

Consortium for Hall Effect Orbital Propulsion System

EPIC WORKSHOP

Naples - May, 10th 2023

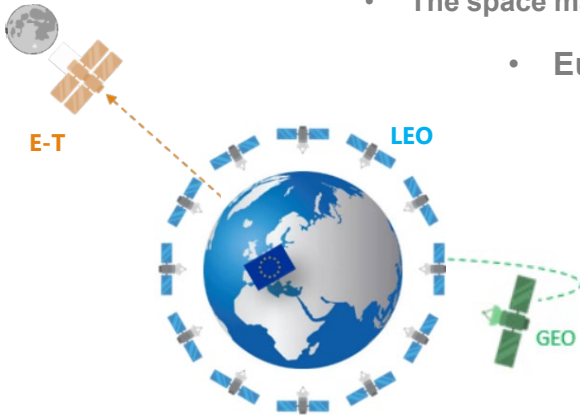


CHEOPS projects have received funding from the European Union's Horizon 2020 and Horizon Europe research and innovation programme under grant agreement No 730135 - 101004226 - 101004331 - 101082532

Project Coordinator : Vanessa Vial



European Spirit



- The space market is booming
 - Europe aims at ensuring its role of major player on all markets
 - On going development programs contribute to European leadership
 - Non-dependence is crucial to secure this ambition

Europe offer all **R&D skills** and **industrial know-how** to develop **pillar technologies** of future space applications

Through the **CHEOPS Projects**, **Safran and its partners** aim at **maturing Electric Propulsion Systems** based on **Hall thruster technology** to offer **competitive and reliable European solutions** for the future space market

European strategy for maturation of promising Hall technologies consistent with the three market segment needs to ensure European leadership and sovereignty

