A Stable Liquid Mono-Propellant based on ADN

Eurenco Bofors, Groupe SNPE:

Per Sjöberg and Henrik Skifs
Karlskoga, Sweden

ECAPS, Swedish Space Corporation Group:

Peter Thormählen and Kjell Anflo
Solna, Sweden

Insensitive Munitions and Energetic Materials Technology Symposium
Tucson, USA, May 11-14, 2009

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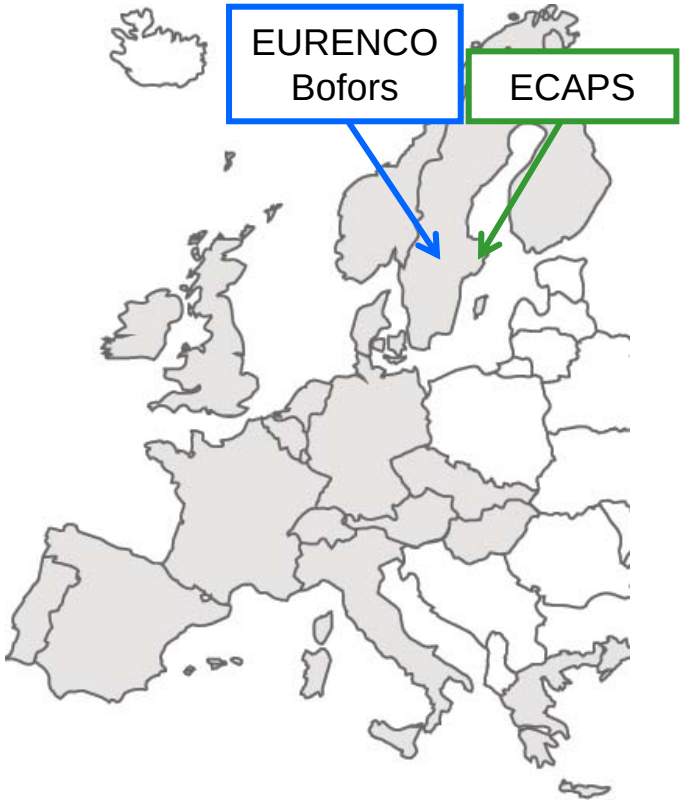
Outline

- EURENCO Bofors and ECAPS
- Properties and production of ADN
- ADN in liquid monopropellants
- High purity ADN
- Monopropellant LMP-103S:
  - *Composition*
  - *Performance*
  - *Sensitivity*
  - *UN Transport classification*
- Acknowledgements



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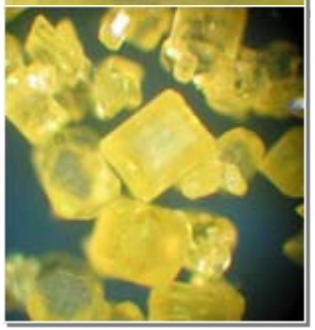
EURENCO Bofors

- Located in Karlskoga, Sweden
- 250 buildings on 744 acres of land
- Website: www.eurenco.com

High explosives and compositions

Single and multi-base propellants

New energetic molecules



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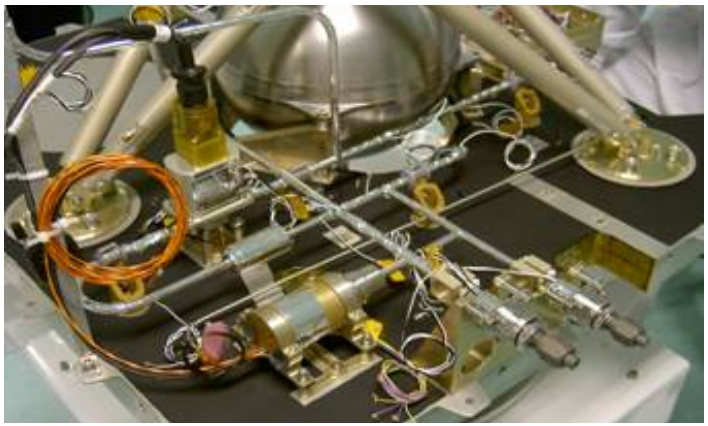

Propulsion systems

Rocket engines for ADN-based monopropellant

- Located in Solna, Sweden
- Owned by Swedish Space Corporation
- Website: www.ecaps.se

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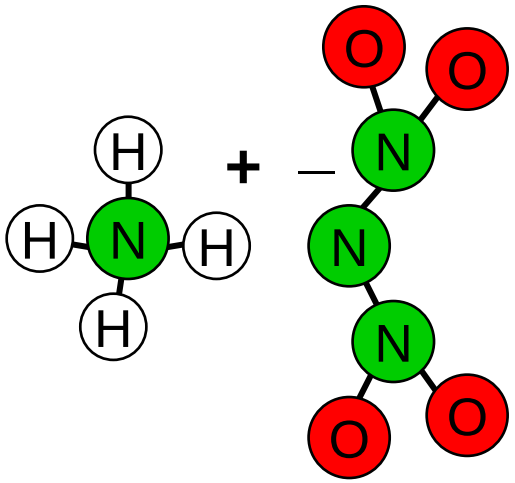
Properties of ADN

- Discovered and produced in the Soviet Union during the 1970s (not known in the west before 1993).
- Synthesised and patented in the US by SRI International in 1991.
- Research to use ADN as a solid propellant is ongoing.
- An energetic material and oxidiser.
- A salt with high solubility in water.

