



Reaching into space
TOGETHER

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ESA workshop on
Avionics Data, Control and Software Systems

CFDP – A FLIGHT SOFTWARE IMPLEMENTATION



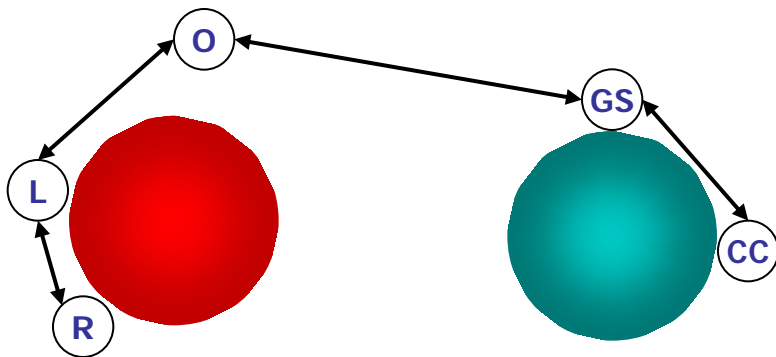
Agenda

- CFDP Context and Overview
- CFDP End to End Test Benches
- CFDP Flight Entity
 - Drivers for implementation
 - Features and Modularity
 - Integration and Portability
 - Communication and Configuration
- Perspectives
- Conclusions

