EPIC WORKSHOP

STATUS – HEMPT-NG2

Dr. Stefan Weis / Peter Holtmann, TD

Ulm, 2023-05-10

The project HEMPT-NG2 receive funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101004140
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European Commission | Horizon 2020 European Union funding for Research & Innovation

Objectives – continued from HEMPT-NG

LEO EPS (700W)

- Improvement and extension of performance of the EPS and its constituents (mostly completed)
- Reduction of complexity on component and system level including testing and documentation to improve competitiveness (continue)
- Implementation of new features and technologies (mostly completed)
- Improving technology maturity (TRL6-7) (main task)

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Main Committed Task

- Maturation and finalization of the design and CDR
- Setup / Provision of (Engineering) Qualification Models
- Qualification on unit level for relevant environment
- Endurance Testing on Thruster Module Level to demonstrate Lifetime, supported by Lifetime analysis.
- System Level Tests such as Functional and EMC testing

→All of this corresponds to reach TRL7

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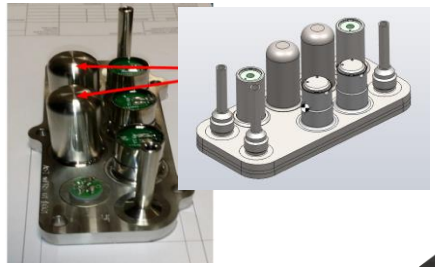
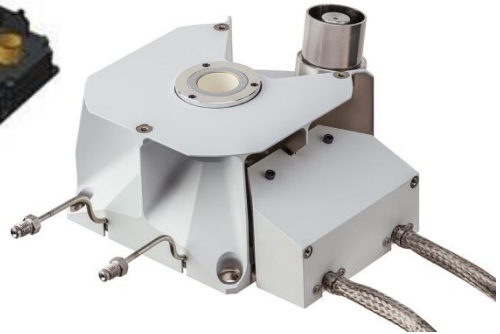
Advantages of HEMPT-NG2 LEO System

- Modular and Flexible System Elements
- Supports multiple working points.
  (high and low ISP)
- Supports Xenon and Krypton
- Minimizes Interfaces (e.g. Thruster module directly plugs to the PPU.)
- Low cost
- PPUs support several fluidic solutions to fit for small and large spacecraft.





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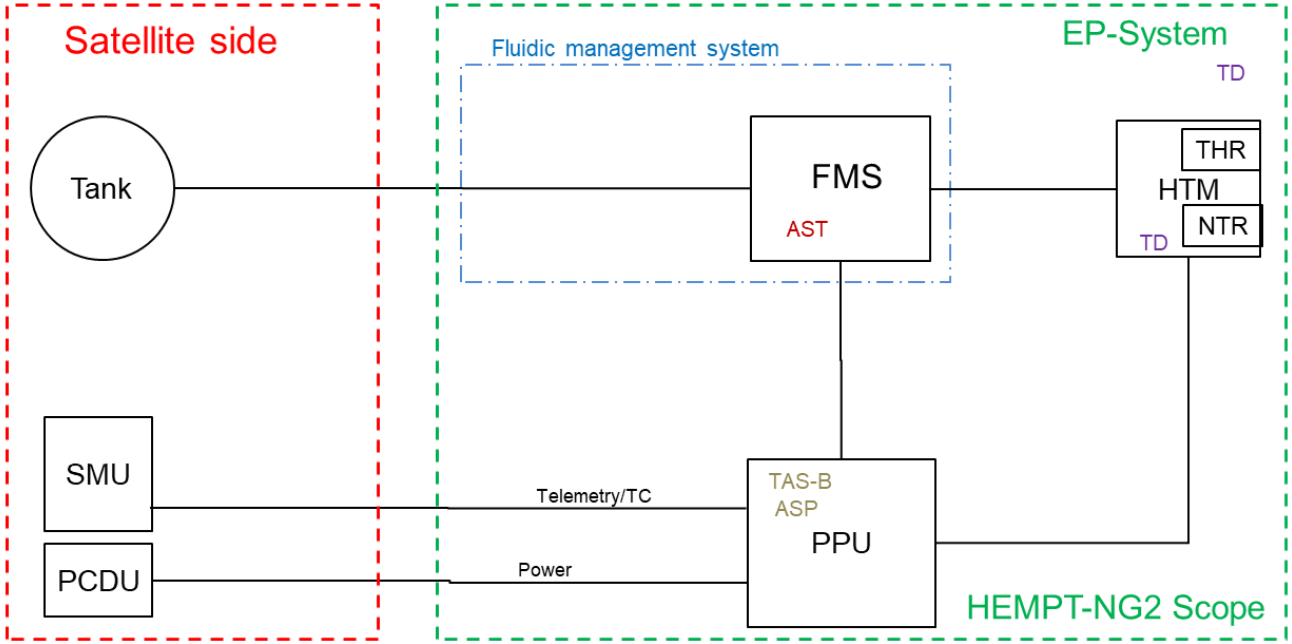
Context Diagram System (Hardware)



HTM	Thruster module
THR	Thruster
NTR	Neutralizer / Cathode
FMS	Fluidic Management System
PPU	Power Processing Unit
SMU	System Master Unit (Satellite Computer)
PCDU	Power Conditioning and Distribution Unit
EPS	Electric Propulsion System