CHEOPS Consortia

4 Projects



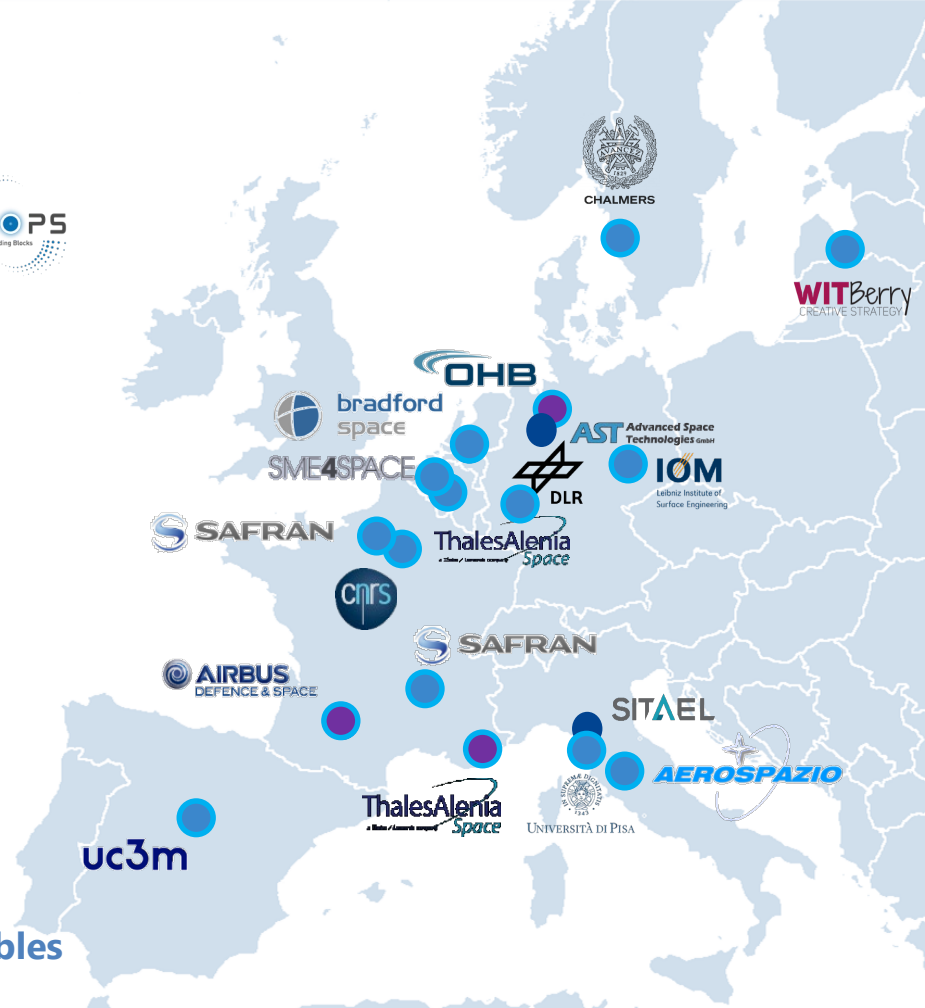
~21 M€ fundings

1 EC expert and 5 PSA members

16 Partners in 8 Countries

- 6 Industrials
 - ➔ System & Thruster/PPU/FMS
 - ➔ Advisory Board for consistency with market needs
- 4 SMEs
 - ➔ Testing activities, Dissemination, Communication
- 6 Universities / Research centers
 - ➔ Numerical tools, plasma physics, Value analysis

EPIC WS23: 7 presentations / 1 poster / 2 round tables



Market Drivers



Governments are entering on the market with dedicated constellations programs

On Orbit Services is a key development driver with dozen of projects with multiple applications (Tug – Services)

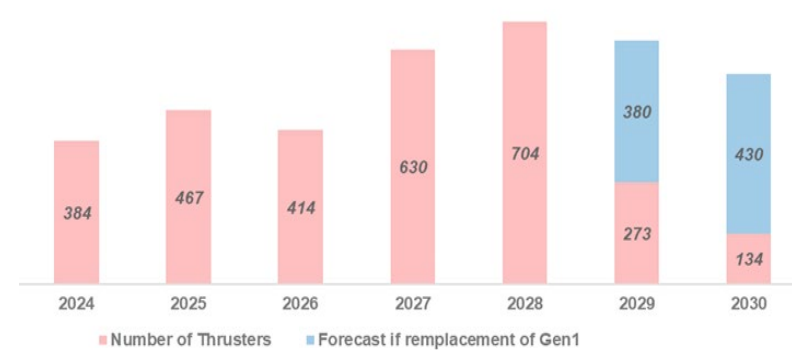
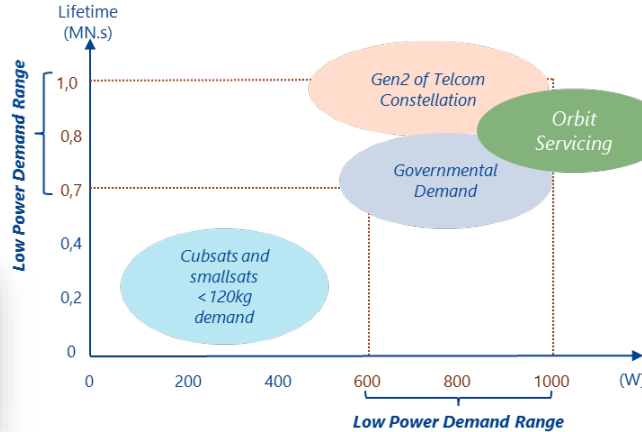
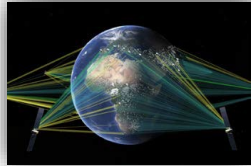
New Players are competing with established companies

*17,000 satellites to be built and launched over the coming years
(7,000 satellites for broadband sitcom)*

Gen 2 of constellations has bigger weight

European electric propulsion systems shall have a key strategic position in all market segments

Low Power Market Needs



- The **actual market** has a 2 power range class with <400W and 650W / 1kW
- **2 different approaches** with cubesats demand and « heavy » platform demand > 400kg
- With the a low mass and size + and aggressive price, the CHEOPS Low Power System can be an **alternative on the 1.2 – 3 kW market by proposing a cluster** of such propulsive system

CHEOPS Low Power System is the good answer regarding the market need and the continuous development of constellations projects

Medium Power market context

The Established approach...

Commercial demand model in number of satellites by orbit								
Contract Notification	2028	2029	2030	2031	2032	2032	2034	2034+
GEO/MEO	15	16	15	16	16	15	15	16
Medium P.	16	32	40	50	50	50	50	50

- ✓ GEO satellites Market will stay stable but will turn 100% electric and more efficiency will be asked from the prime (less redundancy)
- ✓ MEO/MicroGeo will emerge with a need of 3kW class System

&

The Raise of the On orbit Services...