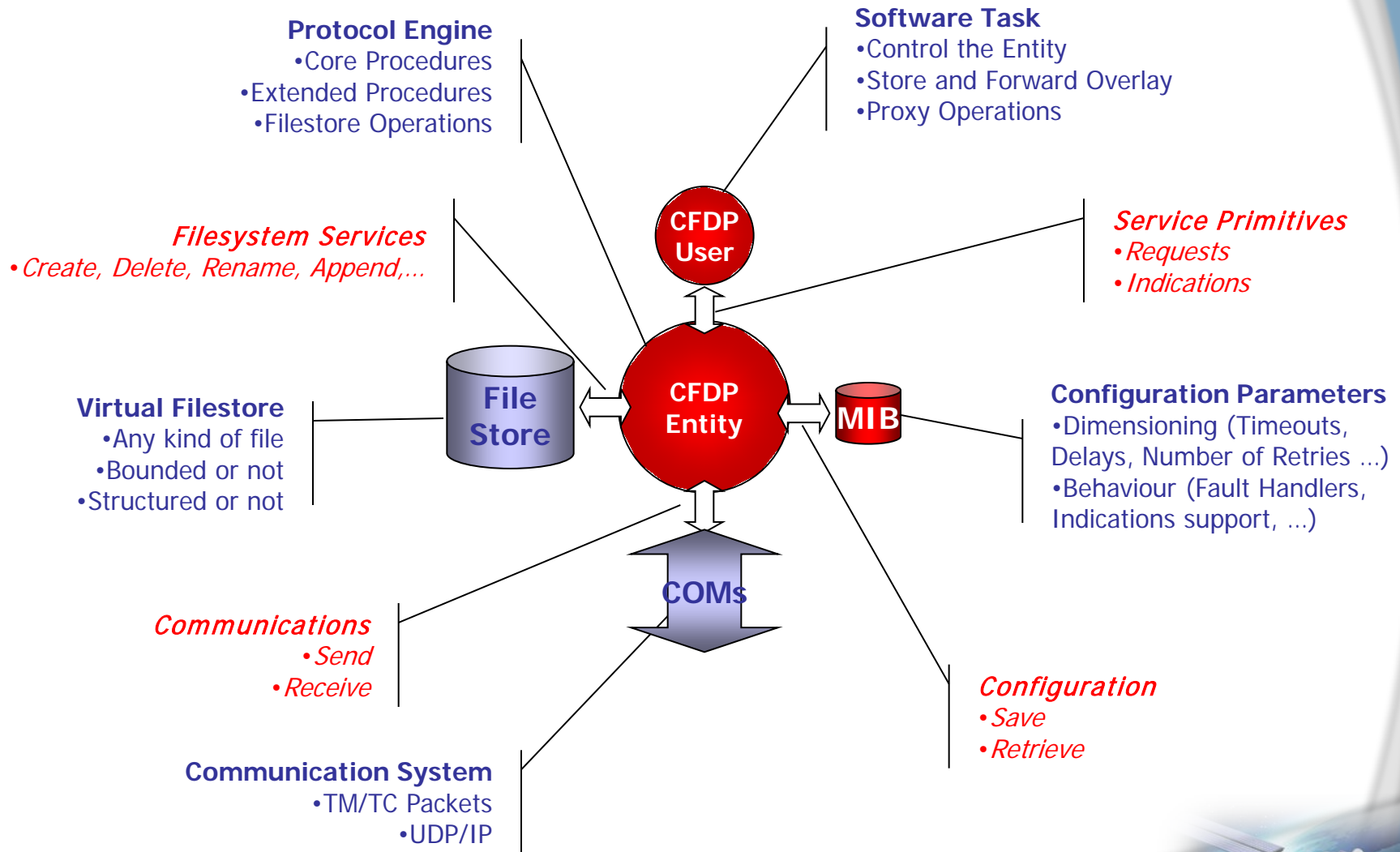


CFDP Protocol : The Context

- On Board Context
 - On Board Mass Memory
 - On Board File System
 - On Board Autonomy
- Mission Context
 - No Direct Connectivity
 - Several Spacecraft
 - International Cooperation
 - Deep Space Missions
- Communications Context
 - Long Delay,
 - Disruptions,
 - Noisy Channels,
 - Assymetrical Links,
 - Limited Bandwidth,
 - Heterogeneous Underlying Networks

