PROPULSION SYSTEMS

♦ Plasma Propulsion System (PPS)
♦ Propulsion System Services (PSS)
♦ Monopropellant Propulsion System (MPS)
♦ Unified Propulsion System (UPS)
Skills
- System and Propulsion Engineering.
- Units selection, qualification and procurement.
- Propulsion functional analysis.
- Detailed design of Propulsion system, manufacturing, integration and tests.
- Lunch pad activities.
- Satellite operation in ground control center.

Applications
- Attitude and Orbit Control for:
  - Telecommunication satellites
  - Low Earth Orbit constellations
  - Interplanetary mission

Main features
- Power Bus: 50 or 100 Volts regulated
- TM/TC Bus: 1553, OBDH or RS485
- High specific impulse and High thrust density
- Low power-to-thrust ratio: 16 W/mN
- High modularity: architecture and working point according to mission
- EMC and RF compatible

Production
- Pre-integrated and tested before integration onto spacecraft

Background since 1996
- French Technological Satellite: STENTOR
- Geostationary Telecom Satellite: ASTRA-1K
- Alpha bus : Alphasat XPS

Technical description
Typical diagram propulsion system:
- A parallel architecture providing full redundancy of thrusters, regulators and power processing units
- High pressure storage capability
- Simple, compact, lightweight gas distribution system
- Power Processing Unit with Thruster Selection Unit providing high modularity
- Thruster orientation mechanism with two axis rotation capability
- Compatibility with two types of thrusters: SPT-100 and PPS-1350
Gas Module & Thruster Module:
Pre-integrated & on SpaceCraft

Astra1K
AlphaSat

S/S integrated onto spacecraft

AlphaSat Gas Module

Astra1K

TYPICAL PERFORMANCES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total impulse</td>
<td>up to 4.0 10^6 Ns</td>
</tr>
<tr>
<td>Thrust</td>
<td>80 to 90 mN</td>
</tr>
<tr>
<td>Orientation capability</td>
<td>+/-12°</td>
</tr>
<tr>
<td>Power consumption</td>
<td>1500 W</td>
</tr>
<tr>
<td>Tank MEOP</td>
<td>150 bar</td>
</tr>
<tr>
<td>Specific Impulse</td>
<td>1510 to 1670 s</td>
</tr>
<tr>
<td>Dry mass</td>
<td>120 kg</td>
</tr>
</tbody>
</table>

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A multi-disciplined, experienced team of people with advanced degrees:

- capable of supporting all types of chemical (mono-propellant and bi-propellant) or electrical (Hall effect) propulsion systems design and analysis
- from advanced projects up to in-orbit operation

Our good knowledge of the interfaces and interactions with the spacecraft and its life cycle, make our propulsion systems design and analysis particularly relevant.

**Engineering Design and Analysis**

- Propulsion system development plan
- Architecture trade-off
- Propulsion system and equipment specifications
- Fluid mechanics and thermodynamics analysis
- Propulsion subsystem performance analysis
- Definition of layout onto spacecraft structure
- Analysis of equipment design, qualification status
- Propulsion system and equipment test specifications
- Spacecraft interaction assessment: plume effects, end of life prediction analysis
- Course for engineer and operators
- Mechanical and thermal analysis
- Analysis: FMECA, Reliability, safety, contamination, performances, observability and commandability
- Design of specific ground equipment

**Launch pad activities**

- Propellant tanks filling (Xe, He,N2 MON, MMH, Hydrazine)
- Launch site safety tests (Kourou, Plesetsk, Baikonour, San Diego, Xichang, Van der Zandt, CapCanaveral)

**Support for In-Orbit Operations**

- Definition of monitoring
- User manual for operations
- Qualification of operational procedures
- Analysis of in-flight results

**Equipment Procurement**

- purchase market survey
- management of sub-contractors
- Statement of work and contract negotiation
- Review of design, manufacturing and test processes

**Propulsion System Manufacturing and Test**

- Tube bending and welding
- Cleanliness control
- Integration of equipment
- Integration of thermal control components
- Performance tests: pressurization, valve activation, leakage, fluidic tests
- Electrical functional tests
- Vibration and thermal cycling
Experience

