ADCSS 2018 – C&C for Exploration ExoMars 2016 and 2020 Landers

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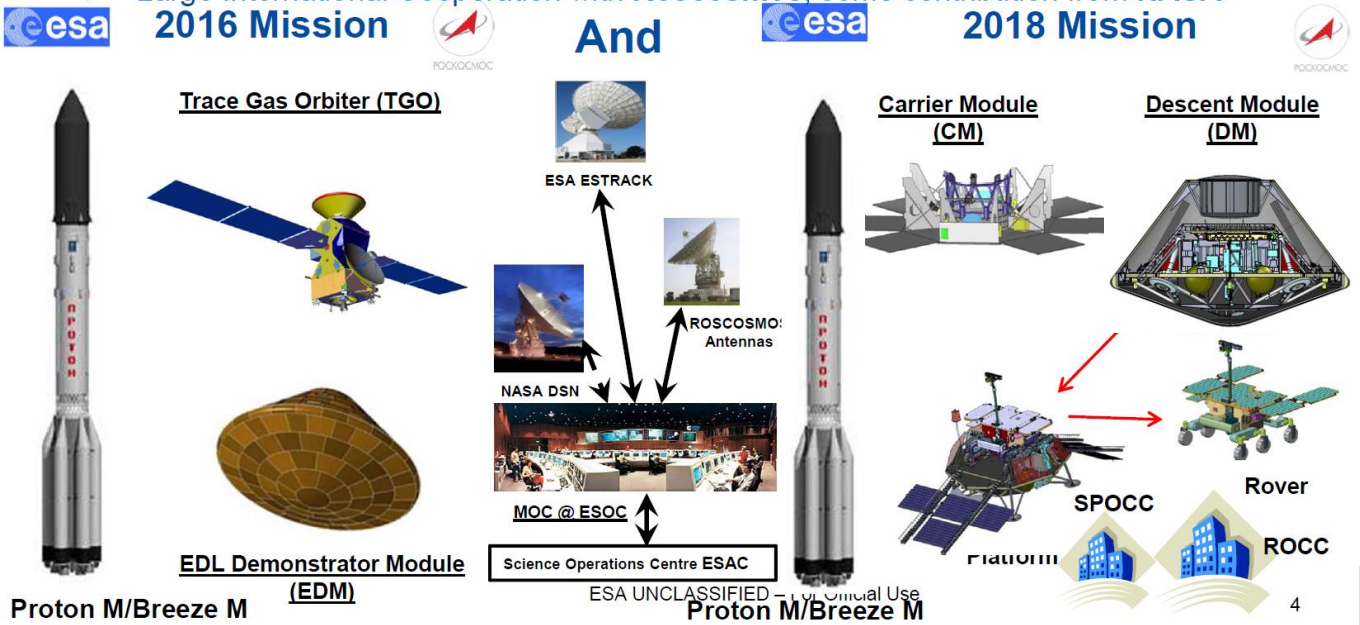
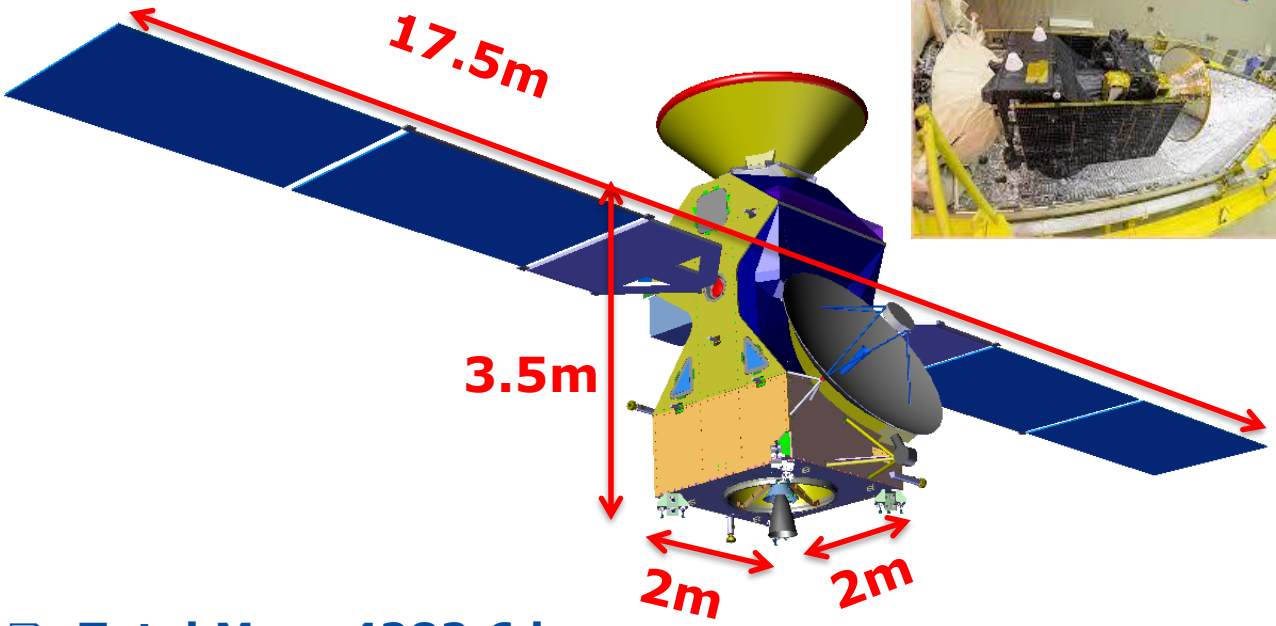
ExoMars Programme Overview

Two missions, one in 2016 and one in 2020, respectively

- The 2016 flight segment consists of a **Trace Gas Orbiter (TGO)** and an **EDL Demonstrator Module (EDM) – Schiaparelli**
- The 2020 flight segment consists of a **Carrier Module (CM)** and a **Descent Module (DM)** with a **Rover** and a stationary **Landing Platform**
- Large international cooperation with **Roscomos,** some contributions from **NASA**



2016 Mission – SCC Overview

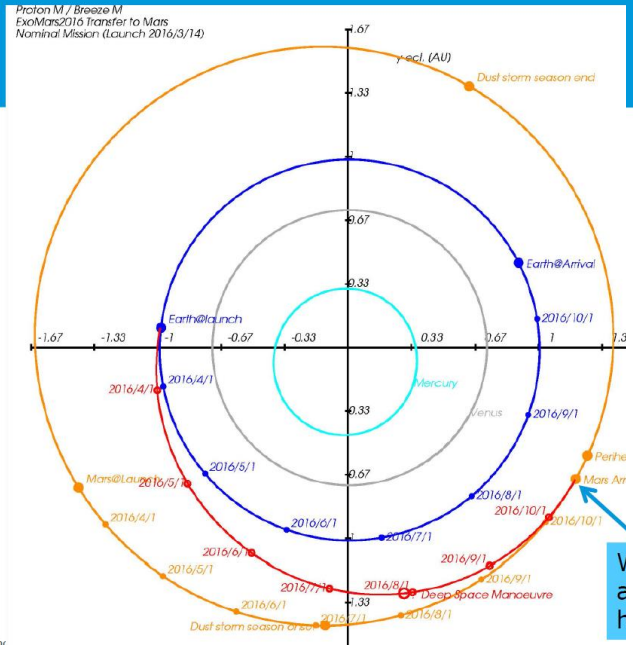


SCC on shaker for mechanical testing

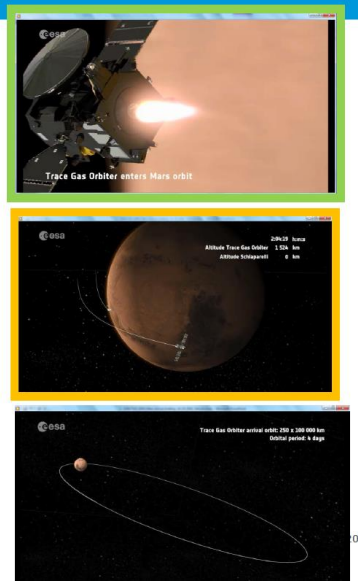
- **Total Mass 4282.6 kg**
  - TGO Mass 3706.3 kg (incl. 2427.5kg propellant and 8.5 kg of pressurant)
  - EDM Mass 576.3 kg (incl. 46.2 kg of propellant)

