OPS Concept for EUCLID

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Abstract

Euclid is an ESA mission selected for launch in 2020 in the Cosmic Vision program. It's main goal is to understand the origin of the accelerating expansion of the Universe.

Euclid will have an operational orbit around Sun-Earth-Libration-Point 2 and will generate about 100 GB of science data per day. To transfer these data to ground a high telemetry rate via K-band is required. The weather depending quality of a K-band link requires a failure detecting downlink protocol with automatic retransmissions of corrupted or missing data segments. For this purpose the CCSDS File Delivery Protocol (CFDP) was selected.

This presentation will provide an overview about the planned on-board file system, file transfer and concept of operations for Euclid.

Agenda

1. Background about Euclid
2. Storage and Download of Data
3. Operations Concept
4. Current Status
5. Ideas (and Bonus Slides)

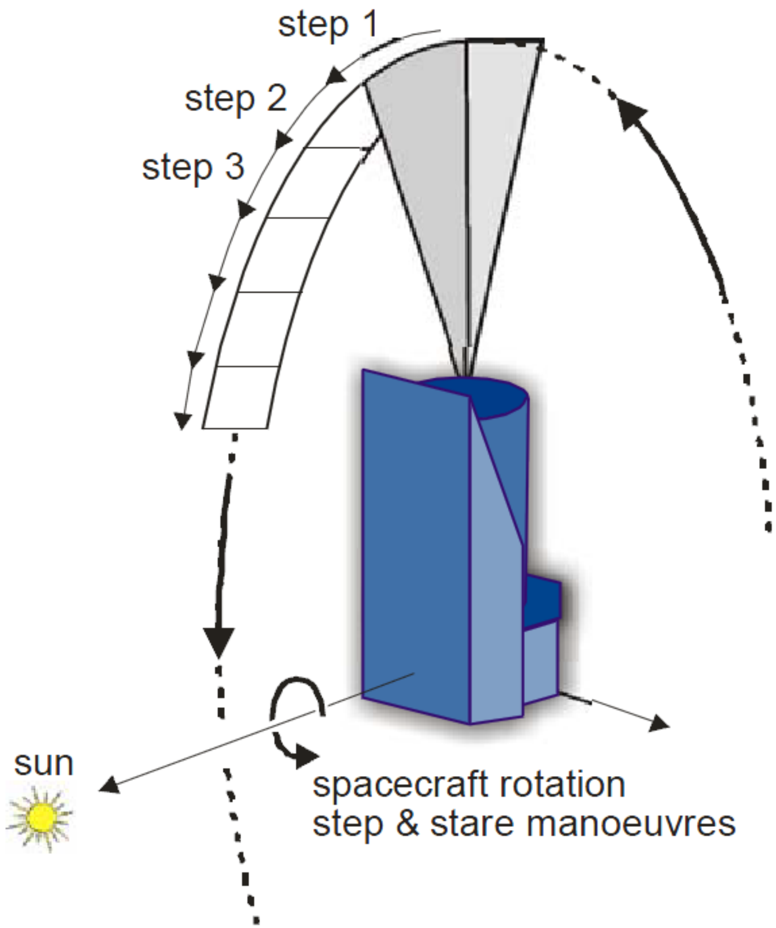
BACKGROUND

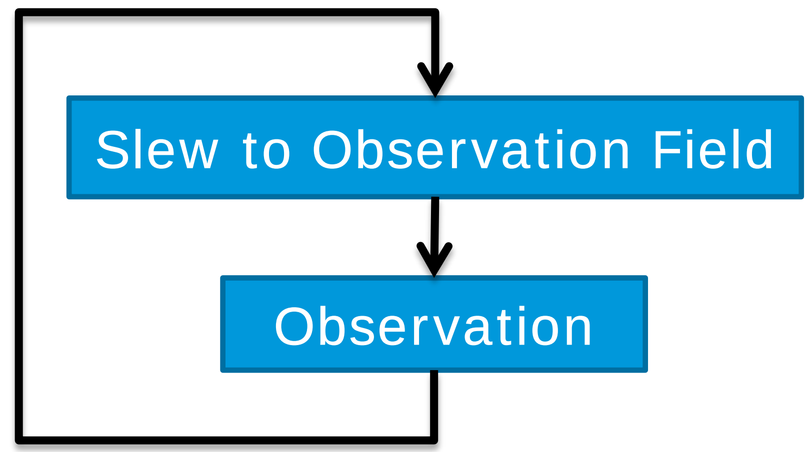
“Offline” Mission

Euclid will be an “offline” mission:

- High level of on-board autonomy for routine operations and failure discovery, isolation and recovery
- Recording of scientific data and housekeeping telemetry (instruments and service module) in MMU
- Daily ground contact for 4 (TBC) hours
  - Dump of stored data from MMU
  - Uplink of new Mission Timeline commands

Science Operations Concept





Ground contact parallel to on-going science activities, due to low gain antenna and steerable high gain antenna.