ADN = Ammonium DiNitramide

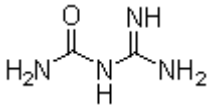


Production of ADN

- EURENCO Bofors is the largest producer of ADN.
- Produced from GuDN.
- ~99.6 % purity.

GuDN $\rightarrow$ KDN $\rightarrow$ ADN

Gu = Guanylurea



K = Potassium

A = Ammonium

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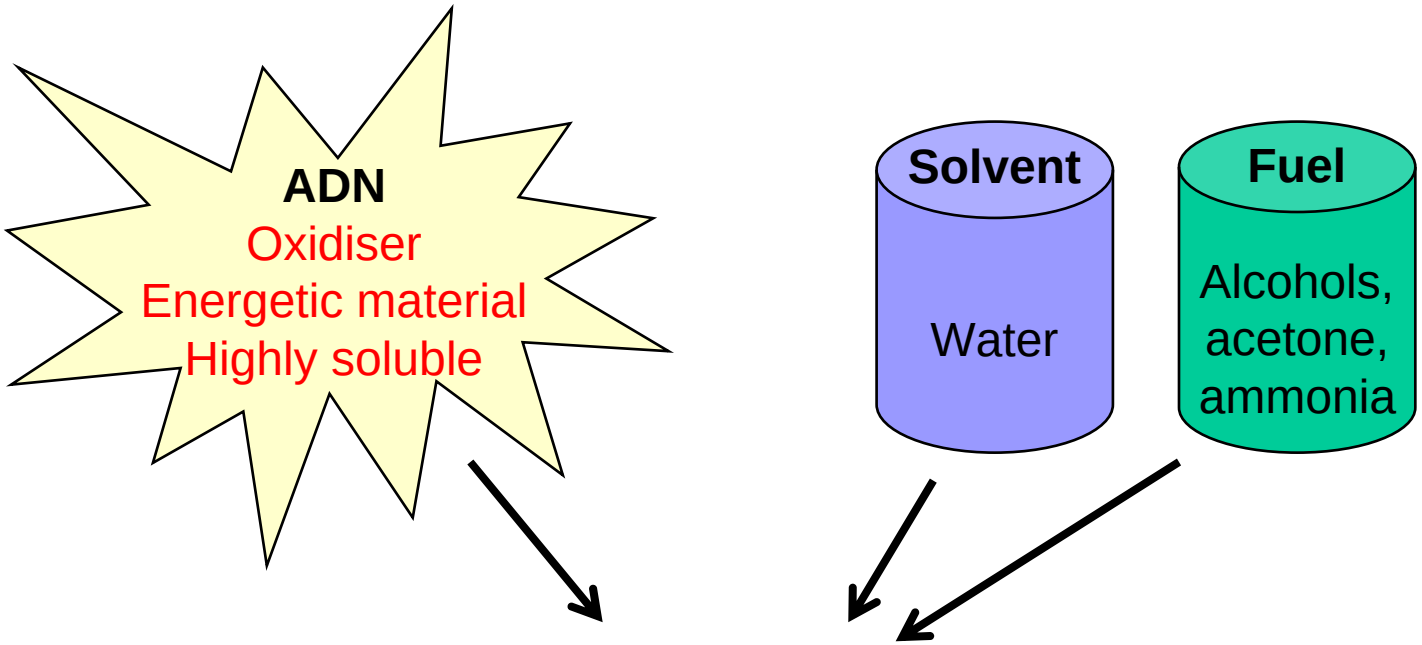
ADN in liquid monopropellants



Invented in 1997 by the Swedish Space Corporation (SSC) and the Swedish Defence Research Agency (FOI).

Careful selection of solvent and fuels makes the ADN-solution much less sensitive than pure (solid) ADN.

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Benefits of ADN-based monopropellants