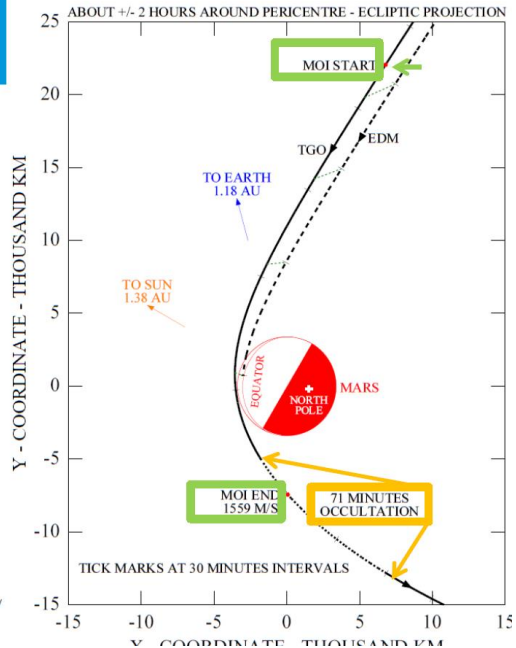
2016 Mission Overview

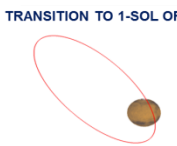
Interplanetary Transfer (last 7 months)

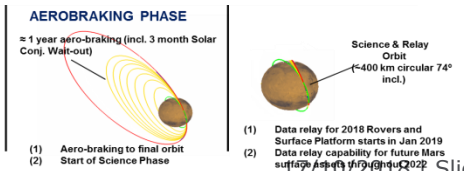


MOI : 3 critical hours (TGO)

