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EUCLID: Data Handling Architecture and CFDP Tailoring

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- CDMS requirements for EUCLID mission

- EUCLID: CDMS Functional Architecture
  - CDMU and MMU

- Data Handling requirements for EUCLID mission
  - TM/TC and PUS SVCs

- EUCLID: Data Handling Functional Architecture

- EUCLID CFDP Tailoring
  - MMU File Store
  - MMU CFDP User Definition
  - MMU CFDP Entity Definition
  - MIB
  - Class 1 Uplink
  - Class 2 Downlink (deferred NAK)

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- Control and Data Management System (CDMS) in EUCLID, in addition to the nominal tasks, is in charge to acquire, store and transmit to ground 850Gbits per day of scientific data generated by the VIS and NISP instruments.

- It is required to store 72 hours of Science data, considering contingency, which means 2,5Tbits storage capability

- If margins are considered non volatile Mass Memory is requested with storage capability of 4Tbits (EOL)

- CDMS architecture shall consists of:
  - Control and Data Management Unit (CDMU)
  - Mass Memory Unit (MMU)
  - Communication links between the two units and with the other satellite system components (S/C units and Payloads)

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- CDMU interfaces with:
  - Platform subsystems (AOCS, EPS, TT&C) and mechanism (APME, MDE) via Platform MIL-STD-1553B bus#1
    - TM/TC Communication Frames @10Hz
    - Not packet terminals
  - MMU, VIS and NISP via Science MIL-STD-1553B bus#2
    - TM/TC Communication Frames @ 64Hz
    - Packet terminals
  - X-band transponder via direct serial link
    - up to 16kbps uplink
    - up to 26kbps downlink
  - Other devices via discrete/ analogue signals (RTU section)

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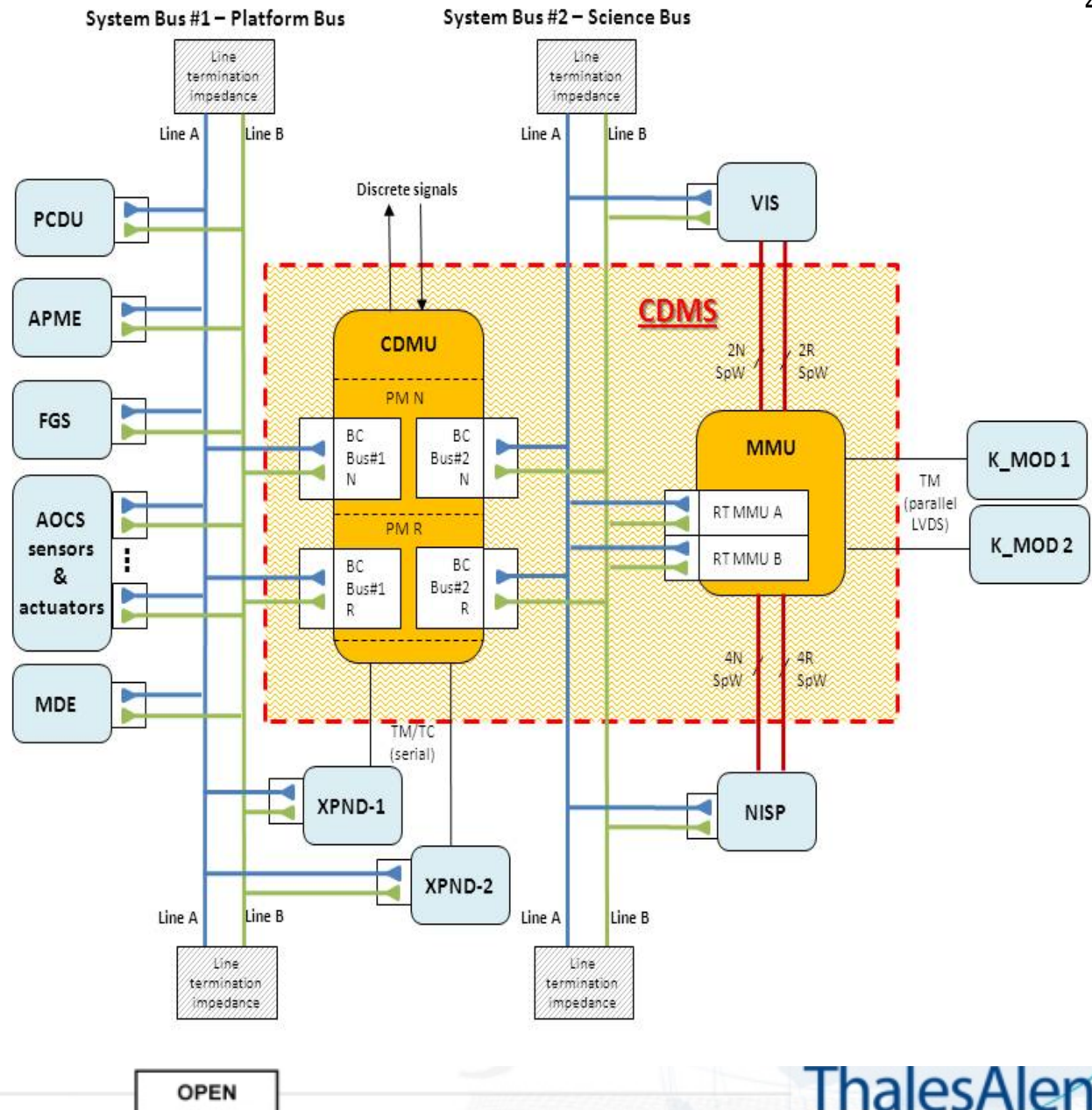
MMU interfaces with:

- NISP instrument via 4 active SpaceWire links
  - 4 links with DRM A,
  - 4 links with DRM B
- VIS instrument via 1 active SpaceWire link
  - 2 SpW (N+R) with DRM A
  - 2 SpW (N+R) with DRM B
- K-band modulator to download TM via Direct parallel link up to 75Mbps downlink
- CDMU via Science MIL-STD-1553B bus#2
  - TM/TC Communication Frames @ 64Hz
- CDMU via dedicated HW lines which provide monitors to the CDMU (BSM) and which acquire commands from the CDMU (HPC)