Commercial demand model in number of satellites by orbit								
Contract Notification	2028	2029	2030	2031	2032	2032	2034	2034+
Medium P.	56	136	216	216	216	216	216	216

Acceleration of the need to have a space industry 100% made in Europe

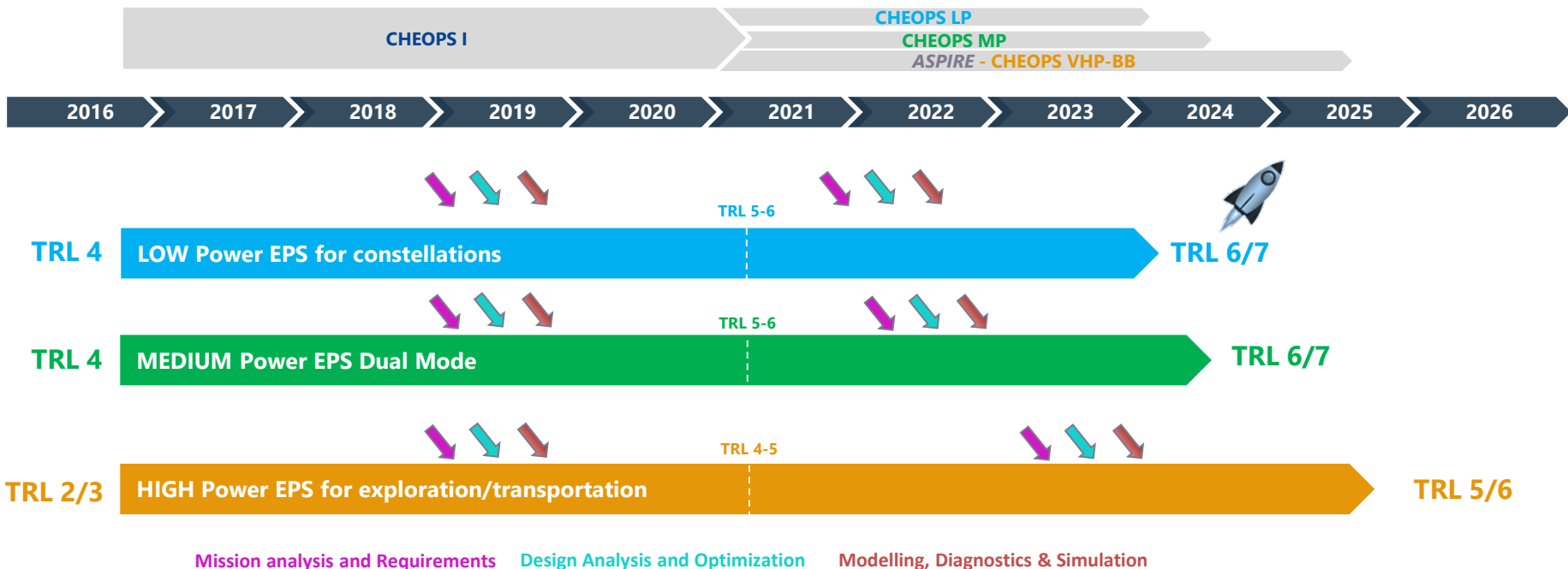
A significant share of the 5kW-class EPS market has been lost by Russia

New competitors with alternative solution will emerge...

