

FILE BASED OPERATIONS (FBO) FOR COPERNICUS MISSIONS CFDP FILE TRANSFER PROTOCOL IMPLEMENTATION WITHIN THE MILA COMMON PLATFORM

A MULTI-SITE & TRANSNATIONAL CO-ENGINEERING & TEAM WORKING

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GIANLUCA ARANCI (MILANO) – ORION AZZIS (CANNES) – TOMAS DI COCCO (ROMA) – LUCA GIGANTI (MILANO)

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FILE BASED OPERATION WITH CFDP – FBO KESAKO?

/// New paradigm initiated by ESOC in GOIRD:

- / Maximise use files made of packets for commandability and observability instead of unitary packets
- / File transfer using CFDP (CCSDS File Delivery Protocol)
- / PUS-(A/C) ST13 tailored out!! Several answer self-contained TM to one single request TC are now explicitly allowed.

/// Relationship with PUS services:

- / PUS-C ST21: Load and Execute request sequencing from file. TC file made of TC packets interleaved with delays (like Actions Sequences)
- / PUS-C ST6: TC(6,19) Patch from file & TC(6,20) Dump to file. File are in binary format.
- / PUS-C ST18: TC(18,13) Load OBCP from file. File in OBCP language.
- / Private File Based Operations service:
 - PUS ST207 for Copernicus and PUS ST23 for PLATO → PUS ST24 & ST25 for PUS-C revision 1
 - Management of downlink manager that automatically select files to be downlinked according to their folder priority and age of creation
 - Enable data source storing to automatically generate files made of selected telemetry packets

FILE BASED OPERATION WITH CFDP – MILA COMMON PLATFORM

/// MILA Common Platform

/// stands for Multi-application Innovative and Modular Platform

/// is a set of elementary bricks common to Thales Alenia Space France @Cannes and Italy @Roma

/// MILA Platform is currently adopted & instanciated on 3 High Priority Copernicus missions:

/// CHIME

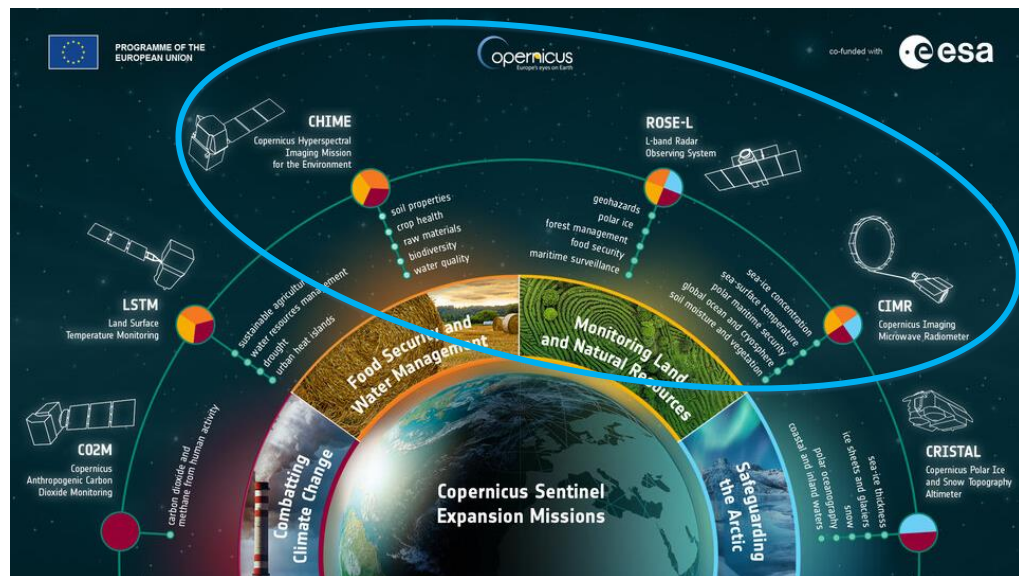
- Hyperspectral Imaging Mission for the Environment

/// CIMR

- Imaging Microwave Radiometer

/// ROSE-L

- L-band Synthetic Aperture Radar





FILE BASED OPERATION WITH CFDP – MULTISITE CO-ENGINEERING

/// CFDP implementation for TT&C link relies on:

HW:

