One Year of In-Flight Results
from the Prisma Formation Flying Demonstration Mission

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www.ohb-sweden.se
The PRISMA Mission

Background and Status

Objective and Background:

- *Demonstration of Technologies related to Formation Flying and Rendezvous in Space*
- **OHB Sweden is Prime Contractor**
- **Funded by Swedish National Space Board**
- **Further supported by DLR (D), DTU (DK), CNES (F), SSC-ECAPS (S)**

Status:

- *Launched clamped together on Jun. 15, 2010*
- *Tango separated from Mango on Aug. 11, 2010*
- *Nominal mission completed by mid Aug. 2011*
The PRISMA Mission

Platform Summary

**Mango**
- 3-axis stabilized
- Attitude Independent Orbit Control
- 100 m/s Delta-V
- 145 kg launch mass
- 2.6 m “wing-span”
- 3 propulsion systems
- 4 RF systems

**Tango**
- 3-axis stabilized
- Solar Magnetic control
- No orbit control
- 40 kg launch mass

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The experiment lists

### GNC Experiment Demonstrations

<table>
<thead>
<tr>
<th>Passive formation flying</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous formation flying (AFF)</td>
<td>OHB Sweden</td>
</tr>
<tr>
<td>Autonomous formation control (AFC)</td>
<td>DLR</td>
</tr>
<tr>
<td>RF-based formation flying</td>
<td>CNES</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Forced motion</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximity Operations (PROX)</td>
<td>OHB Sweden</td>
</tr>
<tr>
<td>Final Approach and Recede (FARM)</td>
<td>OHB Sweden</td>
</tr>
<tr>
<td>Forced RF-based motion</td>
<td>CNES</td>
</tr>
<tr>
<td>Collision avoidance</td>
<td>OHB Sweden / CNES</td>
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<td>Autonomous Rendezvous (ARV)</td>
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</tbody>
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### Hardware Flight Demonstrations

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HPGP Motor Tests</td>
<td>ECAPS</td>
</tr>
<tr>
<td>Microthruster Motor Tests</td>
<td>Nanospace</td>
</tr>
<tr>
<td>Relative GPS receivers</td>
<td>DLR</td>
</tr>
<tr>
<td>Vision Based Sensor (VBS)</td>
<td>DTU</td>
</tr>
<tr>
<td>RF Sensor Tests</td>
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</tr>
<tr>
<td>LEON-3 on-board processor</td>
<td>OHB Sweden</td>
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<tr>
<td>PRIMA MEMs mass analyzer</td>
<td>IRF</td>
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<tr>
<td>Digital Video System</td>
<td>Techno Systems</td>
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</tbody>
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Operations concept

Early input from experimenters (>2 years) key to developing the timeline.

Close cooperation between exp. and dev. team both prior and after launch.

Experimental mission based on the assumption that not all experiments will be 100% successful on the first execution.

By nature, this may result in autonomous abortion of experiments during flight.
Operations concept

The result is fast, flexible and responsive team that has allowed for maintenance of the demanding timeline, even in the event of anomalies. Interaction to experimenters and their requests is kept focused and changes or decisions can be made quickly, in some cases in just a matter of one orbit.

“This proximity [of Flight Director, GNC Expert, Operator and Experimenter] allowed a better reactiveness in presence of anomalies that proved to be a key element in the respect of the timeline.” - CNES Experiment Team
Mission timeline


- Basic Mission
- Microthruster 1
- HPGP 1
- GPS Calibration
- AFF Early Harvest
- FFRI Initiation
- FFRI Envelope Part 1
- HPGP 2 Part 1
- PROX GPS Part 1
- FFRI GKC 1 Part 1
- ARV Coop (without PROX)
- Eclipse Session
- HPGP 2 Part 2
- HPGP 3 Part 1
- PROX GPS Part 2
- HPGP 3 Part 2
- PROX/FARM VBS Part 1
- Routine Operations over Christmas
- Return from Routine operations
- AFT Completion of Experiments
- HPGP 3 part 2
- PROX/FARM VBS Part 2
- FFRI GKC 2 Part 2
- FFRI GKC 2
- ARV Non-Coop with PROX Part 2
- Handover day to CSOC
- ARV 2
- AFT Completion Part 1
- AFT Completion Part 2
- HPGP 4 #1
- AFT-VBS-CR #1
- Easter holiday
- HPGP 4 #2
- AFT-VBS-CR #2
- HPGP 4 #3
- HPGP 4 #4
- HPGP 4 #5
- PROX-VBS #1