Higher performance than monopropellant Hydrazine

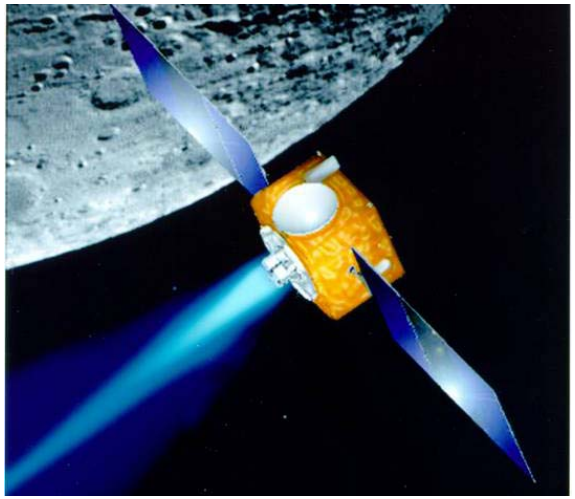
⇩

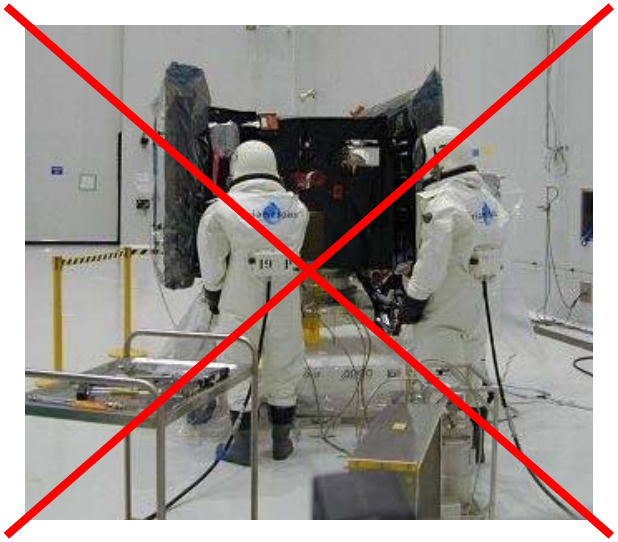
Extended mission or reduced tank volume

Much less toxic than Hydrazine

⇩

Reduced fuelling cost





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High purity ADN

- Space applications require high purity propellants, i.e., > 99.999 % purity * (“standard” ADN is ~99.6 %).
- An ADN purification process has been developed by EURENCO Bofors and ECAPS, which fulfils the high purity requirements.
- A pilot-plant-scale purification system is operational, owned by ECAPS and operated EURENCO Bofors.

** Compare with, e.g., Ultra Pure™ Hydrazine.*

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Monopropellant LMP-103S

Space propulsion requirements:

- Performance
- Purity
- Compatibility
- Radiation tolerance
- Storage stability
- Transport classification
- Handling safety
- Density
- Viscosity
- Vapour pressure
- Speed of sound
- Specific heat capacity
- Conductivity
- Thermal conductivity

⇨

Monopropellant LMP-103S:

ADN	60-65 %
Methanol	15-20 %
Ammonia	3-6 %
Water	balance

(by weight)

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Performance of LMP-103S

Compared to Hydrazine:

6 % Higher specific impulse *
&
24 % Higher density (1.24 kg/L)

⇩

30 % Higher density impulse

**** >2300 Ns/kg demonstrated.***

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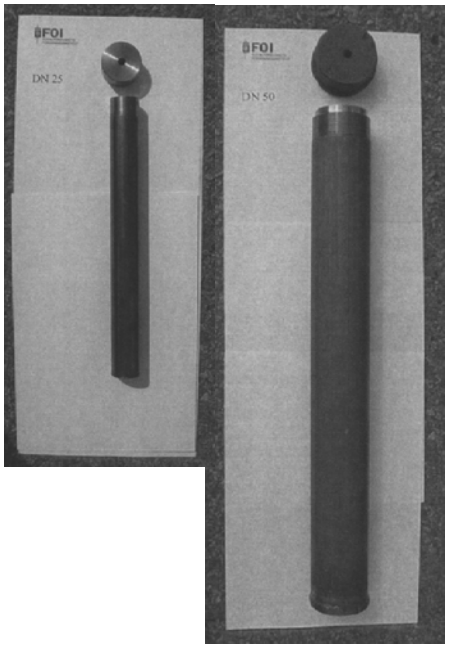
LMP-103S safety tests – Sensitivity

Detonation test



DN 25 and DN 50

Detonable!

⇨

Large scale gap test

Critical diameter

Tests performed by the Swedish Defence Research Agency (FOI)

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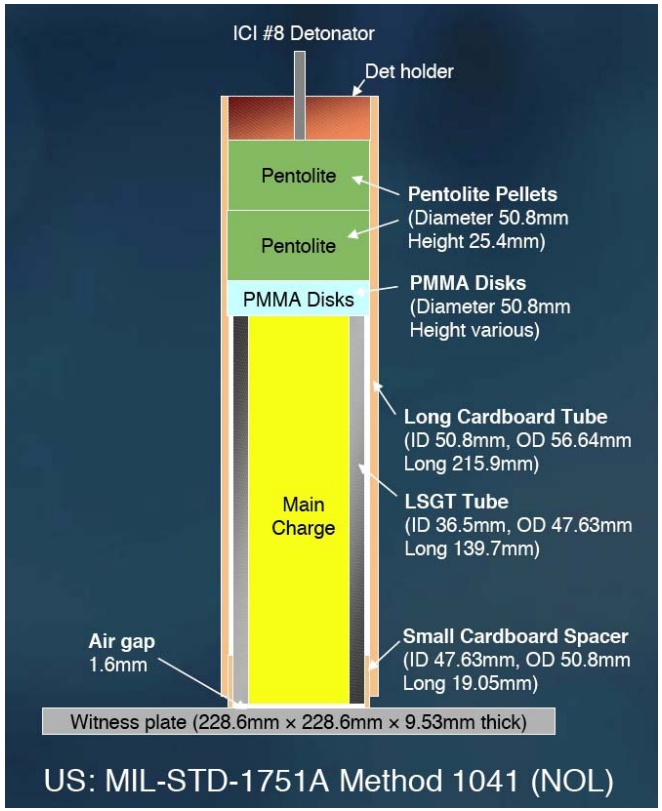
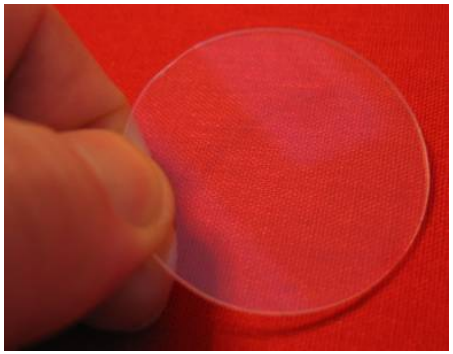
NOL Large Scale Gap Test – Setup