On-board stored Data

- About 100 GB of on-board stored data per day
    - Generated by about 21 observations

- High TM rate for downlink (75 Mbps)
    - About 3h downlink time (ignoring retransmissions of lost data)

- High TM rate requires a K-band link

STORAGE AND DOWNLOAD OF DATA

Communication Concept

- Parallel X-band and K-band links
  - X-band: Housekeeping TM and TC uplink
  - K-band: Download of recorded data from MMU

- Challenges:
  - High data volume and data rate
  - K-band communication from L2 distance is not reliable (sensitive to weather)

    → CFDP was selected to ensure completeness of downloads

Consequences of CFDP

CFDP transfers files, not TM packets

→ "Traditional" packet stores to be replaced by on-board file system

→ Bonus: Instruments can create big science files, e.g. in "FITS" format

(instead of cutting science data into small TM packets)

Science Files

- Each observation results in science data of about 5 GB (combined output of both instruments, VIS and NISP)

→ Data of one instrument is less than 4 GB per observation

- 4 GB is maximum file size for CFDP and some file systems

→ One science file per instrument per observation

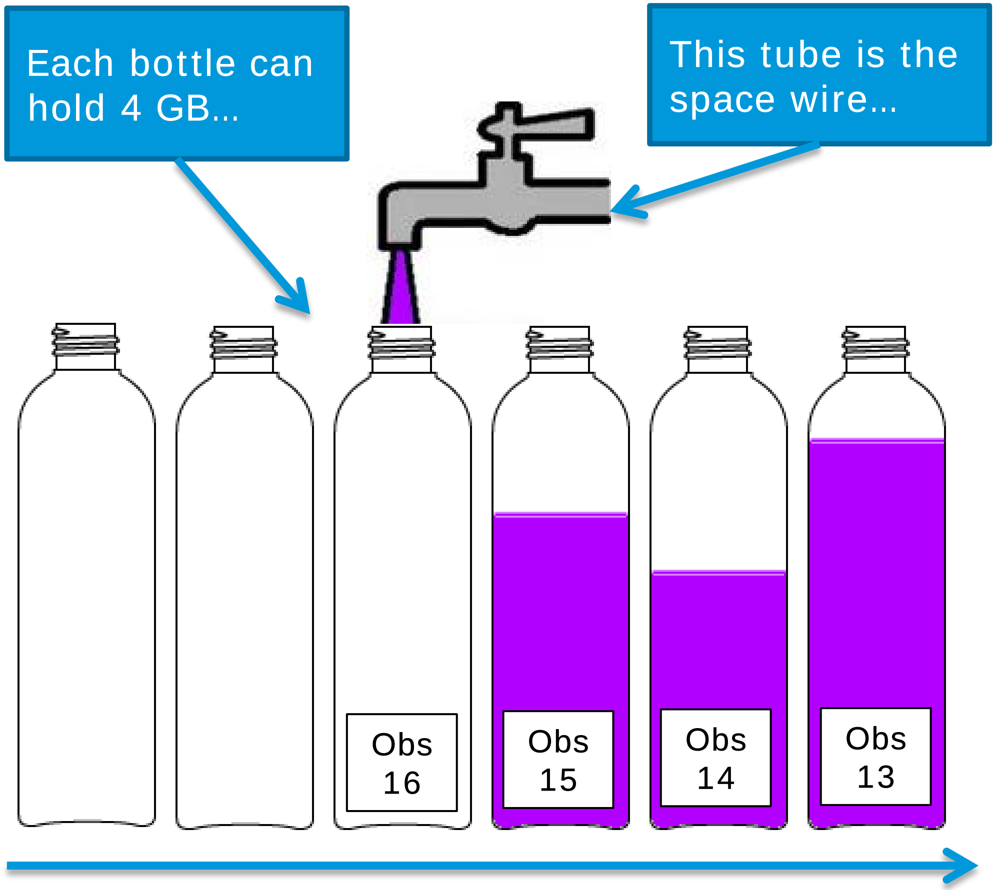
Housekeeping Telemetry

- Files are used as containers to store H/K TM packets
- CDMU routes H/K TM packets to MMU for storage into files
- Files shall regularly replaced (e.g. one file per day)
- Downloaded H/K files will be ingested into the Mission Control System to process the TM packets