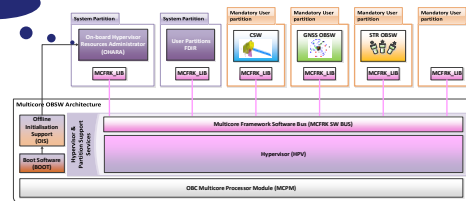
- OBC SMU-NG (GR740 & reprogrammable FPGA based computer)
- Hi-Rel Integrated Processor Avionics Controller (IPAC) Core product line
- Developed at Milano Gorgonzola
- Manufactured at L'Aquila

SW:

- CFDP application to support
 - CFDP TT&C Up & Downlink management
 - PDHU Directive routing for closing the class 2 of the CFDP Science data Downlink
- CFDP application nested within the Multicore System Partition Software developed at Roma

Documentation:

- Multicore System Partition Software SSS
- CFDP tailoring SSS based on CFDP B5 standard & OIRD
- PUS tailoring based on HPCM OIRD §6.27
- Documentation issued by Avionics team in Cannes & Rome



<https://chapellede.limban-duomo/>



<https://bonjourrome.fr/monument-rome/>



<https://www.cannes-france.com/decouvrir-visiter/plus-beaux-monuments/les-monuments-et-leur-histoire/>

HW/SW IMPLEMENTATION TRADE OFF WRAP-UP

/// Uplink ↑

/ By HW = FW:

- Collect CFDP File Data and Route CFDP Directive to CFDP SW application
- Check File data consistency and CFDP timers
- Compute cumulative checksum
- Buffer File Data for temporary file reconstruction,
- Once file consistency is confirmed, DMA moves file to mass memory when file is for deferred use
- Format & send CFDP Directive to Ground upon SW request

/ By SW:

- Decisions management and requests to HW
- Manage CFDP Directives: METADA, ACK, NAK, FINISHED Grant uplink transaction for HW resources
- Check file consistency comparing expected and computed checksum
- For immediate execution TC file, move file from buffer to PUS ST21 dedicated folder in RAM
- Deferred NAK strategy only when class 2

/// Downlink ↓

/ By HW = FW:

- Extract, format CFDP File Data from mass memory and send to Ground
- Compute cumulative checksum for EOF preparation
- Format & send CFDP Directive to Ground upon SW request

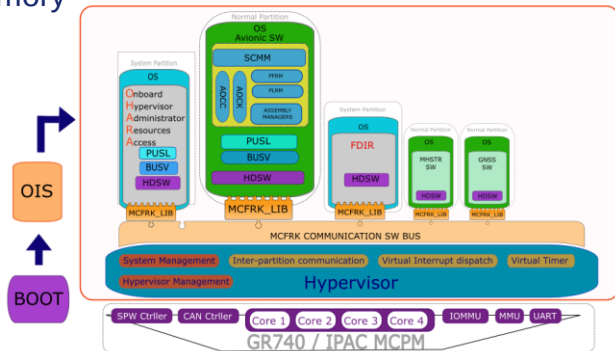
/ By SW:

- Downlink manager for parsing files by folder priority and age of creation
- Decisions management and requests to HW
- Manage CFDP Directives: METADA, EOF, ACK

CFDP SW INTEGRATION WITHIN THE MULTI-CORE SW WRAP-UP

/// The CFDP manager:

- / Is located inside the system partition
- / is implemented as a single high priority thread and inserted in the TAS MCSW deterministic scheduling mechanism
- / manages the HW downlink processor pool
- / manages the HW uplink processors pool
- / is interfaced with Ground via FBO private PUS 207 service
- / uses a proprietary Filesystem to abstract the physical Mass Memory



