

# PPU DEVELOPMENTS AT THALES ALENIA SPACE IN BELGIUM

EPIC WORKSHOP 2023

10 MAY 2023



# PRESENTATION PLAN

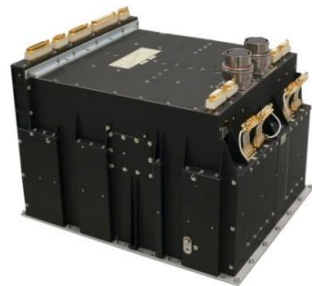
## /// Thales Alenia Space in Belgium

FIRST ENTITY CREATED IN CHARLEROI WITH THE NAME "ETCA", IN 1963

59 YEARS' EXPERIENCE IN POWER SUPPLIES FOR SPACE APPLICATIONS

ELECTRIC PROPULSION ACTIVITIES SINCE 1996

TODAY 3 ENTITIES: CHARLEROI, LEUVEN, HASSELT



## /// Outline

### / BACKGROUND

- PPU Mk1 / Mk2
- PPU Mk3 / Mk3-EVO

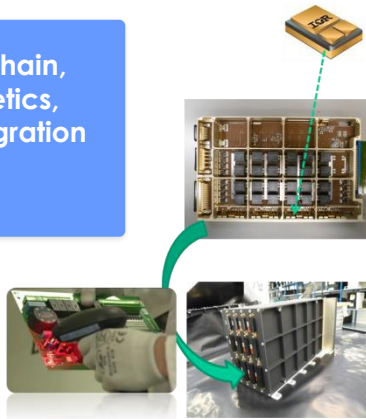
### / DEVELOPMENT'S ACTIVITIES

- 5-7kW HET PPU
- 6kW GIE PPU
- Low Power PPU HEMPT
- Low Power PPU HET



# TAS-B: A STRONG AND EFFICIENT INDUSTRIAL BASE

A complete supply chain, from hybrids, magnetics, PCBA to products integration & test



Permanent & continuous improvement, with LEAN, to reach Industry 4.0 state of the art



High level set of production and test means

Electrodynamic Shaker



Thermal vacuum - test chamber



Pyroshock test facility



EMC tests chamber



# THALES ALENIA SPACE IN BELGIUM

/// A wide range of products dedicated to Thales Alenia Space and our clients around the world

## PRODUCTS FOR

### PLATFORM ELECTRONICS



PCU - PCDU

Strong heritage  
( ~ 200 FM's) for  
all types of Power  
Conditioning and  
Distribution Units



PPU

A European leader in  
power supplies for  
electrical propulsion  
( > 110 FM's)



Avionics

New generations  
of avionics for  
GEO (SDIU) and  
LEO/MEO (RTU)  
applications

### PAYLOAD ELECTRONICS



TWTA

Annual  
production: 200  
Travelling Wave  
Tube Amplifiers



DC/DC

Annual  
production:  
> 150 units

### SOLAR PANELS



PVA

Automated  
production of  
Photovoltaic  
Assemblies using  
a 4.0 approach

### LAUNCH VEHICLES



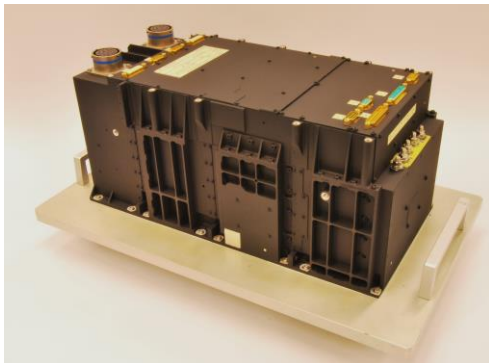
POWER SUPPLIES

The leading supplier of  
electronics for  
European launchers:  
Ariane, Soyuz and  
Vega

**New Space : We are preparing the future**  
with the development of the next generation of equipment already initiated

# PPU Mk1-2: LEGACY PRODUCTS

## /// PPU Mk1 for 1.5kW HET



- ! Thruster: PPS1350-G or SPT-100
- ! Anode supply: 300V or 350V up to 1.5 kW
- /// **Flight Heritage** since September 2003
- ! **Smart-1** reached the Moon, 4 958 hrs operation
- ! **13 telecom satellites** in flight with 2 PPU Mk1 for Station Keeping
- /// **36 PPU Mk1 FM's** delivered to 6 customers
- /// **Obsolete Product**

