ADCSS Conference, ESTEC
FDIR Experience at Airbus

Gunther Lautenschläger
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FDIR Introduction

- FDIR engineering is a **core spacecraft element** challenged during all project lifecycle.
- FDIR is **spread** over **spacecraft system** as well as over the various **subsystems** and **equipments**.
- FDIR is one of the **earliest** (e.g. in terms of redundancy concept) as well as one of the **latest** system engineering tasks and by this essential for the success of the project.
- FDIR solutions shall be **simple**, **in time** and **cost efficient**.

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FDIR Development Process

FDIR Goal

- Ensure spacecraft **safety**
  - Avoid **irreversible loss** of the **nominal mission** upon the occurrence of a failure

    e.g. critical sun exposure,
    overrate on thruster stuck open,
    complete battery depletion

- Optimise the mission **availability**
  - Minimise mission service **outages** due to anomaly management and to **continue** the **nominal mission**

    e.g. minimise entry into **Safe Mode** by local reconfiguration

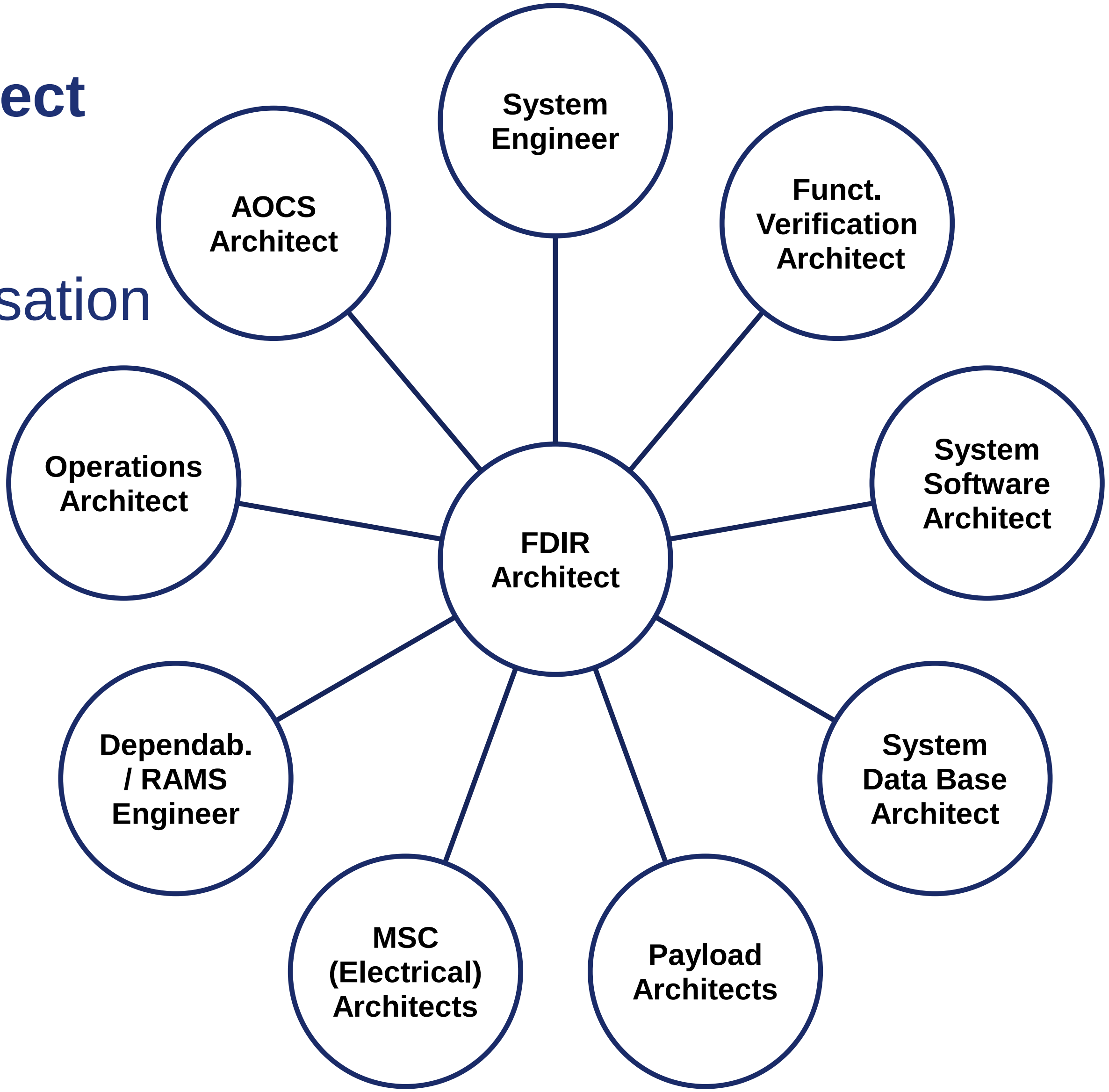
  - Minimise Ground Operations required after on-board FDIR

