FLIGHT DEMONSTRATION OF NEW THRUSTER AND GREEN PROPELLANT TECHNOLOGY ON THE PRISMA SATELLITE

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ECAPS

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Introduction and Outline

• Objectives
• PRISMA Mission
• HPGP Propulsion System Description
• Research & Development
  - Propellant
  - Thruster
  - System
• Assembly, Integration & Test
• Conclusions
• Acknowledgments
Objectives

“High Performance Green Propellants” (HPGP)

The objective in 1997 was to develop (within 10 years) a new storable monopropellant, thrusters and system for small satellites which compared to Hydrazine:

- has significantly better performance
- is “Green” i.e. significantly less hazardous and environmentally benign
- reduce the overall mission cost

The objective for the first flight demonstration of the HPGP technology is to reach TRL 7
- The mission also offers the opportunity to perform Back-to-back comparison with a comparable hydrazine system
**PRISMA Mission**

- Customer: Swedish National Space Board
- Prime Contractor: Swedish Space Corporation
- Contributions from DLR and CNES

- Autonomous Formation Flying
- Homing and Rendezvous
- Proximity Operations
- Flight Demonstrations of 2 New Propulsion Technologies
  - HPGP - ECAPS
  - Micropropulsion - Nanospace

- Main Satellite: Wet Mass: 150 kg, Dim: 1 x 0.7 x 0.7 m
  - $\Delta V$ Capability $>150$ m/s
- Target Satellite: 50 kg
- Orbit 900 km
- Launch scheduled for 2009
PRISMA Propulsion Systems

- Hydrazine RCS
- HPGP RCS
- Micropropulsion (MEMS)
PRISMA HPGP Propulsion System Design

Conventional Hydrazine System Architecture

• Operation in Blow-down mode

• All Fluid Components are COTS with extensive flight heritage

Novel Propellant and Thruster Technology

• 2 x 1 N HPGP Thrusters

• Propellant load is 5.5 kg of LMP-103S

*ECAPS holds patents worldwide for a family of ADN-based Propellants, Catalyst, Thruster Design and Manufacturing Methods*
PRISMA HPGP Propulsion System
Hydraulic Schematic & Lay-out

Propellant R&D

Pressurant Service Valve

LMP-103S

Orifice

Filter

FCVs

Thrusters

COTS Components Compatibility Testing

Dry Mass: 3.8 kg
Wet Mass: 9.3 kg

Thruster R&D

Pressurant Service Valve

FCVs
PRISMA HPGP Propulsion System

Propellant LMP-103S

- Formulation & Performance
- Classification & Safety
- Storability & Compatibility
- Propellant Manufacturing
- Fuelling
Propellant LMP-103S

Formulation and Performance

• LMP-103S is a storable monopropellant consisting of a blend of ADN (NH$_4$N(NO$_2$)$_2$), Water, Methanol and Ammonia

• LMP-103 has 6 % higher theoretical specific impulse and 24 % higher density as compared with hydrazine, thus improving:
  
  **Density Impulse up to +30 %**

• The performance improvement has been verified by firing tests

• Higher performance has been demonstrated by tuning the composition
Propellant LMP-103S
Classification & Safety

- LMP-103S has been approved for transport to according to **UN Class 1.4S**
- LMP-103S has **UN No: 0368**
- LMP-103S is classified as an **1.3 Substance** explosive hazard
- Moderate toxicity. Vapour toxicity (due to ammonia and methanol) is 2500 times less than for hydrazine
Propellant LMP-103S

Storability

• LMP-103S has short term stability from:
  
  \[-7^\circ C \text{ to } +120^\circ C\]

• LMP-103S has long term stability from:
  
  \[+10^\circ C \text{ to } +50^\circ C\]

• Accelerated propellant storability test (STANAG 4582) indicates:
  
  \[> 20 \text{ years of storage life}\]