## /// PPU Mk2 for 2.5kW HET



- ! Thruster: PPS1350-G (1.5kW), PPS130-E (2.5kW), SPT-100 (1.35 kW)
- ! Anode supply: 220V – 350V up to 2.5 kW
- /// **Qualified** since July 2014
- /// **16 PPU Mk2 FM's** delivered to 2 customers
- /// **12 PPU Mk2 FM's in flight**
- /// **Obsolete Product**

# PPU Mk3 AND EVOLUTIONS

## /// PPU Mk3



- ! Thruster: PPS-5000 or SPT-140 (or XR-5)
- ! Anode supply: 100V - 400V up to 4.5 kW
- ! Bus voltage: 100V
- /// **Qualified** since March 2016
- /// **68 PPU Mk3 FM's** have been **ordered** by four Primes
- /// **54 PPU Mk3 FM's** are already **delivered**,
- /// **31 PPU Mk3 FM's** are **in-flight** on 9 full electric satellites

## /// PPU Mk3-E/-EVO: Evolution of the PPU Mk3

- ! Keeping same mechanical, electrical and thruster interface
- ! More robustness to export control regulation with European parts
- ! More flexibility thanks to a new sequencer based on DPC
- ! PPU Mk3-E EM successfully coupled with SPT-140 (4.5kW) in November 2021

### /// 4 PPU Mk3-E FM's are already delivered

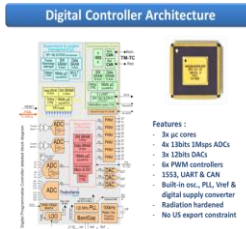
- ! More powerful anode supply: 100V - 400V up to **5 kW**
- ! More robustness to MEO radiation environment
- ! PPU Mk3-EVO EM successfully coupled with PPS-5000 (5kW) in April 2023

### /// 18 PPU Mk3-EVO FM's have been ordered

## /// PPU Mk3-EVO Low Power for 1.5 kW HET

- ! Variant of PPU Mk3-EVO to address 1.5 kW HET
- ! Benefiting from commonalities with the PPU Mk3 production line
- ! PPU Mk3-EVO LP EM successfully coupled with SPT-100 (1.35kW) in February 2022

### /// 4 PPU Mk3-EVO Low Power FM's are already delivered



# PPU FOR 5-7KW HET (1/3)

In the frame of the EPIC H2020 CHEOPS project (GA 7301138), TAS-B started the development of a competitive Dual Mode PPU to drive 7kW HET for Geo Telecom or Navigation either

- High thrust mode: lower voltage and high current
- High Isp mode: higher voltage and lower current

## /// Modular architecture

- Anode module
- Prop Ctrl module
- Motherboard module

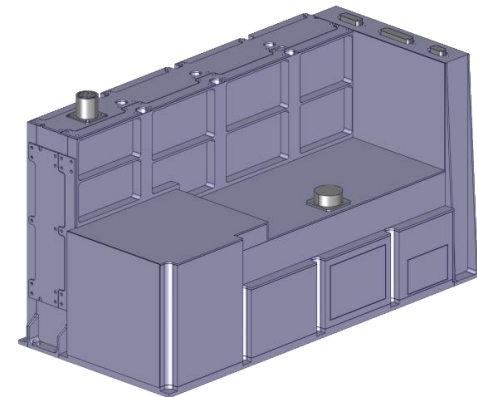
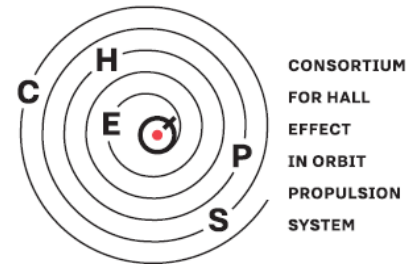
## /// Anode module

### High thrust mode and telemetries

- Single power module delivering up to 7kW from 100V regulated bus
- Full-bridge with competitive High Power / High Voltage planar transformer
- Digital control implemented in TAS-B Digital Processor Controller
- GaN transistors
- Isolated output current sensor
- Technologies dedicated to high power management

### Input Switch protection

### Auxiliary Power Supply for low-level supply



# PPU FOR 5-7KW HET (2/3)

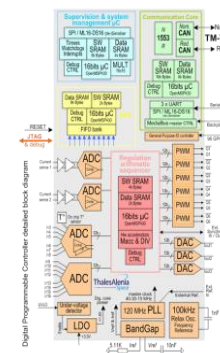
## /// Prop Ctrl module

- ! Magnet supply and telemetries
- ! Ignitor and keeper supplies and telemetries
- ! Cathode heater supply and telemetries
- ! Isolation and proportional valve driver supplies
- ! Pressure sensor interface and supply
- ! TAS-B Digital Processor Controller implementing:
  - Thruster supplies sequencing including automatic start-up of thruster
  - Pressure regulation and discharge current regulation by action on the proportional valve
- ! Input Switch protection
- ! Auxiliary Power Supply for low-level supply