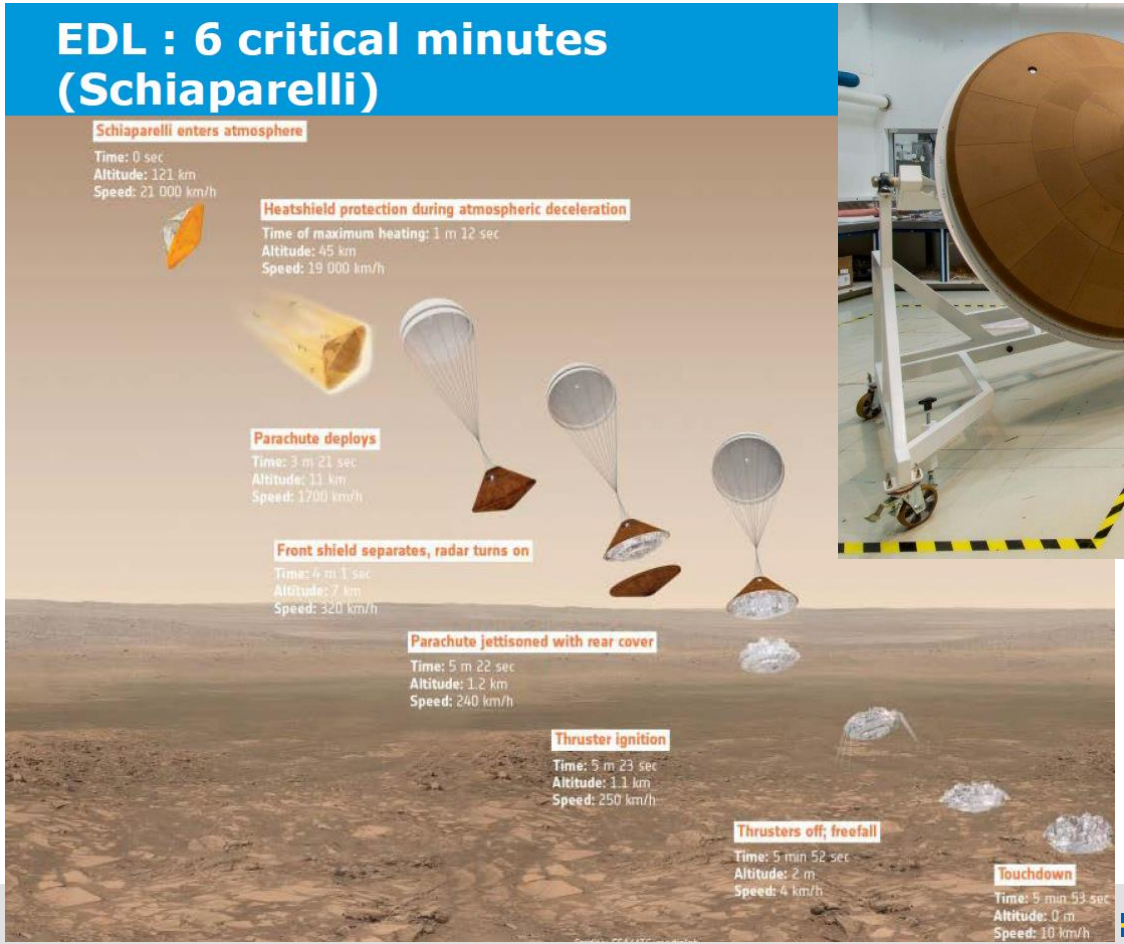


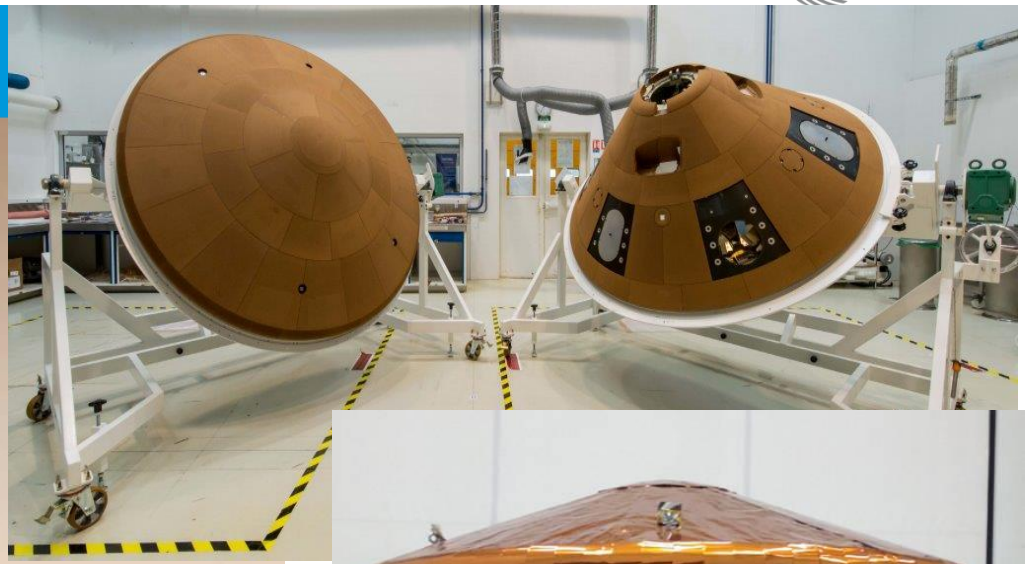




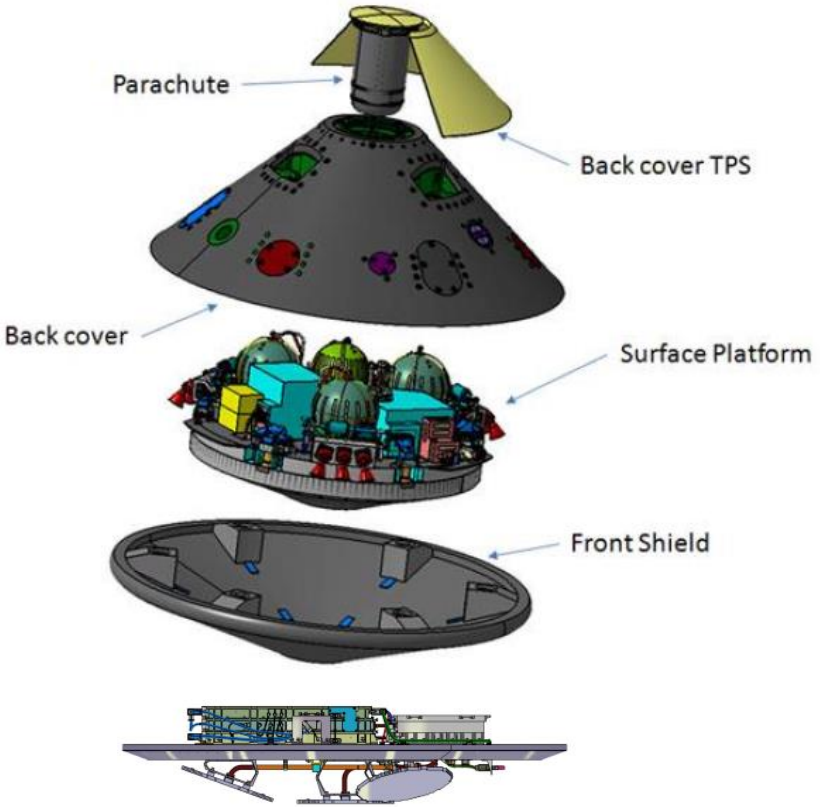


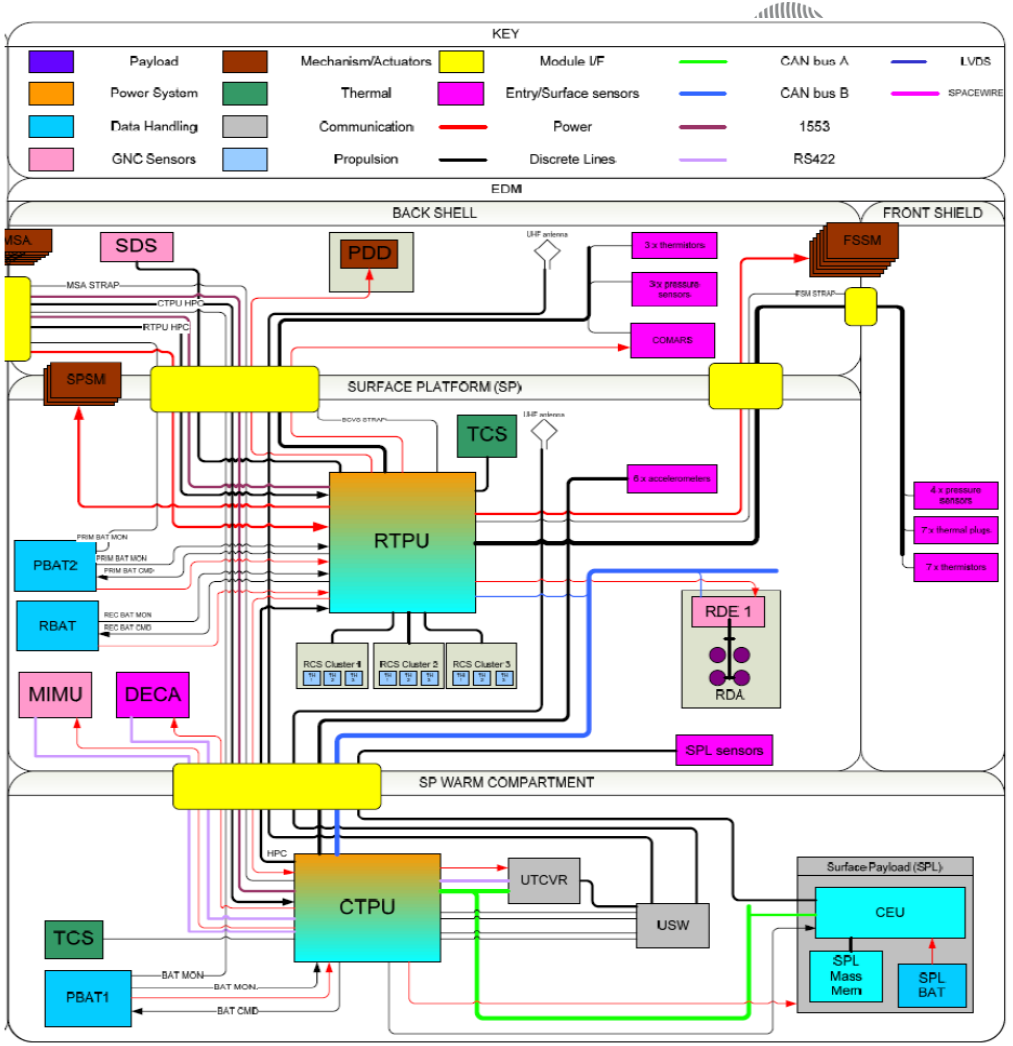
2016 Mission Overview - EDM





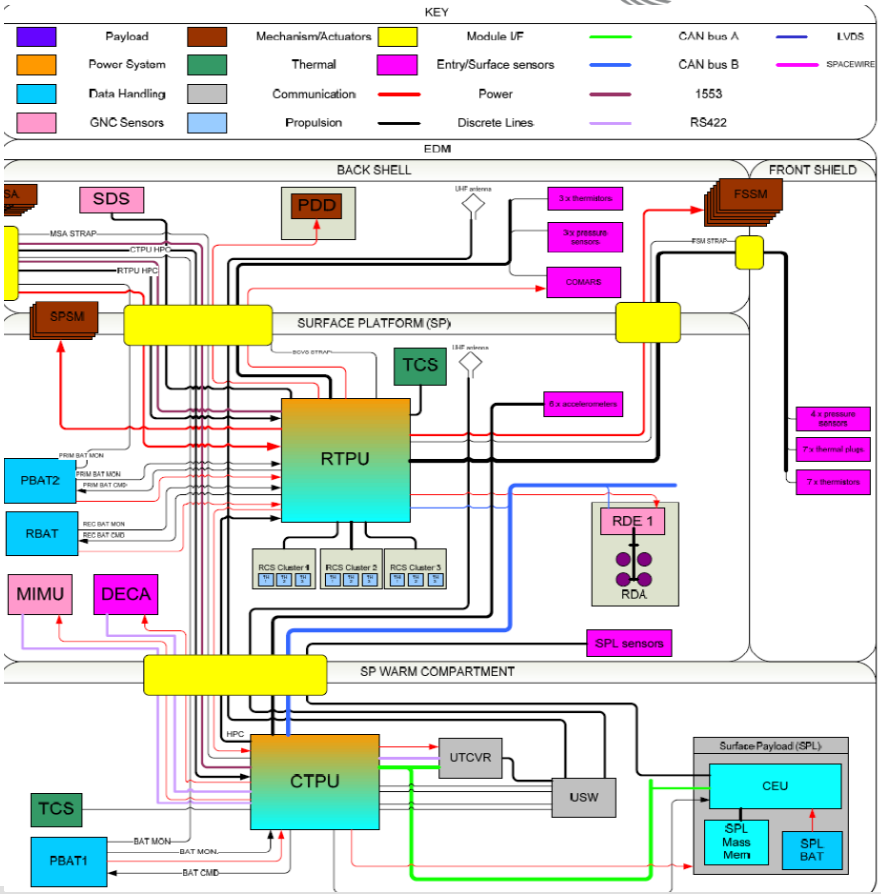
EDM – Avionic architecture





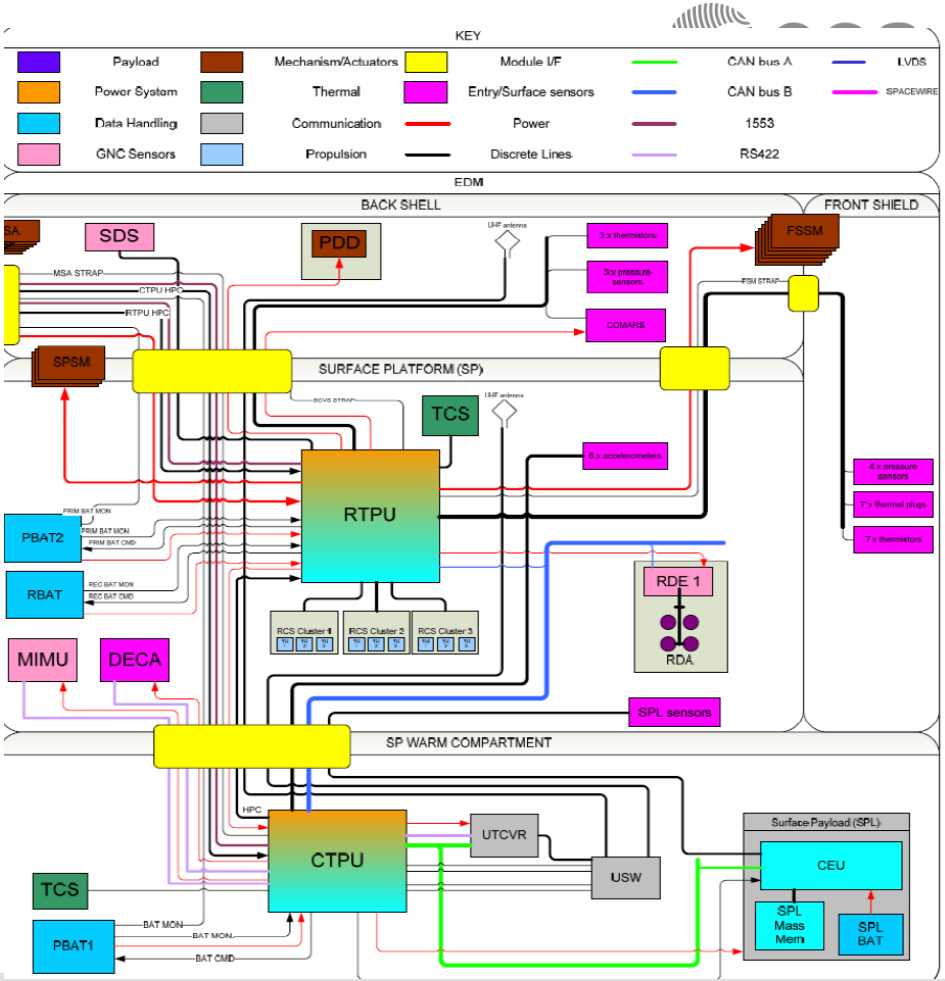
EDM – DH subsystem

- CTPU: classic OBC architecture (no redundant) with power section including an hibernation timer (supplied by dedicated DC/DC) for low (zero)-power mode. Power distribution section with 4 LCL lines + 4 heater lines, one main DC/DC (135W output power). One rechargeable battery but without charging section. RT for TGO 1553 on payload bus
- RTPU: classic RTU (no redundant) including a power distribution section with 4 LCL lines + 8 heater lines, one main DC/DC (220W output power), two rechargeable batteries (28V and 60V) but only one charging module, one THR driving module (9 400N THRs in pulse mode), one pyro activation module (RCS, PDD, FS and BCV sep); RT for TGO 1553 payload bus
- Battery switches to manage safely battery charge without charging modules