Raw Data over Space Wire – introducing the "Bottle Filling Machine"

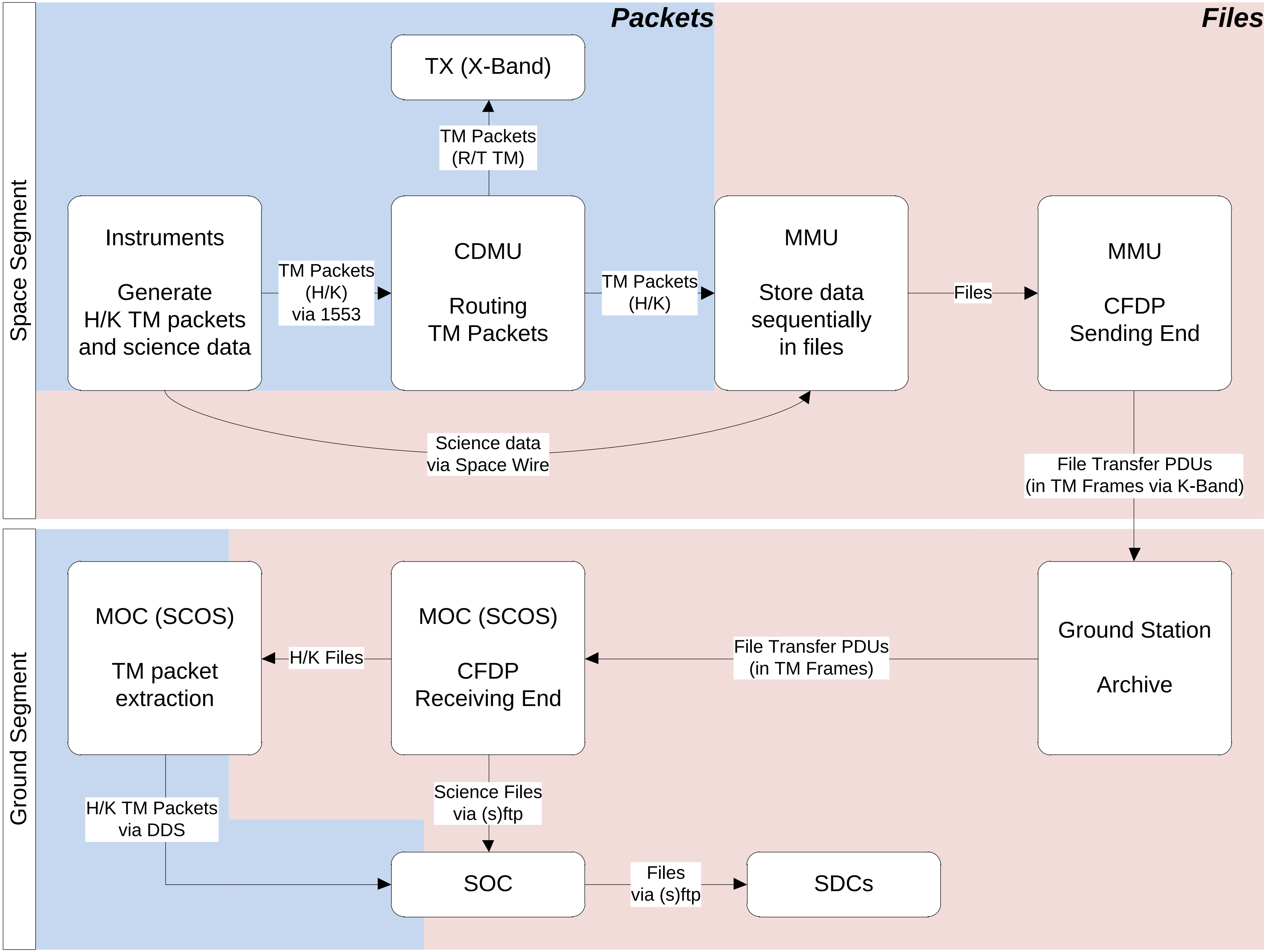
New MMU concept:

- MMU simply writes data from space wires into the assigned files (this could be files of any standard, e.g. FITS)
- Via (MTL) TCs the next file can be assigned (i.e. the next empty bottle is named and will be filled)



Data Flow and Interfaces

1. Instruments science data to MMU	via space wire
2. Instruments H/K TM packets to CDMU	via 1553 bus
CDMU H/K TM packets to MMU	via space wire
3. MMU to MOC	via CFDP
4. MOC to SOC (science files)	via (s)ftp
MOC to SOC (H/K TM packets)	via DDS
5. SOC to SDCs	via (TBD)