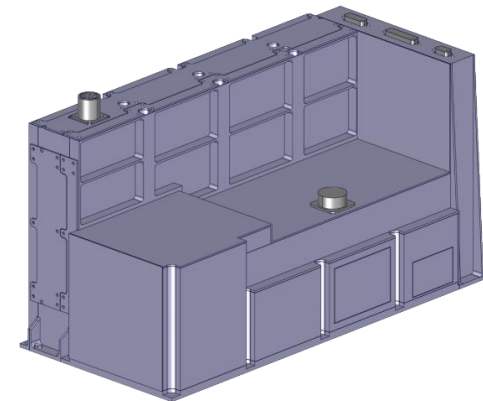
## /// Motherboard module

- ! Power and communication interconnections
- ! Interfaces to the platform
  - 1553 bus
  - ON/OFF TC/TM

## Digital Controller Architecture



- Features :
- 3x  $\mu$ c cores
  - 4x 13bits 1Mps ADCs
  - 3x 12bits DACs
  - 6x PWM controllers
  - 1553, UART & CAN
  - Built-in osc., PLL, Vref & digital supply converter
  - Radiation hardened
  - No US export constraint





# PPU FOR 5-7KW HET (3/3)

## /// Full PPU Breadboard with thruster, cathode and FMS supplies

- / Anode module with 250V/7kW and 500V / > 3kW capability
  - Good measured efficiency in both configuration

- / Digital control of converter validated

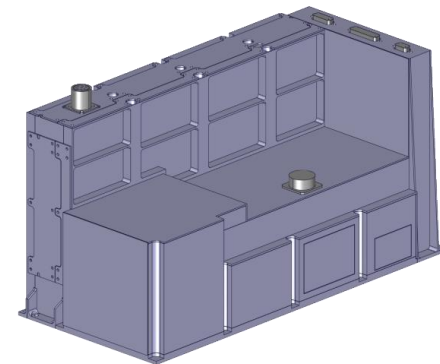
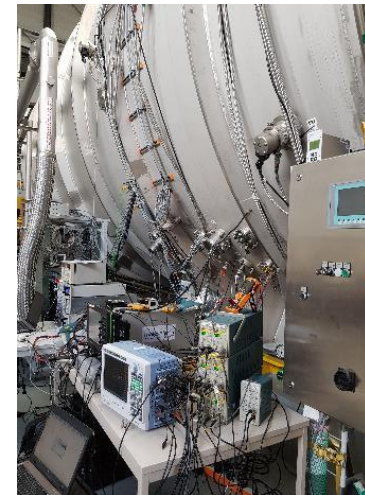
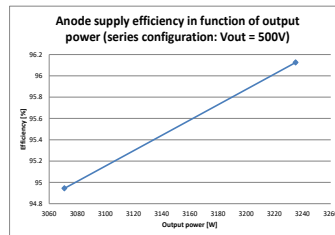
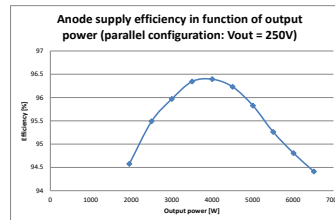
- / Digital control of FMS validated

## /// Successfully coupled with 7kW HET in March 2021 at DLR Gottingen facilities

- / Good operation of the PPU supplies
- / Digital regulation of the FMS validated

## /// EPIC H2020 CHEOPS Medium Power project (GA 101004226) paves the way for the development of the PPU Mk4

- / Kicked off in March 2021
- / Co-engineering with thruster manufacturer and architecture validation
- / PPU EM coupling test with 7kW HET targeted in 2024



# PPU FOR 6KW GIE (1/2)

For platforms requiring high specific impulse, TAS-B develops a PPU to drive 6kW GIE

## /// Beam Supply Module

- Single power module delivering up to 6kW, voltage up to 1600V
- 100V Regulated bus
- Full-bridge with transformer and digital control
- Technologies dedicated to high power management

## /// PROP CTRL Module

- Neutralizer heater supply
- Neutralizer keeper and ignitor supplies
- Acceleration Supply
- Valve control supplies