EDM – DH subsystem (2)

- 2 platform buses based on CAN like RS485 + CANopen:
  - Bus A (surface bus): CTPU, DREAMS (PL) and UHF Transceiver
  - Bus B: CTPU, RTPU and Radar Doppler Altimeter
- Classic DH interfaces (ASM, TSM, BSM, HPC, BDM)
- HPC used for Battery relay switches
- Ad-hoc interfaces for accelerometers, pressure transducers, payload during entry and sun sensors
- RS485 for MIMU acquisitions
- RS422 for camera images acquisitions
- RS422 for TM/TC Interface with UHF transceiver



EDM – DH subsystem (3)

- GNC main control loop at 10 Hz
  - THR commands at 10 Hz
  - Radar TMs acquired at 20 Hz (linear velocity and distance from ground)
  - IMU data (angle and velocity) acquired at 100 Hz
- CSW control loop at 10 Hz
  - HK TMs (RTPU) acquired at 10 Hz
  - Commands at 10 Hz
  - UHF transceiver management @10Hz
- 100ms TM/TC windows (60ms for TMs and 40ms for TCs) separated by SYNC messages

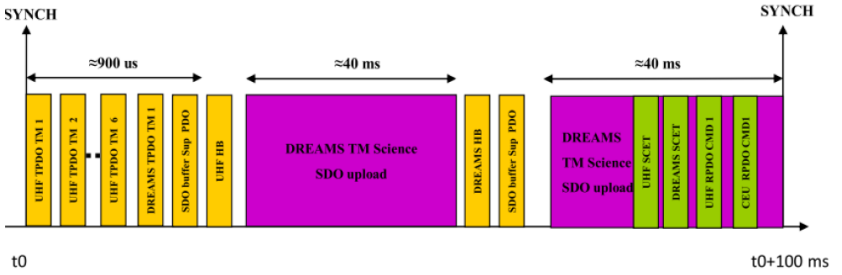


Figure 5-28: EDM CAN bus A TM/CMD window

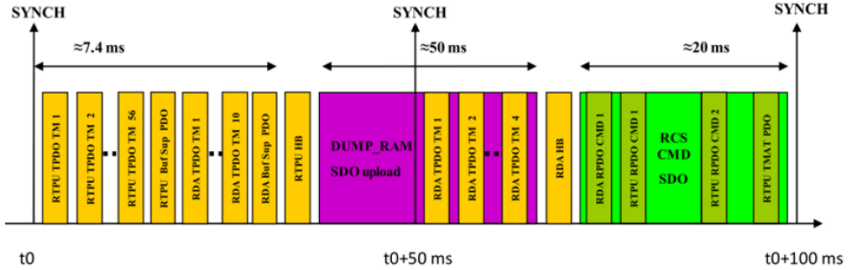


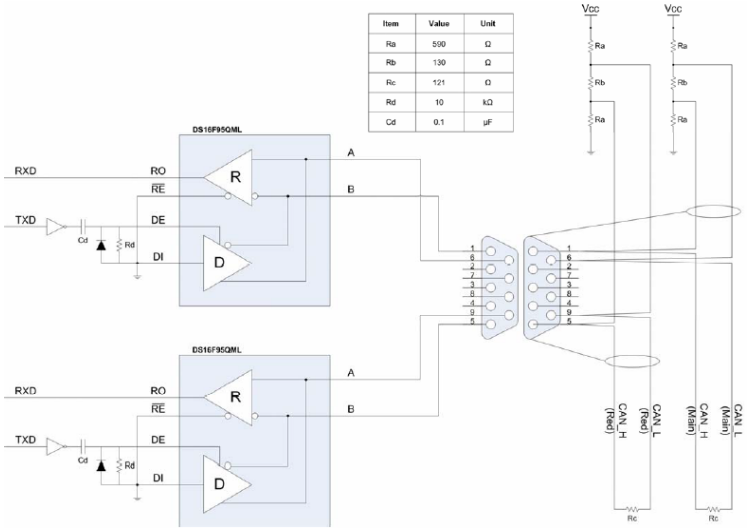
Figure 5-29: EDM CAN bus B TM/CMD window

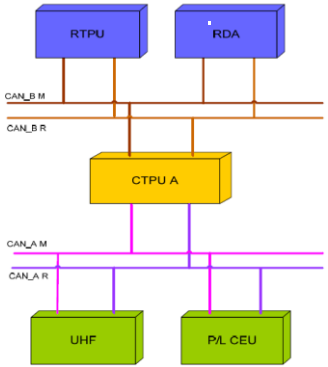
EDM – CAN bus architecture

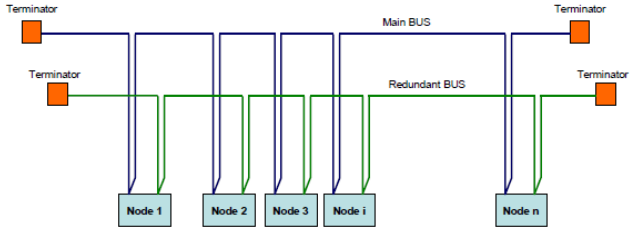
- 2 buses, each one based on two physical redundant buses (redundancy management disabled during EDL) with selective bus architecture. CANopen protocol selected for EDM CAN networks (first time in European space applications).
- All slave nodes are equipped with ESA/SITAEL CANopen Controller IP core (developed under EXM program), CTPU runs a tuned CANopen SW stack from Vector.
- CAN "shock" at the beg (workshops, new TMTC ICDs, DCFs, tuning of necessary HW – CAN controllers + DMAs in the OBCs-, tuning of necessary SW – how to handle CANopen SW stack task-, long validation of the CCIPC core), but at system level simple validation of the networks due to few terminals and short bus length (electric waveforms and correct implementation of DCFs, no tool needed for protocol validation).
- Physical layer based on CAN-like RS485

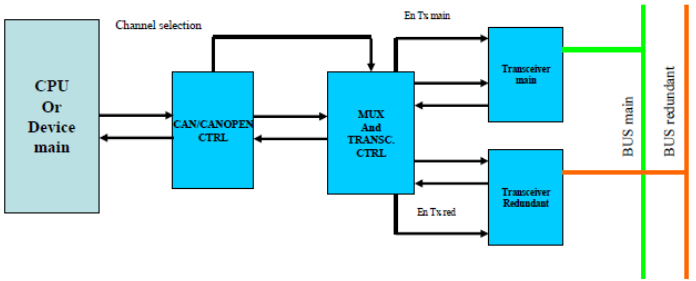
EDM – CAN bus architecture

- TM/TC protocol based on CANopen (mainly PDOs, SDOs used for reliable commands and large data exchange , i.e. SW patch/dump , THR commands and for science telemetry download)
- 100ms TM/TC windows within SYNC messages. 1Mbps.
- Bus redundancy management via Heartbeat message.