Packets
Files
Space Segment
TX (X-Band)
TM Packets (R/T TM)
Instruments
Generate H/K TM packets and science data
TM Packets (H/K) via 1553
CDMU
Routing TM Packets
TM Packets (H/K)
MMU
Store data sequentially in files
Files
MMU
CFDP Sending End
Science data via Space Wire
File Transfer PDUs (in TM Frames via K-Band)
Ground Segment
MOC (SCOS)
TM packet extraction
H/K Files
MOC (SCOS)
CFDP Receiving End
File Transfer PDUs (in TM Frames)
Ground Station
Archive
H/K TM Packets via DDS
Science Files via (s)ftp
SOC
Files via (s)ftp
SDCs

OPERATIONS CONCEPT

Mission Planning and Execution (TBC by SGS)

Observation:

- Observation is defined by time and coordinates (when and what shall the telescope observe?)
- Result of an observation will be a science file

Mission Planning:

1. SGS uses unique ID for each observation
2. Resulting science file shall have ID in file name
3. After file transfer from MOC to SOC, files can easily be referred to observations and directly processed

Example for a Mission Timeline

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1. TC: Slew to observation field 15
2. TC: Open new file (store-ID “VIS”, filename “VIS_OBS_15”)
3. TC: Open new file (store-ID “NISP”, filename “NISP_OBS_15”)
4. TCs: All (instrument) TCs for observation 15

5. TC: Slew to next observation field 16
6. TC: Open new file (store-ID “VIS”, filename “VIS_OBS_16”)
7. TC: Open new file (store-ID “NISP”, filename “NISP_OBS_16”)
8. TCs: All (instrument) TCs for observation 16

...

Download Strategy (1/2)

- The ground CFDP entity will be implemented in the Mission Control System at MOC
    - Advantage: Incomplete downloads can continue via a different ground station
    - Cost: High network bandwidth between MOC and ground stations (~100 Mbps) required → no problem in 2020…

Download Strategy (2/2)

- Two file transfers in parallel
    - Efficient bandwidth usage (no delays between two single transfers)
- After successful downloads, files shall be deleted by ground commands

Operations Scenario – Routine Ops (1/2)

- Required pass duration:
  - Time needed to download recorded data
  - Margin for manual activities
  - MMU recording space to be dimensioned for a duration of minimum 72 hours
    - to cover the contingency case of "missed pass" combined with "no other ground station available within the next 48 hours"

Operations Scenario – Routine Ops (2/2)

- Download of recorded data
    - 3h required without losses and retransmissions
- Upload of new Mission Timeline commands
- Science observations can continue during ground station pass (steerable HGA)

Operations Scenario – Contingency

- Ground station unavailability
  → No files downloaded

- Bad weather
  → Download of some files only (or none at all)

- Options for recovery of data already recorded on-board
  - Trickle down during subsequent passes
  - Short notice scheduling of additional station time (if available)

CURRENT STATUS

Current Status

- Discussion and exchange of thoughts during the initial Project/ESOC Progress Meetings

- Work was done in the Operations Working Group

- System Requirements Specification comprises CFDP

- Prototyping within ESA quite advanced
  - Space segment demonstrators
  - Ground Station Equipment development in progress and already tested
  - MOC Mission Control System development in progress and already tested

IDEAS

Improving CFDP Handshaking

Splitting CFDP downlink PDUs between X and K-band:

- CFDP data via non-reliable K-band
- CFDP directives via reliable X-band

- Improved handshaking, not only relying on timeout checks for lost directives

- However, S/C design more complicated/expensive

CFDP for File Upload

- So far MMU shall only store data for download (not upload)
- Upload of files required for MTL, OBCPs, TC-Files, software images, etc.
- CDMU could host an additional internal MMU for these files
  - This MMU is only used to store uploaded files. For this concept implementations already exist (based on PUS service 13) and can be reused with low effort
- In case of only one MMU to store all kind of files, the chances are quite good to use CFDP in both directions

QUESTIONS ?

BONUS SLIDES

Estimation for Losses on K-Band

1. Full loss (with any stronger rain, possibly with any rain, depending on the link margin), expected for 1% to 2% of the time.

2. Intermediate/scintillation range with cut off of the scintillation frequency at ~10 Hz. (i.e. link conditions can be assumed as constant over 0.1 s).

3. Good range (here the K-band link works as well as any other radio link), expected for 90% of the time.

Possible S/C Implementation