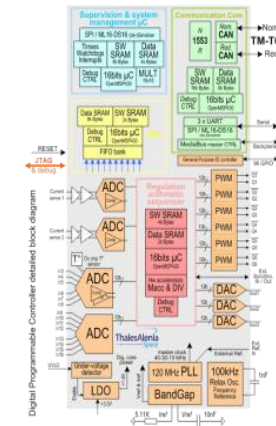
## /// RFGPS module

- RFG main supply
- RFG auxiliary supply

## /// Key technologies

- Competitive High Power / High Voltage planar transformer
- Use of TAS-B Digital Processor Controller ( $\mu$ controller dedicated to space applications)
- Use of GaN transistors

## Digital Controller Architecture



- Features :
- 3x  $\mu$ c cores
  - 4x 13bits 1Mps ADCs
  - 3x 12bits DACs
  - 6x PWM controllers
  - 1553, UART & CAN
  - Built-in osc., PLL, Vref & digital supply converter
  - Radiation hardened
  - No US export constraint

# PPU FOR 6KW GIE (2/2)

/// PPU Breadboard with most critical supplies designed, developed, manufactured and tested: :

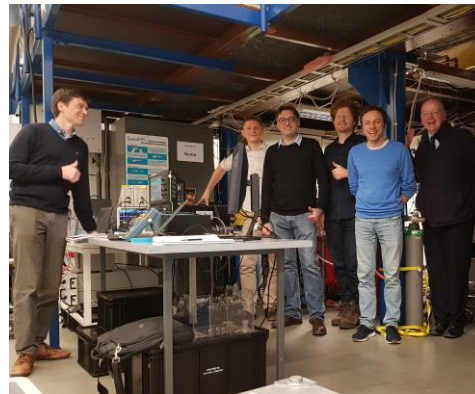
- / Beam supply tested up to 1420V / 5 kW
- / RFGPS, with beam current regulation loop
- / Acceleration supply with NRP clamping circuit

/// Successful coupling test with RIT-2X performed in March 2020 at Giessen University

- / Good operation of PPU supplies (beam supply tested up to 4kW)
- / Beam out events measured, protection circuit operated as expected
- / Good management of the supplies during start-up
- / Ramp-up to nominal operating point

/// The test of the PPU EM is on-going for coupling test with the RIT-2X mid 2023

- / Modules (Prop Ctrl, Beam Supply, RFGPS, TM/TC) are already tested independently
- / Integration tests with sequencing of supplies on the modules are on-going on a dedicated tool



# LOW POWER PPU FOR HEMPT (1/3)

In the frame of the EPIC H2020 HEMPT-NG project (GA 730020), TAS-B started the development of a competitive HEMPT PPU to drive HEMPT for LEO applications

## /// Anode Module

- Competitive PCB module delivering 700W, voltage up to 800V
- Non Regulated bus
- Push-pull inverter with resonant topology

## /// Neutralizer / FMS Module

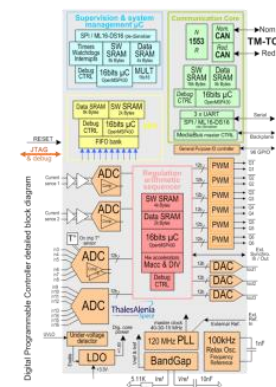
- Heater, Keeper supplies
- EPG-limiter (clamping of the floating ground of the thruster)
- FMS supplies with regulation loop for the discharge current

## /// Key technologies

- Competitive PCB planar transformer
- Use of TAS-B Digital Processor Controller ( $\mu$ controller dedicated to space applications)
- Use of GaN transistors



## Digital Controller Architecture



- Features :
- 3x  $\mu$  cores
  - 4x 13bits 1MSPS ADCs
  - 3x 12bits DACs
  - 6x PWM controllers
  - 1553, UART & CAN
  - Built-in osc., PLL, Vref & digital supply converter
  - Radiation hardened
  - No US export constraint



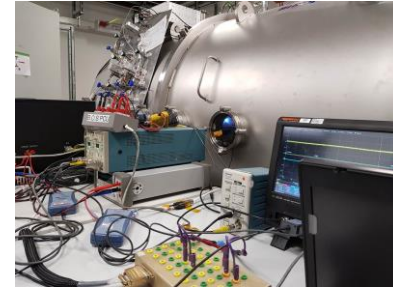
# LOW POWER PPU FOR HEMPT (2/3)

## /// PPU breadboard developed, manufactured and tested

- / Including all the supplies required to drive the HEMP Thruster and FMS
- / Digital control implemented in a DPC performing the digital regulation of the discharge current by action on the duty-cycle of the thruster valve.