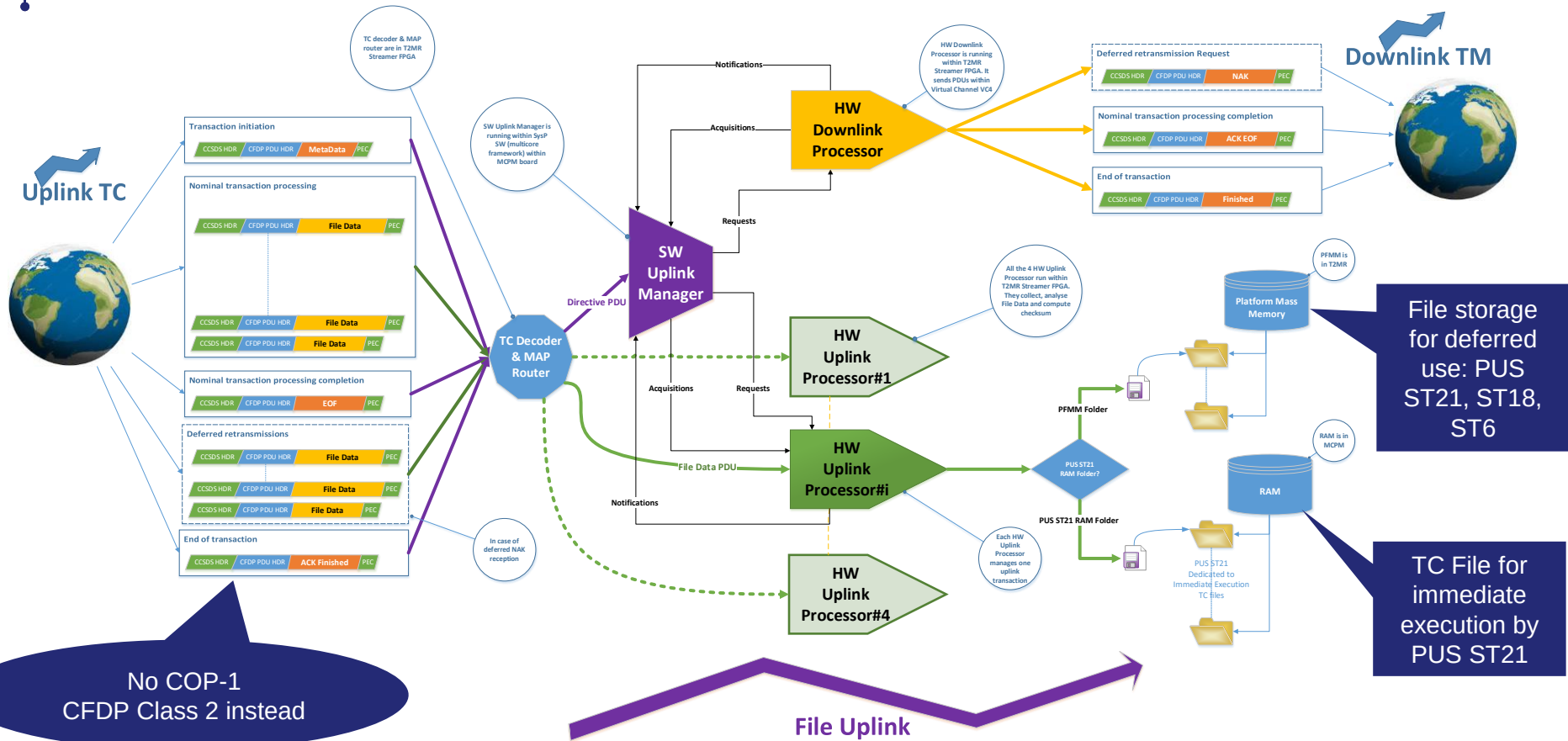
/// The FBO private PUS 207 service:

- / manages the CFDP transactions, downlink manager
- / manages the data sources for autonomous creation TM files within folders based on white list definition
- / can compress fixed length housekeeping packet according to Pocket + CCSDS 124.0-B-1

/// The file system architecture is based on:

- / single level of directories
- / each file is represented with a linked list of blocks to physical memory
- / the file system tree is described by a table called FAT (File Allocation Table) mirrored in SGM
- / is interfaced with Ground via **PUS 23**

IMPLEMENTATION - FILE UPLINK USE CASE



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IMPLEMENTATION - FILE DOWNLINK USE CASE (1/2)

/// Prerequisite

- Files are created on board by data source management that stores selected packets within files: mostly LTTM housekeeping files