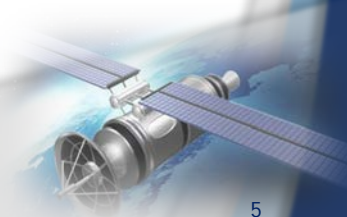


CFDP Protocol: Architecture Overview

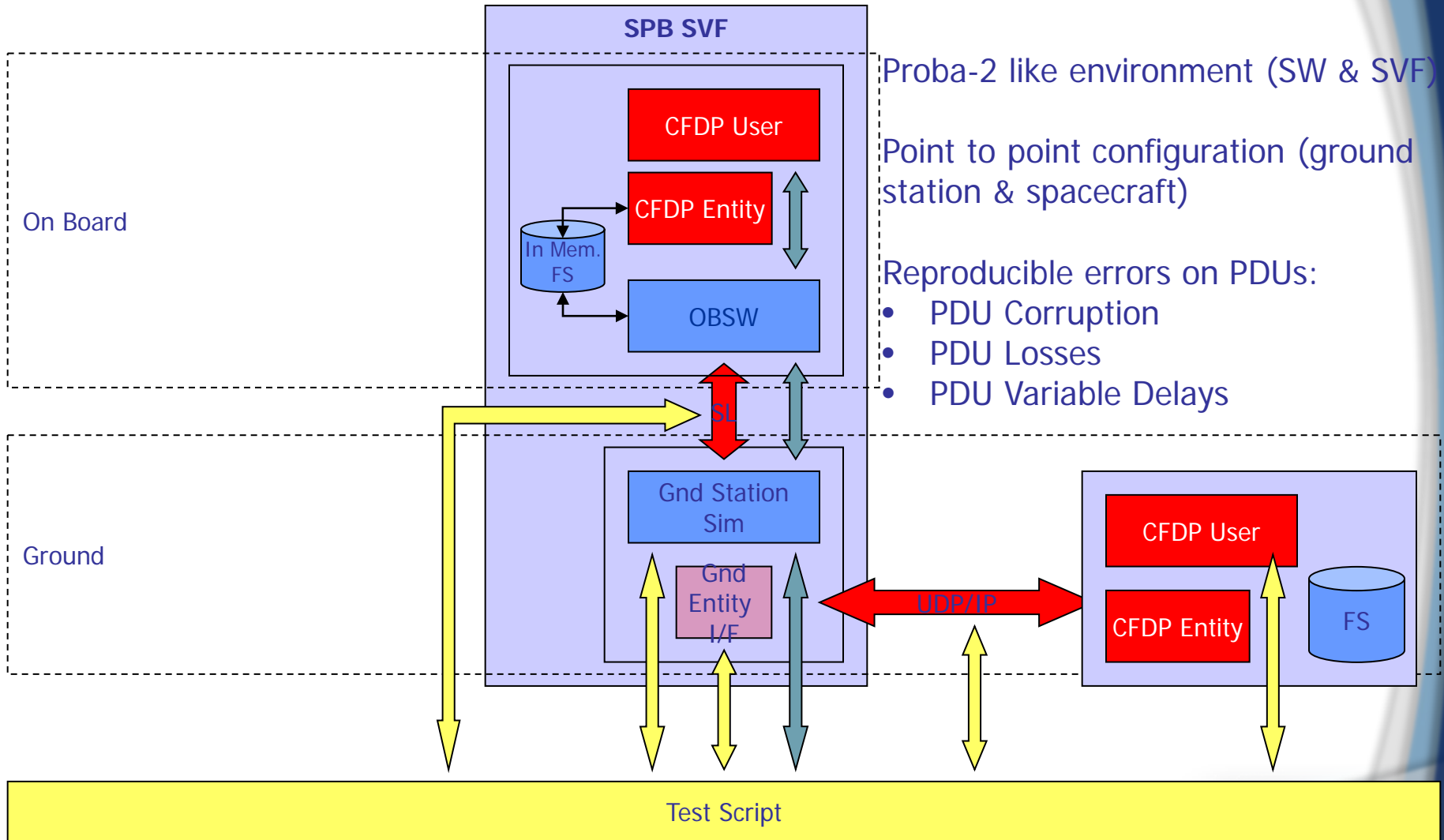


CFDP Test Bench: Objectives and Outcomes

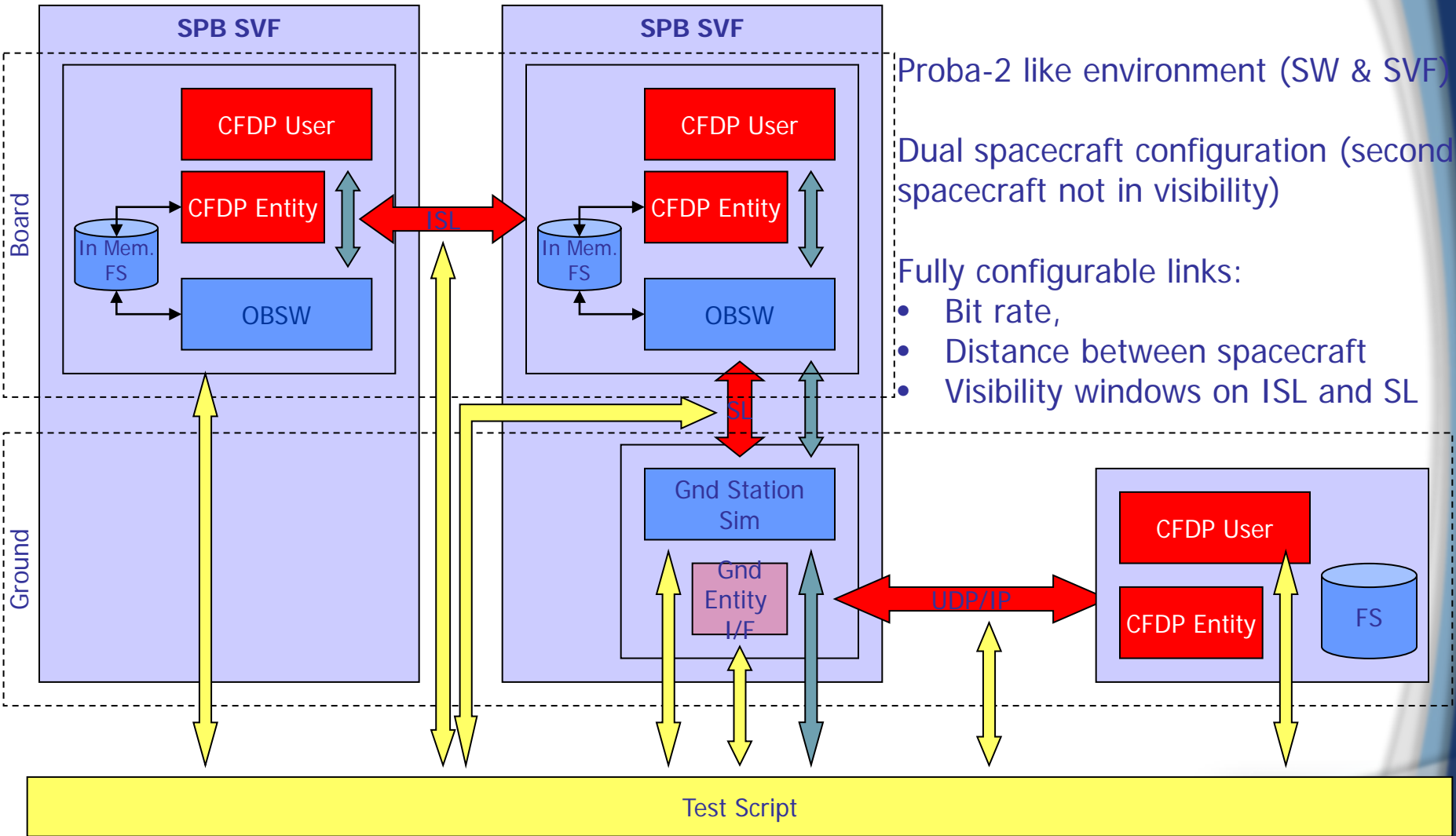
- Objectives
 - Develop a Test Bench allowing to **validate** CFDP Flight Implementations in an **end to end** representative environment
- Outcomes
 - A **Test Infrastructure** Based on the Proba2 OBSW and SVF and that integrates existing CFDP Flight and Ground Implementations
 - A **Test Suite** of more than 200 characterisation tests that can be automatically executed.