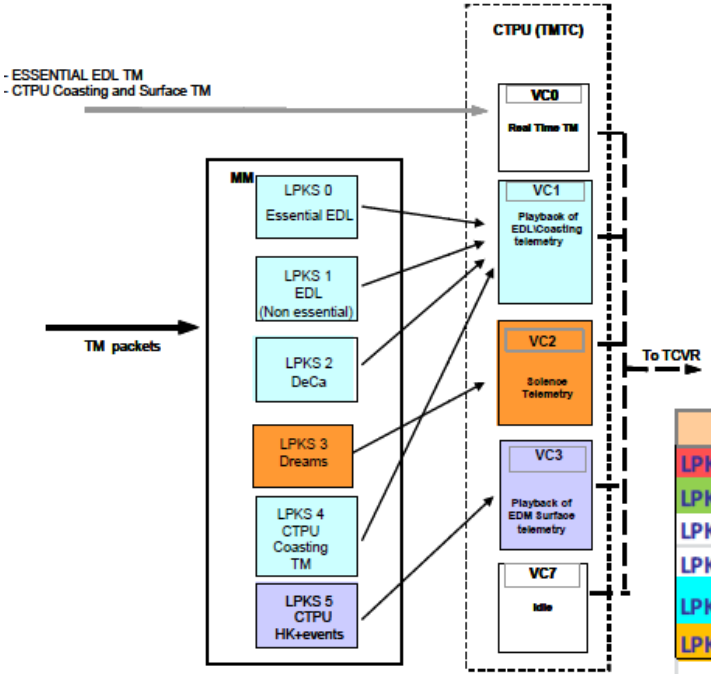


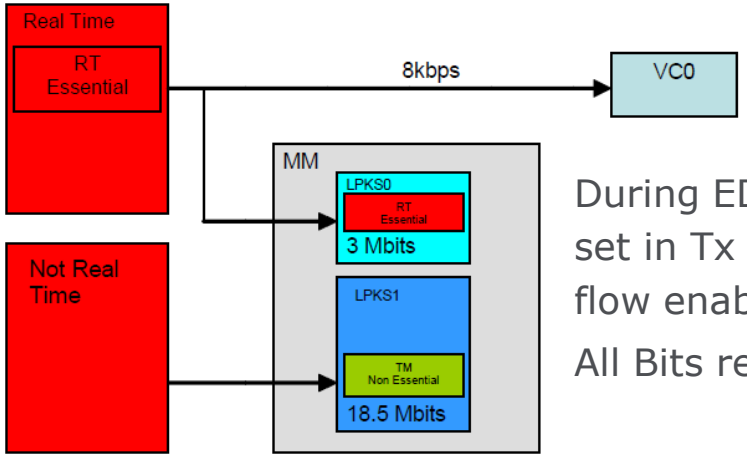
EDM – DH budgets

- Bus A:
  - UHF: 1 PDO at 10Hz (transceiver configuration and status), 4 at 1 Hz (RX and TX analogue status, forward and return link status)
  - DREAMS: 1 PDO at 1 Hz (configuration and status), 1 SDO at 10 Hz (science, patch&dump)
  - Average bus load: 6kbits/s (EDL), 110kbits/s (surface)
- Bus B:
  - RDA: 4 PDOs at 20Hz (velocity and distance from ground), 4 at 1 Hz (radar configuration and status), 1 SDO for EEPROM download
  - RTPU: 20 PDOs at 10 Hz (pyro prearm/arm/fire/output status, THR LCL/valve status, pressure transducer/sun sensor status, heater switches status), 37 at 1 Hz (thermistors and thermocouples), 1 SDO for THR commanding (18 bytes) at 10Hz
  - Average bus load: 55kbits/s (EDL)
- IMU: updated every 10ms, 10 words (3 angles and 3 velocities 3 status 1 checksum), 16 bits each, at 200 Hz

EDM – DH budgets

- Packet stores configuration
- MM budget



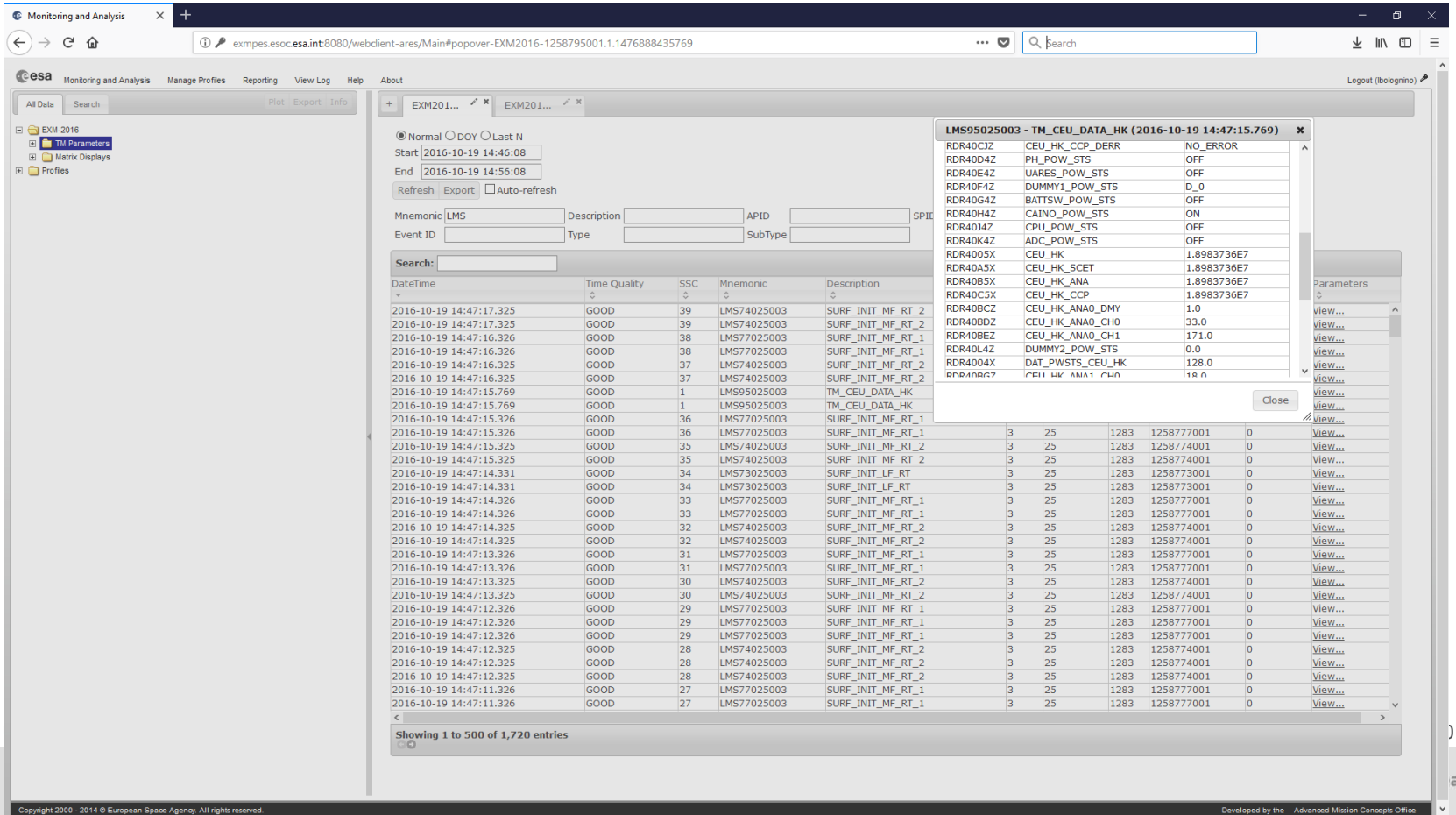


During EDL UHF transceiver was set in Tx Force, no Prox-1 control flow enabled, 8kbps.

All Bits recovered by TGO.

MM Budget		[Bits]	[Mbits]	Limits
LPKS 0	EDL essential data	2890256	2.8	100
LPKS 1	EDL NON Essential Data	38684080 b	36.9	
LPKS 2	DECA Data	32149340.16	30.7	
LPKS 3	Dreams Data	52428800	50.0	
LPKS 4	Coasting Data	70903680 b	67.6	
LPKS 5	Surface data	12134400 b	11.6	
		TOTAL	199.5 Mb	200 Mb

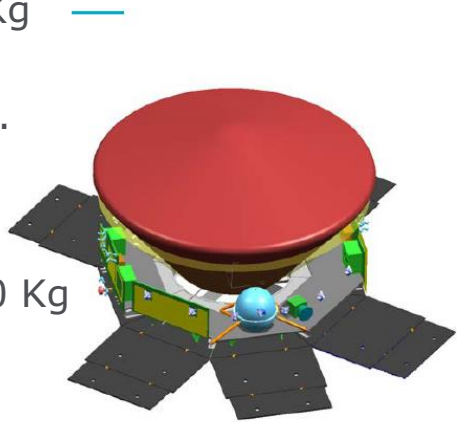
A “CAN trace” log from Mars

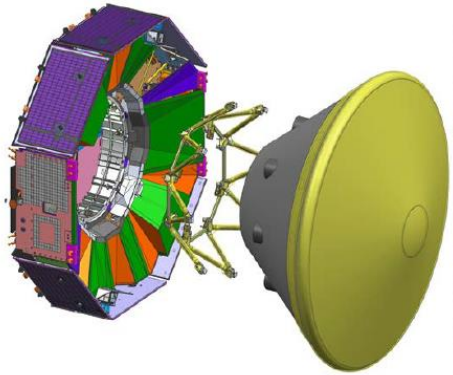


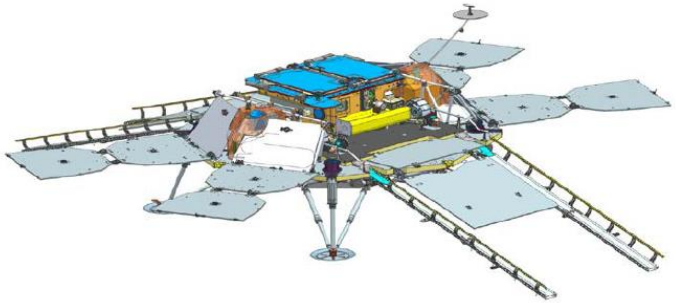
2020 Mission – SCC Overview

The ExoMars 2020 mission SCC has a 2,900 Kg mass at launch of which, 120Kg and 145Kg propellant for the carrier and DM respectively. SCC includes:

- Carrier Module (Eu), 850 Kg
- DM-CM separation system (Ru) , about 40 Kg
- Descent Module (Ru) mass of 2,000 Kg including
  - Landing platform and Rover
  - Significant European contributions from 2016 mission and new
- Rover Module (Eu), total mass 345 Kg at launch, mobile mass 310 Kg. Life time 218 sols, inclusive of 9 PPL (ESA, NASA, ROS)

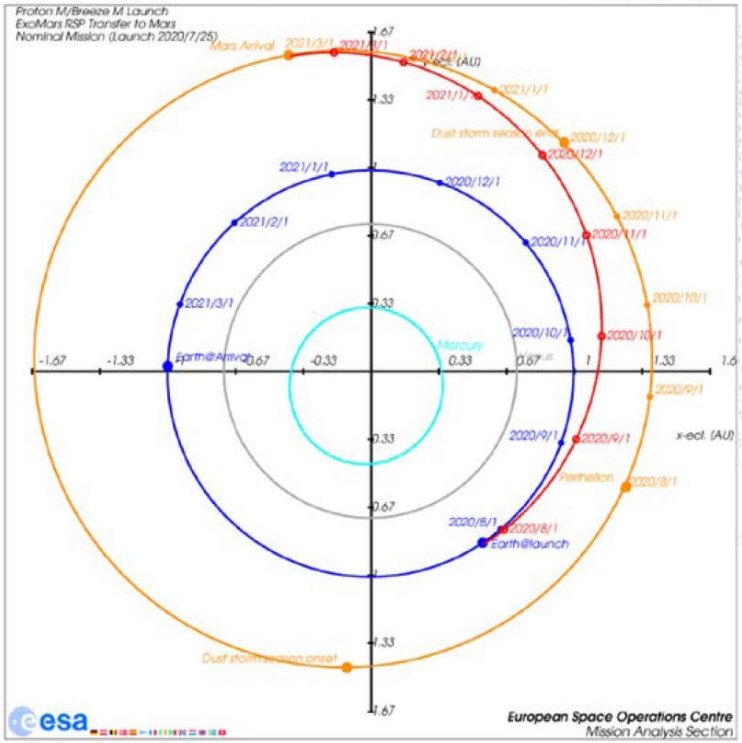




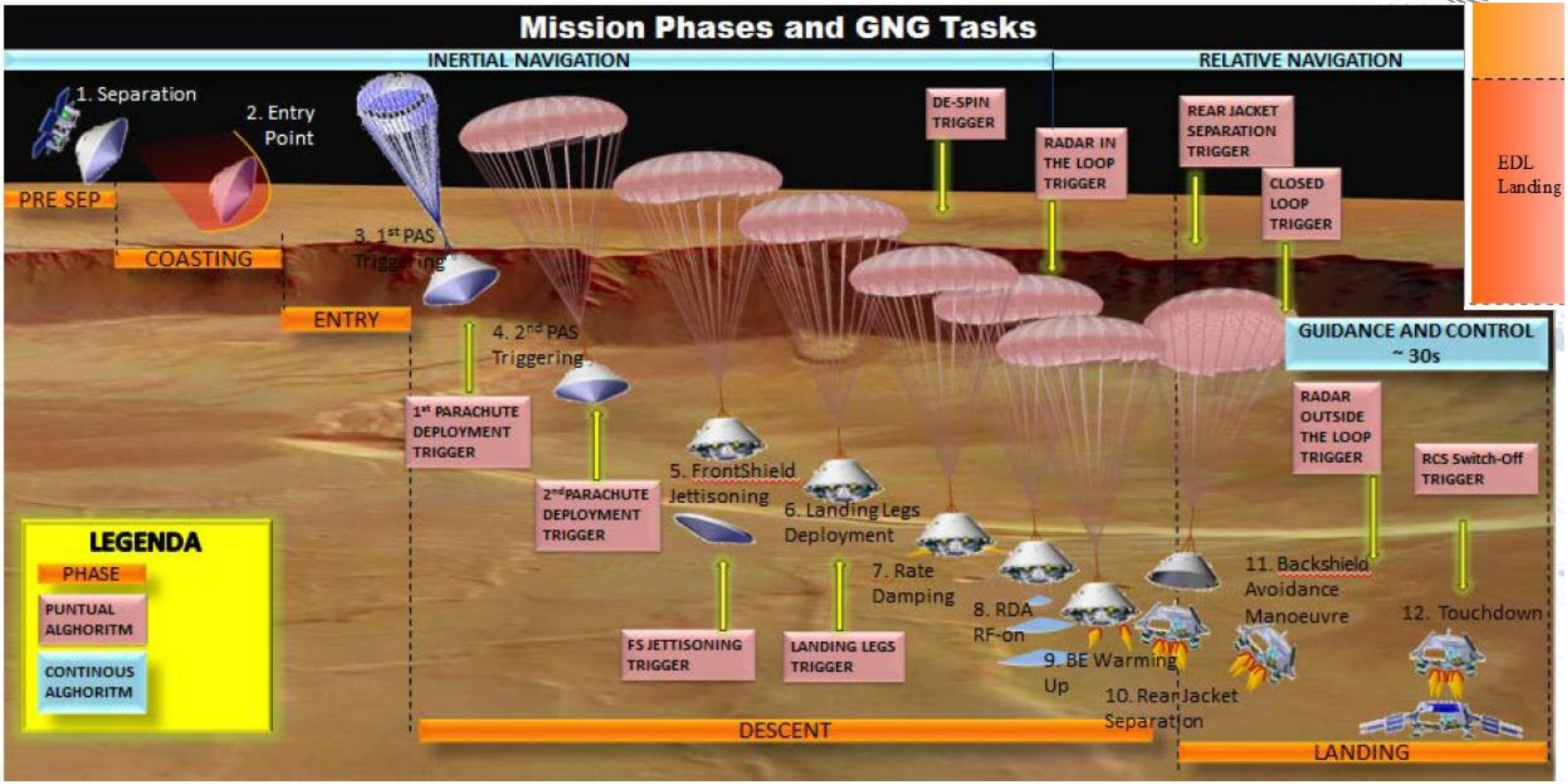


2020 Mission overview

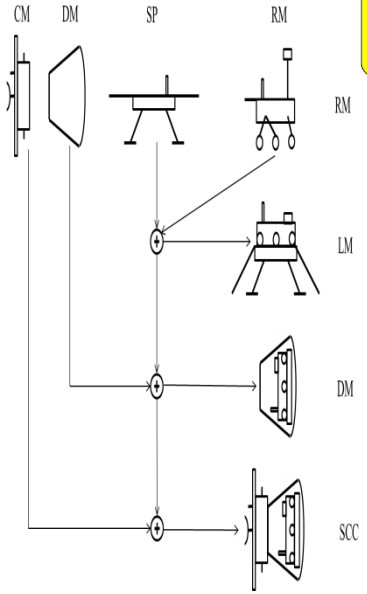
Phase	Event	Remarks
Launch	Liftoff and Escape: 2020/7/25 (LPO)-2020/8/13 (LPC)	20 day launch window with 6 days of launchability
Early Orbit Phase	• Launcher Injection Correction (LIC=TCM1) within 7 days after launch • Clean-up manoeuvre (TCM2) within 20 days after launch	
Interplanetary Transfer	• Sun pointing attitude for 50 days after launch • Earth pointing attitude for remainder of cruise	
Approach phase	• Increasing navigation campaign • TCM3-5 at EIP -30, -8 and -2 days • Targeted CM-DM separation at EIP-30 minutes	
EDL	Mars landing on 2021/3/19 for any day of the LP (Ls 19 deg)	
Surface Phase	• Conjunction event in early October, 2021 • Assumed begin of global dust storm season (Ls 180 deg): 2022/2/25	• The conjunction event will cause an interruption of surface operations of TBD days • The actual start and the effect of large dust storm events are TBD