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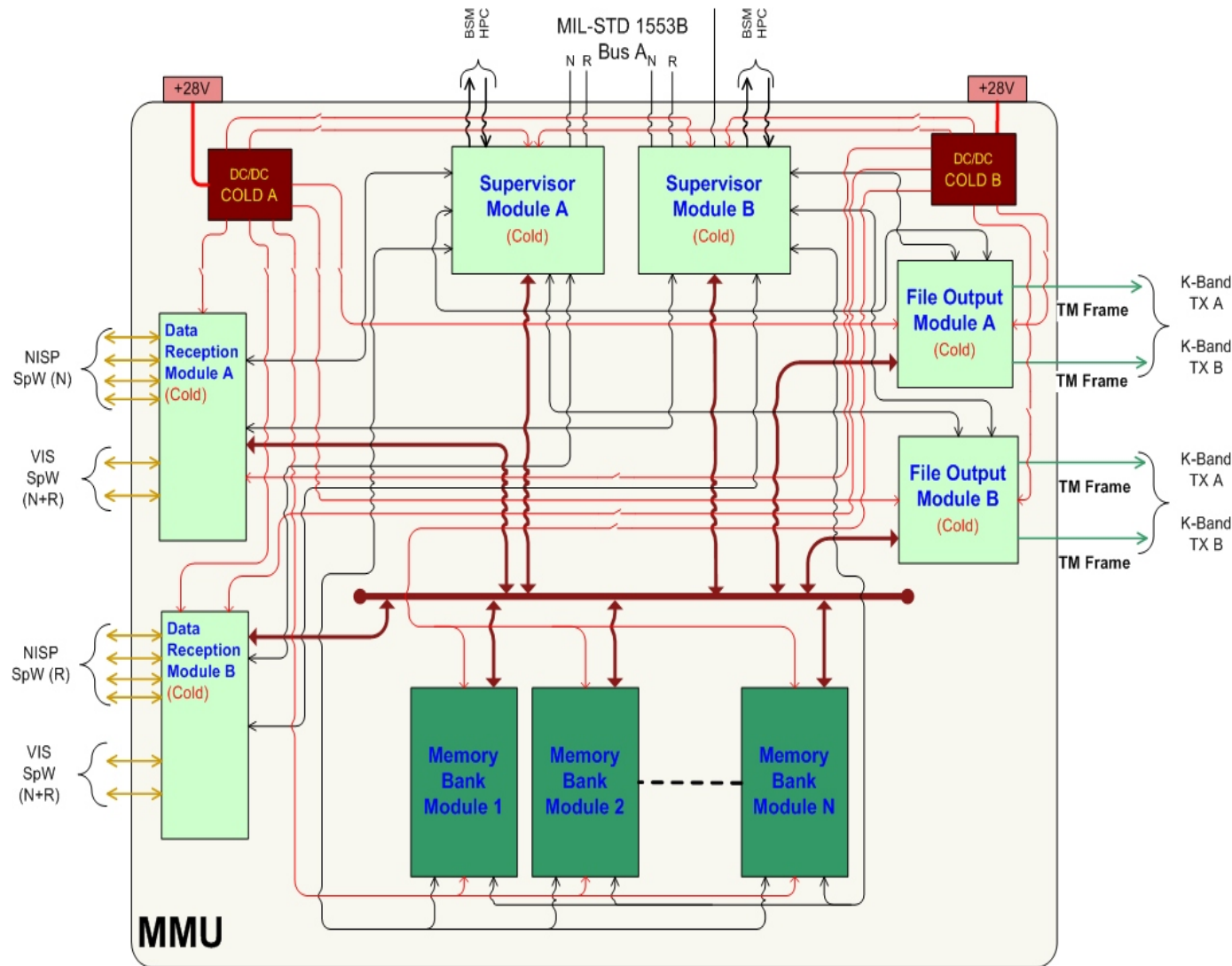
DH Requirements for EUCLID mission: TM/TC

- MM stores in separate files organised in a File System structure :
  - Science data from instruments
  - TM data from Instruments and CDMU (including platform TM)
  - SW images
  - OBCPs
  - FGS catalogue
- MM Transmits to ground (downlink only) via direct K-band link files using CFDP protocol
  - Files can be also transmitted via X band in case K band is not available (weather conditions) compatibly with available bandwidth
  - CFDP PDU Directives are always transmitted to ground via X band
- Real Time TM and Essential TM, generated by CDMU, are transmitted to ground via X band TM link