... but the CHEOPS MP EPS is a tailored and reliable product for this segment

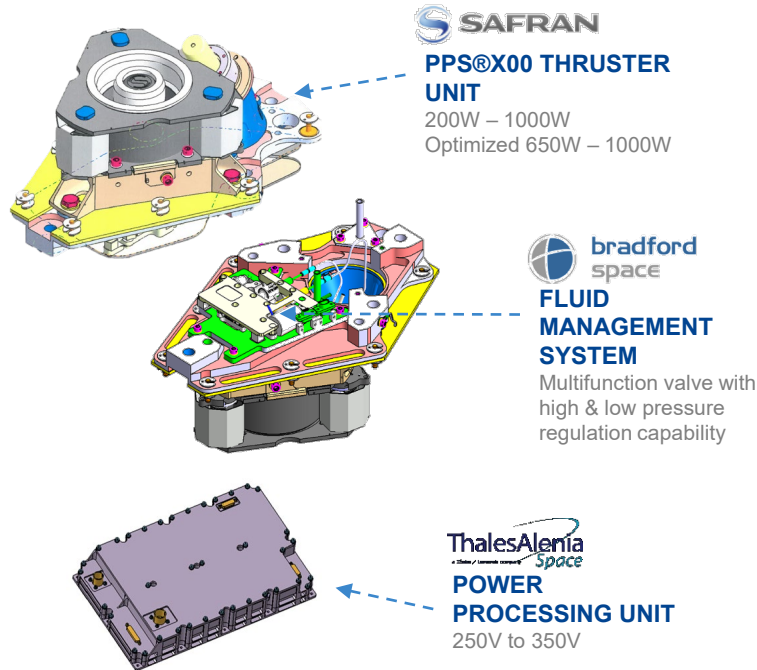
***On Orbit Services will be the Key driver for the Medium Power initiative...
... but need of the Western countries to find a Western supplier***

CHEOPS Timeline





CHEOPS Low Power EPS Overview



Subkilowatt class propulsive system

Development driven by **Small and large constellations** market needs

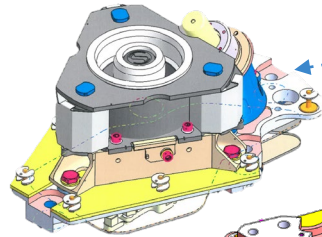
⇒ More competitiveness, larger production capabilities, versatility, compacity, ready-to-use, short time-to-market
⇒ Technical, economic, industrial challenges

Optimized design, functions, operating range
New technologies

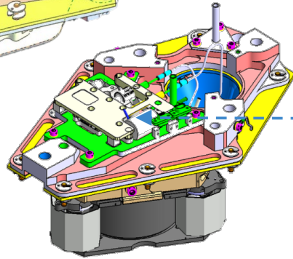
Specification, design and development logic recently adapted to the current situation (power budget & krypton)

Multiple characterization and validation tests

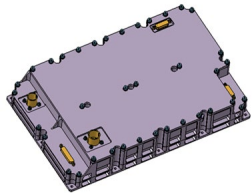
CHEOPS Low Power EPS KPI



SAFRAN
PPS@X00 THRUSTER UNIT
200W – 1000W
Optimized 650W – 1000W



bradford space
FLUID MANAGEMENT SYSTEM
Multifunction valve with high & low pressure regulation capability



ThalesAlenia Space
POWER PROCESSING UNIT
250V to 350V

0,7 (1) MN.s

1 kW-class European HT using Kr (Xe)