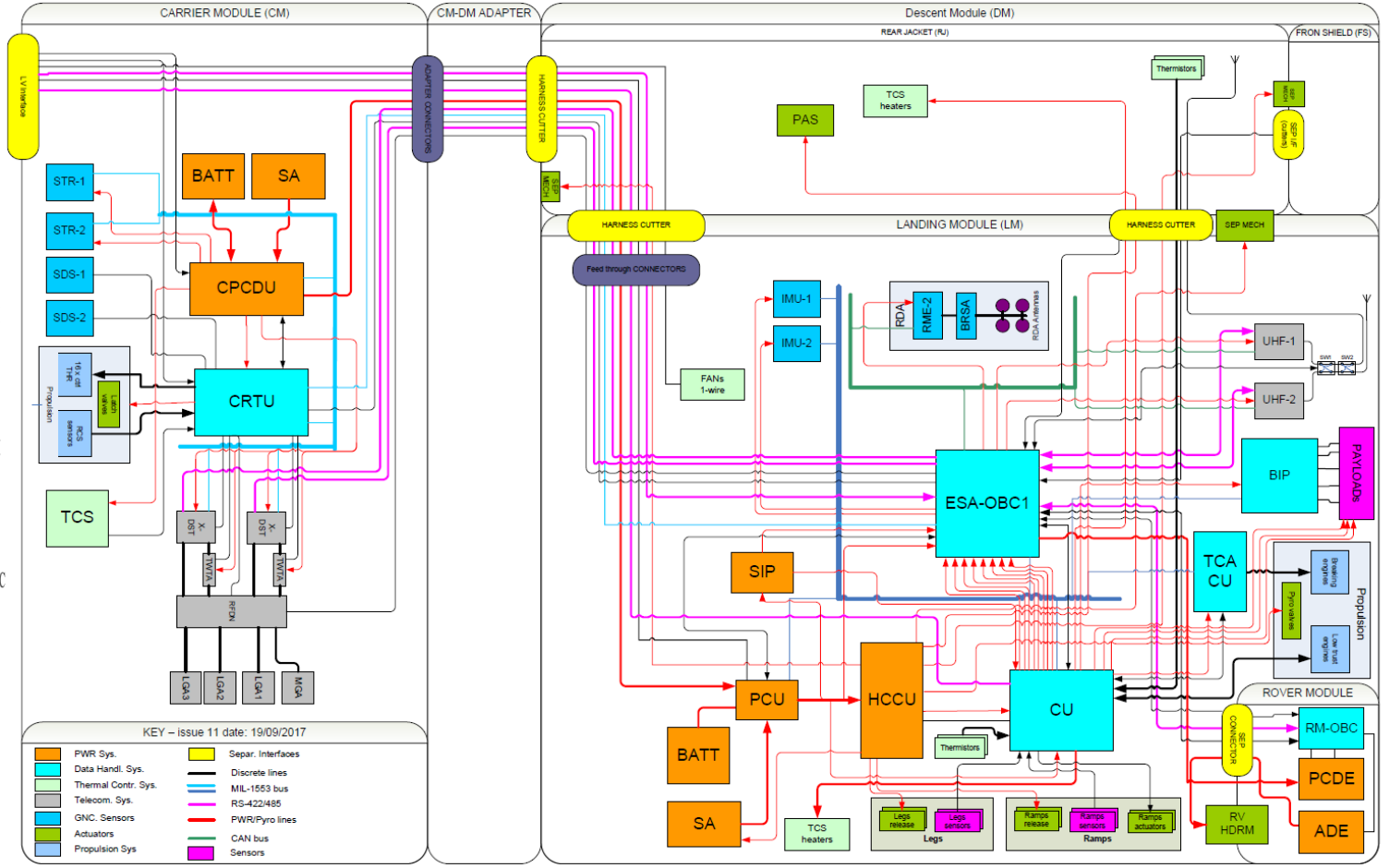


2020 Mission overview - DM



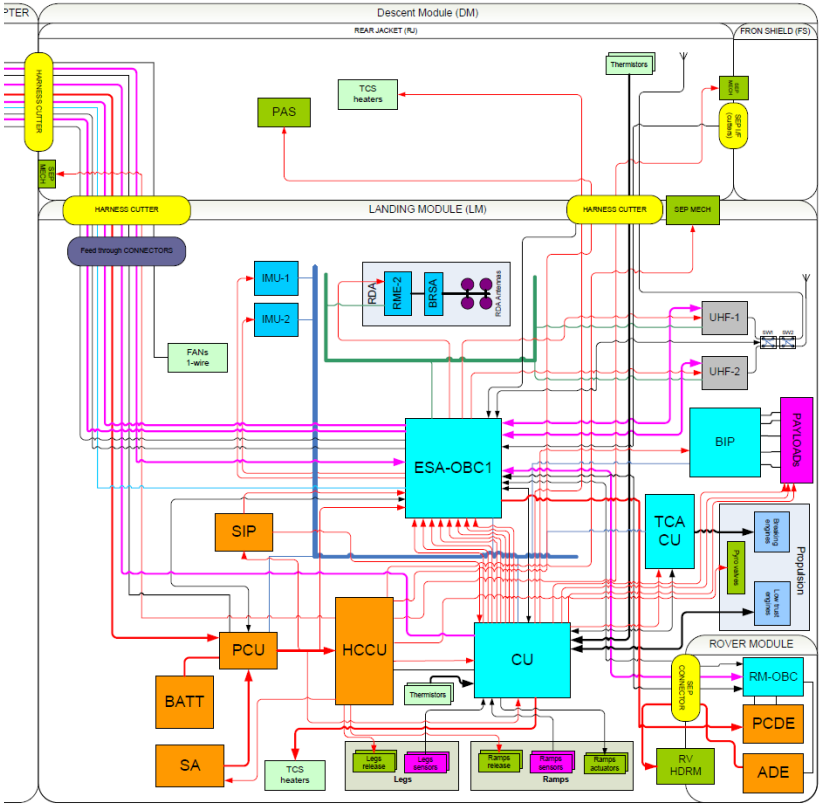
SCC avionic architecture





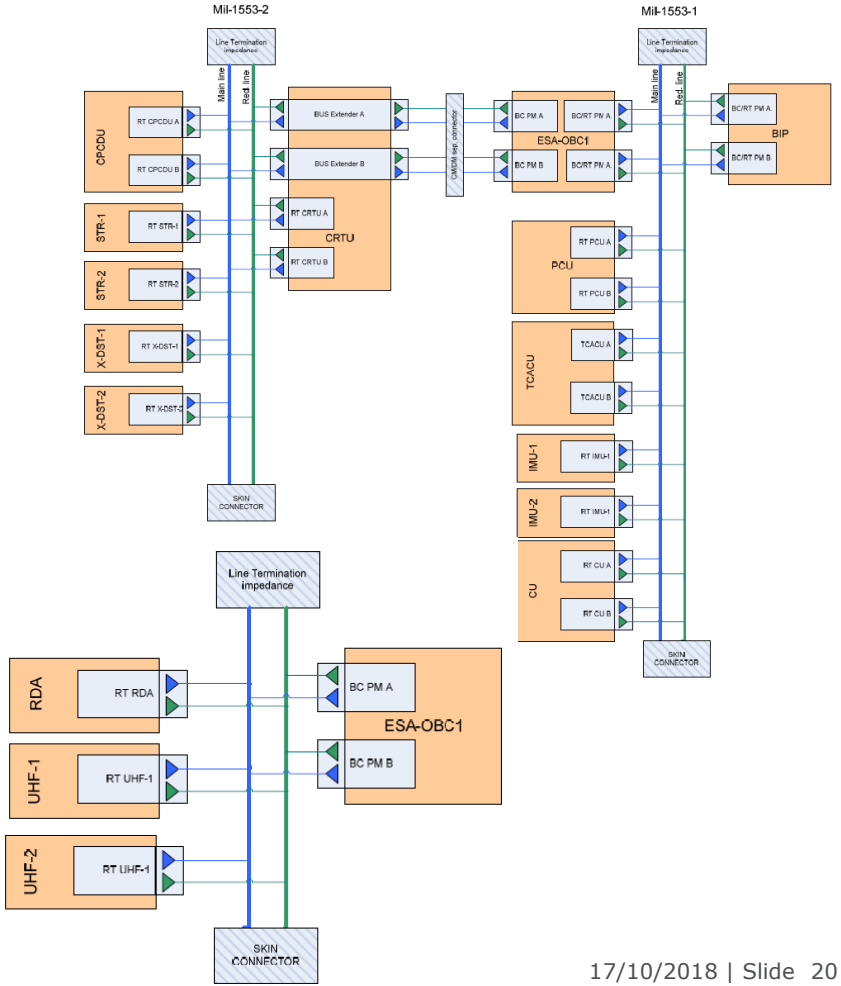
DM – DH subsystem

- ESA OBC1: classic OBC architecture (redundant) including a dedicated low power mode (switch-off of inactive "hot" sections), a power distribution section with 4(+4) LCL lines + 2(+2) heater lines. Management of CM in cruise and DM during EDL and surface, FDIR, GNC SW and sensor/actuator I/F, X-band transponder and RFDN, TM/TC data rate selection, Mass Memory data storage and CM/DM separation activation.
- CRTU (CM): classic RTU (redundant) with propulsion boards for THR driving and two 1553 bus extenders (option for CAM).
- CU: Russian "RT" unit dedicated to interface OBC1 to Russian units for commanding purposes, for actuating Low Thruster Engines (LTE), controlling the DM heaters and DM pyros and monitoring purposes (TCS thermistors, Russian units health status)
- DM TCACU to control and monitor the Breaking Engines.
- BIP to interface Russian P/L.