- TC uplink is performed via X band following ECSS standards
- TC Segment MAP-ID is used to route TCs from decoder to:
  - MAP-ID = 0 => CPDU (High Priority Commands)
  - MAP-ID = 1 => CDMU SW (PUS TC Packet and CFDP PDUs)
- CFDP PDUs are included in CCSDS packet format without data filed header
- TC containing CFDP PDUs are routed to MM by the CDMU SW using APID field
  - Two SW Systems are defined CDMU SW and MM SW which exchange commands/data each other
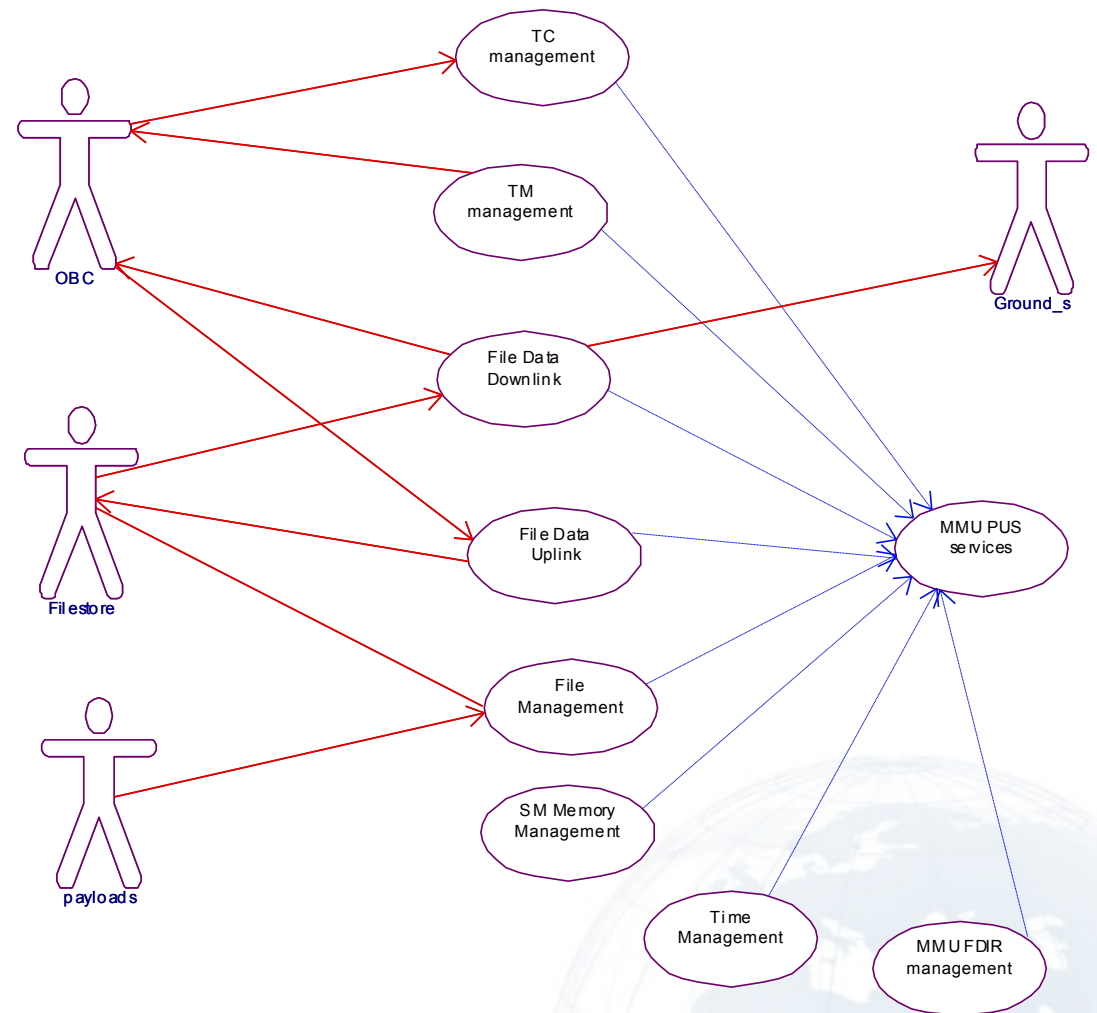
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DH Requirements for EUCLID mission: PUS SCV

- CDMU SW implements standard and private PUS services.
  - Some of the standard services have been extended to directly manage data recorded in files: PUS SVC 6 (Memory Management), PUS SVC 18 (OBCP Management)
  - Dedicated private service has been specified to manage Packet Sets definition (SVC 130)
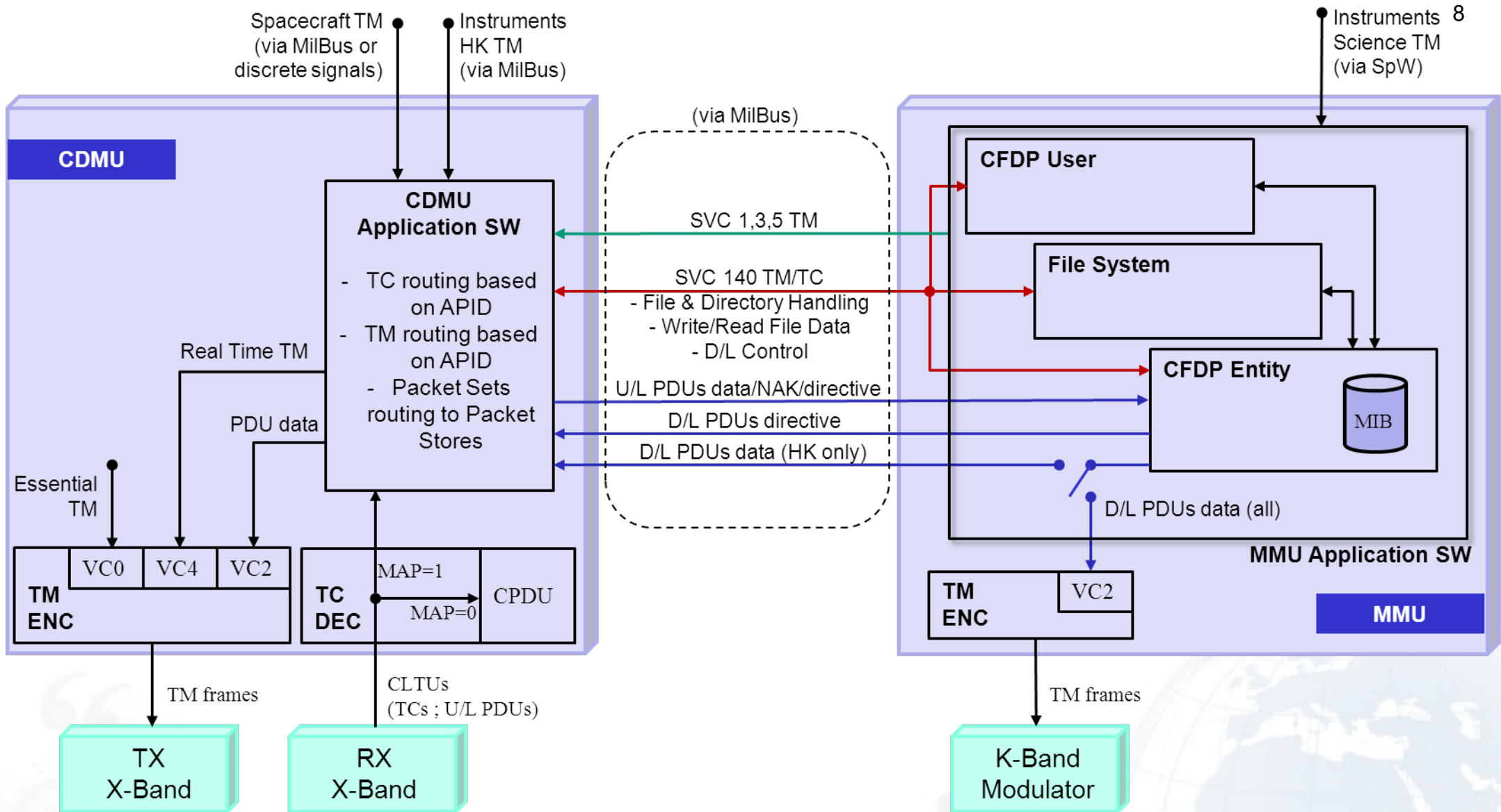- MMU SW implements PUS services that are needed to manage functions in charge of the MM
  - SVCs (1, 3, 5, 6, 8, 9, 17) are standard services
  - Dedicated private service is needed for File Handling & Transfer (SVC 140)

