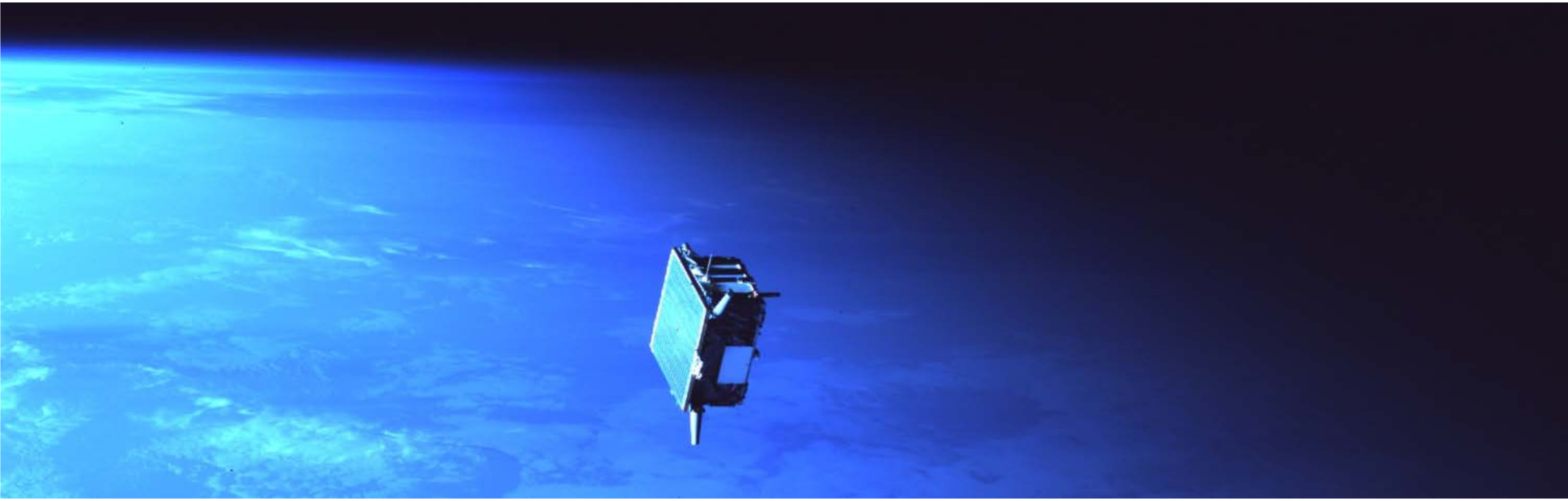
In-Space Demonstration of High Performance Green Propulsion (HPGP) and its Impact on Small Satellites



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25th Annual AIAA/Utah State University Conference on Small Satellites

10th August, 2011

Prisma Satellites

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Outline

1. The PRISMA Mission
2. PRISMA Propulsion Systems
3. Launch Campaign
4. In-Space Demonstrations
5. In-Space Performance Results
6. HPGP Comparison with Hydrazine
7. HPGP in Future Small Satellite Missions

The PRISMA Mission

Objective and Background:

- Demonstration of Technologies related to Formation Flying (FF) and Rendezvous in Space
- Main Satellite ”Mango” and Target Satellite ”Tango”
- Demonstration of High Performance Green Propulsion (HPGP) System
- OHB Sweden is Prime Contractor

Status:

- Launched clamped together on 15 Jun 2010
- Tango separated from Mango on 11 Aug 2010
- Nominal mission completed by mid Aug 2011
- Planned extensions in to 2012

