MEMS – Sensor Bus
Application to the telemetry subsystem
for the ARIANE 5 launcher

R&T CNES

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CONTENTS

OBJECTIVE OF THE STUDY

Use of New Sensors Technologies and Components for Cost Reduction. 2 New concepts envisaged.

- MEMS (micro electro-mechanical systems) = low cost sensors for the automobile market. Mostly analog ; sometimes including conditioning.

⇕ Seldom both

- Smart Sensors (IEEE 1451 standard) = with electronics inside = mostly related to the Bus Sensor Concept ; including New Functions such as self-identifiable sensors, self-compensated (offset, non linearities) sensors ; « plug and play » concept at the limit.

EADS SPACE TRANSPORTATION

RECURRING COST FOR THE ARIANE 5 TELEMETRY

Telemetry stands for **20%** of the cost of avionics.

TM cost structure :

- Sensors = 20 %
- Harness & AIT(Assembly Integration & Test) = 35 %
- Electronics Boxes and Data Engineering = 45 %

MEMS (Sensors)

Smart sensors (Harness & AIT; Electronics Boxes and Data Engineering)

DIFFICULTY with MEMS : INTERFACE CONSTRAINTS + VERY HARSH ENVIRONMENT

- „Intrusive“ sensors (pressures (in majority), temperatures, tank levels) with strong leakage constraints.
Other sensors with mechanical interface constraints anyhow.
➔ MEMS must be specially adapted for Ariane = <u>overcosts</u>

⇨ POSSIBLE SOLUTION : STANDARD MECHANICAL INTERFACE

- Cryo zones (He = 4 °k ; LH2 = 20 °k ; N2 = 77 °k ; LOX = 90 °k)
Hot spots (nozzles) > 1000 °c …

⇨ SOLUTION ? (Silcon Carbide technology = 600 ° C ?)

POTENTIAL CANDIDATES FOR MEMS REPLACEMENT

Out of 275 analog (operational) sensors per launcher,

⇨ Potential candidates for MEMS (Non intrusive with acceptable temperature) amount to 50 ONLY**.**

⇨ But they are often costly Vibrations sensors, accelerometers and gyrometers …

ARIANE 5 / QUALIFICATION LEVELS OVERLOOK

FOR ALL EQUIPMENT

SINE VIBRATIONS	1 cm 0-peak (5 - 16 Hz) 10 g 0-peak (16 - 60 Hz) 22,5 g 0-peak (60 - 200 Hz) 10 g 0-peak (200 - 2000 Hz)	
RANDOM VIBRATIONS	20 g rms (20 - 2000 Hz) 4 mn	Acoustics vibration test is generally replaced (except for large structures) by random vibration test.
ACOUSTICS VIBRATIONS	140 dB max (- 10 kHz)	
MEAN SHOCK 1/2 sine wave	50 g ; 11 ms	
PYRO SHOCK		Pyro shock are not applicable to electronics equipment , unless very close to the pyro shock (pyro devices)
ACCELERATIONS	7,5 g (3 mn)	
VACUUN	10^{-3} to 10^{5} pa	Generally combined with thermics
THERMICS	- 40 (if P < 20 W) to + 70 °C (except cryo zones) ; 5 hours	

NOTA 1 : Safety factor = 1,25 (7,5 g = 6 x 1,25)

NOTA 2 : electronics components range [-55° à +125°C]

EXAMPLES OF CANDIDATE MEMS

4 criteria taken into account

Sensor	Type	Fabricant	full scale	Sensitivity	Linearity - hysteresis	Temperature
Ariane Sensor						
candidate MEMS						
EGCS-AR5-50-DF3	accelerometer	entrant	+/- 5 g	360mV/g - 450 mV/g	0,4% full scale	-40/80°C
KXF00 - F50		Silicon Designs	5g	800mV/g	0,5% FS	-55/125°C
CE 254 M501	vibration at ordinary temperature	VIBROMETER	50g	50mV/g	1%	-45/125°C
MMA2202D		motorola	50g	40mV/g	?	-40/125°C
NE115 / A5 / 140-TD	differential pressure	NE-TECHNOLOGIE	140mbar	7,14 mV/mbar	< 0,15% FS	-40/100°C
3000 series		MERIT SENSOR	5 psi -350mb	75 mV	< 0,15%	-40/150°C

