SOLAR ELECTRIC PROPULSION WITH DIRECT DRIVE

EPIC WORKSHOP 2023, GILLES BOUHOURS / KEVIN DANANCIER

Date : 16/05/2023
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Ref Modele : 83230347-DOC-TAS-FR-011

Solar Electric Propulsion with Direct Drive

1. USE OF (SOLAR) ELECTRIC PROPULSION
2. DIRECT DRIVE : what is it ? advantages ?
3. STUDIES performed and main results
4. DEVELOPMENT LOGIC
5. DIRECT DRIVE OBJECTIVES
6. ACKNOWLEDGEMENTS

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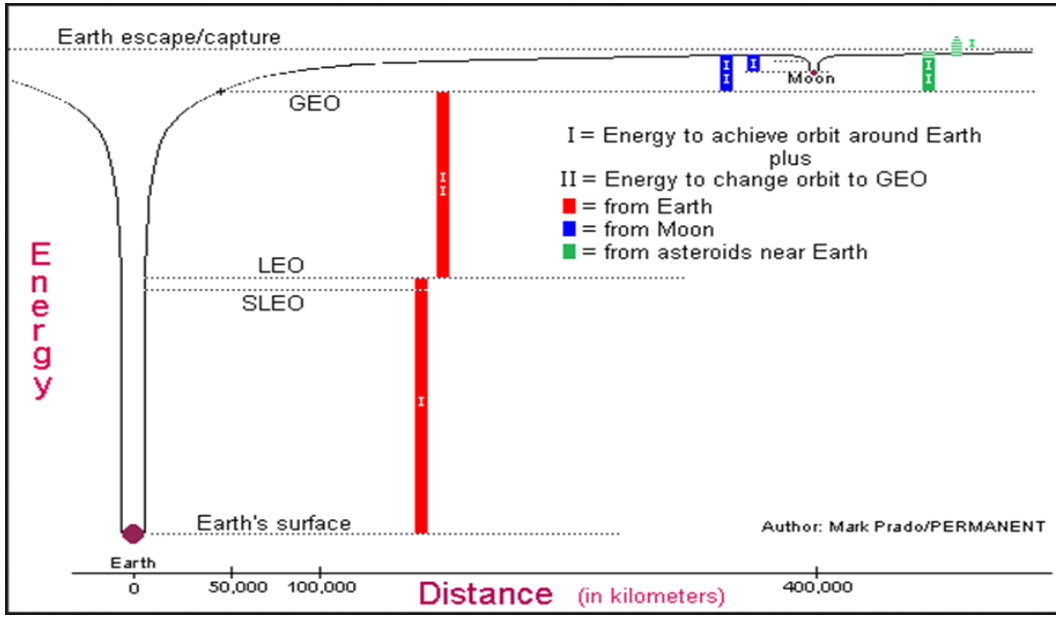
ELECTRIC PROPULSION CLOSE TO LARGE BODIES (EARTH, MOON,…)

/// A launcher as Ariane 64 (at lift off: 860 tons, 15 000kN, Isp ~400s) can send:

- >20 tons in LEO 300km
- 20 tons at 400km for ISS
- 11,5 t in GTO,
- 6,9 t Earth escape (Vinfinity = 2.5 km/s)

(from AR6 User's manual Issue 2 rev 0)

/// Electric propulsion provides ~N with Isp > 1500s



/// **Relative required energy to change altitude of a spacecraft around Earth** (from https://www.permanent.com/space-transportation.html)

/// **Technical Optimum:**

- Take off from large bodies with a (chemical) launcher,
- Then switch to electrical propulsion when low thrust feasible (~300km LEO around Earth) to save ergol mass.

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SOLAR ELECTRIC PROPULSION AND ITS USEFUL DOMAIN

/// Solar Electric Propulsion is to supply Electric Propulsion with photovoltaic cells converting Solar flux in electric power.

/// Solar flux decreases quickly with sun distance ($1/d^2$)

/// Beyond the asteroïd belt, using solar array to power high power electric propulsion does not seem interesting.

/// **Solar Electric Propulsion can be used extensively:**

- **around Earth,**
- **to/from Moon and Mars,**
- **in Asteroid belts.**

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WHAT IS HIGH VOLTAGE DIRECT DRIVE WITH MAXIMUM POWER POINT TRACKING ?

