BepiColombo Avionics:
First ESA Mission with On-Board SpW Network

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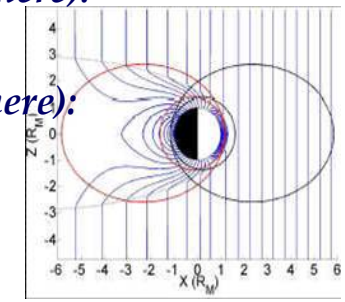
BepiColombo Mission

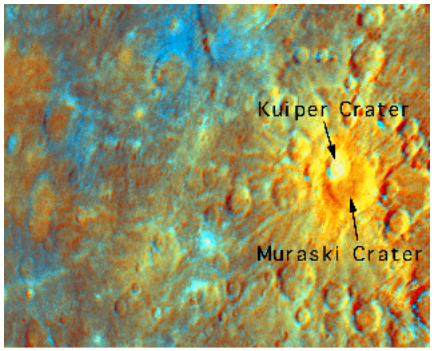
- *Mercury is the innermost Planet but not well known [only 45% of its surface has been seen in detail]*
- *Mercury is hard to observe from ground*
- *Mercury has not been visited since more than 30 years [last visit 1975; Mariner 10 fly-by; USA]*

SAG select **BepiColombo Mission :** Europe's first mission to Mercury

Science Objectives:

- **Study** *Origin and evolution of a planet close to the parent star*
- *Study Mercury as a planet: form, interior, structure, geology, composition and craters*
- *Investigate Mercury's vestigial atmosphere (exosphere): composition and dynamics*
- *Study Mercury's magnetized envelope (magnetosphere): structure and dynamics*
- *Investigate Origin of Mercury's magnetic field*
- *Confirm Einstein's theory of general relativity*