CFDP Test Bench



CFDP Test Bench



Proba-2 like environment (SW & SVF)

Dual spacecraft configuration (second spacecraft not in visibility)

Fully configurable links:

- Bit rate,
- Distance between spacecraft
- Visibility windows on ISL and SL

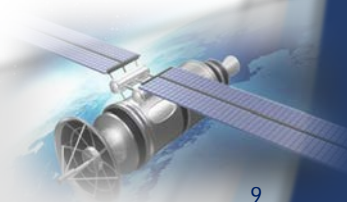
CFDP Flight Entity: Previous Implementation

- Functionnaly Very Good but not suitable for On Board Software
 - Design
 - Not Easily Portable
 - Not Really Modular
 - Implementation
 - Results from Incremental Development (to support standardisation)
 - Violation of Flight Software Coding rules
 - Not Easily Maintainable
 - Validation
 - To be Formally Validated
 - Testing revealed some problems



CFDP Flight Entity: Drivers for new Entity

- A Ready to Fly CFDP Flight Entity
 - Portable Library
(Standard Interfaces, Passive Library, ...)
 - Modular Library
(Services tailored to the Mission Needs, Feature Management, ...)
 - Flight Quality Level Software
(Coding Rules, Documentation ...)
 - Optimized Library
(Data Copy Minimization, ...)
 - Transaction Priorities
(on a same link, ...)
 - Validated Library
(Using the Test Bench ...)