IN FLIGHT
(with PPU) :

Solar Array

100 V → PPU →

Hall Effect Thruster 250-400V

IN DEVELOPMENT
(with Direct Drive) :

250 ~ 400 V →

/// High Voltage Reduced current for same power (/3) OR increased power (x3 or x4)

⇒ Reduced (mass and size) power units for a given power

⇒ or PCU 20kW/100V ~ PCU 60kW /300V (at first order, if Solar Array and battery voltages increase)

/// High Voltage supplies directly (Direct Drive) Hall Effect Thruster

- Reduced PPU mass and size (/2 to /3)
- Improved efficiency and reduced dissipation for end to end power chain (S.A. to users)

/// With maximum power peak tracking MPPT(and then variable bus voltage), more power at beginning of life

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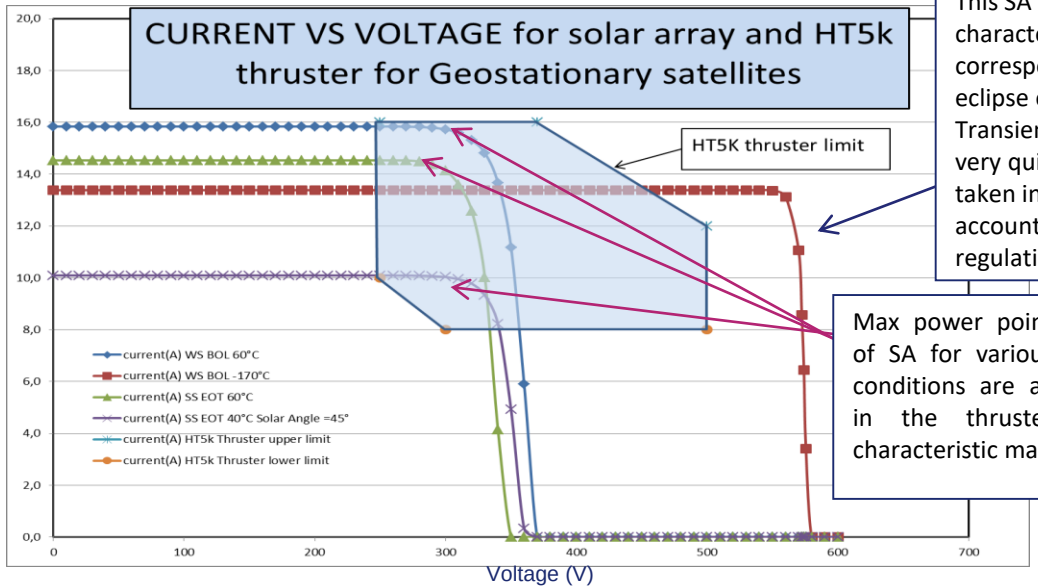
MORE DETAILS ABOUT
HIGH VOLTAGE DIRECT DRIVE MAXIMUM POWER POINT TRACKING



Superposed solar array and Hall Effect Thruster current vs voltage characteristics (geo SatCom)

Thruster power is adjusted by flow rate to cover I/V solar array characteristics.

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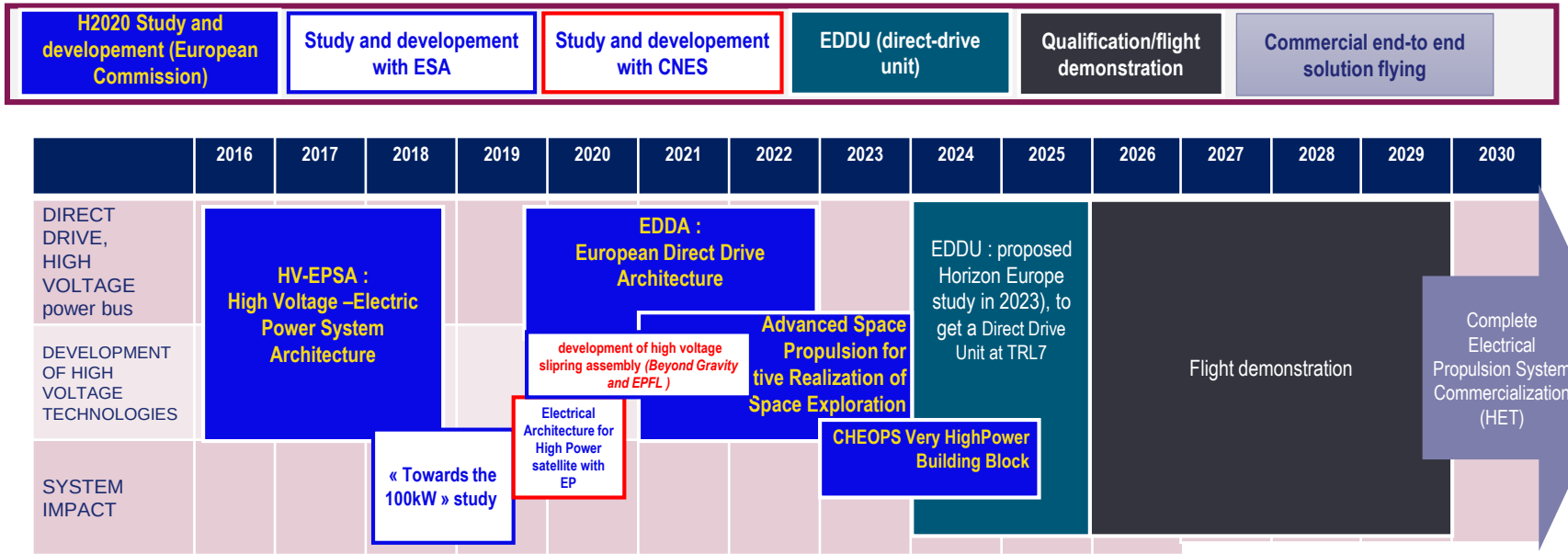
DIRECT DRIVE DEVELOPMENT LOGIC