    e.g. **duration of CRP** to restore operational configuration
    to continue **nominal mission**

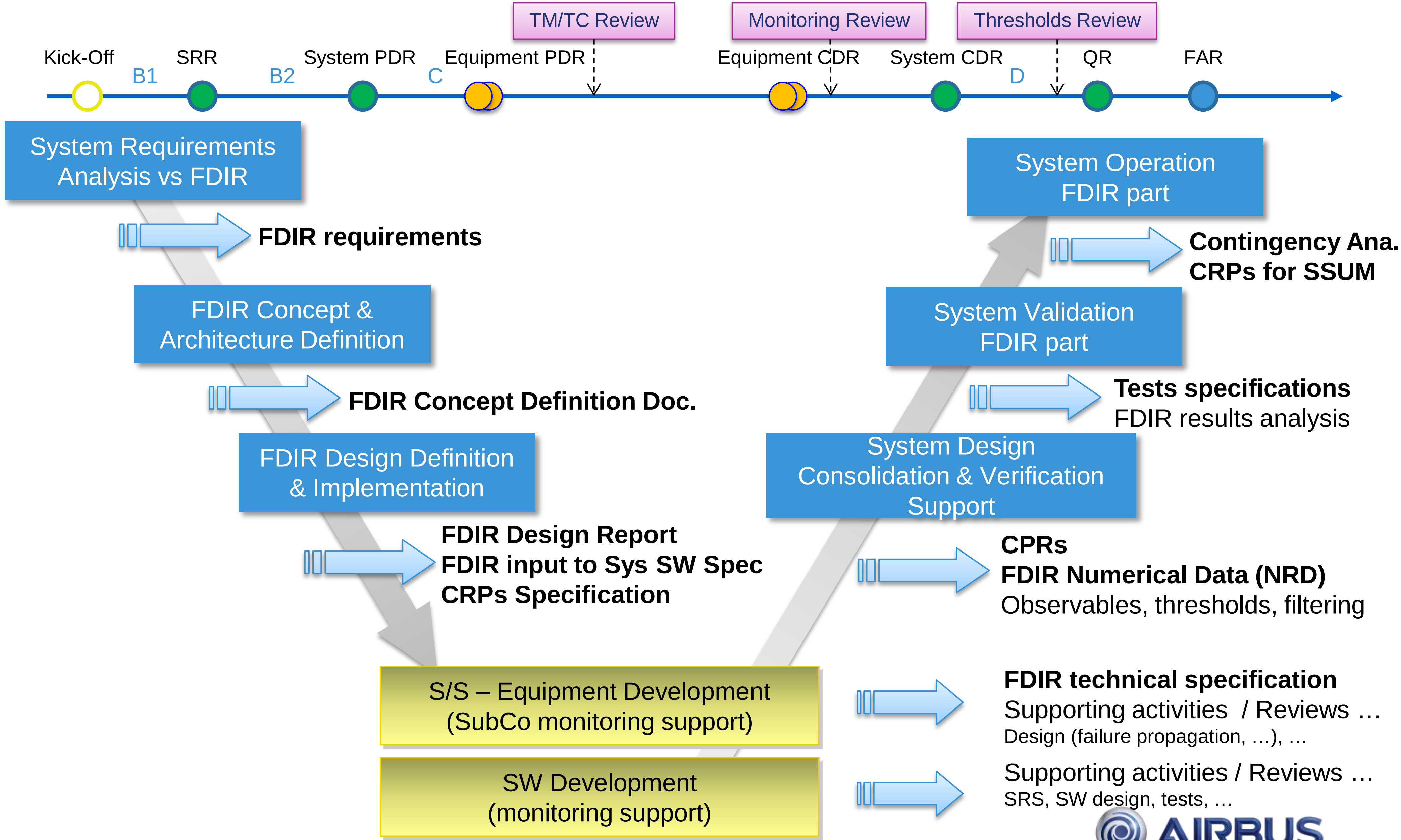
FDIR Development Process

Interfaces of the FDIR Architect

- Focus on **overall** S/C optimisation (not only one domain)
- FDIR **Co-Eng**ineering
- Engineering **loops** for **refinement** (but avoid costly iterations)



FDIR Development Process



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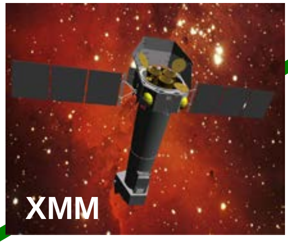
FDIR Related to Mission Classes

AVAILABILITY WEAK

RESET
+ Ground ACTION

AVAILABILITY LOW

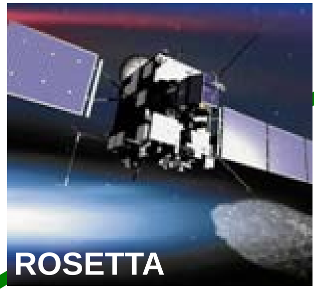


SAFE MODE
+ Ground ACTION

AVAILABILITY MEDIUM

BACK-UP MODE
+ Ground ACTION

AVAILABILITY HIGH per phase



Autonomy
Back-up MODES
SAFE/Survival MODE

AVAILABILITY Very HIGH

Autonomy, Hot-Redundant
Back-up MODES
SAFE/Survival Mode

The FDIR concept depends on the **mission class**.

FDIR complexity relates to the System **AVAILABILITY** requirements

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FDIR Main Stakes

The following main themes in the FDIR process were identified as stakes:

- Quality and phasing of the engineering effort
- Lack of a shared vision between project actors
- Lack of Standardisation & Design policies

FDIR Main Stakes

Quality and phasing of the engineering effort

- FDIR design spans across nearly all project phases and all spacecraft disciplines with a highly dynamic and an **iterative detailed design feedback**.
- Trace between system requirements and design solution is sometimes **too quick**
- FDIR **verification strategies and means** for dedicated test functions have to be defined early, including test cases, which are not testable on the flight model.

➔ Substantiate and justify **design choices** of system requirements, to **balance** design with validation effort

FDIR Main Stakes

Shared vision between project actors

- FDIR/Equipment design choices may not always be clearly substantiated / shared by other stakeholders
- Late S/C requirements changes impact FDIR design and consequently cause late FDIR requirement changes, which impact FDIR design, configuration and/or related software as well as the resulting V&V activities

➔ Co-Engineering between disciplines across the full development and V&V lifecycle with engineering loops for design refinement

FDIR Main Stakes

Lack of Standardization & Design policies

- The **variance** in the used Equipment's for the different spacecraft's requires for each project a **tailored FDIR** solution
- The different **operational command set** of each spacecraft to handle FDIR activities requires **individual FDIR** design solutions.