1 card = 0.01 inch = 0.25 mm

Substance considered to be Division 1.3 if sensitivity is less than 70 cards

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Large Scale Gap Test – Water reference

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Large Scale Gap Test – LMP-103S

55 cards = 0.55 inch = 14.0 mm

(sensitivity of melt-casted TNT is ~150 cards)

4 negative results at 66 cards, 1 negative at 55 cards and 1 positive at 18 cards.

➔ LMP-103S is considered to be an insensitive Division 1.3 substance.

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Critical Diameter

Water reference

LMP-103S

Negative results with ½” tube ➔ Critical diameter >10 mm (inner diameter).

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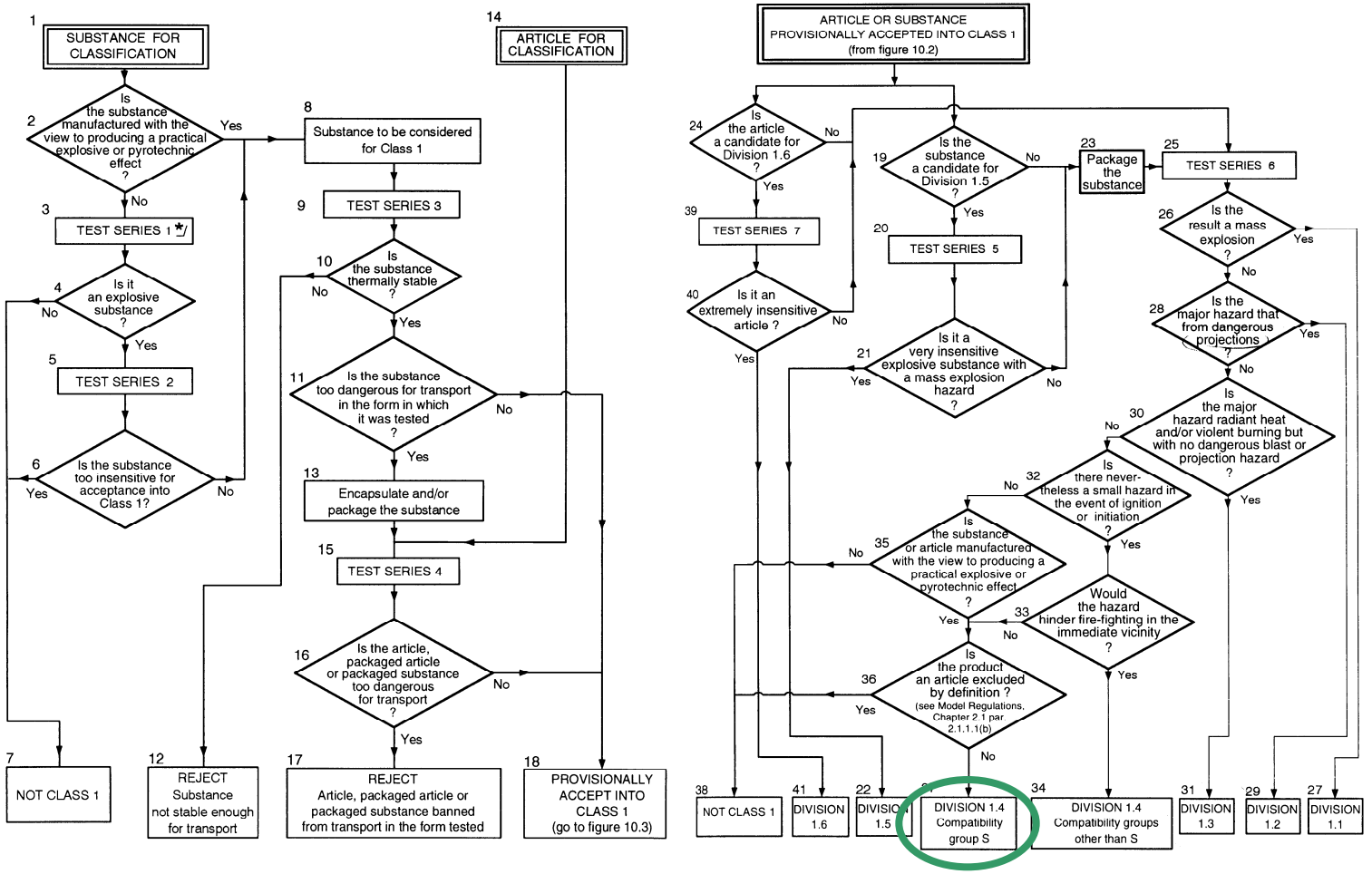
LMP-103S UN Transport classification



UN Class 1.4S makes airfreight possible

(in specific shipping container and following certain packaging instructions)

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Summary

- High purity ADN (>99.999%) can be produced.
- Monopropellant LMP-103S fulfils space propulsion requirements.
- LMP-103S is much less toxic and has higher performance than monopropellant Hydrazine.
- LMP-103S is considered to be an insensitive Division 1.3 substance.
- LMP-103S UN transport classification 1.4S makes airfreight possible.

