FLIGHT OPPORTUNITIES FOR MNT IN-ORBIT DEMONSTRATION WITH ARIANE 5 LAUNCHERS

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Abstract

Flight opportunities are a key issue since technologies not qualified in-orbit are usually seen as risky and are discarded by the Space Industry.
When regarding US both specific shuttle programs and military ones which provide regular and low-cost flight opportunities, it is undeniable that European technology growth suffers from a lack of domestic flight opportunities.
In order to apply MNT's (Micro and Nano Technologies) in the space domain (launchers, satellites, probes,), validation of these devices under space launchers environment is essential.

There are flight opportunities for MNT in-orbit demonstration with Ariane 5 launchers. For that, we propose to develop a recurrent Technology Test Bed (TTB), which could offer standard interfaces with technology experiments.

1. INTRODUCTION

Since the past decade, micro-sensors and micro-actuators based on silicon and other technologies have been developed rapidly. The smart sensors, realised with MEMS (Micro Electro Mechanical Systems), have already proven their great interest in the fields of applications such as automotive, medicine, geophysics.

Since these technologies offer great advantages in terms of reduction of mass and on board power, it should be interesting to apply them in the space domain in order to increase performance and probably to lower overall costs.

But applying MNT's (Micro and Nano Technologies) in the space domain (launchers, satellites, probes,) needs validation of these devices under space launchers environment.

This paper overviews the potential to make in-flight demonstration with the Ariane family launchers. It is aimed at evaluating MEMS COTS (Commercial Off The Shelf) through the integration of one or many sensing elements when possible (pressure, acceleration, etc.) with microelectronic signal treatment circuits and finally at building a flight demonstrator on an Ariane 5 flight within 3 years in order to qualify the MEMS in launching conditions.

The final targets are the development of:

- The recurrent Technology test Bed (TTB) to make flight demonstration of MNTs for space use (transportation, satellites, probes,)
- Low cost and high efficient Sub System Telemetry (SSTM) with MEMS based sensors.

By the way, these elements should open rooms to more in-flight demonstration opportunities for other technologies.

2. MNTS NEEDS FOR SPACE TRANSPORTATION

For today's space transport vehicles like Ariane5 expendable launcher, the miniaturisation is not prerequisite, since the propulsion function drives their overall volume and architecture, and there are places enough for electrical devices and equipment.. But for payloads (satellites/probes/ re-entry vehicles.), the mass and the volume are the major constraints, hence miniaturisation becomes very interesting. And by the way, it should interfere on the launcher by reducing its performance needs so as to change the launchers performance requirements?
As a result, follow-on MNT's technology evolutions should be, at least, the basic prerequisite position of Space Transport Industry!

Nevertheless, there are rooms of interest to use MNTs for space transportation vehicles.

Just, we quote of few:

- **Telemetry** : much more measurements to have a better knowledge of the launcher, resulting in a so called ***"learning launcher",***

- **Multi-sensors guidance** : to have a ***"self-controlled launcher"***, avoiding the use of expensive inertial plants,
- **Active Control:** to reach ***a "Quiet launcher"*** needs to control the propeller vibrations, payload environment and aerodynamics/ flight mechanics for re-entry vehicles.
- **Health Monitoring** : to have ***a "safe launcher"***, for ground and flight controls for example on re-usable launchers,
- **High strength structures:** to realise ***"economical launchers"*** with high-pressure tanks with carbon nano-tubes filaments.

As a consequence, we have to reconsider, at least partially, the architecture of some electrical sub systems to get the real benefit of using Micro and Nano technologies.
The MNTs can procure some advantages like reduction of global cost with better reliability. And also, it allows in the future using the up to date technologies and devices available in the market for our space equipments.

3. WHY IN FLIGHT DEMONSTRATION

Flight demonstrations are a key issue since new technologies like MNT not qualified in-orbit are usually seen as risky and are discarded by the Space Industry. In order to speed up the development completion and the validation phase of MNTs for space use (transport vehicles, satellites, probes.), the flight demonstration through Ariane5 launch is a good opportunity.

The key advantage of in-flight demonstrations is that it is the unique way to test and qualify MNTs under real flight environment especially for acoustic, pressure, temperature, vibrations, space radiation, EMC constraints.

The smart sensors using MNTs have already proven their great interest in other fields. Today, some of the devices are commercially available, referenced as MOTS (MEMS Off The Shelf), that are not specifically designed and fabricated for use in space harsh environments but which can be "spacialised" with minimum technical and financial efforts.