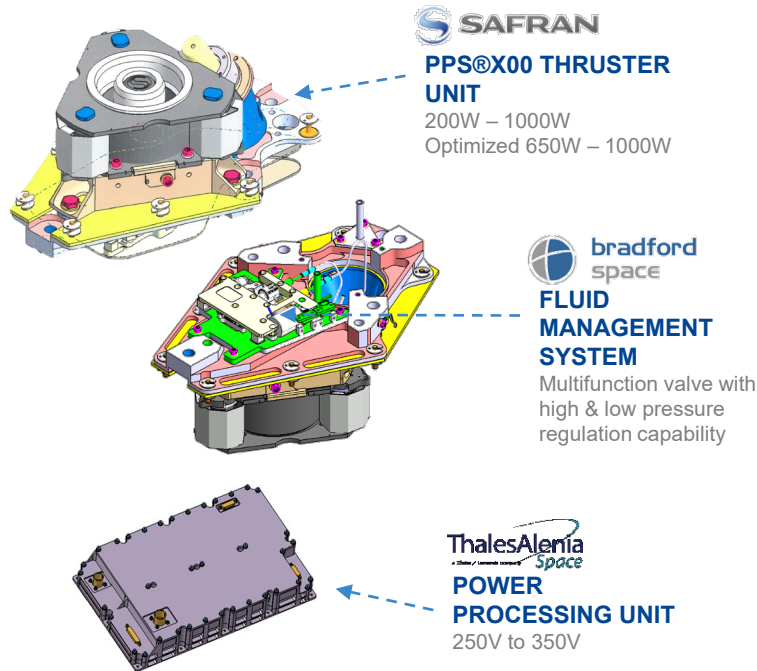
2024

Flight worthiness for IOD/V
2025: 1st deliveries for commercial applications

Kr-Xe

Xenon and Krypton compatible

CHEOPS Low Power EPS development status and next steps

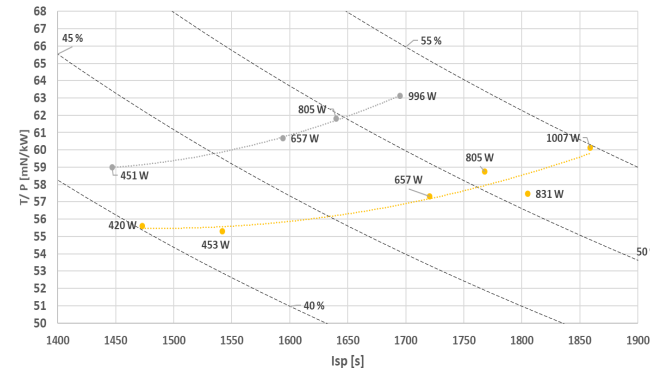
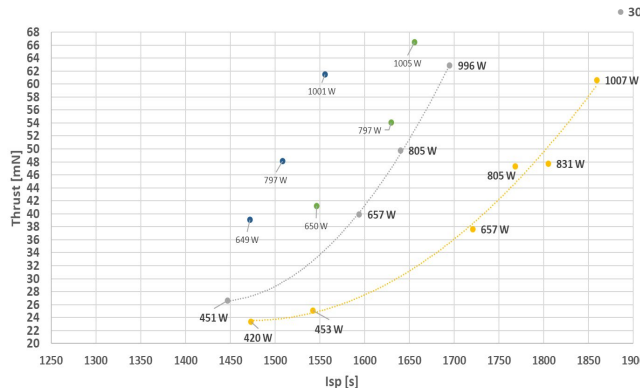
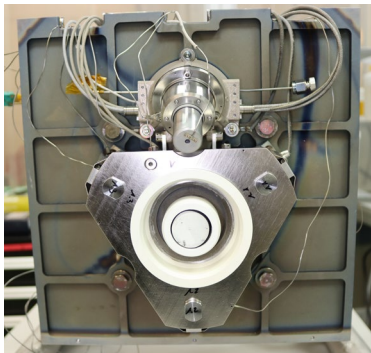


March-April 2023: TU-FMS coupling test successful

Q2 2023: EPS components functional design review
 + recommendations for TU-FMS-PPU coupling test planned
 October 2023

2024 Qualification Status Review = 1st step for qualification phase, ie maturity assessment for IOD/IOV based on « Flight worthiness » justification file and lessons learned

CHEOPS Low Power Thruster Unit achievements (Xe)



[650; 1000] [W] / [300; 350] [V]
 Thrust = [36; 60] [mN]
 Isp = [1575; 1850] [s]

Lifetime Specification

1 [MNs]
 62 [MC]
 7 000 cycles

incl. 1,5 qualification coefficient

Lifetime Demo Anode Subassy.