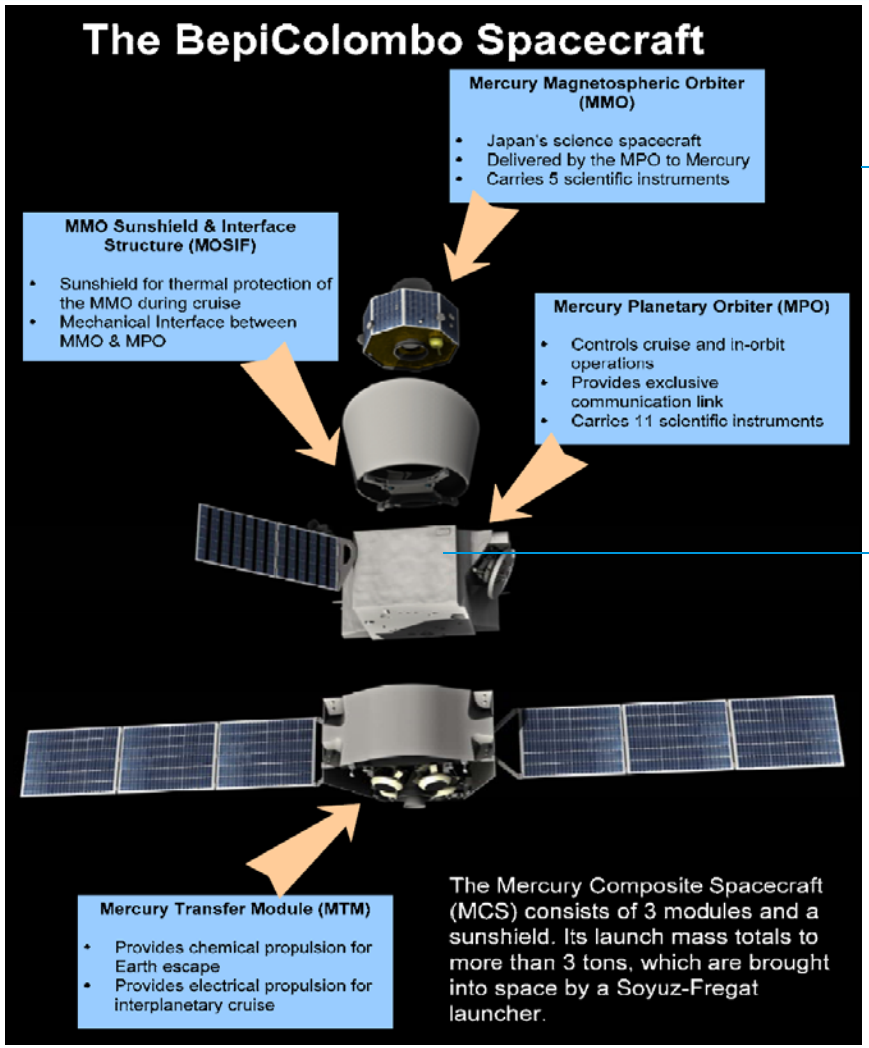




(Courtesy of Mark Robinson and Paul Lucey.)

NASA Messenger (arrival Mar 2011) mission is in orbit and providing science data

BepiColombo Mercury Composite Spacecraft



MMO JAXA Responsibility:

will study Mercury's magnetosphere

Mass: ***284.5Kg***

MPO ESA Responsibility

will study the surface and internal composition of the planet

Mass: ***1172.3 Kg***

Payload-$_{MPO}$

Mass: 60 Kg

BepiColombo Payload Composition

BepiColombo Science Objectives: 11 instruments

- ***SIXS*** — *Solar Intensity X-ray and particle Spectrometer*
- ***MIXS*** — *Mercury Imaging X-ray Spectrometer*
- ***SIMBIO-SYS*** *(HIRC, STC, VIHI)* — *Spectrometers and Imagers for MPO*
- ***BELA*** — *BepiColombo Laser Altimeter*
- ***ISA*** — *Italian Spring Accelerometer*
- ***MERMAG*** — *Magnetic Field Investigation*
- ***MGNS*** — *Mercury Gamma-Ray and Neutron Spectrometer*
- ***SERENA*** *(Elena, MIPA, PICAM)* — *Search for Exospheric Refilling and Emitted Natural Abundances*
- ***MORE*** — *Mercury Orbiter Radio Science Experiment*
- ***PHEBUS*** — *Probing of Hermean Exosphere by Ultraviolet Spectroscopy*
- ***MERTIS*** — *Mercury Radiometer and Thermal Imaging Spectrometer*

ESA Planetary missions

Bepi Colombo Payload: **11 instruments.** Mass allocation**: 60 Kg**

Mars Express Payload: **7 instruments**. Mass allocation: **191 Kg**

Rosettta Payload: **11 instruments**. Mass allocation: **276Kg**

BepiColombo Payload & Platform Design Challenge

		Mass [kg] Allocation	Power [W] Allocation	Science TM Rate Allocation
BELA	Laser Altimeter	12.0	39	100 Mbps
ISA	Radio Science Accelerometer	5.3	6	10 Mbps
MERMAG	Magnetometer	1.8	5	10 Mbps
MERTIS	IR Spectrometer	3.3	8	10 Mbps
MGNS	Gamma Ray and Neutron Spectrometer	5.2	4	10 Mbps
MIXS / SIXS	X-ray Spectrometer/ Solar Monitor	7.3 / 1.3	12 / 2	10 Mbps / 10 Mbps
MORE	Radio Science Ka-band Transponder	3.5	15	10 Mbps
PHEBUS	UV Spectrometer	6.6	4	10 Mbps
SERENA	Neutral Particle Analyser/ Ion Spectrometers	5.4	21	10 Mbps
SIMBIO-SYS	High Res.+ Stereo Cameras visual and NIR Spectrometer	8.3 60	23 140	10 Mbps

How to address the Payload design and interfaces with Platformc in order to support the stringent mass and power allocation resources

PayLoad & PlatForm **Building Blocks**:

- Payload Type of Interfaces: Mech, Therm, Power & *Data Handling & Synchronisation Interfaces*
- Payload Interfaces Avionics: *OBC via TM/TC, RIU via PPS, HK TM, SSMM via Science TM*
- Avionics *Communication Bus(ses)*