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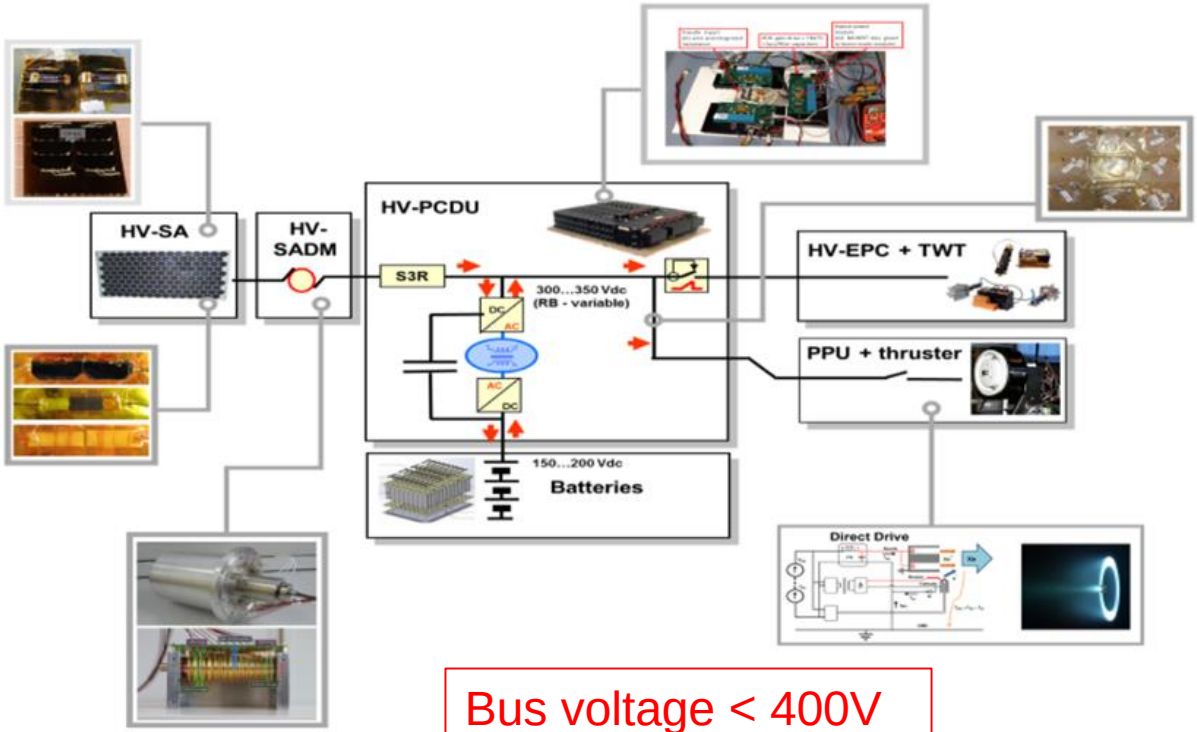
HV-EPSA

HIGH VOLTAGE ELECTRICAL POWER SYSTEM ARCHITECTURE

ThalesAlenia Space	Coordinator, HET 20kW
SITAEL	Electric Propulsion
Together ahead. RUAG	High Voltage Sliprings
EPFL SWISS PLASMA CENTER	
ONERA	Plasma testing
ionix Systems	Harness



Bus voltage < 400V

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EDDA

EUROPEAN
DIRECT-DRIVE ARCHITECTURE

ThalesAlenia Space	Coordinator and system
uc3m Universidad Carlos III de Madrid	Thruster modelling
SITAEL AN ANGEL COMPANY	Electric propulsion and test facility
THALES	HEMP-Thruster
efficient innovation	Management, dissemination

///EDDA aimed at designing and testing :

- **A modular Direct Drive architecture**
- **Compatible with different European thrusters**