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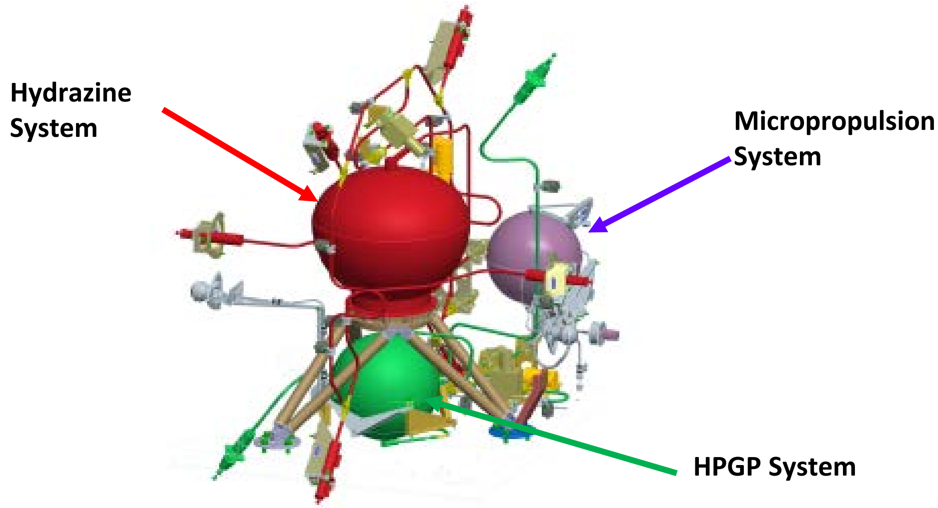
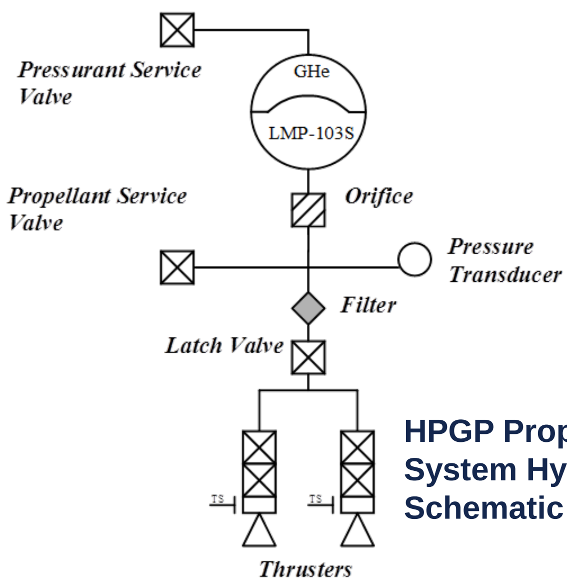
PRISMA Propulsion Systems





HPGP Propulsion System Hydraulic Schematic

Hydrazine propulsion system –

Six 1N thrusters, ΔV capacity up to 120 m/s

- Autonomous formation flying
- Autonomous rendezvous
- Homing
- Proximity operations

