WIRELESS ON SPACE LAUNCHER – ARIANE 5

Astrium
Space Transportation

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Astrium: a 100% subsidiary of EADS
Astrium’s activities are based in three key areas

**Astrium Space Transportation**
The European prime contractor for civil and military space transportation and manned space activities

**Astrium Satellites**
A world leader in the design and manufacture of satellite systems

**Astrium Services**
At the forefront of satellite services in the secure communications and navigation fields
An impressive product and capability portfolio

- Launchers: Ariane, Soyuz, Rockot, Vega
- Ballistic missiles, missile defence
- Future launchers
- Orbital systems: Columbus, ATV, Operations, Atmospheric re-entry systems
- Propulsion & equipment
- System design, system integration & production
Access to space

- Europe’s launcher family

<table>
<thead>
<tr>
<th>Launcher</th>
<th>ESC Type</th>
<th>GTO Capability (dual launch)</th>
<th>LEO Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariane 5 ESC-B</td>
<td></td>
<td>12 t</td>
<td>&gt; 20 t</td>
</tr>
<tr>
<td>Ariane 5 ESC-A</td>
<td></td>
<td>10 t</td>
<td>300 km - 51°6</td>
</tr>
<tr>
<td>Ariane 5</td>
<td></td>
<td>6 t</td>
<td>2.5 t / 5 t</td>
</tr>
<tr>
<td>Soyuz Starsem</td>
<td></td>
<td>1.1 t</td>
<td>1,400 km</td>
</tr>
<tr>
<td>Rockot</td>
<td></td>
<td>1.5 t</td>
<td>700 km</td>
</tr>
<tr>
<td>Vega</td>
<td></td>
<td></td>
<td>700 km</td>
</tr>
</tbody>
</table>
Access to space

- Single Prime Contractor for Ariane 5

- Delivery of the fully integrated launch vehicle to Arianespace in Kourou

- Supplier of all major elements of Ariane 5 (stages, VEB, software, etc.)

- ESA’s single point of contact for future developments
Access to space

- Provider of all major elements for Ariane 5

- EPC, EAP, EPS stages
- Vehicle Equipment Bay
- Flight software
- Mission analysis
- Sub-assemblies

- Performance in GTO: 5.9 to 10 t
- Mass at lift off: 710 t
- Thrust at lift off: 10,600 kN
- Total height: from 45 to 55.9 m
- Maximum diameter: 12.2 m
Access to space

- Preparing for the new generation of launch vehicles and reducing launch costs

- System studies and stage architecture
- Research, technology, development:
  - Study of reusable, semi-reusable and expendable launch vehicle concepts
  - Company and State funding
- FLPP programme

- Technology Demonstrators
  - Pre-X, Ares, Astra
  - Phoenix: test flight campaign in 2004
Man in space

- European contribution to the ISS: hardware elements

- Industrial prime contractor for the core European ISS Elements:
  - Columbus research laboratory
  - Automated Transfer Vehicle (ATV)

- Data management systems for the space station (DMS)

- Robotic systems (ERA)

- Experimental facilities for scientific use

- Astronaut training and simulators for Columbus, ATV and experimental facilities
Man in space

- European contribution to the ISS: Columbus

- ESA prime contractor for the Columbus laboratory, the European space research facility

- Pressurised laboratory

- Designed for microgravity research
  - Physics
  - Chemistry
  - Biology
  - Medicine
  - Human physiology
  - Space and Geosciences

Length: 8 m
Diameter: 4.5 m
Payload: 10 active payload racks
Launch mass: 12.770 tonnes
Crew: designed for 3 crew members
Man in space

- European contribution to the ISS: ATV

- ESA prime contractor for the Automated Transfer Vehicle for logistic resupply of the International Space Station, launched on board an Ariane 5 (July-October 2007)

- Cargo
- Propellants
- ISS-reboost
- Waste removal

Length: 10.05 m
Diameter: 4.57 m
Payload mass: 7 tonnes net
Launch mass: 20 tonnes
Navigation: autonomous, based on GPS data
Exploring the Universe

- Atmospheric re-entry systems
  - Thermal protection systems for interplanetary probes
    - ARD: development, integration and tests.
      Successful mission in October 1998
  - ISS Servicing: CARV, PARES
  - Interplanetary exploration: Mars EDLS, EVD
  - Expert: re-entry testbed
  - NASA X-38: essential hardware and software
  - IRDT: inflatable re-entry technology system
Programs characteristics (1/2)

- Our development programs are very long

- Use of up to date technologies (at program decision time)
- Very long lifetime (treatment of obsolescence issues)
- Complex systems with high reliability & safety needs
- Functions in very harsh environments
Programs characteristics (2/2)

- Once qualified, the configuration is difficult to modify
  - To preserve reliability
  - To optimize production flow
  - To avoid re-qualification costs

- Technology is chosen very early in the development cycle, the reasons for changing a component are generally only:
  - To solve a problem
  - To overcome obsolescence
  - To generate very significant savings
Our mission (1/3)

- To give a heavy object (up to several tons) a very high speed (up to $10^4$ m/s) in a short time we need:
  