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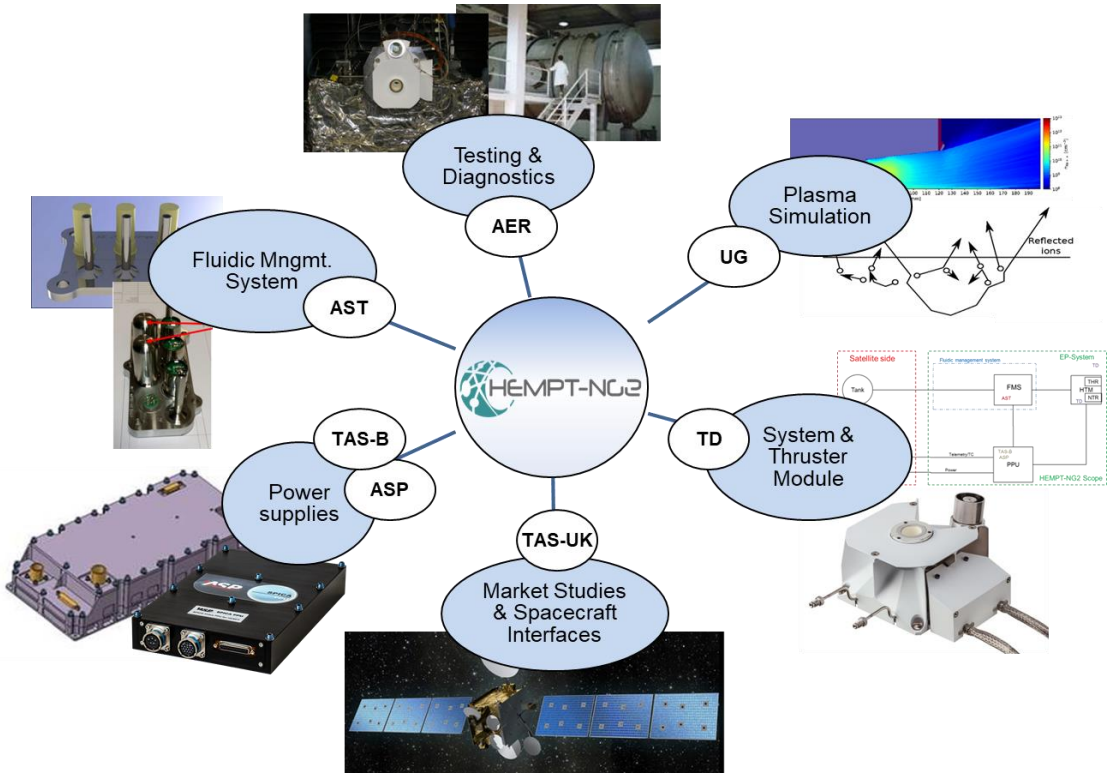
Consortium Overview



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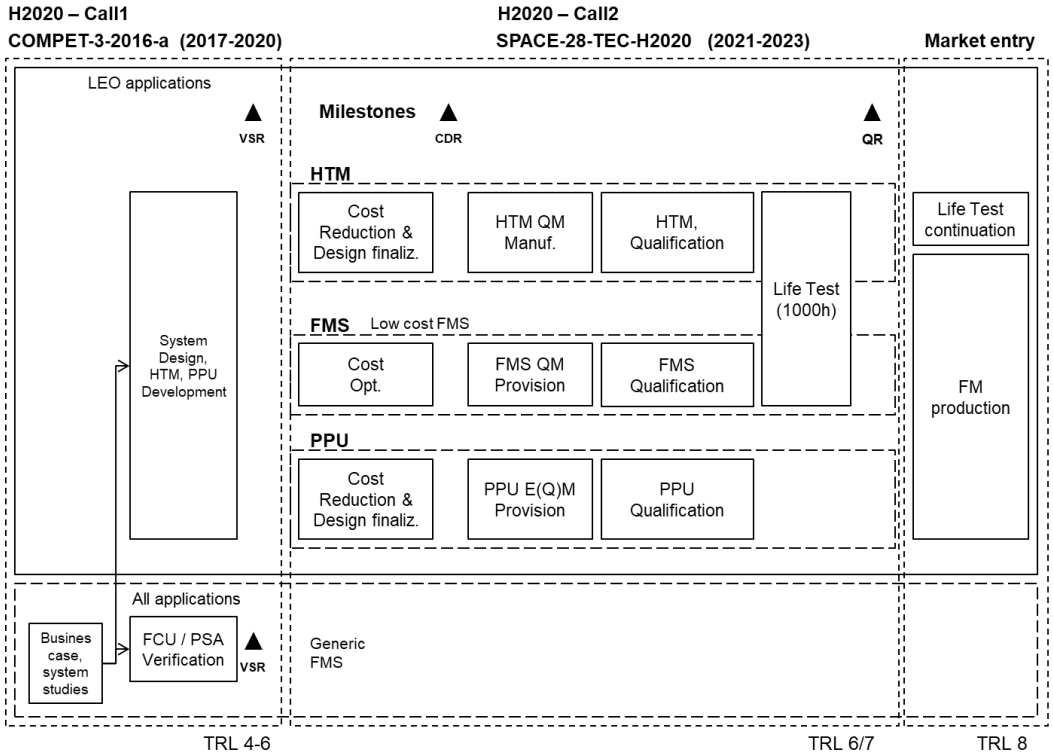
Development logic