HPGP propulsion system –

Two 1N thrusters, ΔV capacity up to 60 m/s

- Specific HPGP Experiments
- FF maneuvers
- Operations with Hydrazine

Cold Gas Micropropulsion system –

Two pods each containing four 1mN thrusters

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Launch Campaign

Loading PRISMA with LMP-103S

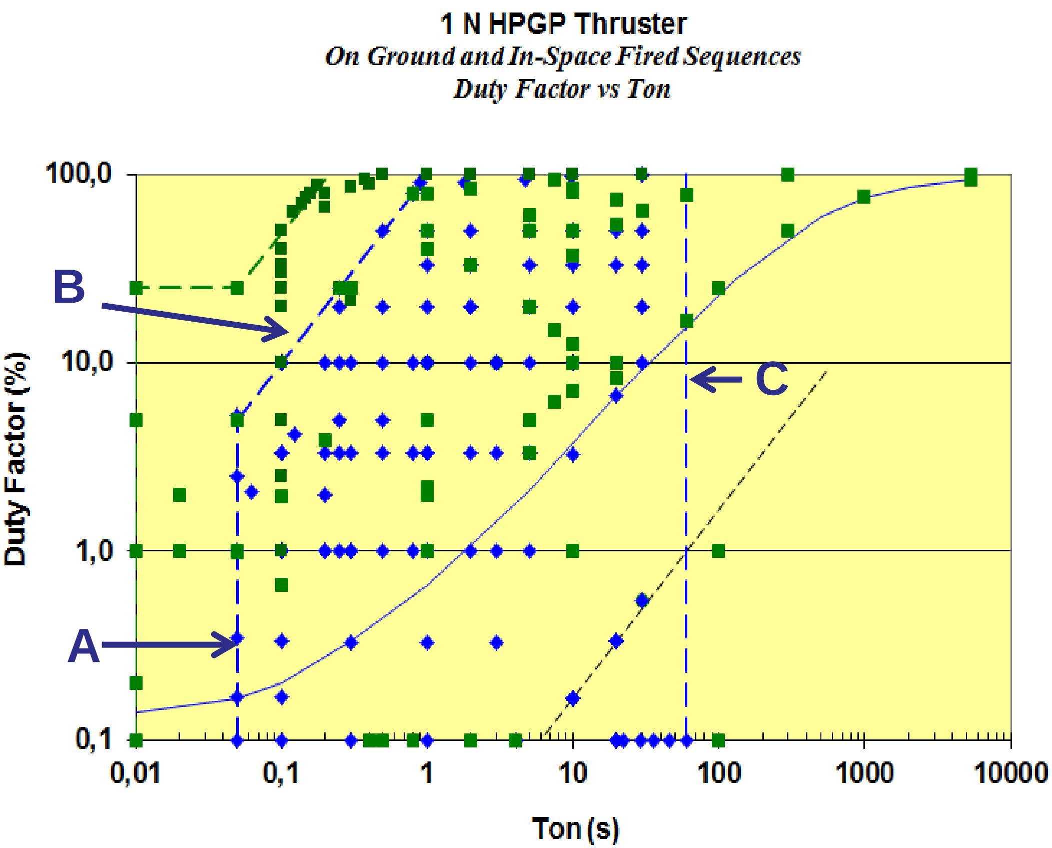
Loading PRISMA with Hydrazine

- HPGP Propellant UN class 1.4S
  - Transported with satellites as air cargo
- HPGP Launch Campaign required:
  - 6 effective working days
  - 3 HPGP personnel
- Handling of LMP-103S (i.e. - loading/de-loading, decontamination) declared by Yasny Range Safety as: **"<u>Non-hazardous operations</u>"**
- Propellant handling and loading **<u>do not require SCAPE operations</u>**
- LMP-103S is **<u>not sensitive</u>** to exposure to air or humidity
- Only limited decontamination of Loading Cart at the launch site is required

In-Space Demonstrations

HPGP OPERATIONS				
Basic Mission				
OPERATIONS	**S/C MODE**	**DAYS**	**OBJECTIVES/REMARKS**	**STATUS**
COMMISIONING	HPGP	1	Low duty Pulse Trains and single pulses up to 10s	Successfully Completed
HPGP BLOCK 1	HPGP 1	4	"Early Harvest" Performance and thermal characteristics	Successfully Completed
HPGP BLOCK 2	Autonomous		Autonomous Formation Flying including HPGP (Provision of ΔV)	Successfully Completed
HPGP BLOCK 3	HPGP 2	20	Performance Measurements	Successfully Completed
HPGP BLOCK 4	Autonomous		Autonomous Formation Flying including HPGP (Provision of ΔV)	Successfully Completed
HPGP BLOCK 5	HPGP 3	7	Performance Measurements	Successfully Completed
HPGP BLOCK 6	Autonomous		Autonomous Formation Flying including HPGP (Provision of ΔV)	Successfully Completed
Extended Mission				
HPGP BLOCK 7	HPGP 4	20	Continuous Firings, Life and Space Environmental Demonstrations. Comparison with Hydrazine TRL 7 Successfully Completed	Successfully Completed
HPGP BLOCK 8	HPGP 5	10	Performance, Life. Planned to start August 24, 211	Planned
HPGP BLOCK 9	Autonomous		(Provision of ΔV)	Under Planning
HPGP BLOCK 10	HPGP 6	2	Performance comparison with Hydrazine	
DECOMMISSIONING	HPGP		Long Firings, Empty the HPGP Propellant Tank	