<table>
<thead>
<tr>
<th>Customer</th>
<th>Program</th>
<th>Conducted activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNES</td>
<td>STENTOR</td>
<td>Development, design, manufacturing, integration and test of the chemical bi-propellant propulsion system of the technological spacecraft.</td>
</tr>
<tr>
<td>CNES</td>
<td>JASON, JASON 2, CALIPSO, COROT, SMOS</td>
<td>Development, design, manufacturing, integration and test of the hydrazine mono-propellant propulsion system (PROTEUS family)</td>
</tr>
<tr>
<td>EUTELSAT SES CHINASATCOM DGA...</td>
<td>AMC12, AMC23, SYRACUSE IIIA/B, PW2, PW7, P3C, CH6B...</td>
<td>Development, design, manufacturing, integration &amp; test of bi-propellant propulsion system for GEO telecommunication spacecrafts (SB4000 platform)</td>
</tr>
<tr>
<td>ESA</td>
<td>@BUS @SAT</td>
<td>Development, design, manufacturing, integration and test of the electrical propulsion system</td>
</tr>
<tr>
<td>ESA</td>
<td>ExoMars EDL</td>
<td>Development, design, manufacturing, integration and test of the hydrazine monopropellant propulsion system</td>
</tr>
<tr>
<td>IRIDIUM</td>
<td>IRIDIUM Next constellation (81 Satellites)</td>
<td>Development, design, manufacturing, integration and test of the hydrazine monopropellant propulsion system</td>
</tr>
<tr>
<td>GLOBALSTAR</td>
<td>GB2 constellation (30 Satellites)</td>
<td>Development, design, manufacturing, integration and test of the hydrazine monopropellant propulsion system</td>
</tr>
<tr>
<td>ESA</td>
<td>SENTINEL 3 constellation (17 Satellites)</td>
<td>Development, design, manufacturing, integration and test of the hydrazine monopropellant propulsion system</td>
</tr>
<tr>
<td>SES</td>
<td>O3b constellation (12 Satellites)</td>
<td>Development, design, manufacturing, integration and test of the hydrazine monopropellant propulsion system</td>
</tr>
<tr>
<td>ESA</td>
<td>Various Phase A</td>
<td>Participation to phase A trade-offs and design activities of various ESA projects : Bepi-Colombo, Wales, Earthcare...</td>
</tr>
<tr>
<td>Internal Studies</td>
<td></td>
<td>Software development for 3D fluidic simulation (stationary and unstationary) taking into account thermal and viscosity effects. Software development for propulsion subsystem performance analysis (based on EcosimPro ESPSS). Simulators for UPS and MPS operations.</td>
</tr>
</tbody>
</table>

Main Partners

Astrium, EADS/LV, OHB, Moog, Bradford, MuSpace, Ampac, Rafael, Aerojet, Snecma, Herakles, Sofrance, Vacco, MT Aerospace

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Updated October 2012
Skills
- System and Propulsion Engineering.
- Units’ selection, qualification and procurement.
- Propulsion functional analysis.
- Detailed design of Propulsion system, manufacturing, integration and tests.
- Launch pad activities.
- Satellite operation in ground control center.

Applications
- Orbit raising, Attitude, orbit control and de-orbitation for:
  - Telecommunication satellites
  - Low Earth Orbit constellations and scientific satellites

Main features
- Very simple and robust subsystem
- Very low propellant sloshing thanks to tank elastomeric diaphragm => high spacecraft pointing accuracy
- All thrusters in stand-by mode can be operated at any time without any valve switching for activating branches : high availability, flexibility and reliability
- Thruster valves have dual series seats with dual coil.
- Redundant catalyst bed heaters
- Design lifetime qualified up to 15 years
- High competitiveness due to O3B, GB2, IRIDIUM constellation heritage

Production
- Pre-integrated and tested before integration onto spacecraft

Background since 1996
- LEO satellites :
  - JASON (first application of PROTEUS family)
  - JASON 2, Calipso, COROT, SMOS
- Deep Space :
  - Herschel, Planck,
  - Exomars landing system (high thrust engines)
- LEO Telecom constellations:
  - Globalstar 2 (30 satellites), O3B (12 satellites), IRIDIUM (81 satellites)

Technical description
Typical diagram propulsion system:
- Mono-propellant system using anhydrous hydrazine propellant and gaseous nitrogen pressurant, operating in blow down mode. The propellant and pressurant are stored in common tanks. An elastomeric diaphragm insures that gas free propellant is supplied to thrusters under all operating conditions.
- The MPS is incorporating :
  - 4 to 8 Reaction Control Thrusters (RCT 1N)
  - 1 to 3 propellant tank (propellant capacity from 30 to 150 kg with a blow-down ratio of 4)
- The MPS is compatible with all launcher constraints. Delta 2, Soyuz, Ariane 5, Falcon 9, Dniepr.
- All-welded design which minimizes mass and ensures leak-tightness, to the exception of screwed connection used for thrusters for easier integration and exchange in case of AIT damage.
- All components have demonstrated long term compatibility with propellants (up to 15 years).
### Mono-propellant propulsion subsystem overview