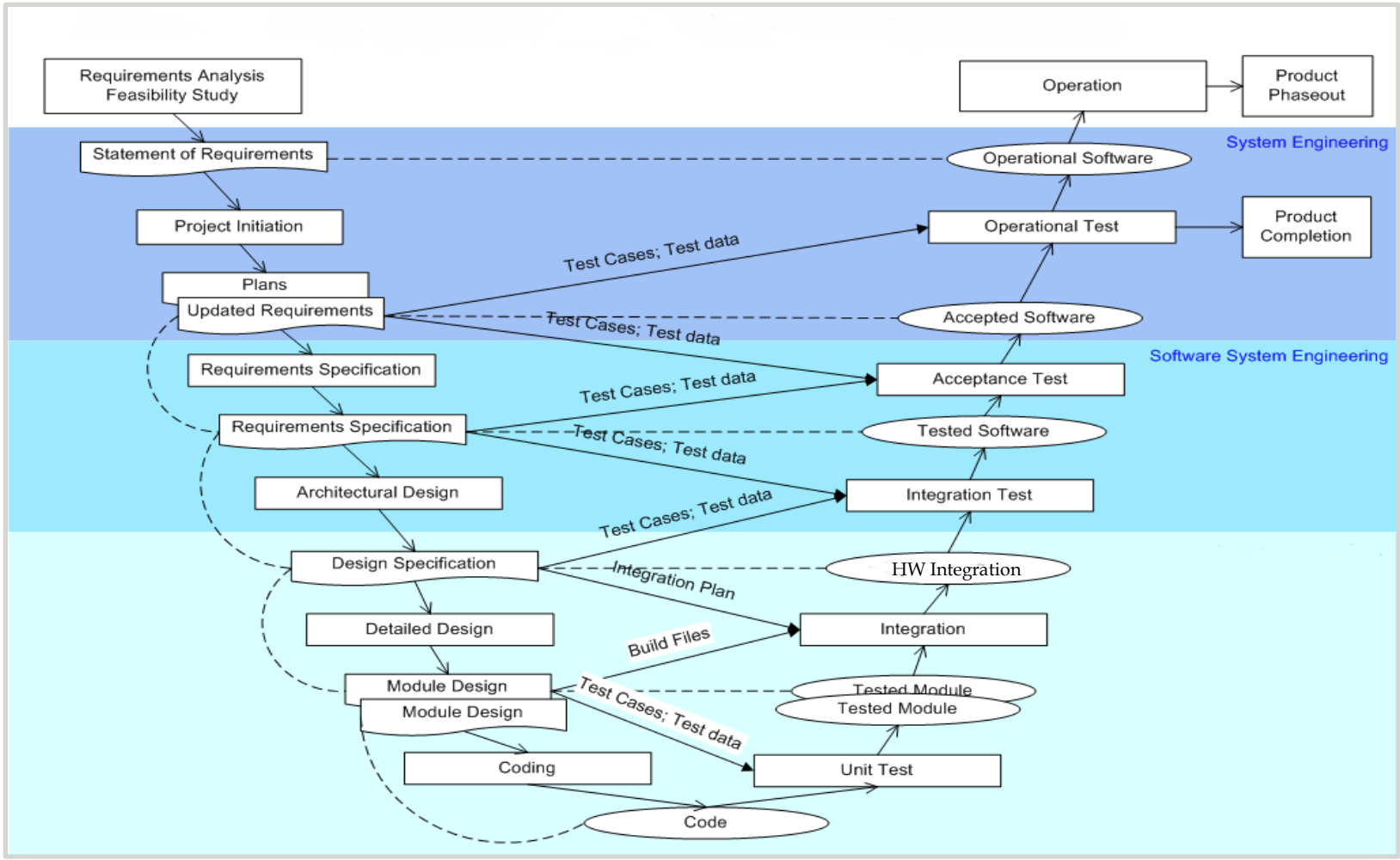
To face the challenge Bepi Colombo Avionics: 2-axes Strategy

1. V shape Development Process : ECSS-E-ST-10C
2. General Guidelines to Implement Bepi Colombo Avionics Architecture

General Guidelines:

1. Foster the usage lighter technology (mass allocation)
2. Foster the usage of less power consuming technology (power allocation)
3. Streamline the instruments interfaces for operations and monitoring
4. Use available qualified technology (Standards, Components, Core IPs, EGSEs)
5. Design Multi-missions Architecture: Use Scalable Architecture (Solar Orbiter mission)
6. Reduce the variety of Software drivers
7. Improve control over the implementation costs
8. Reduce the tests implementation costs (i.e. EGSEs variety)
9. …etc

V-Shape Development Process: ECSS-E-ST-10C



Payload - Platform *Communication Bus(ses)*

SpW, MIL-1553B & CAN

SpW Technology: is selected as a unique interface for TM/TC & PPS Interfaces

Guidelines	MIL-1553B + SpW + PPS	SpaceWire
Foster the usage of less power consuming technology	x	xxx
Foster the usage lighter technology	x	xxx
Use available qualified technology (Standards, Components, Core IPs, EGSEs)	xxx	xxx
Streamline the instruments interfaces for operations and monitoring	x	xxx
design Multi-missions Architecture: Use Scalablet Architecture (Solar Orbiter mission)	x	xxx
Reduce the variety of SW drivers	xx	xxx
Improve control over the implementation costs	xxx	x
Reduce the tests implementation costs	xx	xx

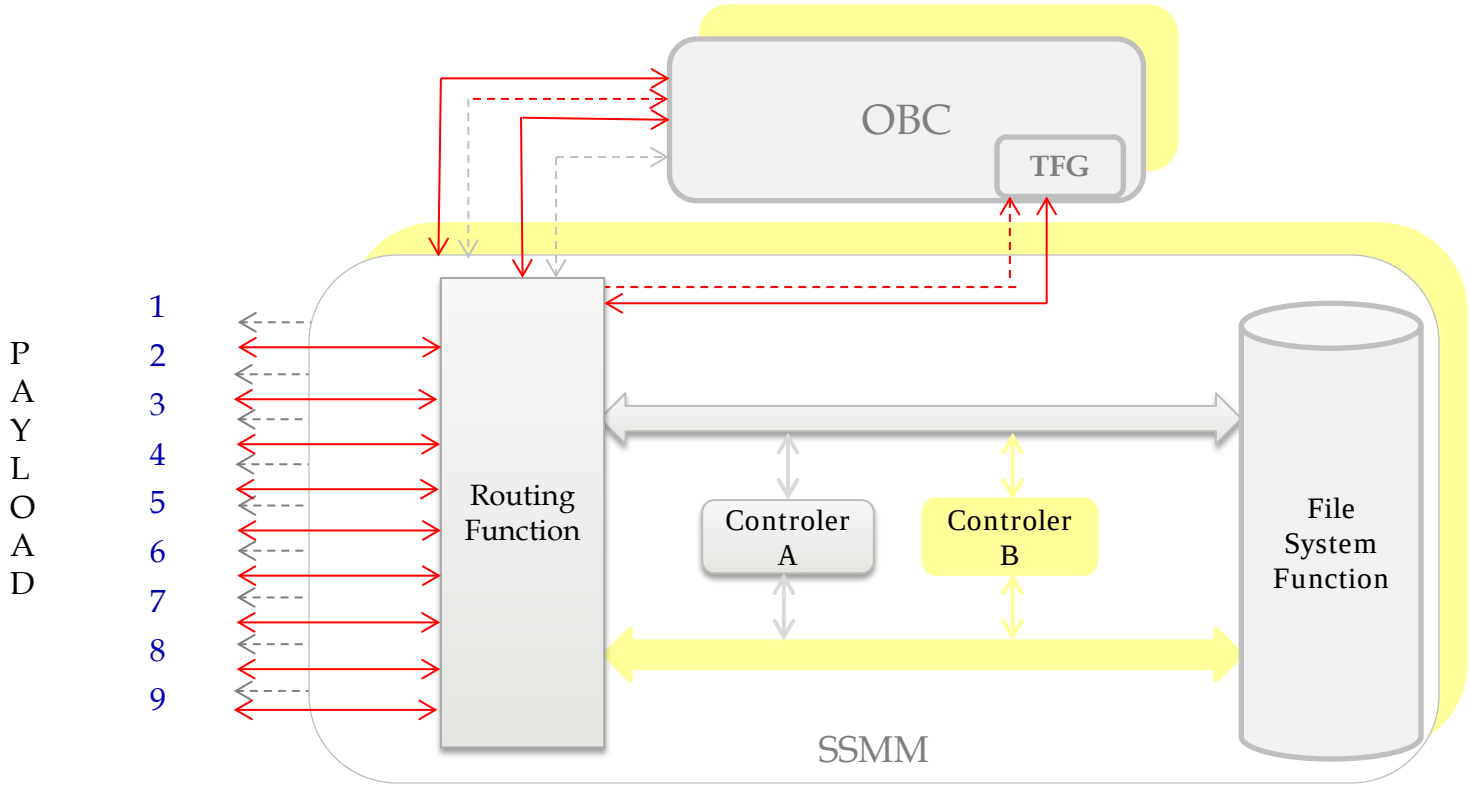
Avionics External SpW Interfaces Specification:
Data Rate: 100 Mbps
- **(A)** TM/TC : SpW/CCSDS Packet Transfer Protocol (ECSS-E-ST-50-53C)
- **(B)** Synchronisation: CUC protocol & PPS scheme SpW time-code based
- Initial SpW-Codec mode: Start on request