  - A «big» propulsion (enough thrust and energy to counter gravity and deliver a few g’s acceleration)
  - Tanks to contain the propellants with enough reactive mass and engines to eject it at highest possible speed
  - GNC (Guidance Navigation & Control) to deliver the payload on the required orbit/trajectory
  - Systems to monitor the vehicle health and ensure safety
Space Transportation

Our mission (2/3)

Payload: 4%
Structure: 50%

23 tons
277 tons Empty Weight

A380
260 tons Fuel

Ariane 5
668 tons Propellants

Payload: 1%
Structure: 13%

100 tons Empty Weight

260 tons Fuel

668 tons Propellants

23 tons
277 tons Empty Weight

Payload: 4%
Structure: 50%

23 tons
277 tons Empty Weight

A380
260 tons Fuel

Ariane 5
668 tons Propellants

Payload: 1%
Structure: 13%

100 tons Empty Weight
Our mission (3/3)

- To do it repeatedly with high level of reliability we need:
  - An in depth understanding of the physical phenomena's
  - A correlation between the models used in the design phase and the encountered and/or induced environment
How do MNT may be an advantage (1/4)

- Functional GNC equipment & harness
  
  - Miniaturization of technologies (cf Moore’s law in electronics) and introduction of highly integrated electronic packaging
  
  - More and more unstable and flexible vehicle control (to reduce the structures mass) require more and more electronics and sensors and could be realized with MEMS
  
  - Use of MEMS (if space qualified) as soon as their performances are equal with bigger equipment for future developments
How do MNT may be an advantage (2/4)

- A better knowledge of actual performance may help reduce exaggerated design margins

- Add new sensors, to map phenomena throughout the vehicle (to identify a deformation pattern or a flexible mode characteristics, to describe dynamic behavior..)

- Introduce new wireless autonomous sensors in remote areas of the vehicle
How do MNT may be an advantage (3/4)

- Telemetry and safety equipment & harness

- More than 600 different measures for any commercial Ariane flight (and much more for a qualification flight)
- New technologies (MEMS) allows « smart sensors » to reduce side equipment
- Wireless data transfer and autonomous power supply could drastically reduce the harness requirements
- RF MEMS will significantly improve the performance of the telemetry chains
How do MNT may be an advantage (4/4)

- Combine multiple functions into structural material
  - Surface treatment
  - Surface electrical resistance
  - Surface thermal properties

- Increase the confidence before launch

  HUMS (Health and Usage Monitoring System)
Wireless communications on launchers (1/5):

- **Wireless : what for ?**

  Our envisioned applications are :
  
  - Low rate sensor communications for versatile sensor networking
  
  - Medium rate interstage data transmission
    - communications after stage separation
    - mechanical and electrical Interface simplification
  
  - High rate communication on launch pad towards ground facilities : simplification on jettisonable connectors.
Wireless communications on launchers (2/5):

- First: think « Industrial process »:
  - Insensitivity to dispersion shall be proven
  - Growth potential shall be fully anticipated
  - Battery replacement shall be avoided (low consumption, low discharge rate, long stockage duration…).

- No data shall be lost, in particular last moments before critical phases
  - Strong requirements on datation: impact on the clock architecture
  - Strong requirements on data ageing: impact on the protocol
  - Real time data transmission to ground (great difference with the Shuttle Invocon application case)

- The internal RF network propagates within a Al-based alloy (or C-C composite) closed volume with low RF power dissipation.
Wireless communications on launchers (3/5):

- This leads to the following quantified requirements:
  - Propagation simulation shall demonstrate an affordable BER: $10^{-6}$
  - Dispersions include:
    - geometry of the propagation volume (wire routing, equipment shapes, dilatation: shall be under $\lambda/10 = \text{a few mm}$),
    - doppler effects on reflected beams while the volume vibrates during the flight
  - Ariane5’s internal diameter is over 5 m; this volume is not symmetrical, and internal details lead to geometrical description containing trillions of meshes for RF simulation
Wireless communications on launchers (4/5):

- RF simulators could possibly be used, but require very powerful machines, and despite the great quality of these tools, results remain uncertain for dispersion reasons.

- Standing wave propagation regimes lead to very harsh fadings, located everywhere close to optimal reception areas, in terms of geometry as well as in term of carrier frequency: danger of link loss versus dispersion.

- Who will trust the results of the simulation outputs?
Wireless communications on launchers (5/5):

Well, what shall we do, now?

- A test campaign is planned to demonstrate the Bluetooth or Zigbee robustness to mechanical dispersion on the volume, in order to kill the « simulation-proven » paradigm.

- RF alternative for internal data transmission may be the infra Red beam mixing TDMA and Carrier Wavelength Multiplexing

- Wireless transmission is more likely to be used for free space RF propagation: EAP-EPC or Launch Pad communications.
Concluding Remarks:

« Fly-by-Wireless » could be:

- For Telemetry systems on Ariane and FLPP (Future Launchers Preparatory Programs) European launchers:
  - Add new sensors, to map phenomena throughout the vehicle (to identify a deformation pattern or a flexible mode characteristics, to describe dynamic behavior..)
  - Introduce new wireless autonomous sensors in remote areas of the vehicle
- Combine multiple functions in structural materials to Increase the confidence before launch by using “HUMS (Health and Usage Monitoring System)”
- Looking for International collaborations
  - To demonstrate wireless functions
  - To do flight demonstrations
THANK YOU
MERCI !