In-Space Demonstrations



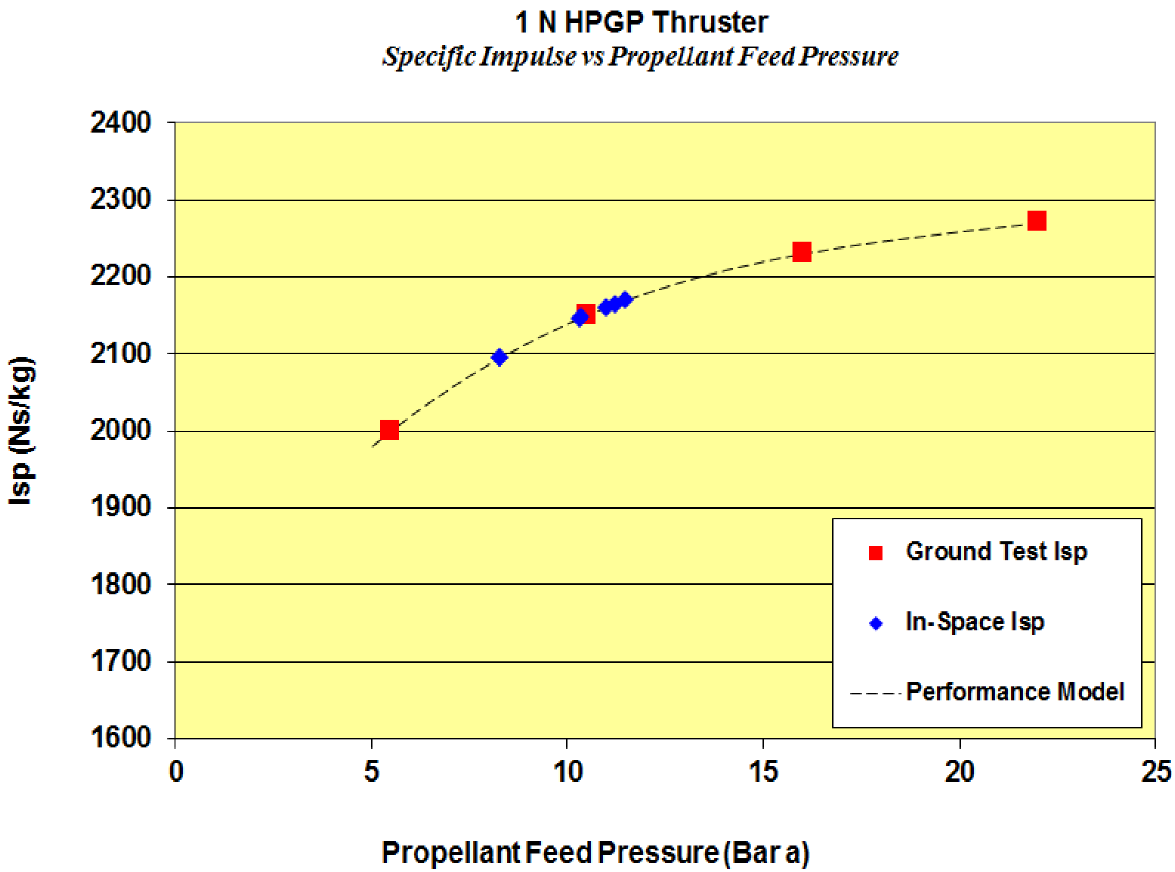
Operational Modes

- Quasi Steady-State (Continuous firing)
- Pulse Mode (Duty factors between 0.15% to 50 %)
- Off-Modulation (Duty factors between 50% to 99 %)
- Single Pulse (Single pulses or low duty factors)

Operational Box Restrictions

- Minimum I-Bit due to the Thruster Driver Electronics (RTU)
- Maximum Command Rate (1Hz)
- Momentum Management due to Reaction Wheels Saturation
- Formation Flying requirements (i.e. maximum orbit change w.r.t. Target)

