowerLink)
  - **Roadmap** for future developments (e.g. OBC board, TT&C board, GNSS board, Mass Memory board)

Two development examples

Integration of more functions under SMU (funded under EOEP)

PowerLink (co-funded EOEP + TRP)

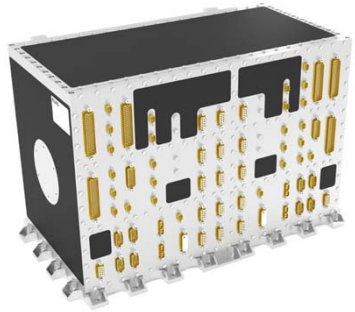
C2SMU - activity completed in 2Q-2018

C2SMU : Complex S/C Management Unit

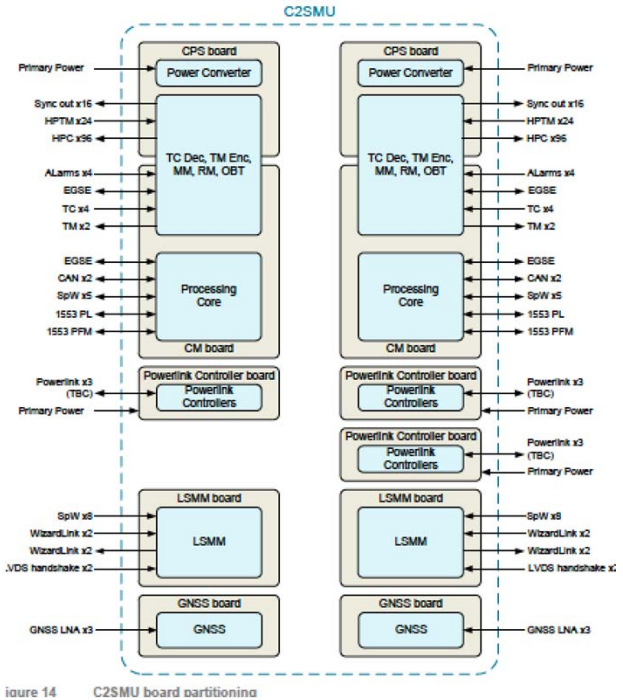
250 k€ funded by EOEP-5 (ESA Ctrct 4000112458) with RUAG SE

Scope:

- Assess integration of multiple developments:
  - OBC with Creole ASIC done under GSTP – by RUAG-Sweden
  - GNSS (AGGA-4 based) board from RUAG-A
  - Large Mass Memory (multi-source possible)
  - PowerLink concept
- Prepare a development roadmap



Extract from Final Report



igure 14 C2SMU board partitioning

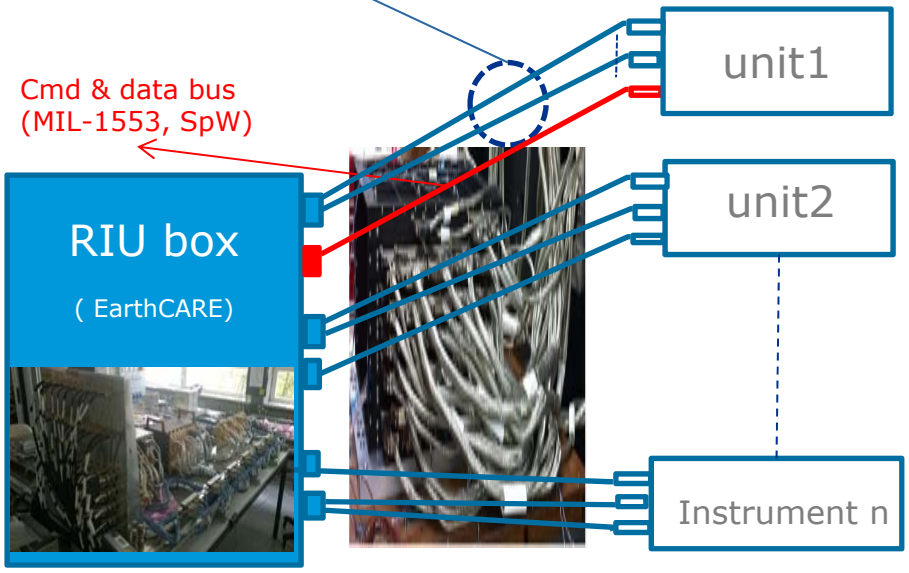
PowerLink: digitisation of discrete interfaces ➔ reduction of RIU

ADCSS Workshop Wedn. 14-Oct-2017 at 14:45)
https://indico.esa.int/indico/event/182/other-view?view=standard