Payload External Interfaces Specification:
- Data rate: 10 Mbps (except BELA 100 Mbps)
- TM/TC : same as avionics protocol
- Synchronisation: same as avionics protocol
- Initial SpW-Codec mode: Auto-start for instrument
- **(C)** Data Storage before transmission: minimum buffer size specified

Specification related to points (A), (B) and (C) have been re-used in future ESA missions w.r.t BepiColombo
→ future ECSS standarts

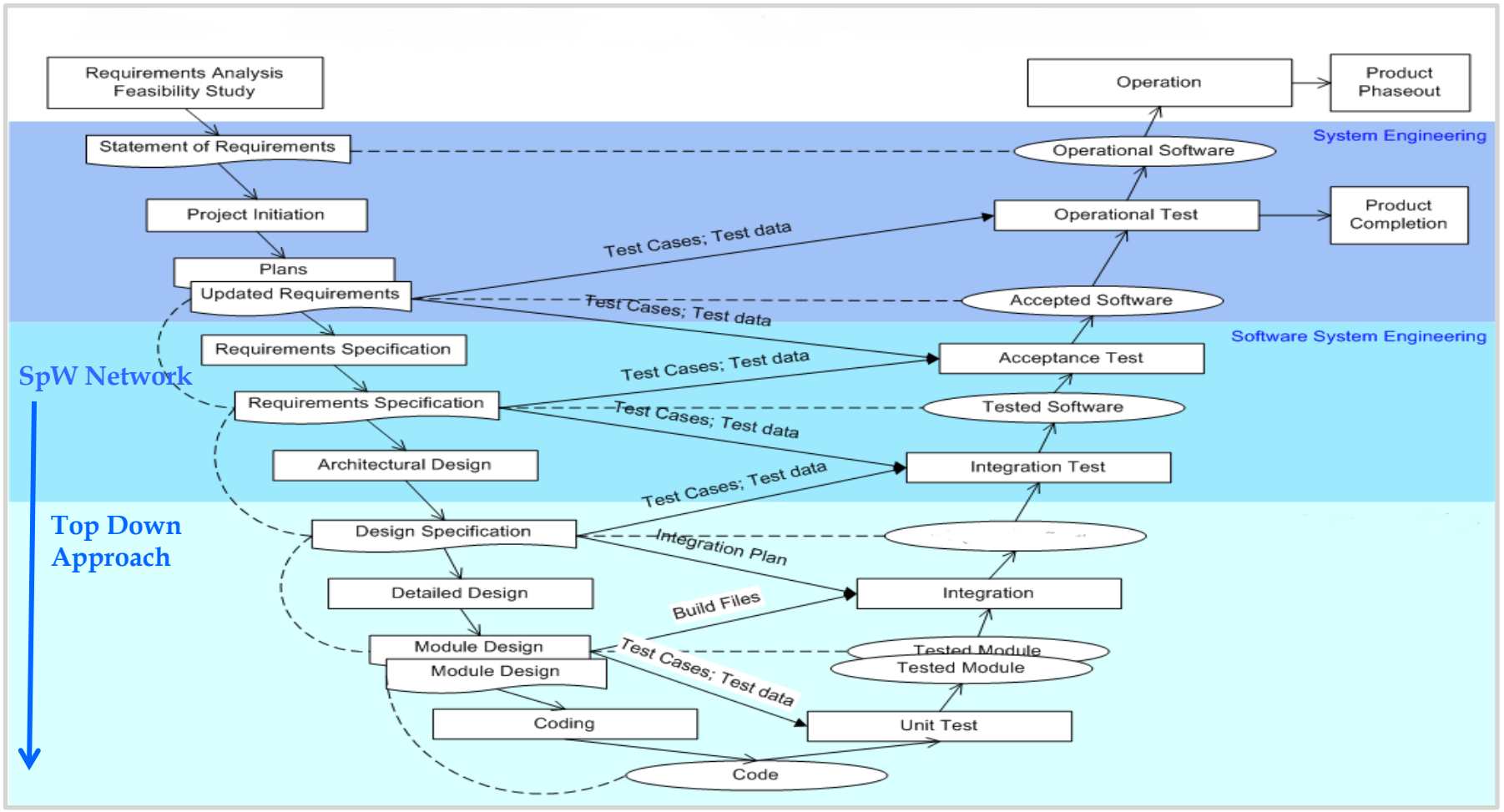
Authorised SpW Components:
- SpW-SMCS 332
- SpW-10X
- ESA IP core SpW Codec type B