DIFFICULTY (worse than with MEMS) with SMART SENSORS : VERY HARSH ENVIRONMENT

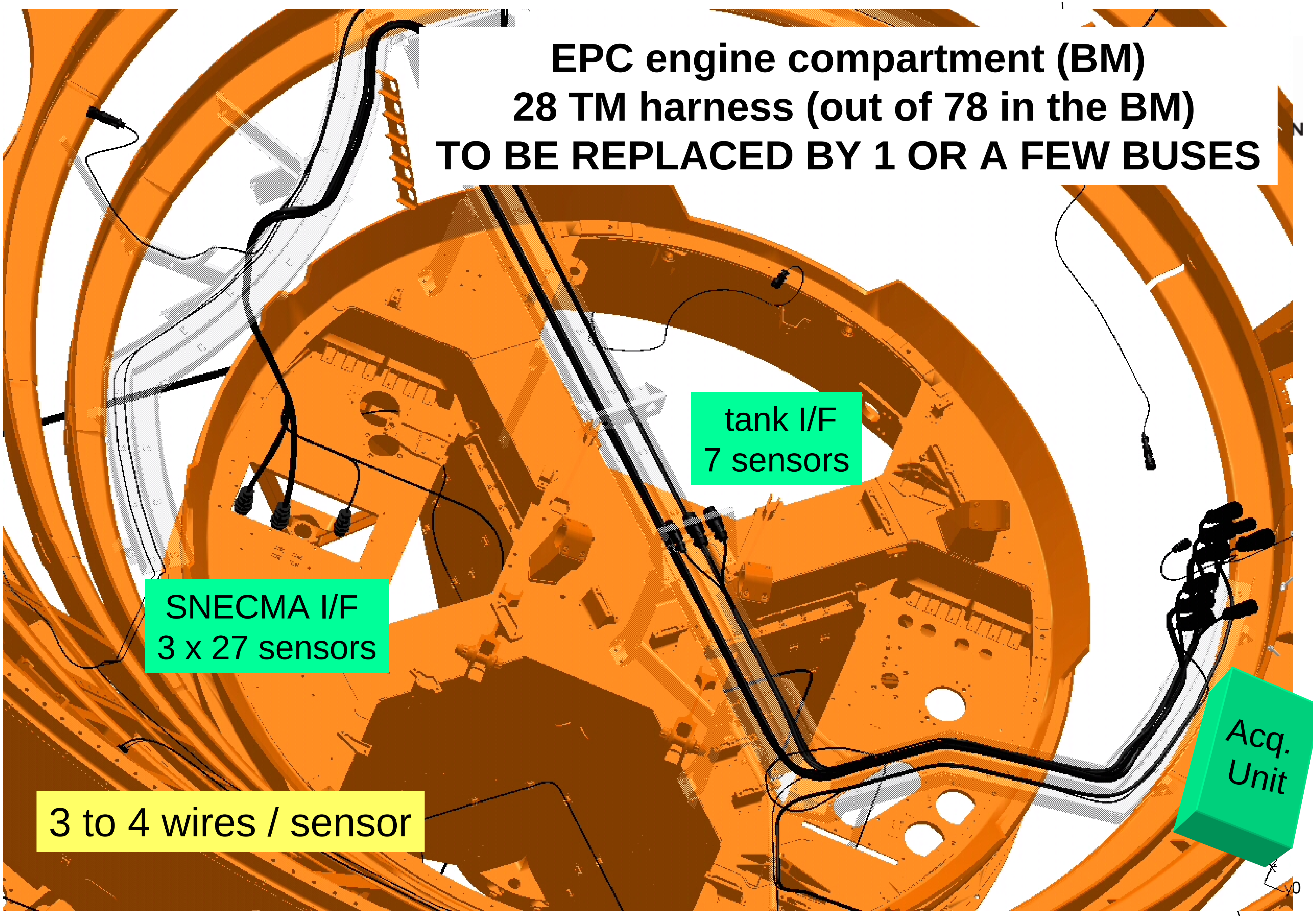
- SENSOR BUS could reduce harness and AIT.

- Smart (self compensated, …) sensors could reduce the data engineering (sensors calibration, Data Base management, …).

➔ BUT harsh environment is not appropriate for electronics inside SMART Sensors.