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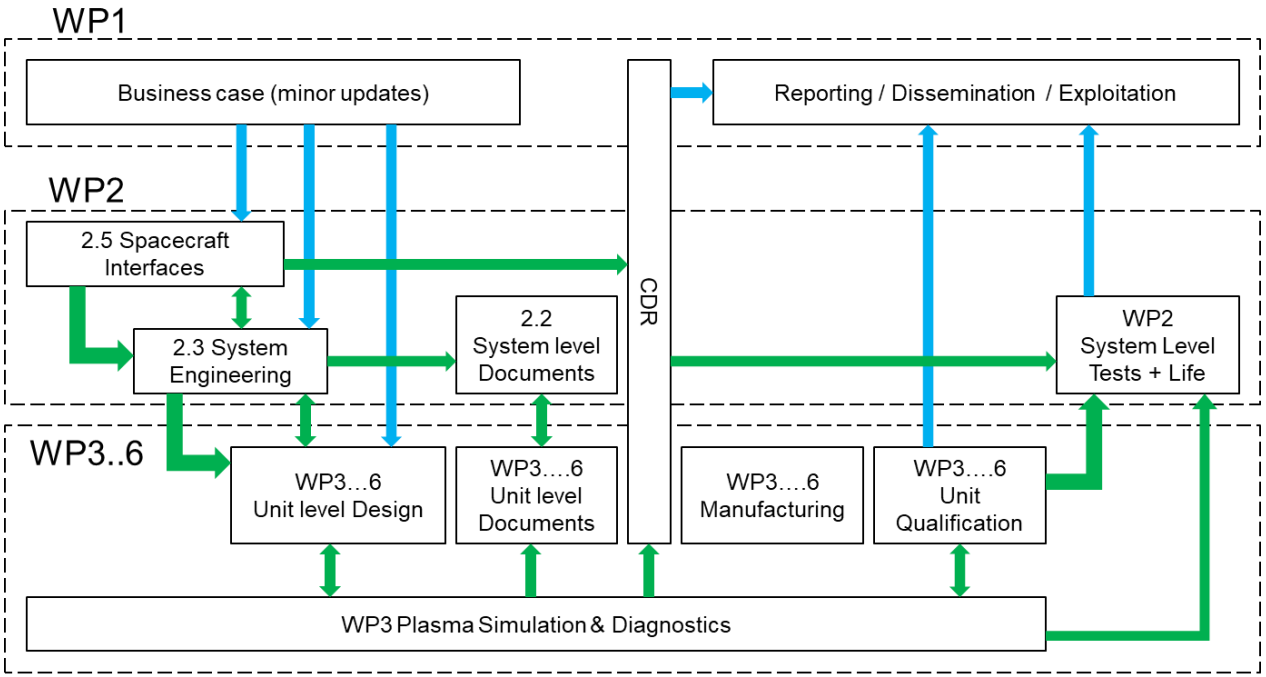
Project Logic



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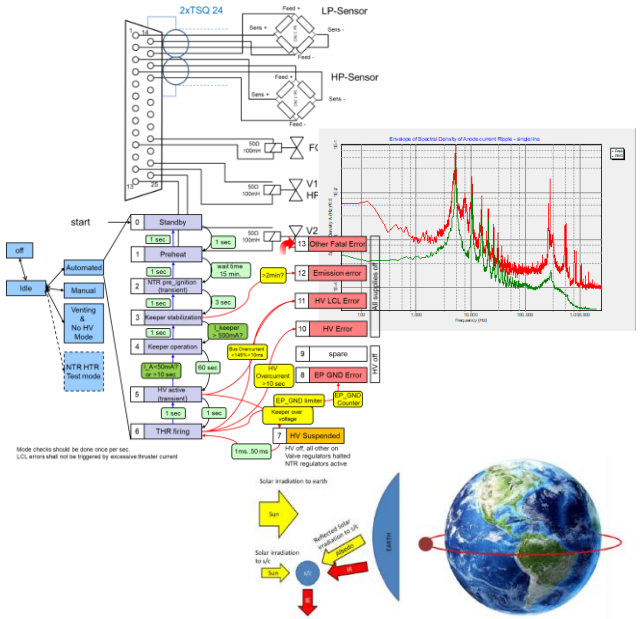
Status – WP2

- System Engineering
  - General Technical Coordination
  - Update unit Specifications to updated system design
  - Synchronize Interfaces of all units
  - Harmonization of specifications
- Spacecraft Interfaces
  - Generic orbital temperature analysis (TD)
  - Spacecraft interface definition (Interface requirement document)
- CDR Datapackage Completed



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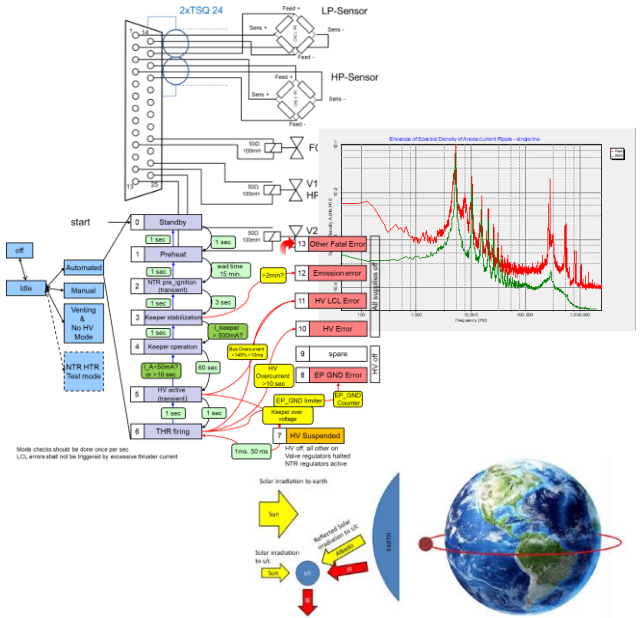
Status – WP2

- CDR Data package Creation
  - Design Analyses (incl. FMECA, thermal…)
  - Design Documents (ICD, user manual)
  - Packing instructions
  - Test Plans
  - DDP update
- Closure of CDR Review
- EMC and Coupling Test
  - EMC & CT Testplan (in review)



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WP3 – Design Activities / Test