~512 kNs / 1660 hrs
 → 77% of OP need

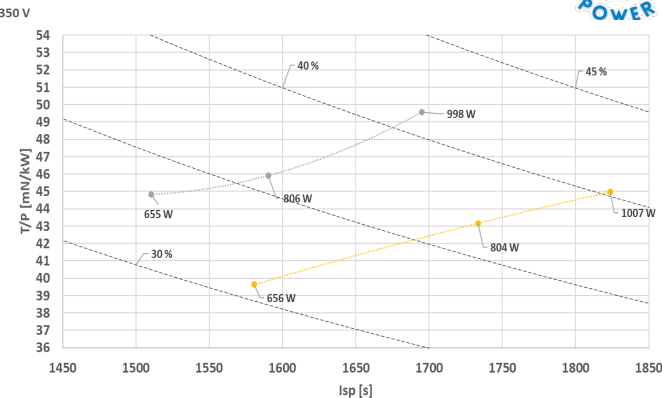
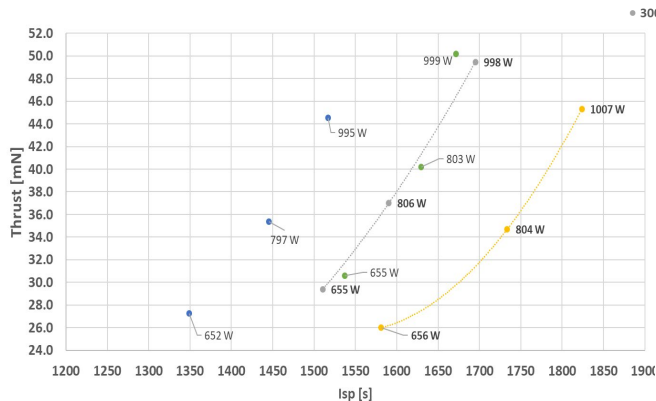
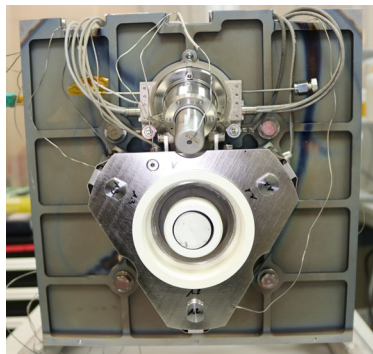
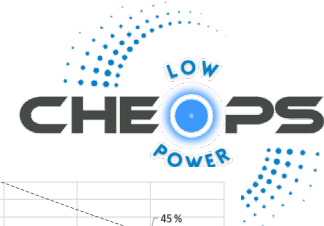
Lifetime Demo Cathode Subassy.

28.4 MC & 2500 hrs
 → 69% of OP need
 7000 cycles
 → 100% of OP need



PPS®X00 performance beyond SoA

CHEOPS Low Power Thruster Unit achievements (Kr)



[650; 1000] [W] / [300; 350] [V]
 Thrust = [26; 49] [mN]
 Isp = [1500; 1825] [s]

Lifetime Specification	Lifetime Demo Anode Subassy.	Lifetime Demo Cathode Subassy.
0.70 [MNs] 56 [MC] 7000 cycles <i>incl. 1,5 qualification coefficient</i>	100 kNs / 555 hrs → 21% of OP need 100% of OP <u>end 2023</u>	11.4 MC & 1000 hrs → 30% of OP need 100% of OP <u>end 2023</u>

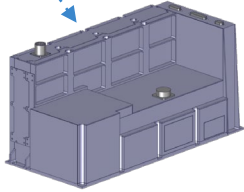


Next steps:
 1/ 3500hrs-3500cycles campaign to start (mechanical tests successfully achieved)
 2/ 5000 hrs-7000cycles on QM targeted in 2024

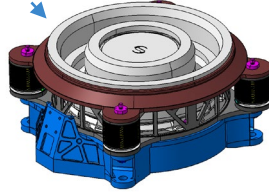
CHEOPS Medium Power EPS Overview



**ThalesAlenia
Space**
**POWER
PROCESSING UNIT**
300V to 450V

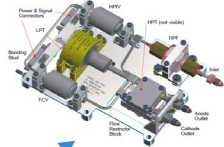


SAFRAN
PPS®5000-X TU
3kW – 7kW
Optimized 4kW – 5kW



**FLUID MANAGEMENT
SYSTEM**

Multifunction valve with high & low pressure regulation capability



Rapid access to space and ROI

Compact

Versatile products for a large market

Architectures studies and trade-off are based on “Value Creation Strategy” activities

System reliability

GTO/GEO Transfer duration

System Mass & Complexity: integration constraints, development

need and time to market

System Cost estimation

Propellant need and cost

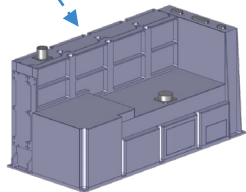
Xe-Kr compatibility

More efficient – More reliable – More flexible – Higher lifetime capabilities

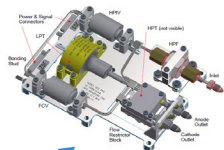
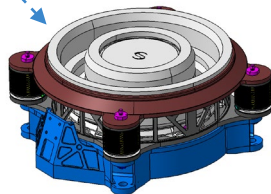
CHEOPS Medium Power EPS KPI (2030 target) - Xe



**ThalesAlenia
Space**
**POWER
PROCESSING UNIT**
300V to >600V



SAFRAN
PPS@5000-X TU
3kW – 7kW
Optimized 4kW – 5kW



**bradford
space**

**FLUID MANAGEMENT
SYSTEM**

Multifunction valve with high & low pressure regulation capability

**HIGH THRUST
MODE (EOR)**

Up to **7 kW**
< 8 kW at System level

~0.51 N (Xe)
P/T target:
14 W/mN (TU)
16 W/mN (System)