First, a precise selection of MNT/ MEMS COTS (Commercial Off The Shelf) devices is needed to replace the space traditional sensors. Then a development of some prototype is required for early launch into space in order to evaluate the metrology performance and reliability of the MNT in space conditions by comparing the results to the traditional sensor.

Thus, the benefit of these in-flight experiences can promote further applications on all space systems (satellites, probes, and re-entry vehicles).

4. LAUNCHERS TRAJECTORIES

Operational since 1996/97, the baseline Ariane 5 launcher has been launched by 15 times up to now. The standard Ariane 5 launcher, designed to place 7 tons payloads into GTO, will carry 10.5 tons in the ESC-A version and 12 tons in the ESC-B version by 2006. Several trajectories are possible with Ariane 5 family: GTO (Geo-stationary Transfer Orbit), SSO (Sun Synchronous Orbit), HEO (High Elliptical Orbits), MEO (Medium Elliptical Orbits), LEO (Low Elliptical Orbits).
The life mission may vary from 45 min to 5 hours.
Hence, there is a wide range of in-flight qualification opportunities.

5. LAUNCHER ENVIRONMENT

Many physical parameters are studied to monitor the performances of the launch vehicle Ariane 5: measurements of temperature, pressure, vibration, acceleration, etc…. For example, the level of temperature ranges from low level 20 Kelvin (cryogenic tanks) up to 1100 Kelvin (engine gases). The pressure range reaches 500 bar, and vibration levels could reach 1000 g. To study accurately these different physical parameters, all kind of sensors are settled in all stages of the launcher. These sensors need to be efficient and reliable in their operating domain.

The number of parameters studied during a flight is high enough, between 570 for a generic launch until 1100 measures for a technological one.

The figure 1 describes the repartition of the physical parameters for 8 flights : V510 to flight V517 (technological flight).

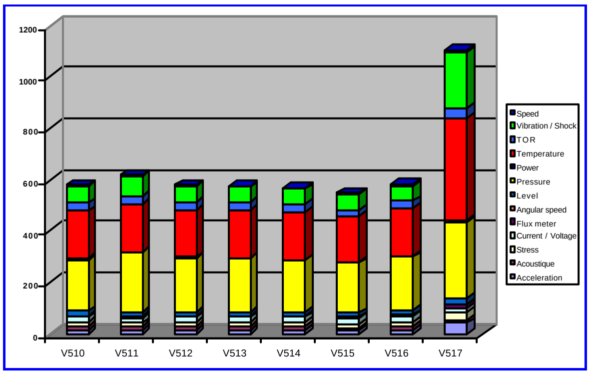

Figure 1: Type of measurements for different flight of the launch vehicle Ariane 5

The range of each sensor depends on the operating domain. There exists various physical ambiences inside Ariane 5 (cf. list in figure 2). To efficiently monitor all kind of measurement we need to have sensors with different technologies. Some sensors need to be very sensitive, some needs to have a large operating range and some needs to have a fast response. These differences lead to use different technologies for a same physical unit studied. For example, it is possible to use either piezo-resistive or piezoelectric systems for vibration measurement.

In the following table, we define the range of minimal and maximal measurements used for the main physical parameters in the launch vehicle Ariane 5.

PHYSICAL PARAMETERS	Minimal Range	Maximal Range	Units
Acceleration	-500	500	m/s²
Acoustic	-40	40	dB
Constraint	-10	10	% deformation
Current	0	2	A
Voltage	0	45	V
Fluxmeter	20	1500	KW/m^2
Angular speed	-100	100	deg/s
Level	0	464	mm
Pressure	$25 .10^{-3}$	500	bar
Power	0	30	W
Temperature	-253	1473	°C
Vibration / Shock	-100000	100000	m/s²
Rotation Speed	250	68000	rpm

Figure 2: Main parameters from Ariane 5

6. TELEMETRY SUB SYS TEM TECHNOLOGY

The Ariane 5 launcher uses a telemetry system, which allows it to know at any instant all the physical parameters of the launcher.

The SSTM (Sub System of TeleMetry) is a mean, which allows the knowledge of the electric state, mechanical state and propulsive state of the launcher from the takeoff to the end of the flight mission. Telemetry system is useful for the detailed study of the performances of the launcher, allows the diagnosis and the study of any eventual anomaly occurring during the flight. The figure 3 shows the Sub System telemetry used for the technological flights of an Ariane 5.