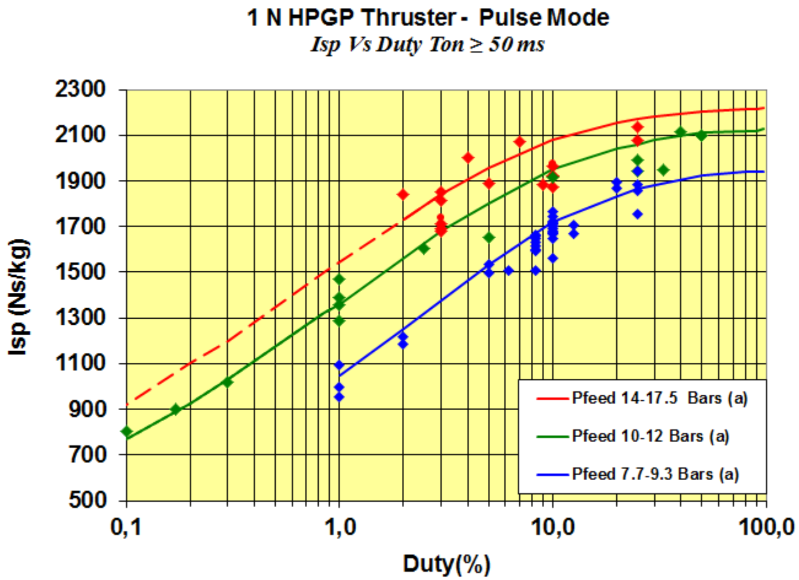
In-Space Performance Results

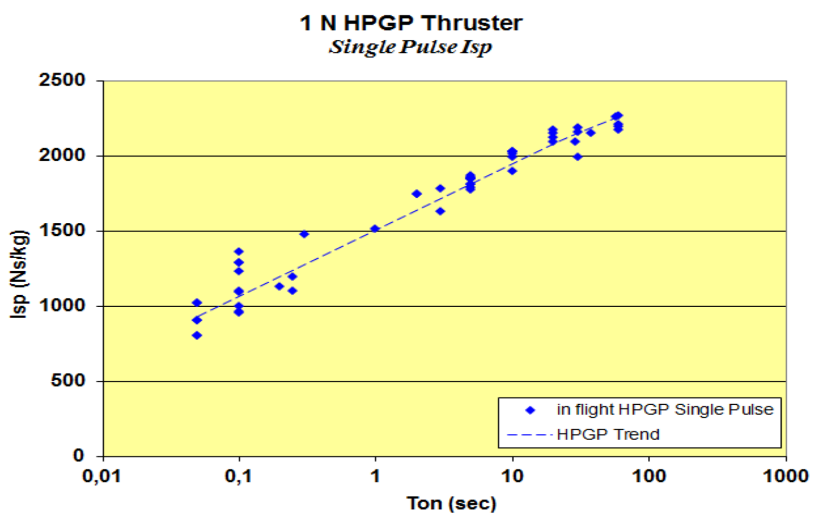


Continuous Near Steady-State Operations:

- ISP ~ 232s BOL – 204s EOL
- 6% -12% better Isp than hydrazine at equivalent thrust

In-Space Performance Results





Pulse Mode Operations:

- Isp depends on duty factor and pressure
- ~12% better Isp performance than hydrazine at equivalent thrust
- Comparable Isp performance to hydrazine at low duty low feed pressure

Single Pulse Mode Operations:

- ISP ~ 231s BOL - 92s EOL
- 10% -20% better Isp than hydrazine at equivalent thrust