≥ 1,700 s (Xe)
low voltage

**HIGH ISP
MODE (SK)**

3 kW to 7 kW
< 3.6 kW / < 8 kW at System level

0.13 to 0,31 N (Xe)
P/T target:
19 W/mN (TU)
23 W/mN (System)

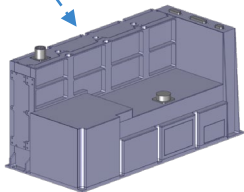
~2,700 s (Xe)
high voltage

Up to **30 MN.s**
Total Impulse design target

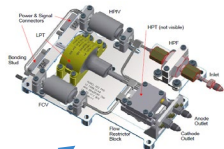
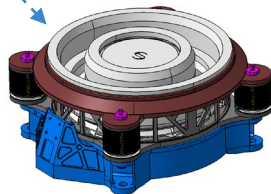
CHEOPS Medium Power EPS KPI (2030 target) - Kr



ThalesAlenia Space
POWER PROCESSING UNIT
 300V to >600V



SAFRAN
PPS@5000-X TU
 3kW – 7kW
 Optimized 4kW – 5kW



FLUID MANAGEMENT SYSTEM

Multifunction valve with higher & low pressure regulation capability

HIGH THRUST MODE (EOR)

Up to **7 kW**
 < 8 kW at System level

~**0.41 N (Kr)**
 P/T target:
 14 W/mN (TU)
 16 W/mN (System)

≥ **1,720s (Kr)**
 low voltage

HIGH ISP MODE (SK)

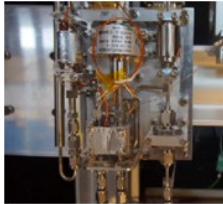
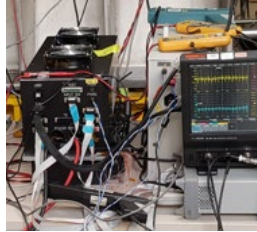
3 kW to 7 kW
 < 3.6 kW / < 8 kW at System level

0.1 to 0,25 N (Kr)
 P/T target:
 19 W/mN (TU)
 23 W/mN (System)

Up to **3,000s (Kr)**
 high voltage

More than **20 MN.s**
 Total Impulse design target

CHEOPS Medium Power EPS – achievements and next steps



Coupling tests carried out enabled to validate

- ◆ Pressure loop model
- ◆ Discharge current loop with optimized pressure loop
- ◆ Ignitor circuit with correct start-up of cathode
- ◆ Oscillations behavior (**No parasitic**) in the discharge electric line including the PPU, FMS and thruster unit, when operated under nominal conditions
- ◆ Behaviour of the system as a whole, at the different tested operating points