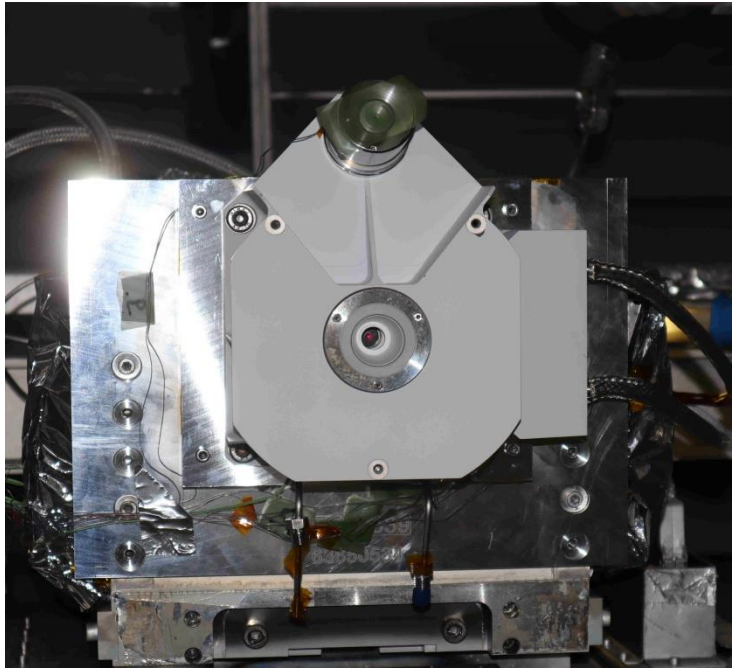
HTM Design / Engineering

- Definition of workplans
- Finalization of design
- Cost optimization mainly NTR
- HTM storage and handling tools designed

Test / Qualification:

HTM EQM was manufactured and subjected to standard qualification testing sequence (Performance, Vibration, Shock, TV testing)

Design now in conformance to TV, vibration and shock environment.
Endurance Testing has reached 4500h with Kr
HTM thermal cycle pretest started



HTM-EV0 EM in this photo in ULAN vacuum chamber

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WP3 – Environmental Quallification

- One Qualification model was subjected to all relevant environment:
- mechanical
- thermal vacuum
- Performance test with Xenon

- Following Qualification model will be tested with Krypton

HTM-EV0_EQM3 Qualification with Xenon

Parameter / Unit	Performance Test	Mechanical Test	Thermal Vacuum Test	Thermal Cycles	Performance Test
	45min ambient pulse 29.03.2023		45min ambient pulse 26.04.2023		45min ambient pulse 05.05.2023
Thrust, mN	26,75		26,7		26,75
Anode current, A	1,165		1,165		1,165
Anode voltage, V	600		600		600
Anode power, W	700		700		700
HTM mass-flow rate, mg/s	1,505		1,51		1,515
HTM Isp, s	1815		1807		1800

HTM-EV0 EQM Performance during Qualification sequence

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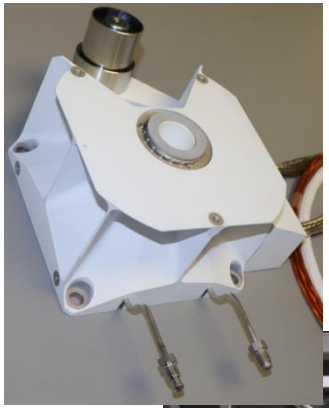
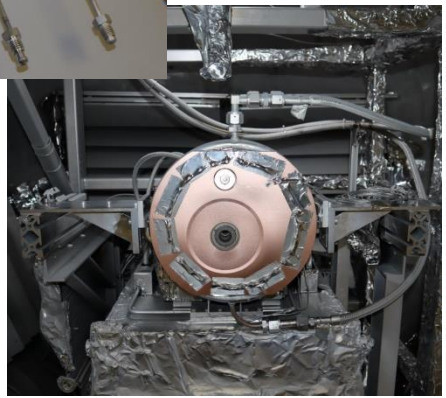
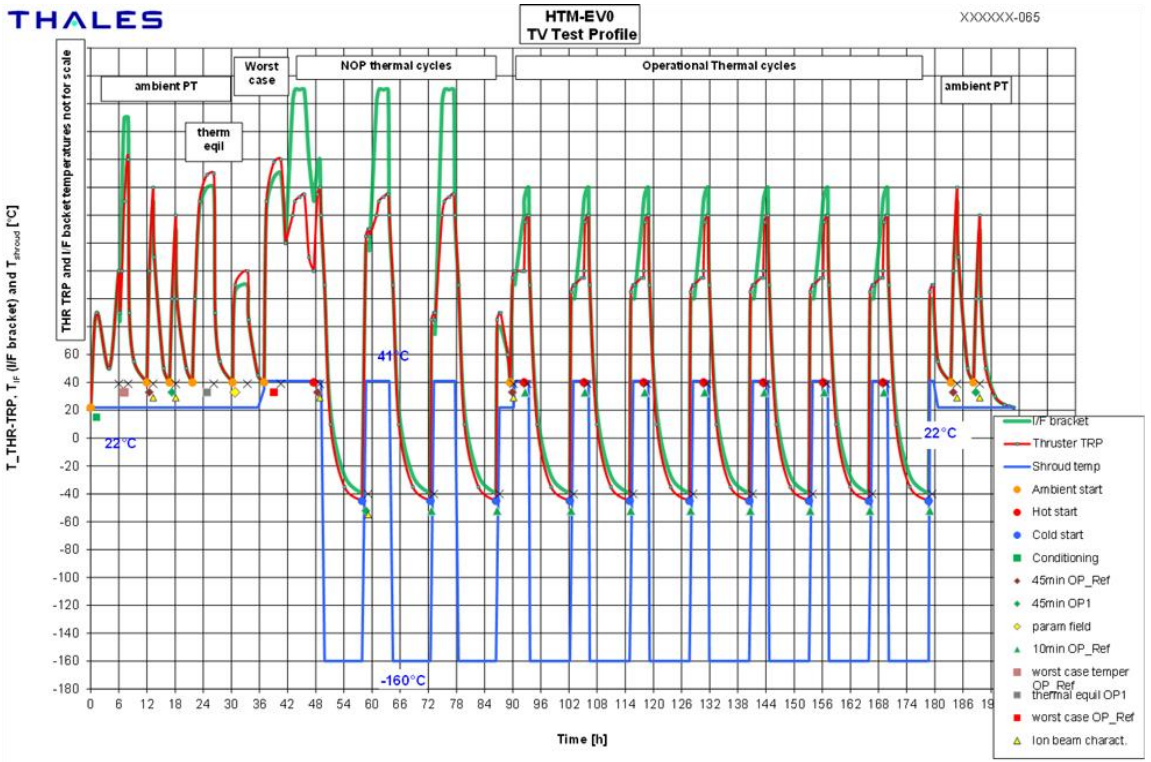
Setup TV Test