The SSTM is dedicated to various tasks. The acquisition and transmission of physical information is done in three main parts. Physical information is taken by the sensors. The treatment of this information is done by a system in charge of conditioning the signal.
The information is coded through a Unit Acquisition System. Since the takeoff until the end of the mission, the measurements are sent to ground stations via emitters.

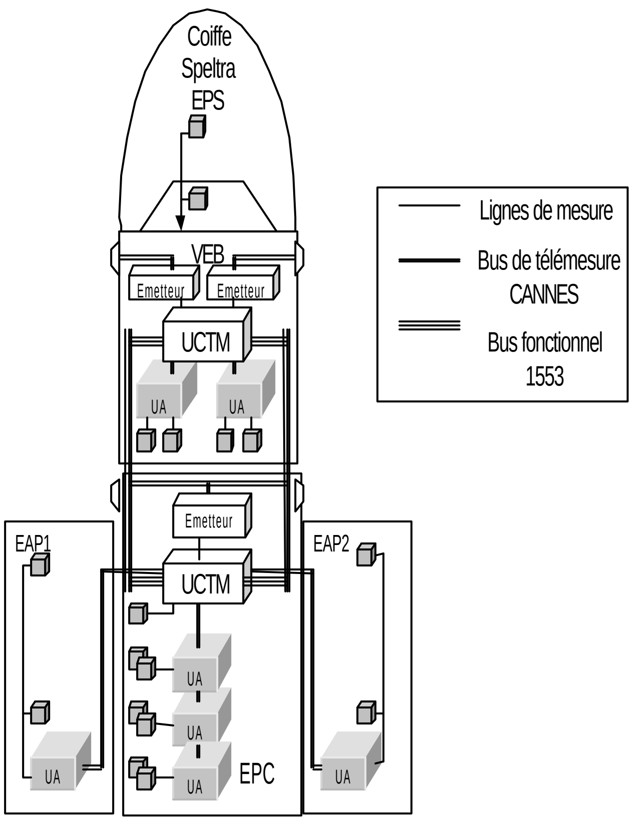

Figure 3: SSTM of the launch vehicle Ariane 5

7. TECHNOLOGY TEST BED CONCEPT

This chapter is aimed at defining the concept and the major drivers of a recurrent Technology test Bed (TTB) that could offer standard interfaces with technology experiments. This TTB should be located in a part of the launcher that will stay some times in-orbit. It will not be ejected into orbit, rather staying linked to the launcher, and providing a reduced telemetry down-link.

We can consider two typical missions:

- A short mission where the demonstrated technology, for example a sensor, needs power and data acquisition during the launch and up to one-hour in-orbit. This mission scenario is the less demanding in terms of interface or services from the launcher, but it also offers a flight opportunity only suitable for some specific experiments.
- A long mission where the demonstrated technology, for example a subsystem like thermal cooling, needs a few weeks in-orbit, with a micro-gravity environment, and a limited and periodic telemetry downlink. This mission scenario offers a much more versatile flight opportunity, but will be more demanding in regard with the launcher interface.

We consider only the short mission, for that, some technologies do not require a long-term in-orbit demonstration, or may even just need the launch phase, the concept of a TTB seems attractive. It could:

- Offer at each flight a small accommodation place
- To be a recurrent hardware
- To have some standardised mechanical and electrical interface
- To provide some basic services (power, telemetry downlink), relying or not on its own battery,
- To be seen from the launcher point of view as a "black box", with a guaranteed defined level of safety but with reduced interaction with launcher operator.

To install a "black box" into a launcher, some important issues should be solved:

- It should be "transparent" and cannot, in any case, interfere with the launcher, even though the TTB needs some minimal interfaces with the launcher,
- It could offer some standardised mechanical and electrical interfaces within the launcher, the technology item to be tested will have to respect some critical requirements: allowable mass, safety, orbit and environment that may not be determined.

- The standard TTB concept will facilitate the co-ordination with the launcher authority (Arianespace, ESA, CNES,).