➔ A standardized equipment handling is key for a standardized FDIR design.

FDIR Main Stakes

Currently we are searching/selecting **key factors** to measure the FDIR complexity and related cost. The key factors may be searched in the following domains:

- Programmatic versus **industrial breakdown**
- Mission and system **requirements** like availability, reliability, autonomy and their **variability/constancy** w.r.t. predecessor mission
- Approach and **concurrency** of **FDIR definition/design** on System, Platform and Payload level
- Relation between **HW and SW** specific FDIR requirements
- Number of **modes** and **redundancy combinations**
- Number of **monitors** and **recoveries**

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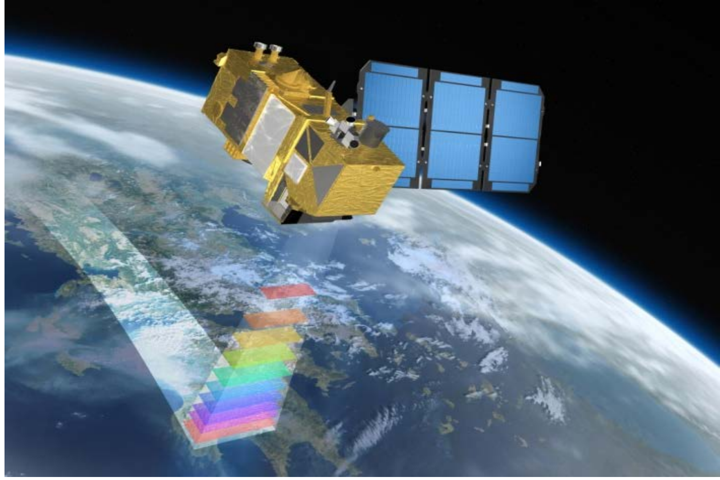

Example Sentinel-2

The Sentinel-2 Ops & FDIR design:

- **Standardized Telemetry**
  The Spacecraft Configuration Vector (SCV) reflects the status of all S/C equipment per unit:
  - Operational status ("operational"; "non-operational")
  - Health status ("healthy"; "not healthy")
  - TM acquisition ("active"; "inactive") => key element for equipment monitoring

  ➔ Advantage: The validity of unit related TM can be derived directly from the SCV and by this activate the related FDIR monitoring.

- **TCs** with **standardized equipment** setup functions,
  which configure each equipment (set of units) to the requested operational status by a standardized TC I/F and related TM feedback via SCV.
  (e.g. one TC to select 3 out of 4 reaction wheels
  with exclusion of the failed unit "not healthy").

  ➔Advantage: Maintains the validity of the full functional chain of the equipment

  ➔Advantage: Simplifies the recovery (only a few simple TCs needed)