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Mission results summary

**AFF** – To date, 5 months of closed loop cooperative satellite formation flying, with 20 days in dedicated AFF experiments. The remaining time has been spent in routine operational formation flight between 30km to 10m relative distances.

**PROX/GPS** – First flight demonstration of close proximity GPS based forced motion relative orbit control over the range of 50m to as low as 2m relative distances.

**ARV** – First flight demonstration of autonomous line-of-sight only based target search, orbit determination, orbit align and approach from 30km to 50m relative distances.

**CNES** – First flight demonstration of autonomous formation flight using a radio electric relative sensor. Position accuracy was achieved in the range of 1-100cm and pointing accuracies of <0.1° over the range of 30km to 3m relative distances.

**DLR** – First comprehensive demonstration of GPS based autonomous formation flight and extraction of relative Precision Orbit Determination (POD).

**PROX/VBS** – The first closed loop proximity operations based on visual sensor had been performed with promising results.
Mission results summary

**ECAPS** – First flight and space qualification of the High Performance Green Propellant (HPGP) 1N thruster system, including 34,000 pulses during 200 test sequences and 2.3 hours of firing.

**Nanospace** – First flight of the MEMS cold gas micropropulsion system. Electrical validation of all MEMS components was possible, although unfortunately full system demonstration could not be performed due to a propellant leak on the high pressure storage side.

**PRIMA** – First flight demonstration of MEMS shutter based low energy (<100eV) ion mass analyzer.

**DVS** – First flight of Techno Systems digital video camera system.

**SW & DHS** – 100% fault free operation of autocoded Model Based Software (MBSW), running on a LEON-3 processor.
Autonomous Formation Flight (AFF)

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Proximity Operations (PROX)

2 meter proximity approach:
Forced Formation Flying Periodic/continuous delta-V
Hi-precision GPS-based navigation by DLR
Fuel Optimal Model Predictive Control
Implemented for elliptical orbits

Deviation from reference with respect to POD(b) & on-board navigation (g)
Forced motion proximity flight results

Virtual structure flyby, centered on Tango position.

Sub 20cm control accuracy has been demonstrated over the entire maneuver.
Autonomous Rendezvous (ARV)

Autonomous acquisition and approach from 30,000m to 50m based purely on visual line-of-sight.
Robotic dance in space...

Six days of Autonomous CNES / FFRF experiments, 9000m down to 20m approach to Tango.
Lessons learned & conclusions

- Value of simulation
- Strengths & limitations of autonomy
- Autonomy & operability
- Time to recovery
Extending the mission…

OHB Sweden invites other organizations to suggest experiments and to participate in mission extension

- Nominal mission completed by mid August 2011
- Expect to have ~50 m/s delta-V by end of nominal mission
- Mango to leave Tango in early 2012
Mission extension – Examples:

• Pre 2012:
  • All on-board or ground based / supported
  • Related to space situational awareness
  • Autonomous FF and relative maneuvers
  • Automated checkout and planning
  • Inspection, servicing, repair, 3D proximity operations
  • Use of dV or not
  • Use of both Mango and Tango
  • Focus on GNC algorithms

• Post 2012:
  • SSA related experiments (open definition of SSA)
  • Attitude control experiments
  • Drag-based FF and relative maneuvers, lower altitudes
  • RDV, Inspection, 3D proximity operations, non cooperative target (neighboring object, S/C or debris)
  • Focus on GNC algorithms
Thank you!

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