DM – DH subsystem (2)

- 3 platform buses:
  - 1553 CM bus (redundant): OBC1, CRTU, CPCDU, STR-1, STR-2, X-DST-1 and X-DST-2
  - 1553 DM bus (redundant): OBC1, PCU, TCACU (thruster control actuator control unit), IMU-1, IMU-2, CU and BIP.
  - CAN like RS485 + CANopen DM bus (redundant): OBC1, Radar Doppler Altimeter, UHF-1 transceiver and UHF-2 transceiver.
- Classic DH interfaces (ASM, TSM, BSM, HPC, BDM)
- Ad-hoc pressure transducers and sun sensors
- Redundant RS422 for rover TM/TC exchange
- RS422 for TM/TC Interface with UHF transceiver (same type for the Rover link)

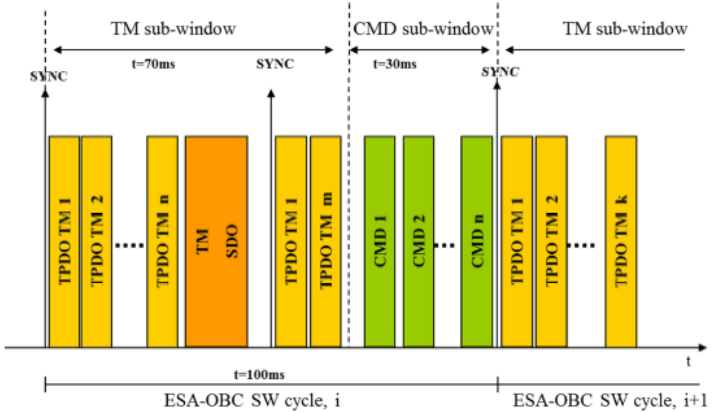


DM – DH subsystem (3)

- GNC main control loop at 10 Hz
  - THR commands at 10 Hz
  - Radar TMs acquired at 20 Hz (linear velocity and distance from ground)
  - IMU data (gyro and accelerometer data) acquired at 100 Hz

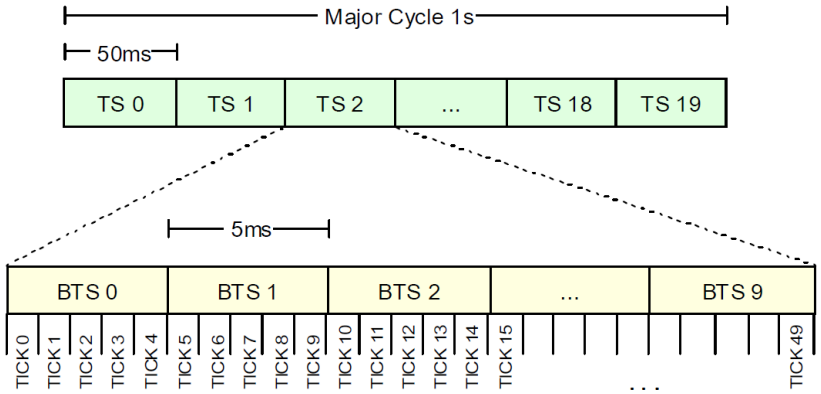
DM – CAN bus architecture

- Architecture inherited from 2016 mission, i.e. single network based on two physical redundant buses (redundancy management enabled during EDL) with selective bus architecture.
- All slave nodes (recurrent units from EXM2016) are equipped with ESA/SITAEL CANopen Controller IP core, ESA OBC1 will run a tuned CANopen SW stack from Vector (recurrent from EXM2016).
- UHF transceiver SW adapted to communicate over a CAN network with 50ms SYNC.
- Physical layer based on CAN-like RS485
- TM/TC protocol based on CANopen (mainly PDOs, SDOs used for reliable commands and large data exchange, i.e. SW patch/dump), 100ms TM/TC windows within SYNC messages (50ms SYNC period). 1Mbps.
- Bus redundancy management via Heartbeat message.



DM – 1553 bus architecture

- Standard 1553 physical and protocol layer.
- Bus Major cycle at 1s, divided in 20 Time Slices (TS) of 50ms.
- Each TS is partitioned in 10 periods of 5ms (Bus Time Slots – BTS). BTS is the time unit used for static allocation of the transactions (a set of 32 commands blocks is associated to each time slot).
- Each BTS is partitioned in 5 periods of 1 ms (ticks). Tick is the time unit used for static allocation of ASW task windows.
- Bus redundancy enabled during EDL.



DM – DH budgets

- Cruise (including BIP check-outs):

Bus	Transferred data in one Bus cycle (1 sec) [kbit]	Bus Occupation	Margin
1553-1	459,18	45,92 %	54,08 %
1552-2	136,70	13,67 %	86,33 %

- EDL:

Bus	Transferred data in one Bus cycle (1 sec) [kbit]	Bus Occupation	Margin
1553-1	304,76	30,48 %	69,52 %

EDL data volume is lower than cruise, because although TCACU commands are added and triggered every 100 ms (640bits command, 1000bits status), BIP check-outs (managed via pre-allocated Data Block transaction to be enabled/disabled) are removed from EDL budget.

- Surface (no IMU/TCACU data, BIP science data transfers):

Bus	Transferred data in one Bus cycle (1 sec) [kbit]	Bus Occupation	Margin
1553-1	337,82	33,78 %	66,22 %

DM – DH budgets

- EDL :

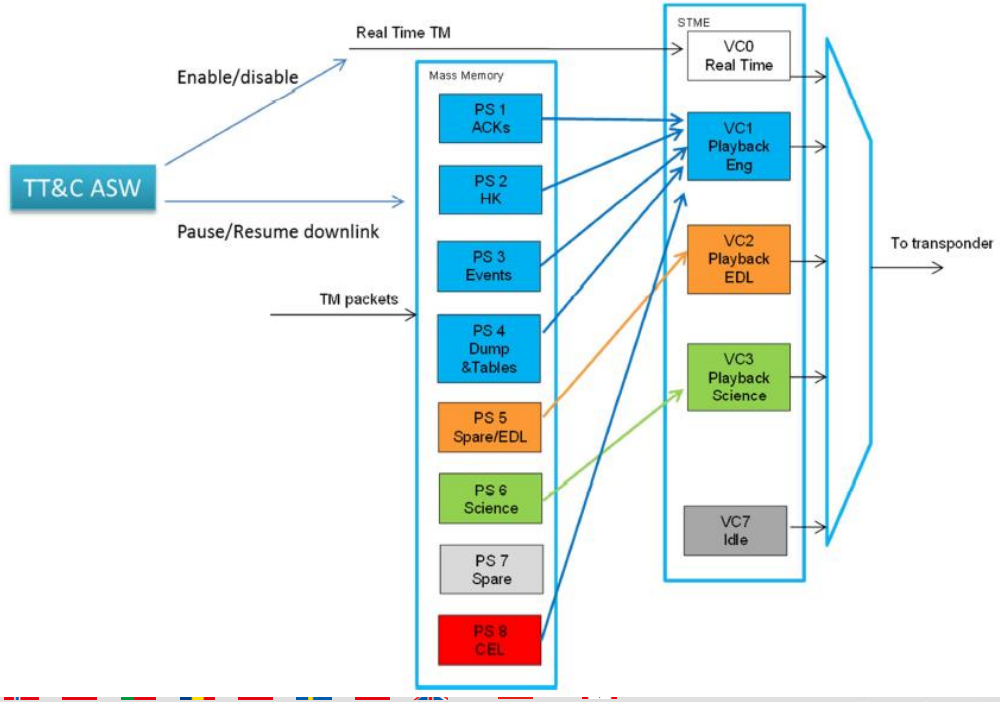
EDL Traffic				
Active Unit	Data volume per CAN cycle w/o stuffing [kbit/s]	Data volume per CAN cycle with stuffing [kbit/s]	Bandwidth margin w/o stuffing [%]	Bandwidth margin with stuffing [%]
RDA	11,61	13,93	98,84%	98,61%
UHF-TCVR	4,32	5,19	99,57%	99,48%
ESA-OBC1	1,12	1,34	99,89%	99,87%
Total	17,05	20,46	98,30%	97,95%

- Surface:

PLTE/SURFACE Traffic				
Active Unit	Data volume per CAN cycle w/o stuffing [kbit/s]	Data volume per CAN cycle with stuffing [kbit/s]	Bandwidth margin w/o stuffing [%]	Bandwidth margin with stuffing [%]
UHF-TCVR	4,32	5,19	99,57%	99,48%
ESA-OBC1	1,12	1,34	99,89%	99,87%
Total	5,44	6,53	99,46%	99,35%

DM – DH budgets

- Packet stores configuration
- Real time TMs fixed to 8kbps during EDL
- MM budget and TM plan in progress (max 150Mbits/sol for SP, considering nominal TGO passings)



Q&A

Discussion