Acknowledgements

R&D partners:

- Swedish Space Corporation (SSC)
- Swedish Defence Research Agency (FOI)
- Edotek Ltd.
- Swerea KIMAB
- ALS Scandinavia
- Bodycote
- SafePac
- Swedish Civil Contingencies Agency (MSB)

Financial support:

- The Swedish National Space Board (SNSB)
- European Space Agency (ESA)
- Swedish Space Corporation (SSC)

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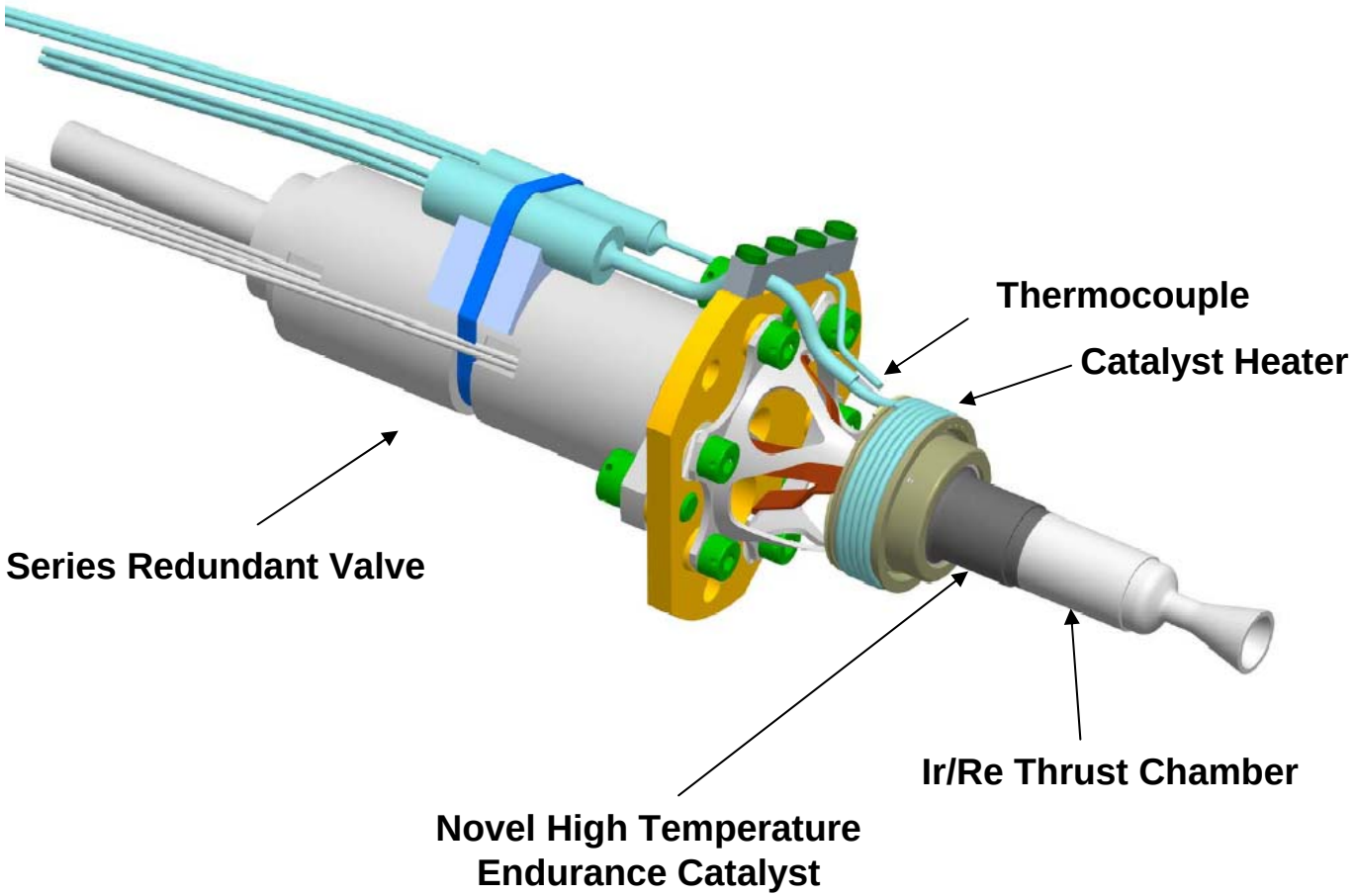
EM Thruster Design



