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Full Electric Mission to Moon (SMART-1) and Technologies: Electric propulsion, rendez-vous, formation flying

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Full Electric Mission to Moon (SMART-1) and Technologies: Electric propulsion, rendez-vous, formation flying
Presentation to the 44th Space Congress
OHB Sweden – A small innovative space company in a small country
From pioneering small satellite builder in Swedish Space Corporation...

**EARLY SATELLITES**

Small scientific satellites in 1980th and 90th

- Viking (1986)
- Freja (1992)
- Astrid 1 (1995)
- Astrid 2 (1998)

**HIGH-PRECISION**

Precise 3-axis attitude control for astronomy and Earth observation
Still operated by OHB Sweden.

- Odin (2001)

**INTERPLANETARY**

First ESA Lunar mission.
Low-thrust transfer to lunar orbit


**FORMATION-FLYING**

Demonstration of Formation-Flying & Rendezvous using GPS, Vision-Based, and RF-navigation.

- PRISMA (2010)
... to Technology specialists in the OHB group

- A small, flexible, innovative team with high technical know-how focusing on new developments
- Total company staff 70 people
- Specialized in Propulsion and AOCS
- Still small satellite capability through new **Innosat** platform:
  - Innovative low cost microsatellite 40 kg
  - First launch planned 2017 with climate research mission

**Orion PQM**

**Innosat**

**Solar Orbiter**
Electric Propulsion and SMART-1
Electric propulsion: From lunar mission SMART-1 to future telecom

**SMART-1**
- From GTO to Lunar orbit
- Testing of EP and satellite technology for interplanetary missions
- High radiation environment through radiation belts

**SGEO**
- Development
- AIT
- Launch
- Chemical propulsion from GTO to GEO
- EP for station keeping in operations (15 years)

**ELECTRA**
- Development AIT Launch
- Full EP (transfer + GEO)
- Cost efficient EPPS & AOCS architecture
SMART-1: First to the moon – from Europe...

- ESA Technology mission to demonstrate use of low thrust for future interplanetary space journeys
- Developed and built in short time by Swedish Space Corporation (today OHB Sweden) using Small Satellite methods
- European Hall Effect Thruster fuelled by Xenon gas
- 15 months orbit transfer with 70 mN (7 gram) thrust
- <80 kg Xenon for full earth-lunar transfer
SMART-1: Accommodation of the EP system

- Pressure regulation panel (BPRU)
- EP Power Unit (PPU)
- Heat-pipes
- 2-axis Thruster Orientation Mechanism
- EP thruster
- Xe-tank (49 litres / 82 kg)
- System Unit
- Thermal insulation
- SMART-1: Accommodation of the EP system
Spiralling out to the moon over 15 months

2004-09-01 08:00:00.000
SMART-1: A tough journey through the radiation belts
Worst possible weather conditions!

- Massive solar storms Oct/Nov 2003
- Immense increase ($x10^5$) of solar protons
Star tracker hot spots

Stars visible in star tracker during normal operations

After passage through the radiation belts
SMART-1 flight experience:
200 μm coverslides, 8% loss of S/A power before reaching hp=10,000 km

Figure 2-3 SMART-1 Solar array output power (W) during the first year of the mission
Around 50,000 moon pictures were taken by SMART-1.
Search for "Peak of eternal sunlight"

Jan 2005

Lunar North Pole from 5000 km
Deemed to end...

Decending orbit due to earth and sun influence
Calculation of point of impact
SMART-1 IMPACT ON THE MOON

Courtesy of Mark R Rosiek, USGS Astrogeology Team, Planetary Geomatics Group and Dr Anthony C. Cook, School of Computer Science and IT, University of Nottingham,
Impact on the moon

Sep 03, 2006, 05.42.22 UT
Canada-France-Hawaii Telescope (CFHT) 3.6m telescope, Mauna Kea

DUST CLOUD OF 20 X 80 KM
Small GEO
Europe’s first geostationary “All-EP” satellite
Hall Effect Thrusters for east-west and north-south station keeping
Electra: Europe's Full EP satellite

- Public private partnership with ESA, satellite operation SES and OHB group
- Combines EP transfer knowledge from SMART-1 with station keeping knowledge from SGEO
- Orbit transfer in 80-200 days depending on launch scenario
Electra: An innovative Electric propulsion system

- Newly developed 4.5 kW/270 mN HET thruster for both orbit transfer and station keeping
- Xenon storage capacity up to 800 kg in new developed tank
- Optimized thruster configuration with four thrusters for all EP operations
- Newly developed robotic THOR boom for thruster reorientation
- High flexibility in COG position allows big variation in payload size
PRISMA – A test bench for future scientific and exploration missions
Needs of future exploration missions

Autonomous Formation Flying
Large apertures and antennas for science missions, stereoscopic or phased imaging.

Autonomous Rendezvous
In Orbit Inspection, Servicing, or debris removal.

PRISMA MISSION IDEA:
"Demonstrate maneuvering techniques and sensor technology for Autonomous Formation Flying and Rendezvous"
The PRISMA Satellites

**Mango**
- 3-axis stabilized
- Attitude Independent Orbit Control
- 145 kg launch mass
- FFRF, GPS, VBS, DVS, Inter-satellite link
- 3 propulsion systems, >200 m/s Delta-V

**Tango**
- 3-axis stabilized
- Solar Magnetic control
- 40 kg launch mass
- FFRF, GPS, Inter-satellite link
Three (!) Propulsion systems on Mango

- **Hydrazine**: Six 1N thrusters
- **Green propellant**: Two 1N thrusters
- **MEMS Micropropulsion**: Two thrusters pods

OHB SWEDEN AB / PRISMA and IRIDES
PRISMA Rendezvous Reconstruction and Video from Orbit
Formation keeping demonstration

Formation pointing to the Moon for 5 hours (5 cm positioning accuracy)
Thank you!