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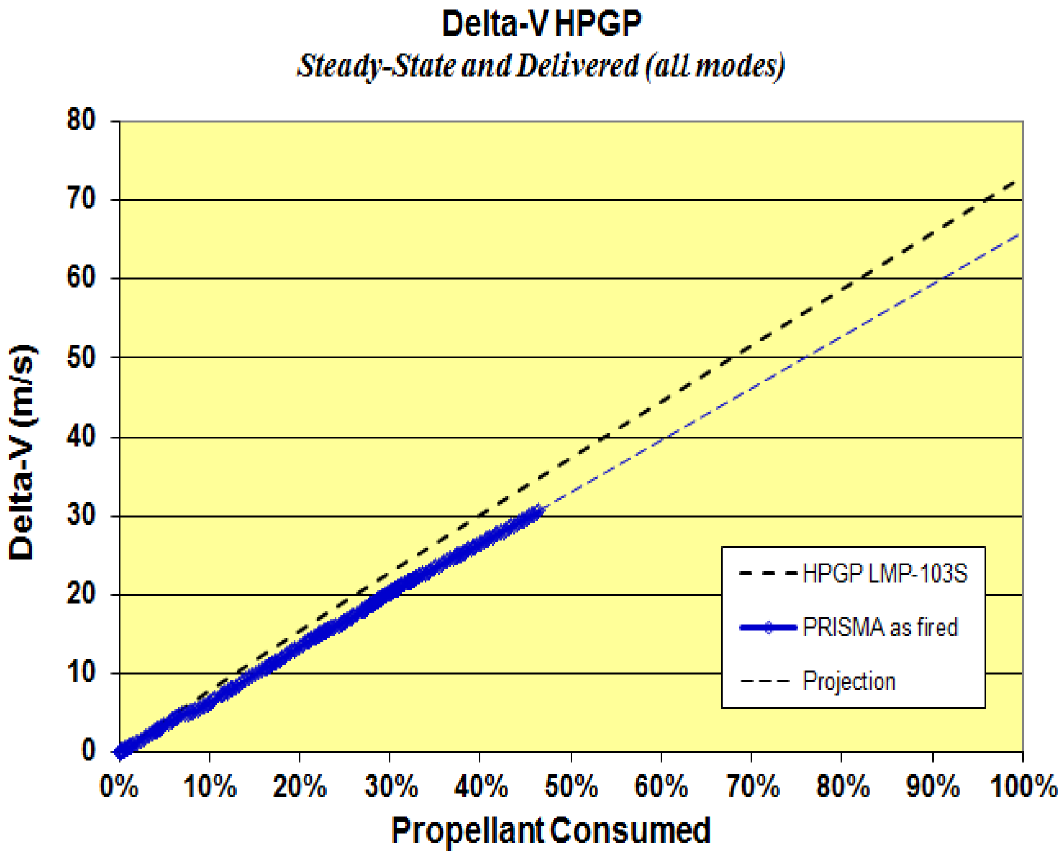
In-Space Performance Results



Accumulated Delta-V to date

- 50% of PRISMA mission
- ~30m/s provided

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HPGP Comparison with Hydrazine

Specific and Density Impulse Comparison	
Steady-State Firing: I_{sp} for last 10 s of 60 s firings	6-12 % Higher Isp than hydrazine 30-39 % Higher Density Impulse than hydrazine
Single Pulse Firing: T_{on}: 50 ms – 60 s.	10-20 % Higher Isp than hydrazine 36-49 % Higher Density Impulse than hydrazine
Pulse Mode Firing: T_{on}: 50 ms – 30 s. Duty Factor: 0.1 – 97%	0-12 % Higher Isp than hydrazine 24-39 % Higher Density Impulse than hydrazine

HPGP in Future Small Satellite Missions

HPGP has already been baselined for several near term missions:

- PRISMA-type systems
  - 5.5kg propellant required with 3 to 4 x 1N thrusters, or
  - 11 kg propellant with 8 x 1N thrusters

- Medium class satellites (up to 1,000kg)
  - 50kg propellant with 8 x 1N thrusters for orbit raising, orbit correction and plane changes

HPGP is also applicable for:

- CubeSat propulsion modules (including orbit raising & de-orbiting)

- ESPA-class satellite propulsion (non-interference with primary payload)

HPGP in Future Small Satellite Missions

For Small Satellite Missions:

HPGP provides up to 32% more efficient propellant than hydrazine, which allows:

- Increased ΔV available (more margin for the mission), or
- Smaller propellant tank (while retaining same ΔV)

HPGP significantly simplifies pre-launch activities

- Simplified transportation
- Propellant handling classified as ”Non-Hazardous Operation”
- Smaller ground support team required
- Reduced man hours for fueling
- Reduced Ground Support Equipment, No SCAPE operations
- Increased ”responsiveness”

HPGP launch campaign 3 x less expensive than Hydrazine launch campaign

Questions?

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