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EUCLID: Data Handling Functional Architecture

Spacecraft TM (via MilBus or discrete signals)

Instruments HK TM (via MilBus)

Instruments Science TM (via SpW)

CDMU

CDMU Application SW

- TC routing based on APID
- TM routing based on APID
- Packet Sets routing to Packet Stores

Real Time TM

PDU data

Essential TM

(via MilBus)

SVC 1,3,5 TM

SVC 140 TM/TC
- File & Directory Handling
- Write/Read File Data
- D/L Control

U/L PDUs data/NAK/directive

D/L PDUs directive

D/L PDUs data (HK only)

D/L PDUs data (all)

CFDP User

File System

CFDP Entity

MIB

MMU Application SW

MMU

VC0	VC4	VC2

TM ENC

TC DEC

MAP=1

MAP=0

CPDU

TM ENC

VC2

TM frames

CLTUs (TCs ; U/L PDUs)

TM frames

TX X-Band

RX X-Band

K-Band Modulator

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- CCSDS FILE DELIVERY Protocol (CFDP) as specified in CCSDS 727.0-B-4 Blue Book has been tailored for EUCLID project

- Objective of the tailoring carried out together with ESA/ESOC in dedicated DM WG meetings was to simplify as much as possible the protocol implementation taking into account the Euclid mission characteristics:

  - User Operations have been considered not useful because Ground and Satellite can communicate directly. Therefore proxy operations and Store and Forward Overlay (SFO) are not applicable. Remote directory Operations, Remote Status report, Remote Suspend and resume operations and all the Directory operations can be done by the private PUS SVC 140.

    - As a consequence Message to user have not been specified

  - File Store Operations have been directly specified via PUS SVC 140

  - Keep Alive Procedures are used by the sender to obtain information about the progress file transfer in order to abort the transaction. In Euclid direct cancellation of transfer can be done by ground

  - Fault Handler Override allow to override the MIB content in a specific transaction. This operation has been considered not needed therefore it has not been specified

  - Flow labels have not been implemented because priority of transfer can be managed directly by ground.

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- Segmentation control is considered not needed because files are considered as array of octects and no specific structured format is requested

- Unbounded File Management has not been used because not clearly specified in the Blue Book and because it seems to increase the SW complexity both on ground and on board in managing open files transactions. Files are transmitted to ground only after they have been closed

- Tailoring was done also to make more efficient the downlink and uplink of files:

  - Uplink of files is requested in Class1 (unacknowledged mode) directly under ground control

  - Downlink of files is requested in Class 2 (acknowledged mode) with deferred NAK

  - Up to 5 downlink concurrent transactions can be active. Files are downloaded one after the other so that transactions are "pipelined" to avoid waiting periods on ground. Retransmission requests are served only after a first attempt of file transmission has been completed

  - Downlink status is requested to be visible in the HK telemetry (name of the file, occurring re-transmissions, progress of transaction)

  - Minor protocol extension introduced in order to allow generation of Prompt NAK directives after EOF to indicate end of retransmission of file segments requested through a NAK PDU from ground (reduces the risk of dead downlink time during retransmission cycles).

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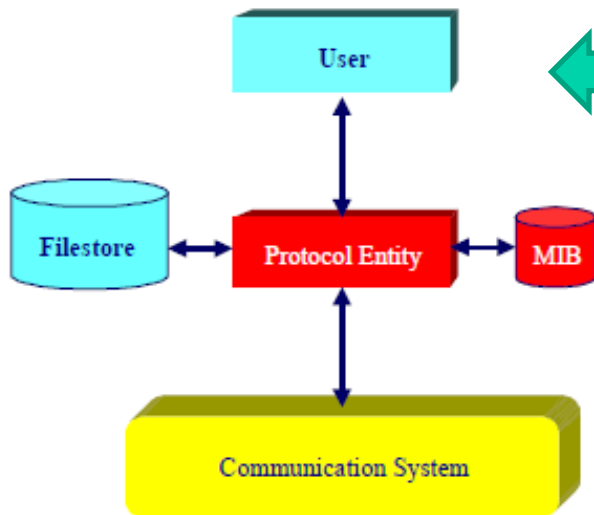
CFDP architectural elements as specified in the CCSDS 727.0-B-4 Blue Book are all located in MMU

- FileStore implementation consists of the root and a second level of directories (No subdirectories allowed).

- Two types of directory are considered : packet store and user defined

- Packet store directories contain:

  - Packet stores files in which HK telemetry belonging to a selected Packet Set is stored

- User defined directories contain:

  - VIS and NISP science data files, SW images data files, OBCPs files, FGS Catalogue files

- Private PUS Service (SVC140) allows to:

  - Create and Delete **directories**, Report Directory content and attributes

  - Create, Delete, Open, Close, Rename, Seek, Read, Write data **files**, Compute file Checksum and Report File data and File checksum

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The MMU CFDP user provides the functions for managing the following interactions with the MMU CFDP Entity:

- initiating the downlink of files between MMU filestore and Ground Filestore (during a file downlink), triggered by PUS 140 TC packets;

- suspending, resuming, or canceling of current downlink transaction, triggered by PUS 140 TC packets or by MMU entity;

- Acquisition of the PUS 1, PUS 5 TM Packets from the MMU CFDP Entity.