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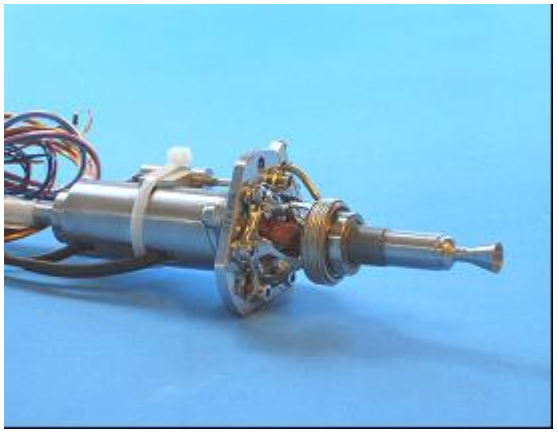
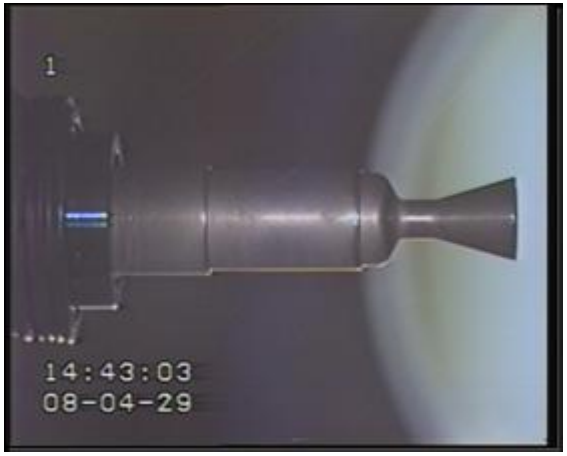
1 N HPGP Rocket Engine

1 N HPGP Rocket Engine Characteristics	
Propellant	LMP-103S
Inlet Pressure Range	5.5 - 22 bar
Thrust Range	0.27 - 1 N
Isp *vacuum*	2010 – 2300 Ns/kg (205 - 235 sec)
Density Impulse	2850 Ns/L
Minimum Impulse Bit	0.01 – 0.05 Ns
Overall Length	176 mm
Mass	0.34 kg
Demonstrated Life	
Total Impulse	50 kNs
Pulses	60 000
Propellant Throughput	25 kg
Accumulated Firing Time	24 hours
Longest Continues Firing	1.5 hours
Status	
Ready for flight on PRISMA 2009 TRL 7	



1 N HPGP Thruster (FM)



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HPGP Propulsion System Design for PRISMA

Conventional Monoprop. System Architecture

- Operation in Blow-down mode
- All Fluid Components are COTS with extensive flight heritage

Novel Propellant and Thruster Technology

- 1 N HPGP Thrusters
- Propellant load is 5.5 kg of LMP-103S

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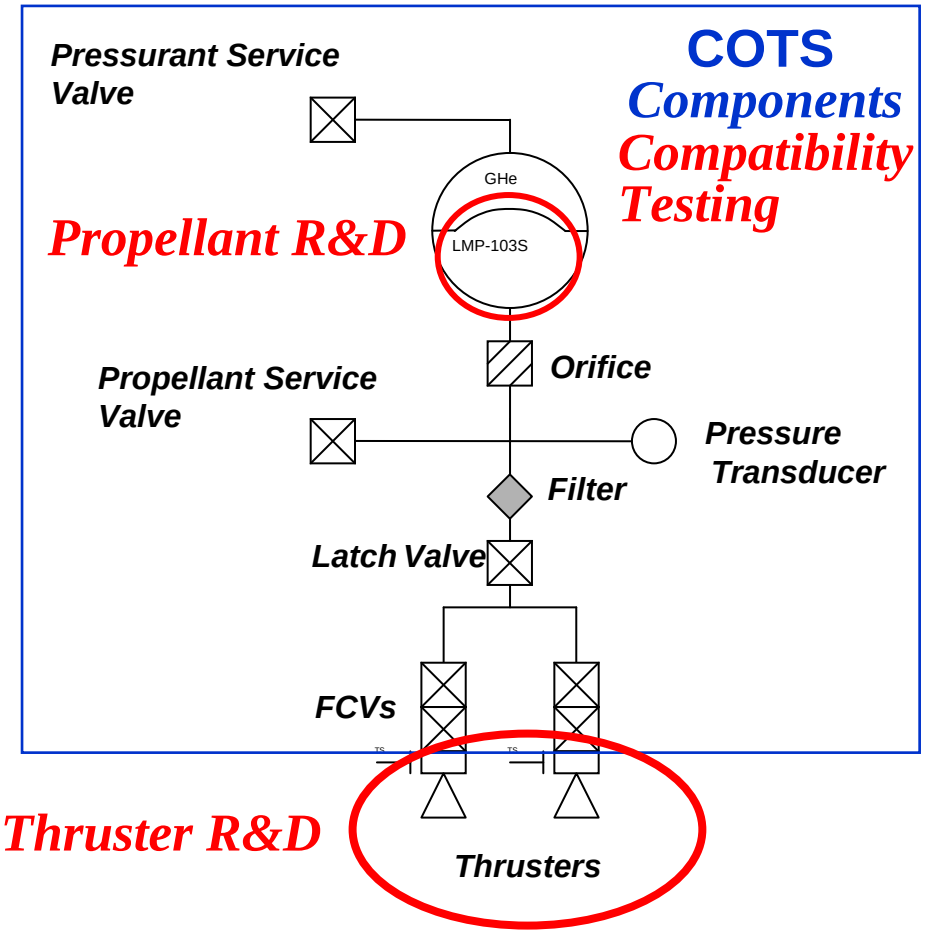
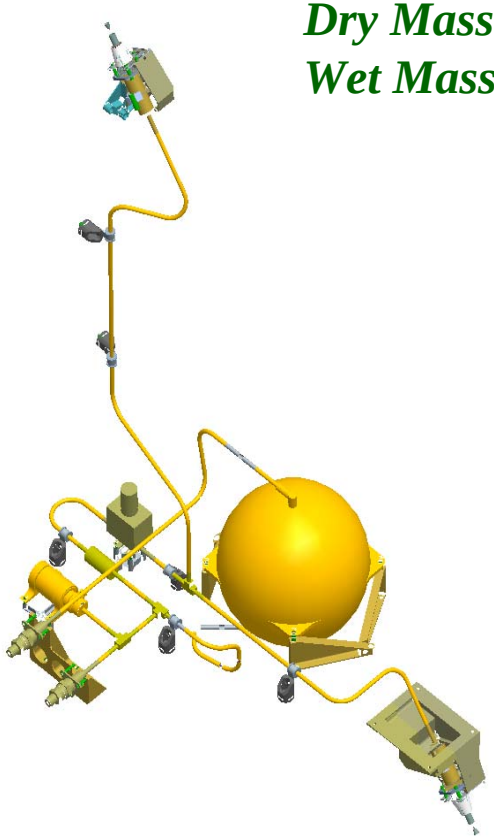
HPGP Propulsion System
Hydraulic Schematic & Lay-out