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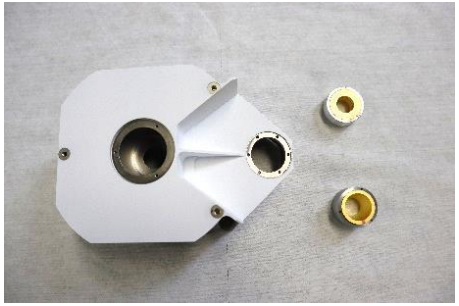
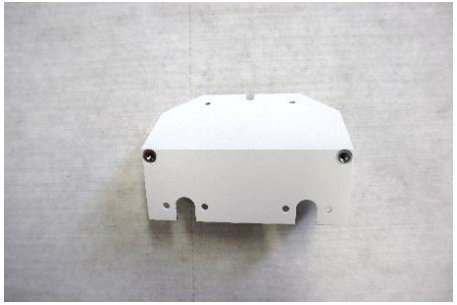
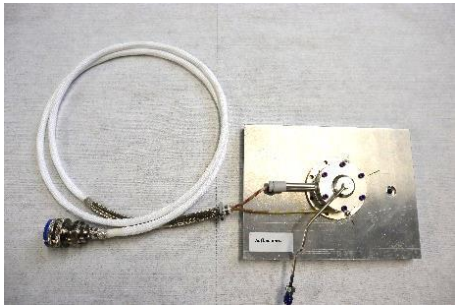
WP3 - HTM Design and Manufacturing

- HTM Manufacturing
  - 2 EQMs Completed,
  - First NTR for thermal cycling qualification manufactured
  - Formal QM open







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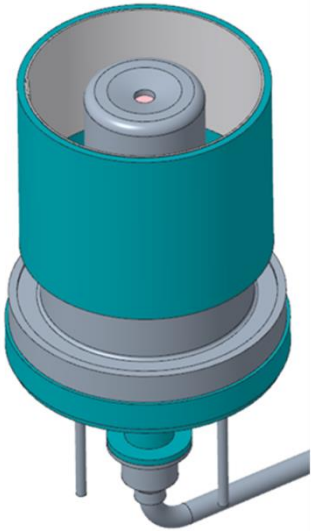
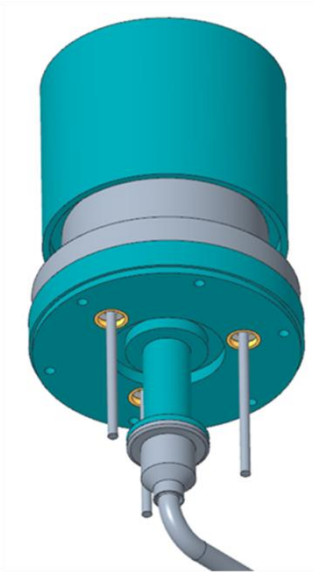
WP3 - NTR HCN6500

- HCN5000 neutraliser, which was qualified in the frame of the HEMP-TIS program as design base for HCN6500
  - Cathode is not changed
  - Cost reduced design
    - Reduction of brazed components
    - This allows faster assembly
    - Simplification of gas feed line assembly
  - Increased heater power w.r.t. HCN5000, technology unchanged
  - Introduction of hot getter to replace purifier of flow control unit





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WP3 - Status NTR

Manufacture NTR for thermal cycling qualification – completed, waiting for test:

- Will be exposed to mechanical environment, then subjected to up to 10k heating cycles

Long time cathode storage – in progress

NTR Endurance test – in progress

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Long time cathode storage – in Progress

Storage at ambient conditions

Cathode No.	Exposure time at ambient conditions (days)	Accumulated equivalent exposure time (days)	Status of test
1	31	15.7	finished
2	60	29	finished
3	1h in water with subsequent drying for 24h	-	finished
4	707	≈ 353	finished
5	432	232	finished
6	112	53	finished
7	-	488	Testing before storage is done
8	-	671	
9	-	884	
10	-	1128	

Current status

- All cathodes tested after storage operated without major findings
- No systematic relationship between cathode degradation and storage duration
- Emission current decreases with longer exposure time → cathodes deliver by far enough electrons for ignition