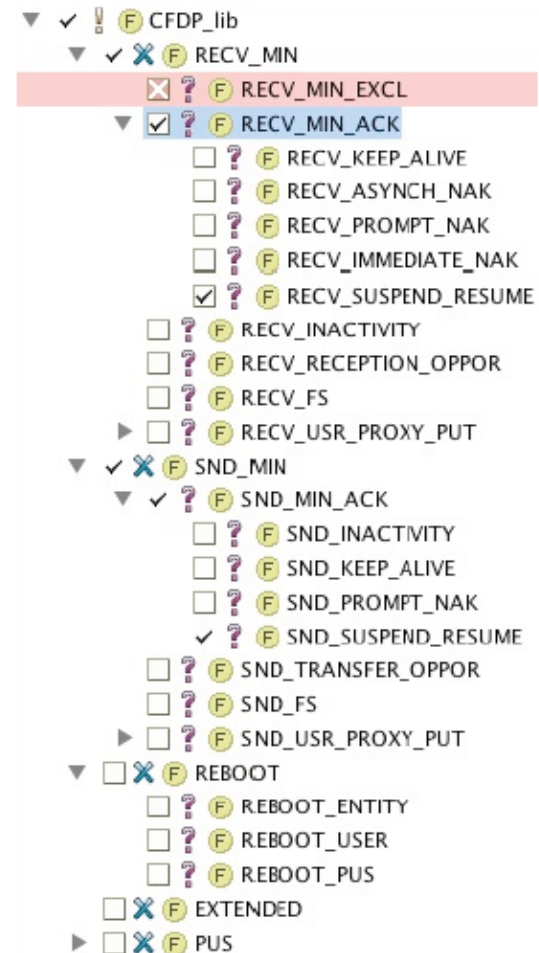
CFDP Flight Entity: Implemented Features

- Class 1 (best effort) and Class 2 (reliable)
- Working as sender, receiver or both
- All kinds of acknowledgements (immediate, deferred, periodic, asynchronous)
- File store operations
- Messages to user
- Proxy operations: Proxy put only (to allow a « get » operation from ground)



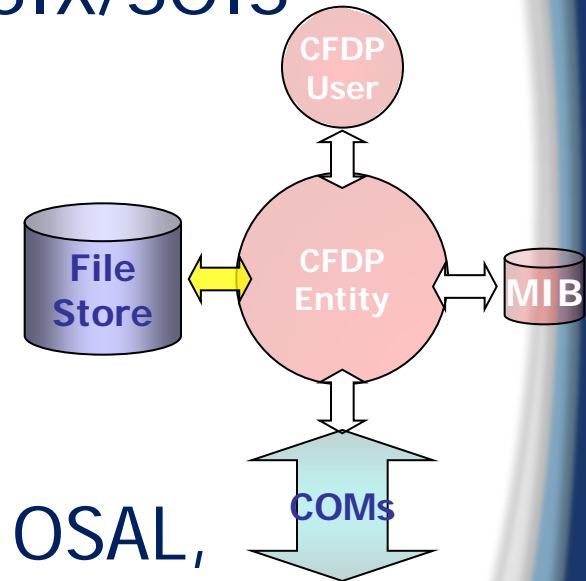
CFDP Flight Entity: Modularity

- Features organized in a feature management tool
- Code is tagged with specific comments recognized by the tool
- Applies at file, function, block, statement level (semantical nodes of the C language)
- Code tagged only with unselected features is removed during pre-processing
- Ensures optimal use of resources (CPU, memory) and no dead code is present



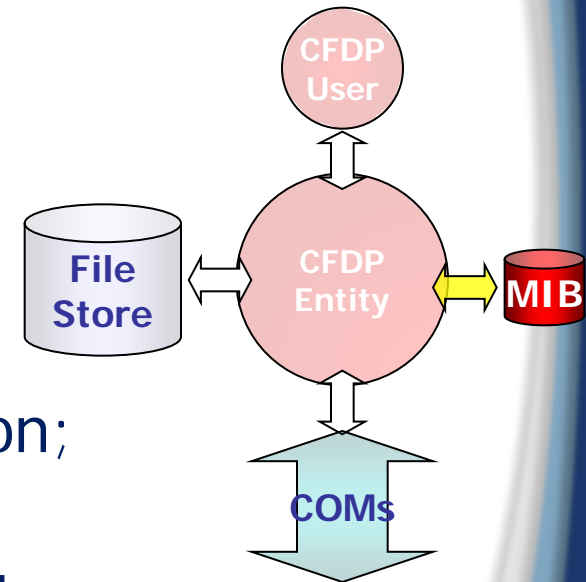
CFDP Flight Entity: Portability/File System

- Well defined interface layers, standard versions provided, can be coded by integrators
- File system: standard directives (POSIX/SOIS compatible):
 - Open, Close
 - Read, Write (with offset, or seek)
 - Get file size, *Set file size*
 - *Rename, Append, Create, Delete file*
 - *Create, Delete, List directory*
- Successful integrations with RTEMS, OSAL, GAMMA file systems, in RAM and mass memory.