BepiColombo Avionics Architecture

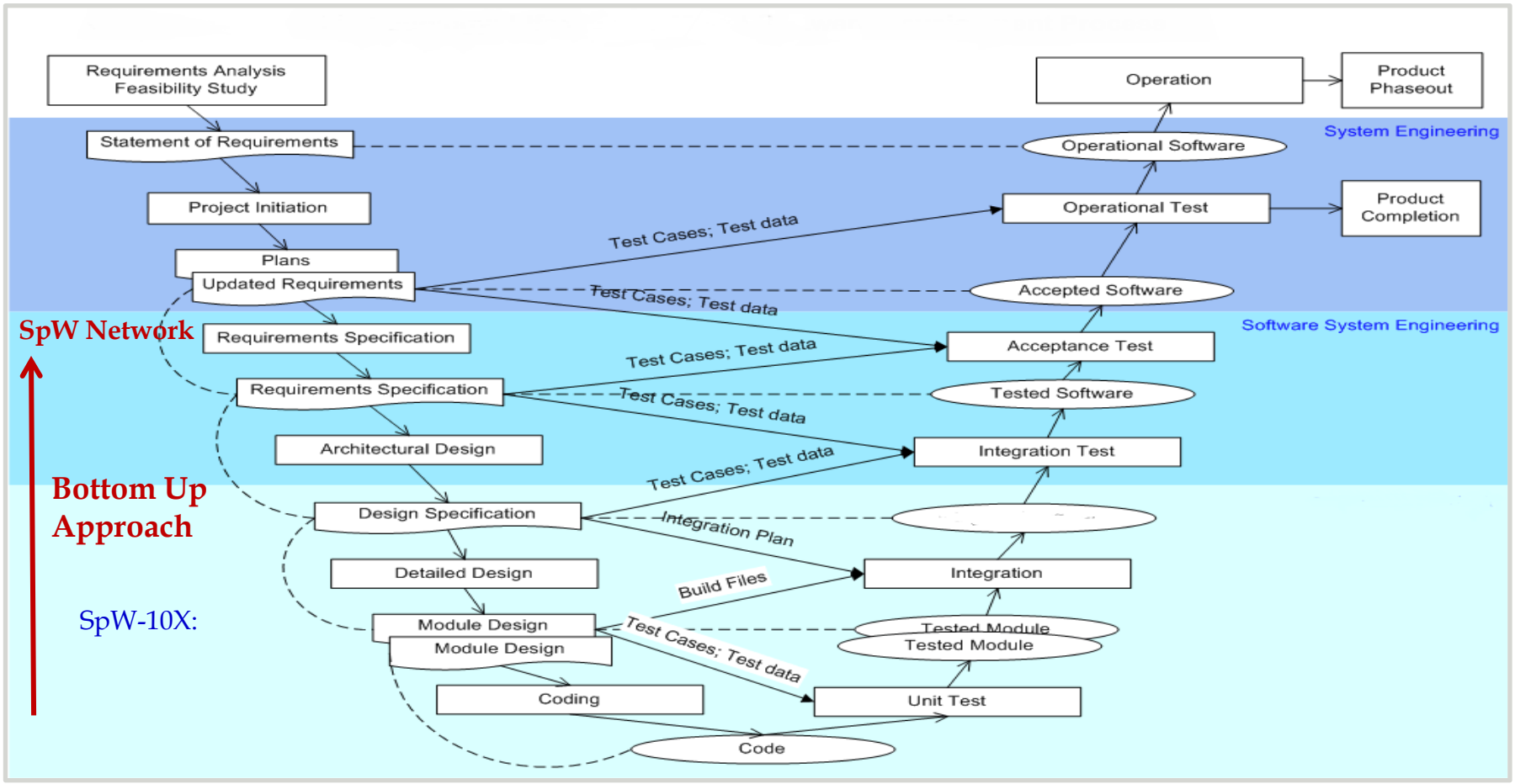


SpW Routing Function: SpW Network

BepiColombo SpW Network Specification



BepiColombo SpW-10X based Network Specification



⇒ Mixes 'bottom-up' and 'top-down' approaches ⇒ SpW Network Functions & Performances = F(SpW-10)

Lesson Learned 1

Pros:

- ✓ Mass and Power Requirement Compliance : Achieved
- ✓ Use available qualified technology: Achieved (Standards, Components, Core IPs, EGSEs)
- ✓ Streamline the instruments interfaces for operations and monitoring: Achieved (Sole SpW I/Fs type)
- ✓ Design Multi-missions Architecture: Achieved (Architecture can handle up to 12 instruments)
- ✓ Reduce the variety of Software drivers: Achieved (SpW Software drivers only)
- ✓ Standardized PUS TM/TC exchanges between Payload & Avionic Units: Achieved (ECSS-E-ST-50-53C)
- ✓ Independent & Concurrent developments of Payload & Avionic Units: Achieved

But streamline interfaces is not just a matter of mass / power optimisation

Lesson Learned 2

Cons :

1. Mixes 'bottom-up' and 'top-down' approaches very difficult
   a) Difficult agreement on SpW Network Implementation to achieve the instrument operations & monitoring
2. Missing SpW Network Specification:
   a. ECSS-E-ST-50-12C well specified up to data link layer but no SpW Network Specification