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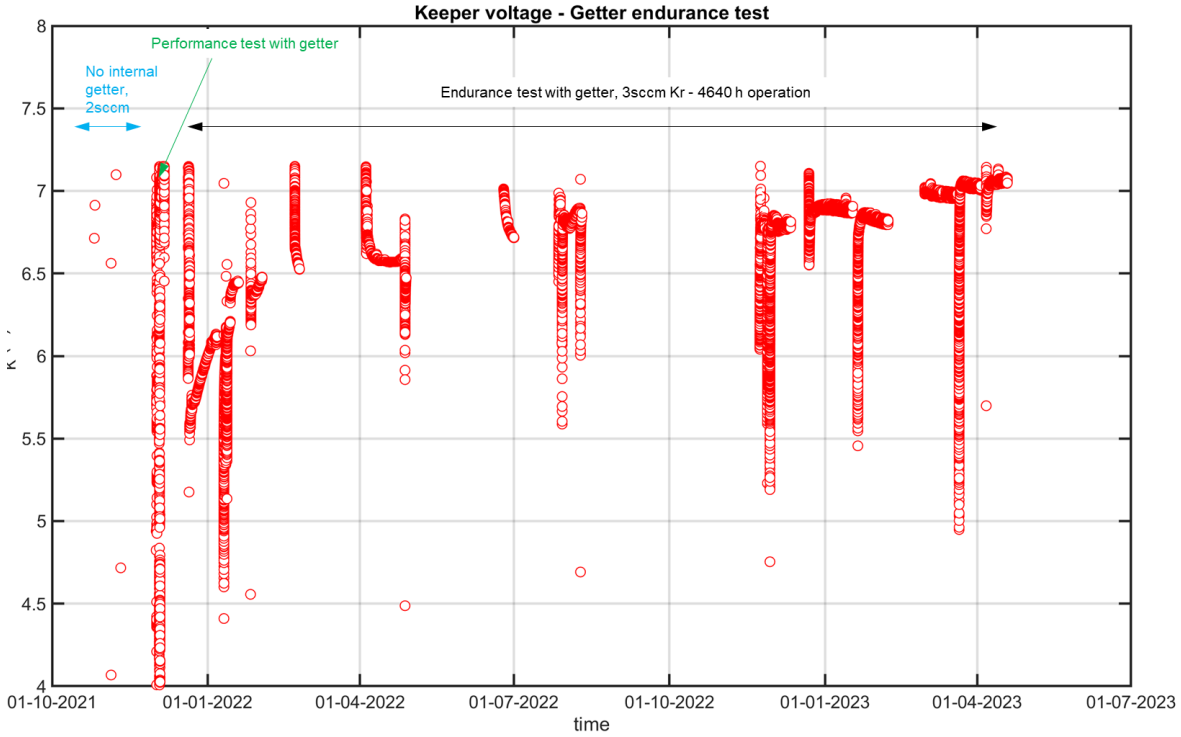
NTR Endurance Test with Kr - 4640h

- Representative operation
- Accumulating operational hours
- Keeper voltage remains low→healthy operation



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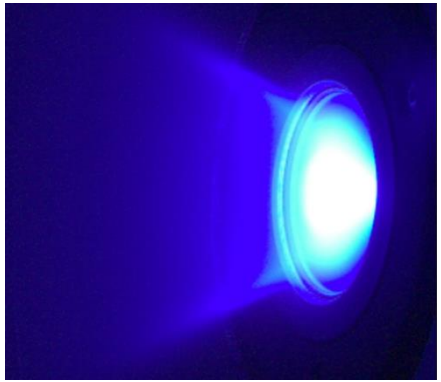
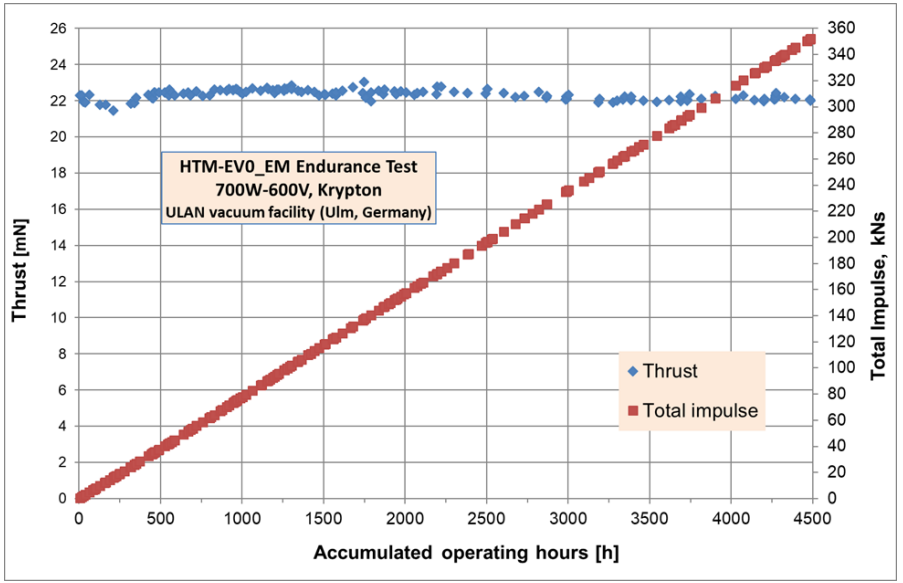
Endurance Testing status

- First Endurance Test on EM being conducted outside HEMPT-NG2, exceeding 4500h (Krypton)
- results are made available for this Project