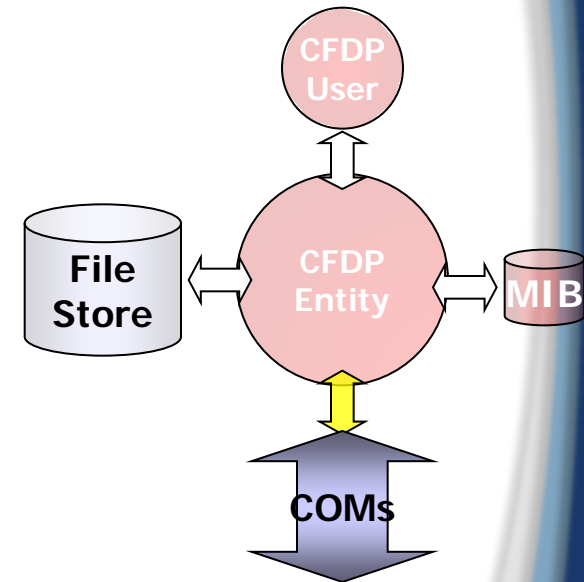
CFDP Flight Entity: Portability/Mission

- The implementation introduces the concept of link and configuration
- Link: communication abstraction with another CFDP entity.
- Configuration: a set of parameters which define the behaviour of the entity (e.g. timers, fault handlers, file segment size,...)
- Each remote entity has a sender and a receiver link; Each link has a configuration; Configurations are modifiable in-flight.
- Allows integration in heterogeneous networks, or evolving travel times (e.g. interplanetary mission)



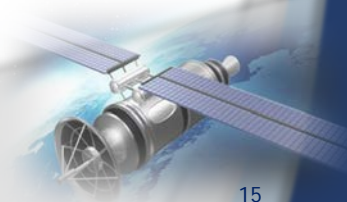
CFDP Flight Entity: Portability/Communication

- Each link can have its own encapsulation protocol
- Successful deployments:
 - Inside PUS packets (dedicated type/subtype)
 - Inside CCSDS space packets (dedicated APID)
- Tradeoff mainly driven by hardware / ground systems



CFDP Flight Entity: Integration / SOIS

- Project carried out for CFDP – SOIS mapping
- Some missing coverage was reported in this frame:
 - Getting the size of a file
 - Deleting a non-empty directory
- These items have been integrated in the SOIS File and Packet Store Services magenta book published in September by the CCSDS.



CFDP Flight Entity: Operations / PUS

- ECSS PUS standard undergoing revision
- File management service being added
- File utilisation spread accross different existing services (e.g. OBCP, memory manager,...)
- No dedicated service for file transfer; Spacebel has a dedicated private service for configuring the CFDP engine
- Initiating transfer should be possible through PUS and through CFDP (CFDP has proxy operations, but PUS could command downlinks from event action or on-board schedule)



CFDP Flight Entity: Current state

- CFDP is a valid and feasible solution for file transfer for space missions
- Spacebel has a software CFDP entity developed according to space software standards
- This entity has been successfully tested at protocol level in multiple configurations and representative environments



CFDP Flight Entity: Perspectives

- Very high transfer rates may require implementing part of the engine at hardware level
- Hybrid configurations: one downlink only engine, IP core, for mass memory; one uplink/downlink engine, software, for file based operations ?
- Implementation of multi-hop capabilities (Store & Forward Overlay / Extended procedures)
- In-flight qualification opportunity



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**THANK YOU FOR YOUR
ATTENTION !**