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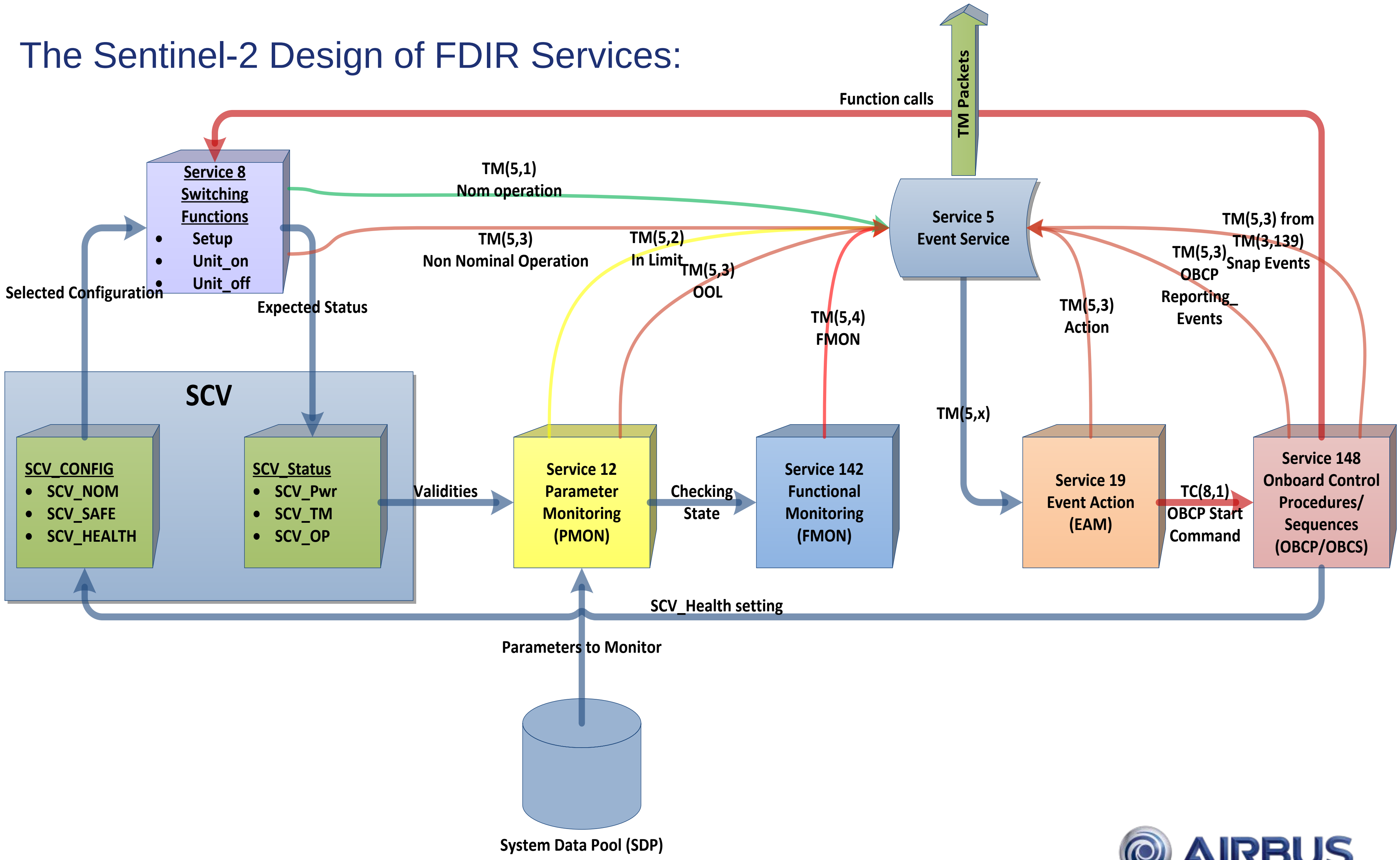
Example Sentinel-2

The Sentinel-2 Design of FDIR Services:



Airbus best practice

We currently strengthen the FDIR process with emphasise on:

- Identify and control the **key factors** for complexity and cost drivers in the development lifecycle (on holistic basis)
- Define **flexibility** in the FDIR solution implementation
- Identify the **right phasing** of the FDIR engineering effort in the project lifecycle
- Streamline the roles and responsibilities in the **FDIR process** with all functional domains (AOCS, Ops, SW, FV, MSC and RAMS)
- **Standardisation** of FDIR design and implementation policies
- Use MBSE techniques to **anticipate** and support early FDIR design definition and justification

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Conclusion

➔FDIR is complex and spans **across all disciplines**

Therefore the FDIR process shall be reviewed and **strengthened** by:

- **Identification** and control of the **key factors** for complexity and cost drivers in the development lifecycle (on holistic basis)
  ➔ These key factors may be discussed controversially depending on the different stakeholders within the project and therefore not easy to be identified and weighted.
- Definition of FDIR **concept** needs to be **anticipated** early in the project
- **Standardisation** of FDIR design and implementation policies
- Use of MBSE techniques to **anticipate** and support **early FDIR design** definition and justification

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