Dry Mass: 3.8 kg
Wet Mass: 9.3 kg

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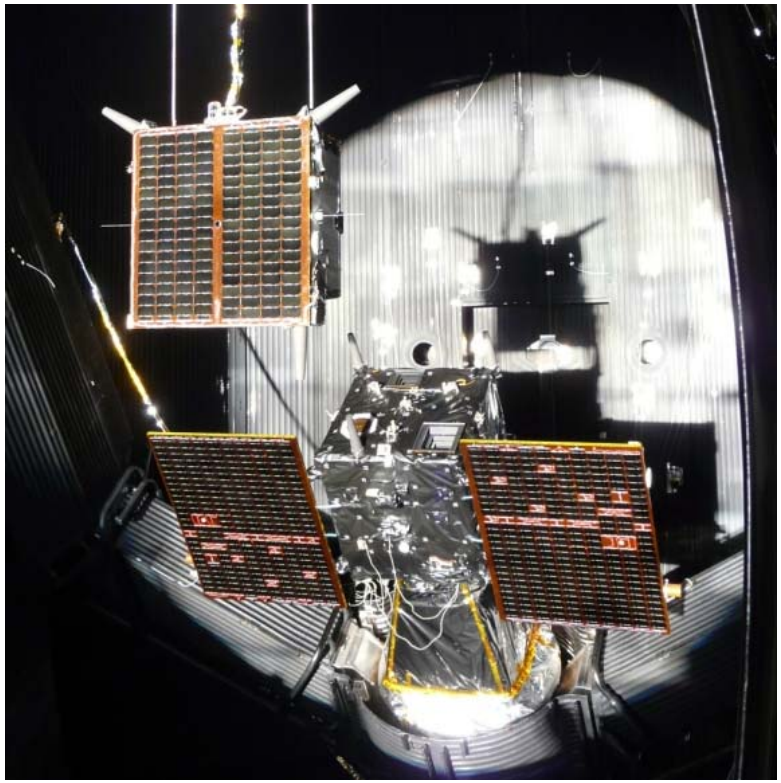
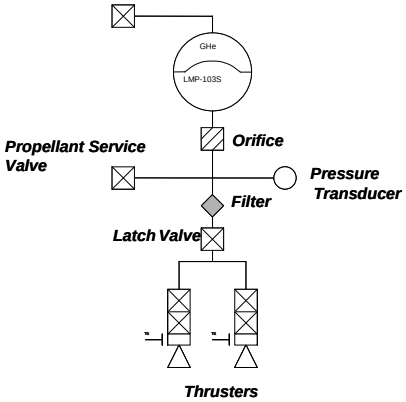
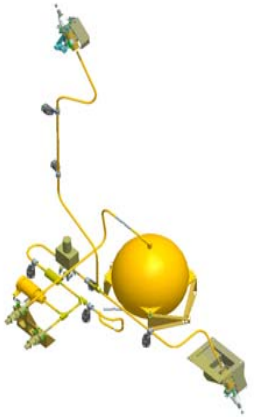
PRISMA