## /// Three coupling of the PPU breadboard with thruster EV0 were successfully performed at Thales Deutschland Ulm facilities

- / First in August 2019
- / Second integrating PMA in December 2019
- / Third with improved PMA performed in September 2020



# LOW POWER PPU FOR HEMPT (3/3)

/// EPIC H2020 HEMPT-NG2 project (GA 101004140) paves the way for the development of the Low Power PPU for HEMPT

/ Kicked off in January 2021

/ Co-engineering with thruster manufacturer completed

/// Design improvement and optimization finalized

/ Internal Design Review completed

/// PPU EM development completed

/ including PCB routing

/ mechanical structures definitions

/// PPU EM manufactured

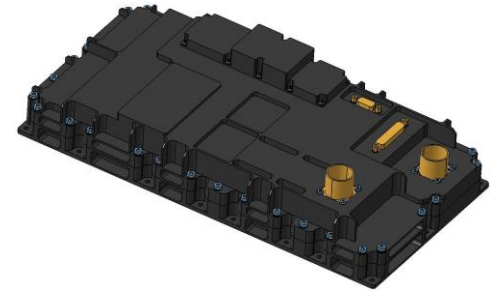
/// PPU EM testing on-going

/ Neutralizer /FMS module test completed

/ Anode module test on-going

/ Coupling test with HEMPT-Ev0 targeted in 2023

/// First commercial order of PPU HEMPT FM's awarded in January 2023



# LOW POWER PPU FOR HET

In the frame of the EPIC H2020 CHEOPS Low Power project, TAS-B develops a competitive Low Power PPU to drive HET PPS-X00

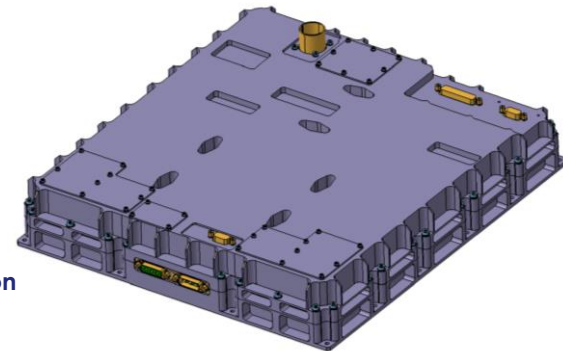


## /// Including all the supplies to drive HET and FMS

- / Single anode supply providing 1kW up to 350V based on resonant topology
- / Heater, Ignitor, magnet supplies
- / FMS supplies with regulation loop for the discharge current

## /// Key technologies

- / Competitive PCB planar transformer
- / Use of GaN transistors
- / Digital control implemented in a DPC performing the digital regulation of the discharge current by action on the FMS.



## /// EPIC H2020 CHEOPS Low Power project (GA 101004331)

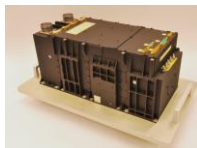
- / Kicked off in February 2021
- / Co-engineering with thruster manufacturer completed
- / Preliminary anode supply breadboard tested up to 700W
- / Design improvement and optimization finalized
- / Internal Design Review completed
- / The development of the Low Power PPU EM for HET is on-going targeting coupling test with PPS-X00 in 2023



# CONCLUSION

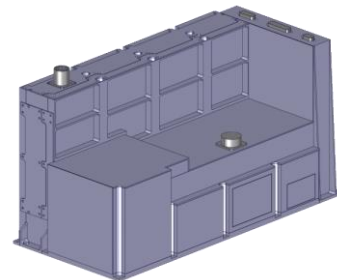
/// Up to now, more than **140 PPU flight models** have been **ordered** to TAS-B by **8 different customers** and more than **110 PPU flight models delivered**.

- / **PPU Mk1** for 1.5 kW HET
- / **PPU Mk2** for 2.5 kW HET
- / **PPU Mk3/Mk3-EVO** for 5 kW HET

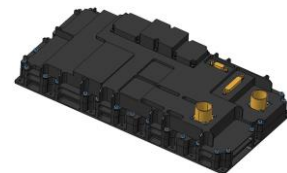


/// Based on this experience, TAS-B is preparing the next PPU generations:

- / **Low Power HEMPT PPU** for constellation market
- / **Low Power HET PPU** for constellation market
- / **PPU for 5-7kW HET** for Geo Telecom or Navigation applications
- / **PPU for 6kW GIE** for Geo Telecom or Navigation applications



/// TAS-B thanks the support of the European Union's Horizon 2020 research and innovation programme and the European Space Agency





## Thank you for your attention

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