• LMP-103S is not sensitive to radiation of 100 kRad (Cobalt 60)
Propellant LMP-103S Compatibility

Compatibility Issues:
- General Corrosion
- Galvanic Corrosion
- Redox Potential
- Stress Corrosion
- Leaching
- Diaphragm Integrity
- Hydrogen Embrittlement
Propellant LMP-103S

Storability & Compatibility End-to-End Test

Storability & Compatibility End-to-End Test with **COTS Components:**
- > 2 year duration
- > 20,000 valve cycles
- Pressure & temperature monitoring
- Temperature range +10 to +50°C
- Regular propellant sampling & Analysis

*Results after 18 months:*
- No pressure build-up
- No corrosion
- Insignificant leaching of materials

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LMP-103S Propellant Manufacturing

• Manufacturing process has been verified for **Flight Quality** (High Purity Grade) LMP-103S propellant

• Manufacturing is ongoing for 50 kg of LMP-103S propellant

*LPM-103S Propellant Plant at EURENCO, Karlskoga*
Propellant LMP-103S

Fuelling

- SCAPE suites are not required
- Unlike Hydrazine, LMP-103S is not sensitive to exposure to air or humidity
- ECAPS has performed >40 fuelling sessions since 1999
1 N HPGP Development Thruster

- >30 Thrusters (Development, Engineering and Prototype models) have been built and test fired since 1999
- TRL-3 was achieved in 1999
- TRL-6 was achieved in 2007
- PRISMA Flight Thrusters are currently integrated into the propulsion system
HPGP Thruster
Thruster Design

- Conventional Flow Control Valve
- Un-cooled Rhenium / Iridium Thrust Chamber
- Novel High Temperature Resistant Thermo/Catalytic Reactor
HPGP Thruster Firing Tests

Test Site – FOI Gröndjön

Firing Test Facility - ECAPS
HPGP Thruster

Firing 30 sec
HPGP Thruster Performance

Density Impulse Comparison between HPGP and Hydrazine

Steady-State Specific Impulse vs Propellant Feed Pressure

Single Pulse Performance @ $P_{\text{feed}} = 22$ Bar

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# HPGP Thruster Life Testing

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PRISMA “Demonstrated”</th>
<th>ESA Contract “Objectives”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulated Firing Time:</td>
<td>&gt; 5 hours*</td>
<td>&gt; 20 hours</td>
</tr>
<tr>
<td>Propellant Throughput:</td>
<td>&gt; 5 kg*</td>
<td>&gt; 20 kg</td>
</tr>
<tr>
<td>Number of Pulses:</td>
<td>&gt; 20 000*</td>
<td>&gt; 50 000</td>
</tr>
<tr>
<td>Thermal Cycles:</td>
<td>&gt; 500*</td>
<td>&gt; 1000</td>
</tr>
</tbody>
</table>

*No indication of degradation after test
HPGP Thruster
Manufacturing, Assembly and Test

Assembly of Flight Thrusters
HPGP Propulsion System
Manufacturing, Assembly & Test

Tube bending
Orbital welding
Precision Cleaning
Radiography of weld joints
Pressure and Leak Check
HPGP Flight System

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Conclusions

• 10 years after the invention of the HPGP concept the first Flight Propulsion system has been successfully developed, manufactured and verified - On time - On Budget

• The initial objectives for developing the new propellant and thruster technology have been met i.e.:
  - Higher performance
  - Less hazardous and environmentally benign
  - Reduce the overall mission cost

• The required infrastructure to manufacture and test 1 N HPGP systems is in place, including catalyst and propellant manufacturing
Conclusions

• Life tests will start in 2007 within the ESA contract. The goal is 20 kg of propellant throughput and accumulate firing time of > 20 hours.

• Propulsion Module RFQ for commercial small satellites have been received and proposals have been submitted

• Up-scaling to higher thrust levels and development of a 20 N Thruster has started (Phase 1)
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