March 2023: PDR close out successful

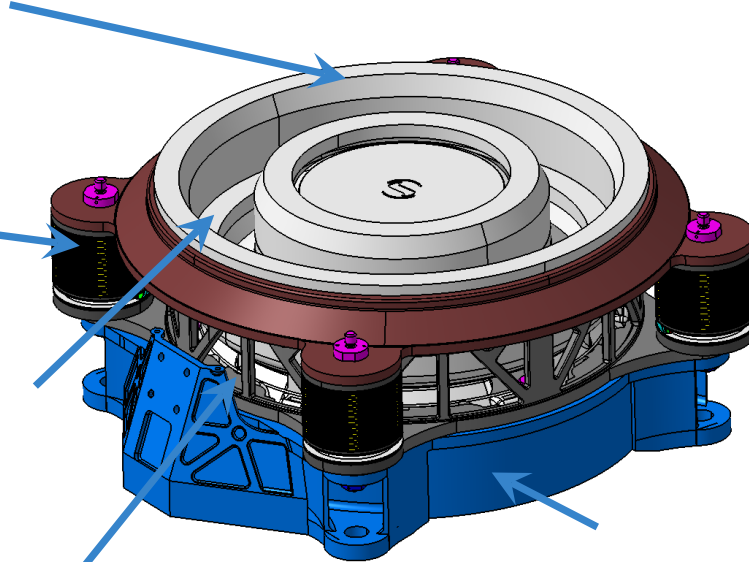
Q2 2024 : Coupling test



CHEOPS Medium Power Thruster Unit « Flight » design



COTS ceramics



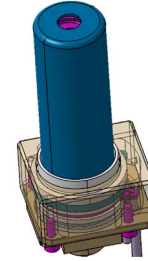
HT/HD coils

Ceramic AM

Magnetic AM

Titanium AM

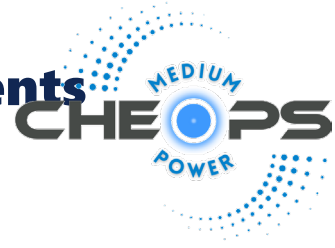
Simplified architecture



COTS emitter
Simplified architecture

- **Low cost architecture**
 - Parts & Processes rationalization
 - Innovative technologies
- **Functional design adapted to future needs**
 - Low erosion
 - High Thrust / High Isp
 - Stability over the operating range

CHEOPS Medium Power Thruster Unit technical achievements



EM Model Test Results

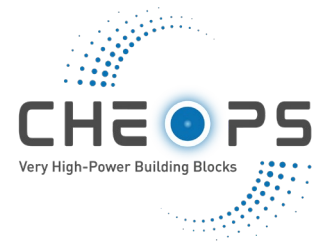
- Between 2,5 kW and 7 kW
- Between 300 and 700 V @3kW.

Performance

- Dual Mode Operating points achieved
- Very stable behavior on all the tested domain
- Very promising results for the next Development Model

Next step: 1000hrs test S1 2024





CHEOPS VHP BB – Key issues

- **Objective: Maturing Building Blocks for 20kW- class thrusters for long-term applications**
- **Major challenges**
 - Manufacturability of large scale parts
 - Long firing time for qualification
 - Cost / Schedule !!
 - Qualification sequence
 - Spacecraft platform configuration & Mission profile ??
 - Power / Voltage range ??
 - Propellant

→ **Extremely long tests would be required but would not be envisageable / reasonable**

Novel approach combining physics-based models with demonstration tests is necessary

CHEOPS VHP BB – Project Overview



- Objective is to complement ongoing thruster-focused development activities with research and development on the future actual use of VHP Hall thruster systems by:

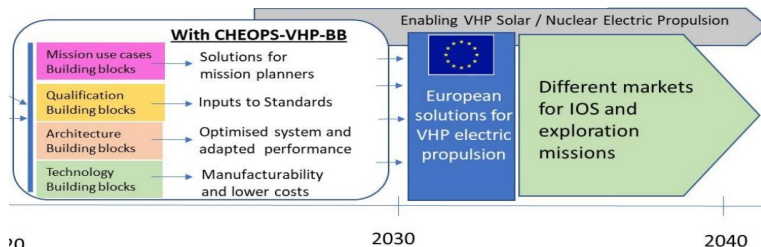
- Defining overall system architecture against various mission use cases
- Proposing robust and cost-effective approach to qualification
- Assessing manufacturability of key components subject to wear, typically the discharge chamber and cathode
- Envisaging alternative propellants and power sources

- Catalogue of missions
- 20kW-based EPS specification

- Qualification methodology foundations (for future ECSS standard)
- Failure mechanism models

- AM techniques for large parts
- 50-100A cathode up to TRL6

- Design rules
- Operation feasibility demonstration up to TRL5



PPS® 20K



Tandem

Perspectives

- **Identification of critical technologies / parts / processes**
 - Development of innovative technologies
 - Industrial tool and Supply chain to be consolidated to meet high production rates
 - Materials under stress: Coating, LaB6, Dilver, Copper, Titanium, Electronic components, Valves
 - Tanks (e.g for applications requiring high quantities of Ar)
- **Europe In Orbit Demonstration programme is the best way to cope with New Space market searching for quick performance demonstration**
 - LP EPS ready for IOD in 2024
 - MP EPS ready for IOD targeted < 2030
- **Progress in modelling / facilities capabilities / diagnostics**
 - European know-how is unique, rare and valuable
 - Essential activities in development projects
 - Need to develop novel approaches and innovative methodologies for future developments

CHEOPS Social networks



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 LinkedIn (/cheops-vhp-bb) and Twitter @cheopsvhpbb

+ Roll ups and goodies !!

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