CFDP USER

- suspending, resuming, or canceling the current transaction
- Acquisition of the PUS 1, PUS 5 TM packets
- Initiate downlink triggered by PUS 140 TC

Ground_s
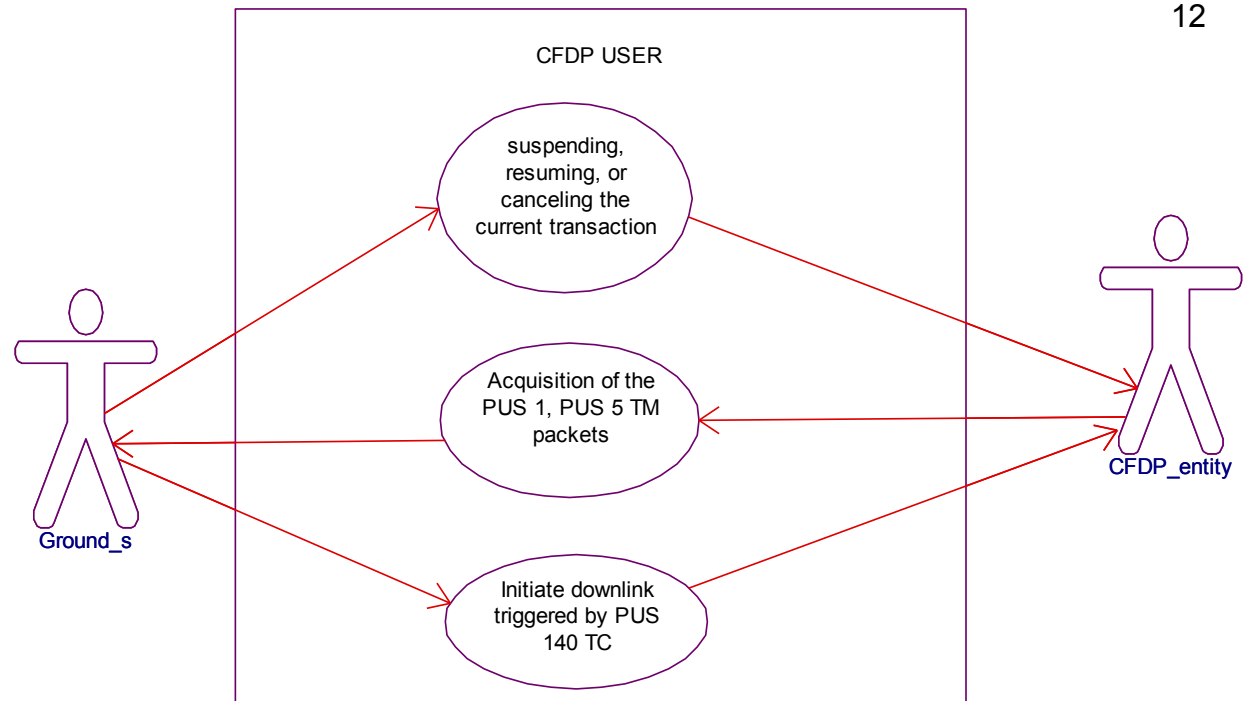
CFDP_entity

File Handling & Transfer Management TC of SVC (140)	TC Name	Request primitive from MMU CFDP User to MMU CFDP Entity
TC(140,50)	Copy File (Download)	Put.request
TC(140,51)	Suspend Copy Operation	Suspend.request
TC(140,52)	Resume Copy Operation	Resume.request
TC(140,53)	Cancel Copy Operation	Cancel.request

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The MMU CFDP entity provides the following functions:

- receiving the PDU TC packets directed to the MMU CFDP Entity (during a Class 1 file uplink)

- generate the PDU TM packet (during a Class 2 file downlink) selecting PDUs to be transmitted in X-band and in K-band