   b. In SpW Stds (ECSS-E-ST-50-12C, ECSS-E-ST-50-51C, 50-52C and 50-53C) are missing the specification of
   SpW network Configuration , Re-configuration in case of failures,
   SpW network FDIR (failure identification at HW and SW level))
   SpW network Monitoring function, SpW network Autonomy, SpW network Communication Services.
3. Missing SpW Physical Layer Specification:
   a. ECSS-E-ST-50-12C includes a physical layer description rather than a set verifiable requirements
   b. No SpW Handbook
4. SpW-10X common mode not compliant
5. ECSS-E-ST-50-12C terminology ambiguity
   a. e.g. auto-start, node
6. Misunderstanding of SpW standard: Link established vs link active,
7. Lack of experience of industry w.r.t SpW harness: cable & grounding (pollution of the low mass cable)
8. Inadequate monitoring function of SpW-10X: Polling the same register for 8 SpW links at 200Mhz!!!!
9. ..etc

Conclusion

Communication Network & Protocols

Set of Individual standards

Conclusion:

- **Specify an avionic communications system** as a collection of building blocks (communication networks, transmission systems, units, instruments) capable of interconnection and interoperation to form an integrated whole.
- The components of the avionics communications system shall serve a common purpose, are technically compatible, use common procedures, respond to controls, and operate in union.