Backup Slides



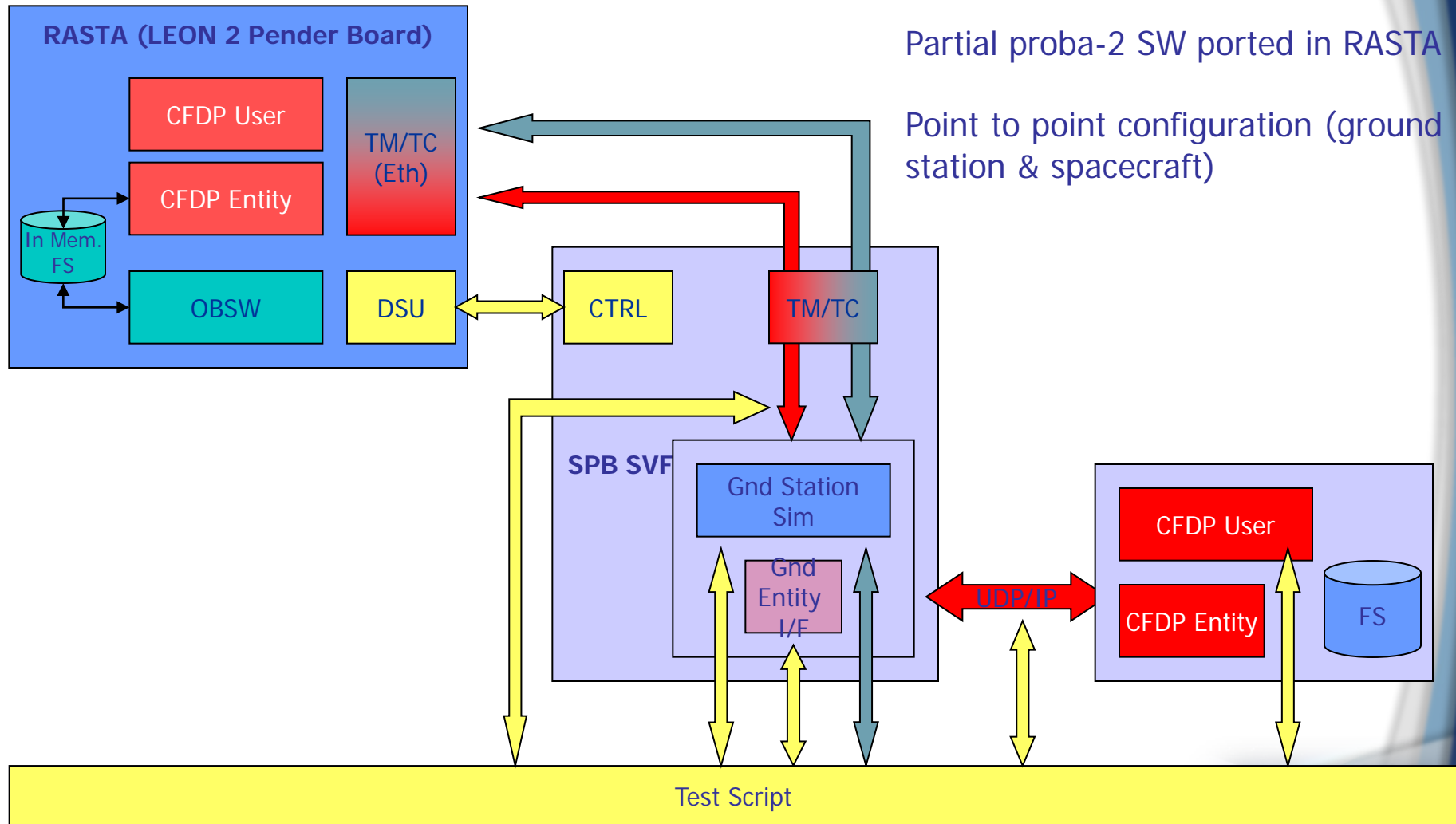
25 October 2012

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20

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CFDP Test Bench: In RASTA



CFDP Test Bench: In VSRF