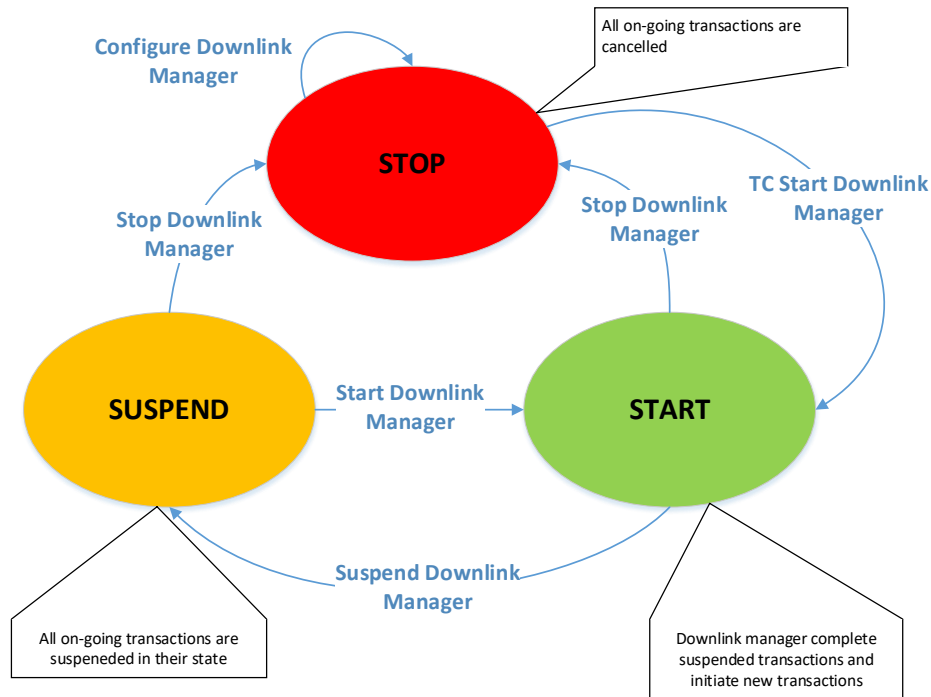
/// Downlink manager role

- Once started the Downlink Manager parses a set of selected directories to queue files downlinks requests, based on directory priority and file age scheme, and processes them relying on its associated hardware down

/// A dedicated virtual channel is used for downlinking the files

/// File autonomous deletion or move to trash folder

- after successful downlink or too old according to maximum age attribute of the folder



///



RETURN OF EXPERIENCE

- /// LEO implementation of the CFDP deviates from original GOIRD ESOC requirement to get a single CFDP application on board for uplink & downlink
- / Platform Avionics: One CFDP solution for the TT&C uplink & downlink
- / PDHT: One CFDP solution for science only in downlink
- /// Pay attention to CFDP B4 to B5 version upgrade
- / Even if it provides advantages and simplifications (removal of waypoints), some formats are changed and class 1 is a bit upgraded
- /// HW/SW mixed solution seems mandatory
- /// Agency CFDP detailed tailoring would have been a good accelerator



TAKE AWAY

/// Interoperable transnational solution

/// Flexible solution based on HW/SW compromise involving large reprogrammable FPGA support

- New high throughput processors allow reducing HW impact
- Letting more room for HW to solve time-critical needs

/// Multi-site & transnational co-engineering & team working

- Maximise understanding of the requirements
- More flexible solution to adapt to each specificity



/// Files replaces packet stores for LEO mission but still interplanetary missions require packet stores for very low data rates conditions



/// Foresee next PUS-C rev 1 alignment

- File based operations are currently streamlined in on going PUS-C revision 1 working group → public review held.
 - PUS ST21 Request Sequencing
 - TC file for immediate execution capability
 - PUS ST24 File transfer management
 - CFDP file transaction subservice
 - Downlink manager subservice
 - PUS ST25 File storage service
 - Data source management

/// Secure performance increase

- Currently Copernicus missions ask for 64Kbps in uplink because ESOC intends to increase this data rate to operate more spacecrafts by reducing the contractual daily visibility.

/// What is the becoming of CFDP class 2 while DTN promotes LTP/BP with CFDP class 1?



THANK YOU FOR YOUR ATTENTION

/// Title of presentation:

- / FILE based Operations (FBO) for Copernicus missions CFDP file transfer protocol implementation within the MILA Common Platform
- / A Multi-site & transnational co-engineering & team working

We are pleased to get your comments and reply to your questions

/// Contact:

- / Gianluca ARANCI gianluca.aranci@thalesaleniaspace.com
- / Orion AZZIS orion.azzis@thalesaleniaspace.com
- / Luca GIGANTI luca.giganti@thalesaleniaspace.com
- / Tomas DI COCCO tomas.dicocco@thalesaleniaspace.com

Grazie
Merci