Autonomous Rendezvous and Formation Flying

SNSB, CNES & DLR







Planned Launch 2009

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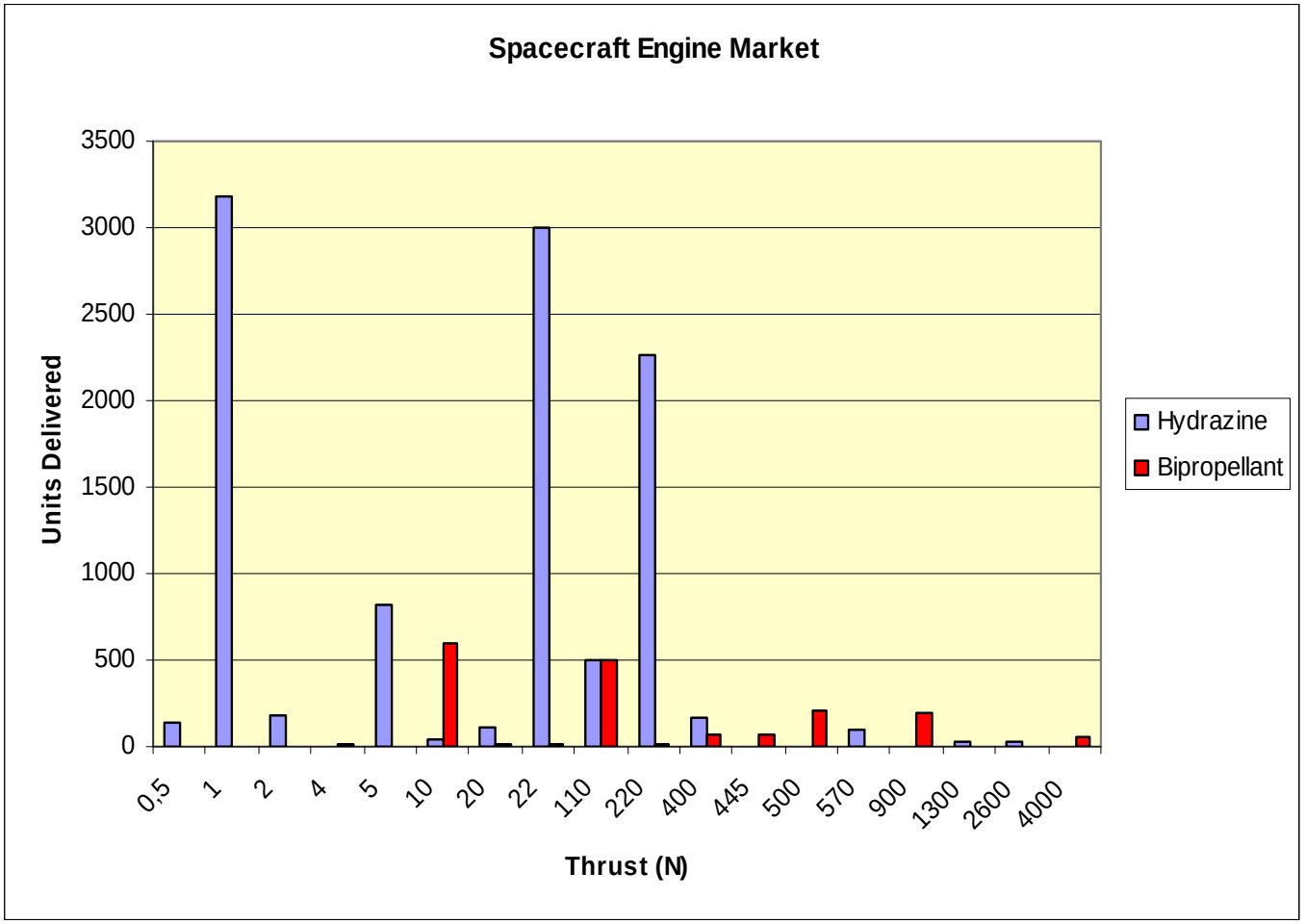
The Chemical Thruster Market



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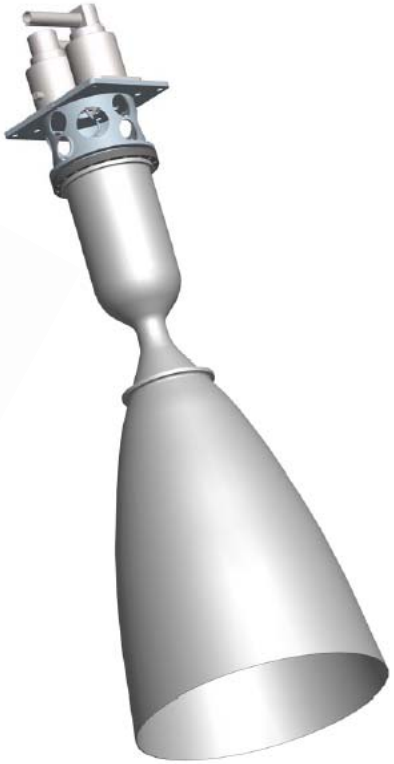
HPGP Rocket Engine Up-scaling

5 N
Under Development
TRL 4

22 N
Under Development
TRL 4

50 N
Under Pre-definition
TRL 2



ACE-220 N
Under Pre-definition
TRL 2

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LMP-103S safety tests

Safety tests:

BAM Impact Sensitivity Test (mechanical impact)

BAM Friction Test (mechanical friction)

Open Fire Test (vapour ignition)

Electrostatic Discharge Test (spark ignition)

KOENEN Test (fast heating)

Small Scale Slow Cook-off (slow heating in closed container)

Detonation Test (detonation wave impact)

Micro-Calorimetric Tests (thermal stability)

Critical Diameter (diameter sustaining detonation)

Large Scale Gap Test (detonation wave sensitivity)

UN-Transport Classification Tests (transport of dangerous goods)

Material Compatibility Tests (construction materials)