Today

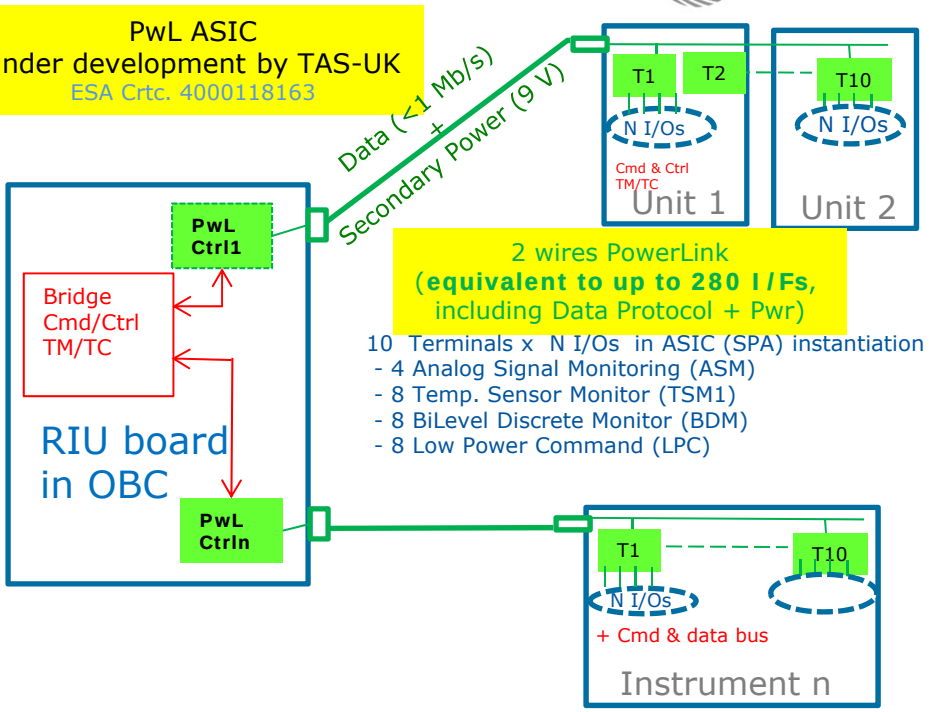
N Input/Output terfaces
(ECSS-E-ST-50-14C: ASM,TSM,BDM,
BSM,ISD,OSD,BSD,SDI : up to 8 ≠ types of sensor/actuator interfaces)

Cmd & data bus
(MIL-1553, SpW)



Present Status: centralised architecture with **bulky and heavy harness**

PwL ASIC
under development by TAS-UK
ESA Crtc. 4000118163



2 wires PowerLink
(**equivalent to up to 280 I/Fs**,
including Data Protocol + Pwr)

10 Terminals x N I/Os in ASIC (SPA) instantiation
- 4 Analog Signal Monitoring (ASM)
- 8 Temp. Sensor Monitor (TSM1)
- 8 BiLevel Discrete Monitor (BDM)
- 8 Low Power Command (LPC)

Future: Decentralised Architecture with
light two-wire PowerLink harness

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Conclusion

EARTH OBSERVATION :

- TECHNOLOGY NEEDS: Higher performance / cost ratio + Opening up to constellations (Space 4.0)

EOP & DATA HANDLING

- Higher data rates : **2 Mb/s (X-band TT&C)** + multi-Gb/s (K-band downlink)
  - Implications in the OB Data Handling too (e.g. SpW deterministic or faster Bus)
- Higher functionality / reliability → higher protocols (PUS, CFDP, DTN)
- Lower Cost → modular approach (miniaturisation, digitisation of interfaces,) where possible
  - Architectural evolution (further integration, digitisation of I/Fs, (de-)centralised intelligence)
  - Standardisation (e-I/Fs + form factor) of modules ➔ multi-suppliers + anticipation of AIT

- On-going System studies in 2019 to build up Roadmap ➔
  - 3 parallel studies (Standard EO Platform) - under Copernicus
  - 2 parallel studies (Data Handling Roadmap) - to enforce the DH standardisation (incl. workshop in 2019)

  ➔ Leading to development of modules in 2020+

THANK YOU

QUESTIONS ?

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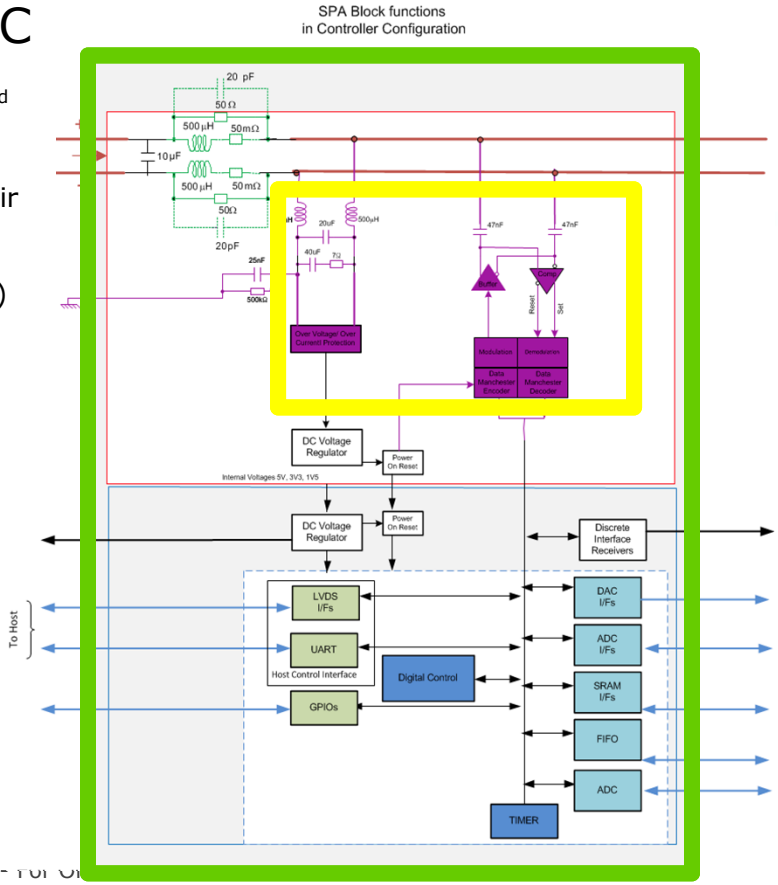
BACKUP slides

Two "building block" outputs of the Powerlink activity

SPA ASIC

(to be made available to 3rd parties by TAS-UK Under equal/fair conditions)

by 2021 (TBC)



Mixed Analog IP Core

(i.e. the part that ensures electrical compatibility)
Key to support future ECSS standardisation