8. TECHNOLOGY TEST BED IMPLEMENTATION

We can implement the "black box" Technology Test Bed concept in different stages of Ariane 5 launchers. The figure 4 shows different possibilities of implementation:

- Near payload/ VEB
- JAVE EPC
- JAVE EAP
- BM EPC
- JAR EAP

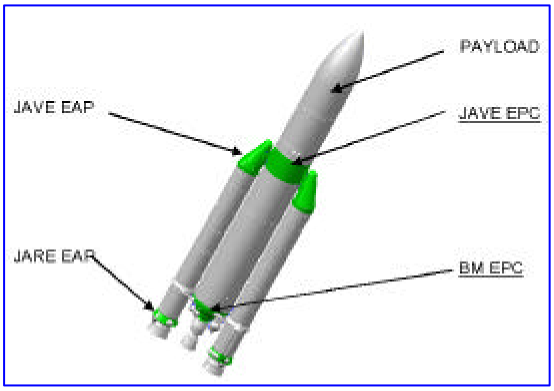

Figure 4: Possibilities of TTB implementation

During flight mission, all sensors are subjected to static and dynamic loads induced by the launch vehicle. To acquire and transmit signals from those sensors to the ground stations, the Telemetry Measurement Unit is required. With the wish to qualify MNTs sensors, a prototype test-bed could be developed since it is compatible with the existing acquisition device. The figure 5 shows a Technology Test Bed prototype for a MEMS sensor.

This test-bed is composed with a part of classical sensors and MNTs sensors. The interest of this experiment is to valid MNTs technology in terms of launch vehicle compliance or to compare their metrology performances with the classical one.

This can be considered as a short mission with the following characteristics:

- Typical demonstrated technology : MEMS sensor like accelerometer or pressure,
- Power and data acquisition required during the launch and up to one hour in-orbit,
- Low power consumption
- Low mass

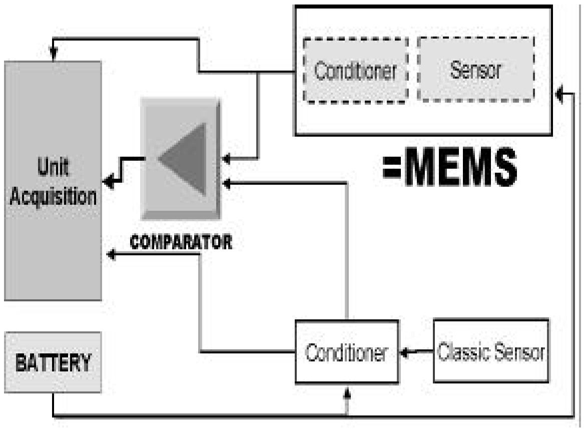

Figure 5 : A prototype Technology Test Bed for a MEMS sensor.

9. CONCLUSION

In this paper we presented the Technology Test bed concept and the possibility of their implementation on different stages of Ariane 5 launchers.
In order to develop Technology Test Bed for MNT on the Ariane5 family, we propose the following works to be carried out during the coming 3 years (2004-2006), through the following phases:

- Phase 1: Identification and evaluation of selected MEMS COTS (MOTS) for space use. This work is already started with ESA/ESTEC contract n°: 16718/02/NL/MV
- Phase 2: Spatialisation (up grading) of MEMS COTS for space transportation (launchers) environments
- Phase 3: Preparation and adaptation of MEMS COTS for a flight demonstrator on an Ariane 5 through a Test bed
- Phase 4: Development of a recurrent Technology Test Bed (TTB) for MNT demonstrator on Ariane 5 family launchers.

This recurrent TTB could offer standard interfaces with technology experiments. This Test Bed would be located in a part of the launcher that will stay some times in-orbit. It will not be ejected into orbit, rather staying attached to the launcher, and providing a reduced telemetry downlink.
Inside this three years period, if we succeed the TTB concept for MNT in Ariane 5 family launcher, then we feel that an important step is made towards the use of MNT in European space sector.

LIST OF ABBERIVATIONS

BM EPC : Bâti-Moteur
EMC : ElectroMagnetic Compatibility
EAP1 : Etage d'Acceleration àPoudre 1
EAP2 : Etage d'Acceleration àPoudre 2
EPC : Etage Principal Cryotechnique
EPS : Etage àPropergols Stockables
JAVE EPC : Jupe Avant Equipée EPC
JAVE EAP : Jupe Avant Equipée EAP
JAR EAP : Jupe Arrière Equipée EAP
MEMS: Micro Electro Mechanical Systems
MNT : Micro Nano Technologies
MOTS : MEMS Off The Shelf
SSTM : Sub System Telemetry
TTB : Technology Test Bed
UA : Unité d'Acquisition
UCTM : Unité Centrale de Telemesure
VEB : Vehicle Equipment Bay

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