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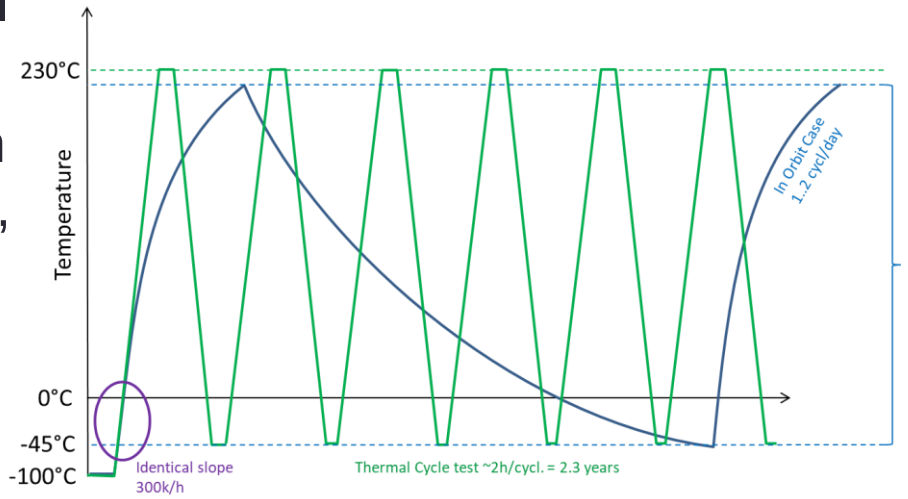
HTM cycling Test - Planning

- Lifetime loads can be separated in operational hours and thermal cycle loads.
- For thermal cycle demonstration the slope from cold start is used, the model is passively cycled. (non functional)
- 10k cycles will take over 900 days (2,4 h per cycle)



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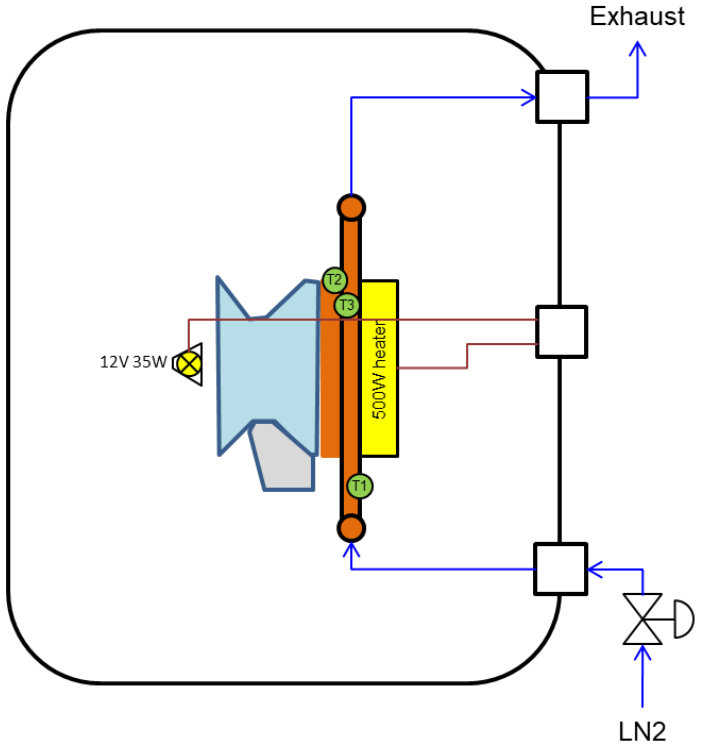
HTM cycling Test - Setup

- Thruster is mounted on thermally controlled plate in vacuum.
- 500W of heating power and liquid nitrogen cooling are used to create the needed slew rate.
- Difficulty is to adjust the cooling power sufficiently smooth (regulation is challenging)
- Monitoring of EUT health through bonding resistance measurement.



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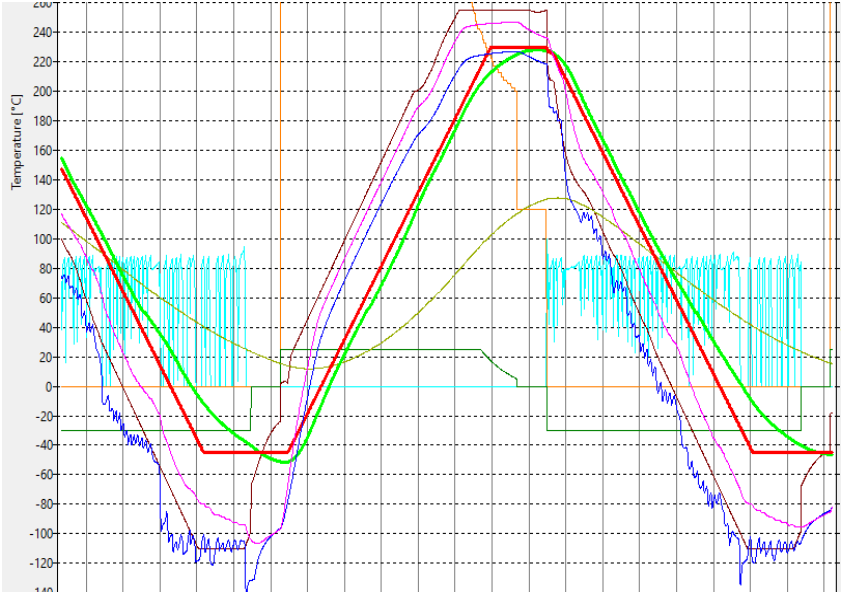
HTM cycling Test – Pretest results

- Pretests confirm test approach feasibility - More than 850 cycles accomplished up to now.
- The test profile is an enormous load on the setup. (exceeds typical *ycle tests by more than a factor of 100.)
- Difficulties in the Setup remain sufficiently small. (heater failure, sensor failure)
- Integrity of EUT so far consistent.
- Formal Qualification-Test will be conducted with dedicated EQM



Achieved Temperature Profile

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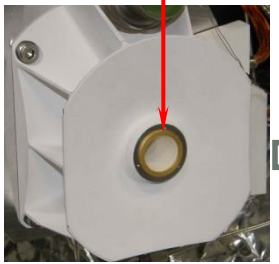
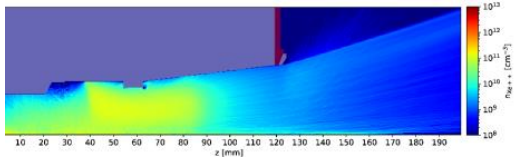
Discharge channel erosion?