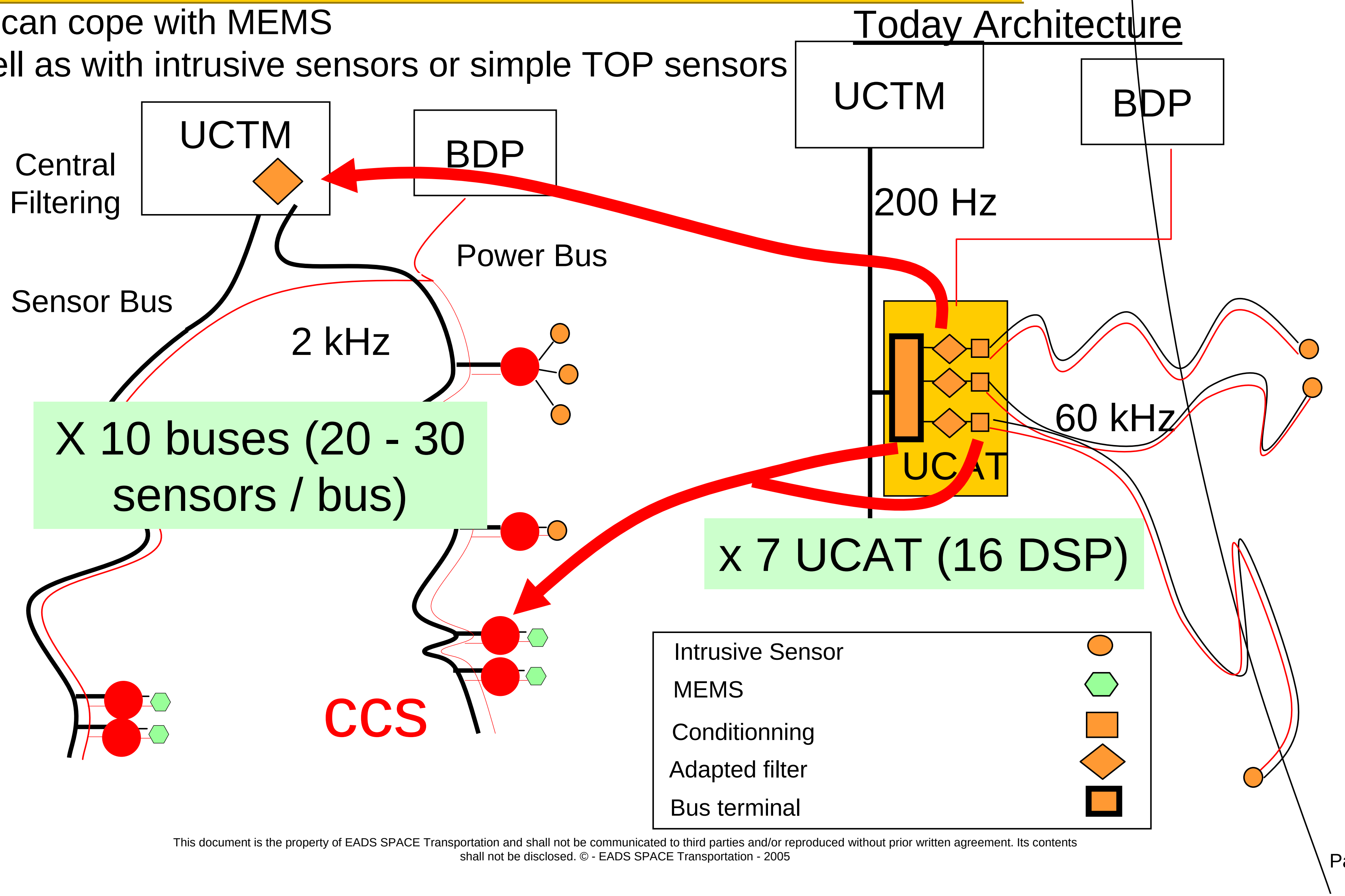
⇨ **SOLUTION :** instead of « Smart sensor » use rather « Smart interface » = CCS (coupleur conditionneur standard), based on the IEEE 1451 standard.

EPC engine compartment (BM)
28 TM harness (out of 78 in the BM)
TO BE REPLACED BY 1 OR A FEW BUSES



BUS BASED TM ARCHITECTURE

CCS can cope with MEMS
as well as with intrusive sensors or simple TOP sensors



ACQUISITION CHAIN MUST BE SIMPLIFIED

- Today system =
  - Standard acquisition at high frequency (60 kHz).
  - Digital filtering (to frequency adapted to each sensor) needs costly DSP x 16.

- CCS (coupleur-conditionneur standard) =
  - Centralized digital filtering.
  - Transmission at medium frequency via the Sensor Bus (4 KHz can meet all requirements, including shocks).

⇒ Suppression of Acquisition Units

CONDITIONS « *SINE QUA NON* » ON THE CCS

- COTS component if possible.
- Low cost (300 to 350 CCS per operational flight, including TOPS : regrouping needed)
- several CCS types required : without conditioning, thermocouple, …

\+ CCS inside HARNESS , close to sensor (but in « temperate » spot) in order to maximize the harness reduction.

⇨ CCS **<** 10 grams **(tbc)**

CONCLUSION / EXPECTED OUTCOMES

- COST REDUCTION : ≅ 30% (in part due to MEMS) of TM Recurring cost.
- Drastic noise reduction and reliability enhancement (less connectors).
- Harness mass reduction (> 10 kg for the upper composite) as well as electrical power reduction.
- simplification of interfaces between stages and sub-assemblies

  ➔ more easy adding of sensors (less impacts on stage definition).
- Possibility of adding a complete Bus to investigate a local problem ➔ not envisageable today.