- generate of the PUS 1, PUS 5, PUS 140 TM packets
  - TM(140,x) in response to TC (140,x) needed to modify MIB
  - TM(1,x) in response to the TC(140,50)
  - TM(5,1) to provide *indications* to the user
  - TM(5,3) to provide *Fault indication* to the user
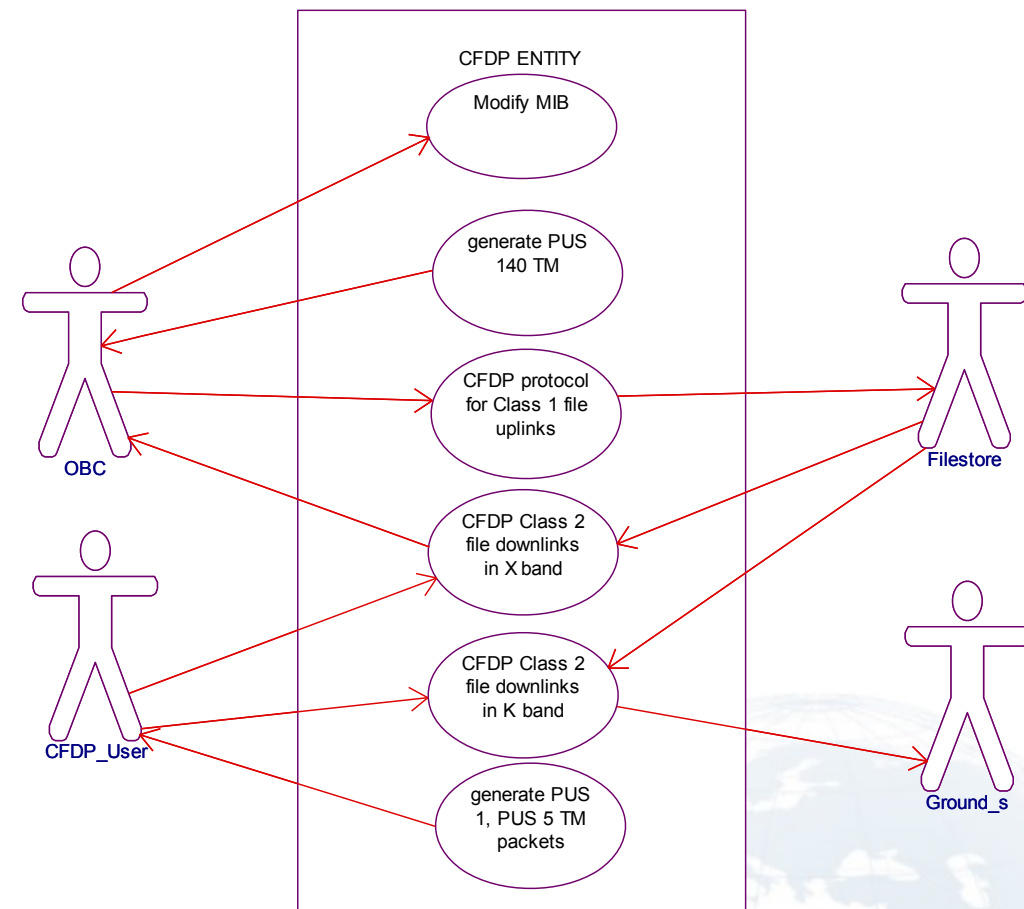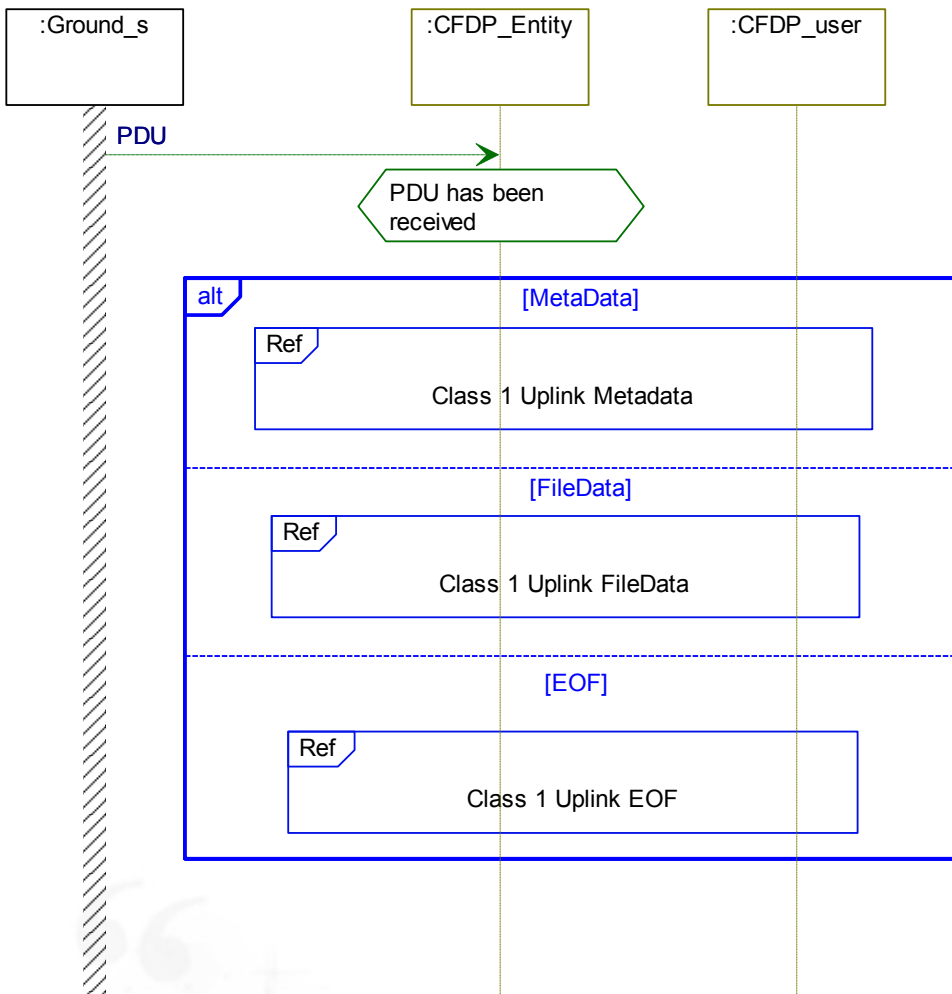

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EUCLID: CFDP MMU MIB definition

Item	Default Value
MMU Entity ID	TBD
EOF-Sent.indication required	True
EOF-Recv.indication.	True
File-Segment-Recv.indication required.	False
Transaction-Finished.indication required when acting as receiving entity	True
Suspended.indication required when acting as receiving entity	True
Resumed.indication required when acting as receiving entity	True
Default fault handlers	See section 5.3.6.2.13
Ground entity ID	TBD
UT address 1	0 (x-band) TBC
UT address 2	1 (k-band) TBC
One-way light time	TBD
Total round-trip allowance for queuing delay	TBD.
Asynchronous NAK interval	TBD
Asynchronous Keep Alive interval	N/A.
Asynchronous report interval	N/A.
Immediate NAK mode enabled	False
Prompt transmission interval.	TBD
Default transmission mode.	Acknowledged
Disposition of incomplete received file on transaction cancellation	Discard
CRCs required on transmission	False.
X-band Maximum file segment length.	1016 octects.
K-band Maximum file segment length.	65534 octects
Keep Alive discrepancy limit	N/A.
Positive ACK timer expiration limit.	TBD
NAK timer expiration limit	TBD
Transaction inactivity limit.	TBD
Start of transmission opportunity	N/A
End of transmission opportunity	N/A

- Management Information Base (MIB) contains all default values of static data needed by the CFDP Entity to perform operations

- Some of these values can be modified by dedicated PUS 140 Commands

- Content of the MIB can be downloaded by ground command.

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# EUCLID : CFDP Class 1 Uplink procedure

- Class 1 Uplink procedure is triggered by the received Metadata PDU

- Metadata PDU is checked against: Transmission Mode, Transaction identifier, Destination Directory Name, Destination File Name, File Size, Max number of active Uplinks.

- If no error TM(5,1) "Metadata Received" is issued and File Data PDUs are expected

- Each File Data PDU is checked against:
  Transaction identifier and Offset.

- If no error data segments are appended to the file until EOF PDU is received.