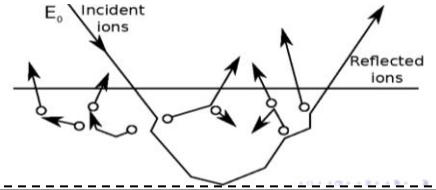


Numerical modeling

Kinetic model of plasma in the channel

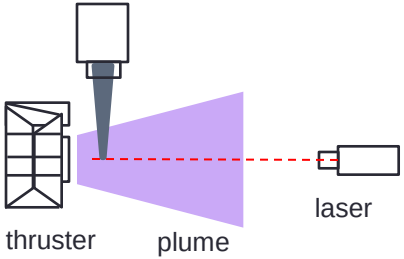


ion-surface interaction



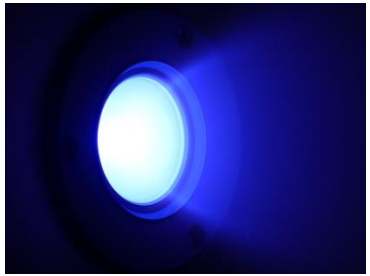
Numerical and experimental studies

detector

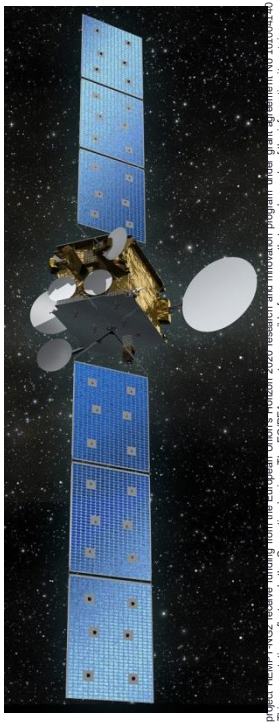


Measurements with advanced diagnostics: LIF, RFA

Validation of erosion modeling in test



Prediction of lifetime in space



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WP3 - Plasma Diagnostics and Simulation

- HTM Plasma Diagnostics and Simulation
  - Thales: Thruster for testing in Aerospazio was provided
  - Aerospazio: Plasma Diagnostics setup in progress
  - Univ. Greifswald: Concurrent Simulation Activities

  - Together, the fidelity of Lifetime prediction will be improved.

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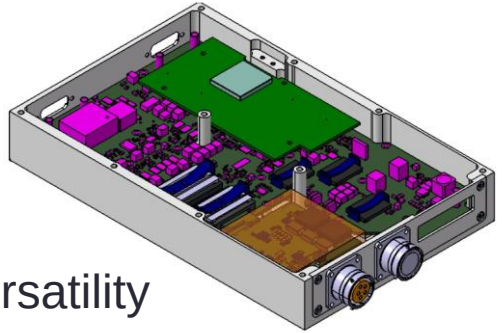
WP4 – PPU - ASP

- PPU optimizations conducted:
  - HW-Design: Design for highly industrialized PCB
  - Testing: Automatic calibration and database creation
- Improvement of HW design to increase flexibility and versatility
- Design, implementation and verification of setup (prototype for automated testing):
  - EGSE H/W duplication (parallel test capcacity)
  - Electronic Loads with better dynamic response.
  - Automated testing successfully verified with PPU from M-PPU project.



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WP5 – PPU – TAS-B

- Co-engineering with Thales Deutschland on the specifications (completed)
- Improvement of design vs. EMC demands is accomplished
- Design optimization has been performed based on
  - Trade-off on the anode supply topology
  - Mechanical architecture definition
  - Manufacturing process
- Internal Design Review accomplished
- Industrialization activities (under an other R&D project)
  - Industrialization of the product has been performed.
  - Manufacturing of the product is completed.
  - The testing of PPU LP alone does start in May 2023.

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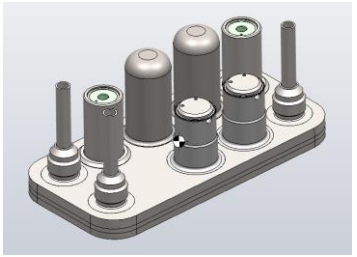
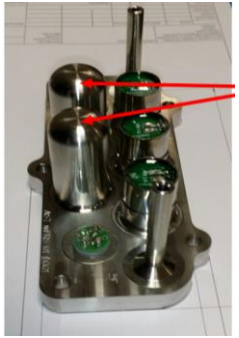
WP 6 – FMS - AST

- **6.1 WP Management**
- **6.2 Documentation**
  - Design and Development Plan (Deliverable D6.1) delivered
- **6.3 FMS design and engineering**
  - Requirement consolidation performed with TD
  - Design Trade off with TD
- **6.4 Cost reduction**
  - Improvement of flow restrictor manufacturing and processing (e.g. characterization)
  - Ongoing internalization of FPB manufacturing processes and evaluation of new fabrication technics
  - New Process for AST Process development activities for orbital welding started
  - Ongoing improvement of manufacturing and characterization processes for flow resistors
- **6.5 Ground Support Equipment**
  - GSE (inert gas compressor) design nearly finished, procument specifiifcations for custom parts generated
- **6.6 FMS MAIT (Manufacturing)**
- **6.7 Qualify Fluidic Management System to TRL6 (in progress)**
- **6.8 Support of higher-level qualification tests (open)**





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Accomplished

- Finalization of specifications
- Finalization of unit designs
- Design freeze on the units
- CDR
- Build of qualification vehicles (partly)
- Qualification tests (partly)

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Next Steps

- Build of qualification vehicles (continuation)
- Qualification tests (continuation)
- Final Coupling & EMC test

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