**Pre-integrated mono-propellant propulsion S/S**

**Pre-integrated module onto spacecraft structure**

### TYPICAL PERFORMANCES

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 years under LEO radiation environment</td>
<td></td>
</tr>
<tr>
<td>1N thrusters</td>
<td></td>
</tr>
<tr>
<td>Thrust range:</td>
<td>0.36N ± 10% to 1.45N ± 5%</td>
</tr>
<tr>
<td>Supply pressure range:</td>
<td>5.5 to 23 bars</td>
</tr>
<tr>
<td>Steady State Firing specific impulse range:</td>
<td>205 to 221 s</td>
</tr>
<tr>
<td>Accumulated burn time:</td>
<td>&gt;45 h</td>
</tr>
<tr>
<td>Total number of pulses / impulse:</td>
<td>279149 / 120 kNs</td>
</tr>
<tr>
<td>Total hydrazine throughput:</td>
<td>60 Kg</td>
</tr>
<tr>
<td>Propellant tank</td>
<td></td>
</tr>
<tr>
<td>MEOP:</td>
<td>24 bars</td>
</tr>
<tr>
<td>Total propellant capacity:</td>
<td>154 Kg</td>
</tr>
<tr>
<td>Expulsion efficiency:</td>
<td>&gt; 99 %</td>
</tr>
<tr>
<td>PRESSURE Transducer accuracy:</td>
<td>± 0.28 % full scale (BOL)</td>
</tr>
<tr>
<td>Total leakage:</td>
<td>&lt; 1.10e-6 scc/s GHe</td>
</tr>
<tr>
<td>Dry mass:</td>
<td>0.230kg</td>
</tr>
</tbody>
</table>

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Skills

- System and Propulsion Engineering.
- Units selection, qualification and procurement.
- Propulsion functional analysis.
- Detailed design of Propulsion system, manufacturing, integration and tests.
- Lunch pad activities.
- Satellite operation in ground control center.

Applications

- Satellite orbit raising
- East/West and N/S station Keeping
- Satellite attitude control
- Satellite attitude momentum control
- Post-operational de-orbiting for:
  - Telecommunication satellites
  - Interplanetary mission

Main features

- Same propellant supply for all apogee maneuvers and station keeping maneuvers: consumption optimization
- Bi-propellant system: thrusters not prone to chemical degradation
- 2 tanks configuration: lower disturbances than 4 tanks configuration, lower operational complexity, avoids non parallel depletion errors
- All thrusters in stand-by mode to be operated at any time without any valve switching for activating branches: high availability, flexibility and reliability
- Liquid apogee engine multiple-burn capability: high accuracy of insertion in GEO than other systems

Production

- Pre-integrated and tested before integration onto spacecraft

Background since 1996

- French Technological Satellite: STENTOR
- Geostationary Telecom Satellite Spacebus Family: 29 Satellites

Technical description

Typical diagram propulsion system:

- The UPS is incorporating:
  - A Liquid Apogee Engine (LAE 400N)
  - 16 Reaction Control Thrusters (RCT 10N)
  - 2 equal adjustable propellant tanks (propellant capacity between 1542 kg and 3260 kg).
  - A set of Helium pressure tanks
- Unique thrusters arrangement allowing complete redundancy with no mission impact in case of any single thruster failure and most double failures.
- Thruster valves have dual series seats with internal coil redundancy. Pyrovalves and pressure regulator have internal redundancies.
- The UPS is compatible with all launcher constraints: Falcon 9, Ariane 5, Protons Delta, Atlas 5, Longmarch.
- All-welded design which minimizes mass and ensures leak-tightness, to the exception of screwed connection used for thrusters for easier integration and exchange in case of AIT damage
- All components have demonstrated long term compatibility with propellants (>15 years).
S/S integrated onto spacecraft

Module 1 onto jig 

Propulsion modules integrated onto spacecraft

TYPICAL PERFORMANCES

<table>
<thead>
<tr>
<th></th>
<th>10N thrusters</th>
<th>Liquid Apogee Engine</th>
<th>Propellant tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum vacuum Specific Impulse (pulse mode):</td>
<td>10N</td>
<td>287 s (at 18 bars)</td>
<td>19.5 bars</td>
</tr>
<tr>
<td>Minimum vacuum Specific Impulse (steady state mode):</td>
<td>293 s (at 18 bars)</td>
<td>8.33 h</td>
<td>3260 Kg max</td>
</tr>
<tr>
<td>Accumulated burn time:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualified inlet pressure range:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                        | 420N |                      |                 |
| Nominal Specific Impulse (steady state mode): | 318 s (at 18 bars) | 4600 s | 99.5% |
| Accumulated burn time: |              |                      |                 |
| Longest single burn: |                |                      |                 |

|                        |                 |                      |                 |
| Total propellant capacity: |              |                      |                 |
| Expulsion efficiency: |                |                      |                 |
| Total leakage: | < 30 scc/h GHe |                      |                 |
| Dry mass: | 192 kg max |                      |                 |

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