- Upon reception of the EOF PDU a TM(5,1) "EOF Received "

- If file obtained has the expected size, checksum is computed and compared against the one contained in the EOF PDU

- If checksum are equal TM(5,1) "Uplink Successful" is issued

- All error cases are signaled to the user by TM(5,3) specific packets and file is deleted

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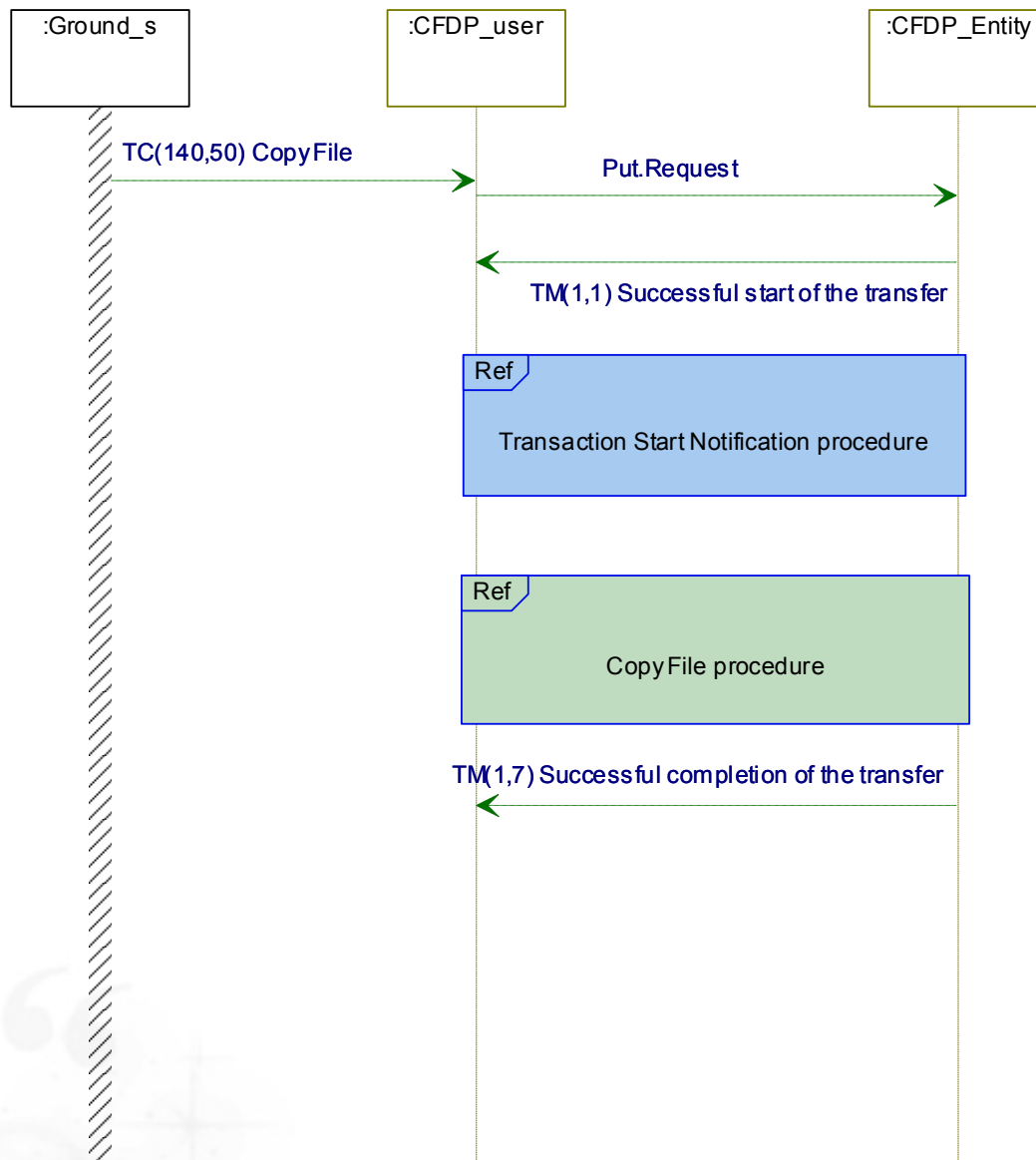
- Downlink procedure is activated by TC(140,50)

- Put request of the CFDP user activate the Put procedure at the sending entity.

- Put procedure is started and TM(1,1) is generated by the sending entity as response to TC(140,50)

- Transaction identifier is notified to the user by the Transaction Start Notification procedure via a Transaction indication: TM(5,1)

- Copy procedure at the Sending Entity is then started

- TM(1,7) is than generated at the successful completion of the copy procedure

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# EUCLID : CFDP Class 2 Downlink procedure: Copy File Procedure
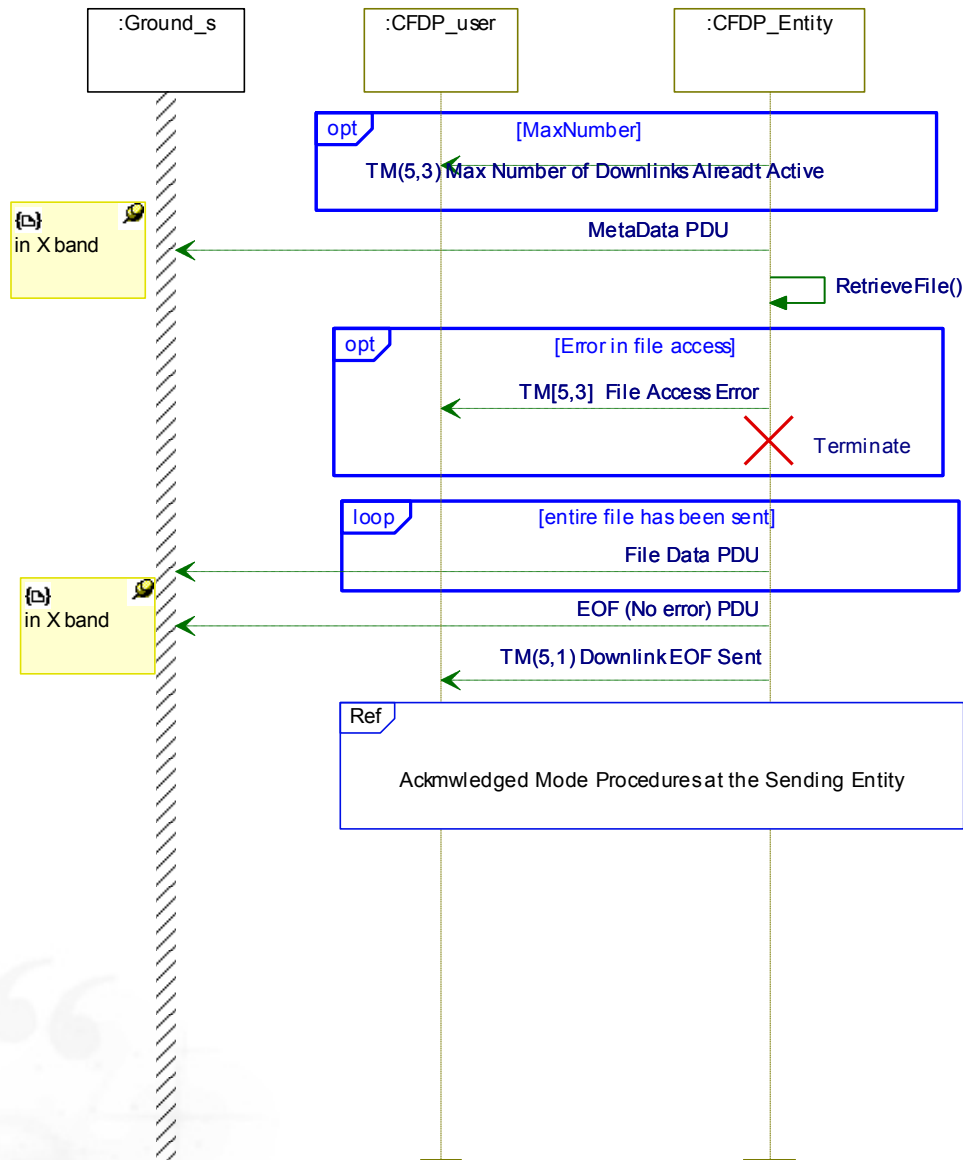
Copy File Procedure:

- checks the number of parallel active transaction

- generate a Metadata PDU to be sent to ground entity via X band

- Retrieve the file from the MMU file store and generate File Data PDUs to be sent to ground entity via K band or X band according to the selected downlink band

- When the entire file has been sent the EOF(No error) PDU directive is sent to ground entity and an EOF-sent.indication is distributed to the MMU user as TM(5,1)

- Acknowledged Mode Procedure at the sending entity is activated

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EUCLID : CFDP Class 2 Downlink procedure: Copy File Procedure
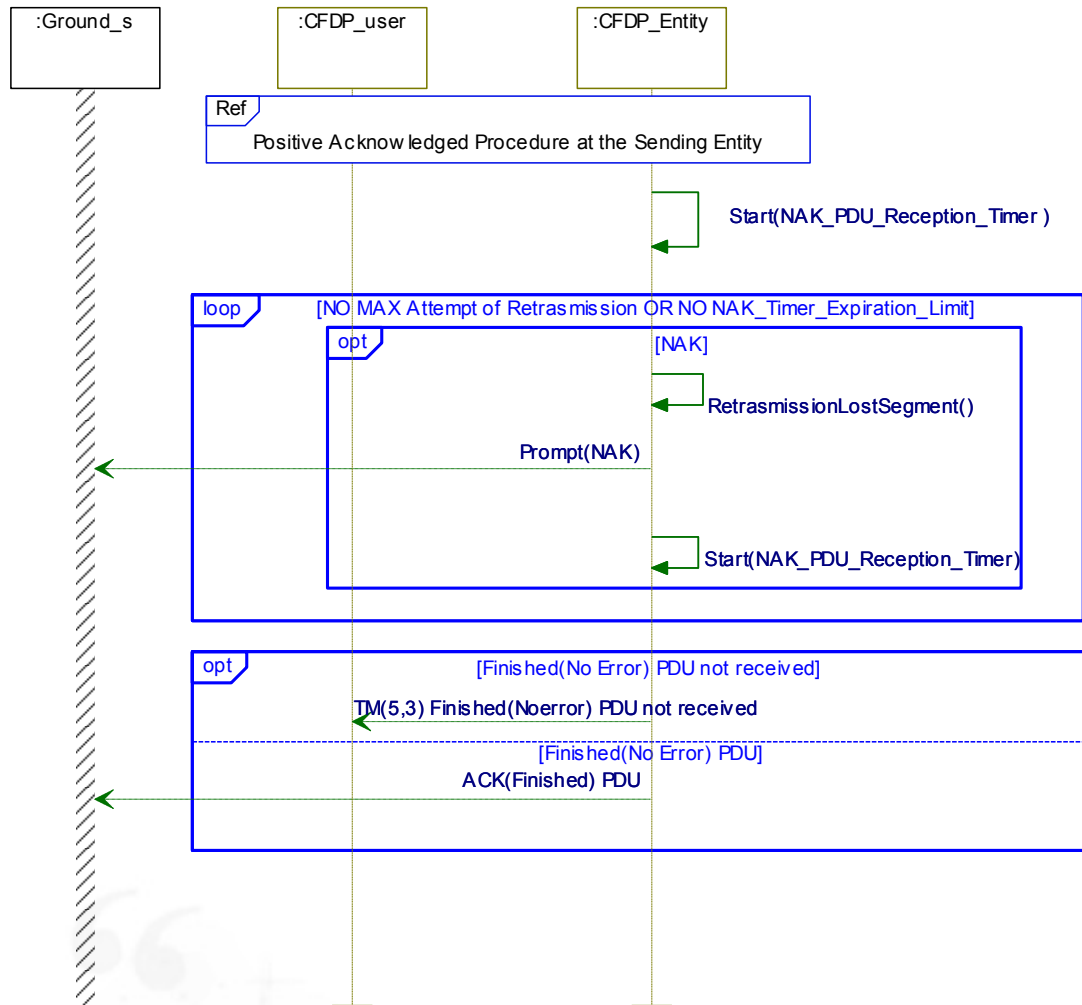
Acknowledged Mode Procedures at the Sending Entity:

- Start NAK_PDU reception timer waiting for requests of retransmission from the ground entity
- If retransmission is requested, retransmit lost segments and generate a Prompt NAK to be sent to ground entity via X band
- Start again NAK_PDU reception timer waiting for requests of retransmission from the ground entity up to a maximum number of attempts
- If Finished(no error) PDU is received from ground entity MMU entity close the copy file procedure issuing and ACK(Finished) PDU
- If If Finished(no error) PDU is not received a TM(5,3) indication is sent to the MMU user

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