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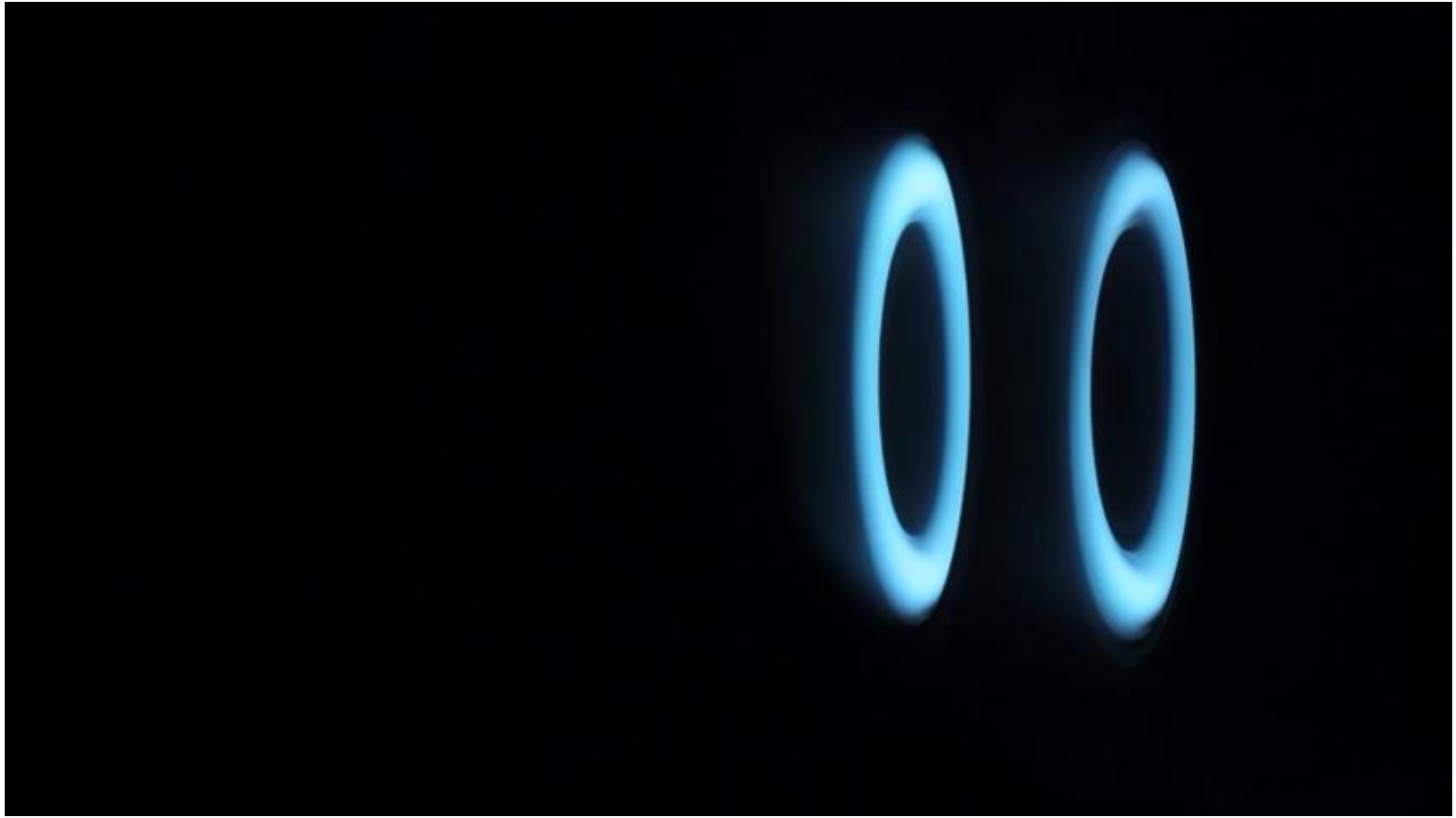
INDIVIDUAL CONTROL OF 2 HETS (SITAEL) AT 300V



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HEMP-THRUSTER (THALES-D) 400V 16A

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ADVANCED SPACE PROPULSION FOR INNOVATIVE REALISATION OF SPACE EXPLORATION

SITAEL AN ANGEL COMPANY	Coordinator, HET 20kW
ThalesAlenia Space a Thales / Leonardo company	Use cases
AST ADVANCED SPACE TECHNOLOGIES	Electric Propulsion
MICROTEST breakthrough innovation	Microelectronics
Imperial College London	Academic partnership
uc3m Universidad Carlos III de Madrid	Academic partnership
UNIVERSITÀ DI PISA	Academic partnership
SME4SPACE	Dissemination

/// Very-high-power thruster system

The ASPIRE project is structured to further mature a very-high-power 20kW Hall thruster system up to TRL 6

/// Reduced cost and duration

To set the grounds for the system qualification campaign at a remarkably reduced cost and duration, thus, addressing the associated schedule, financial and technical risks

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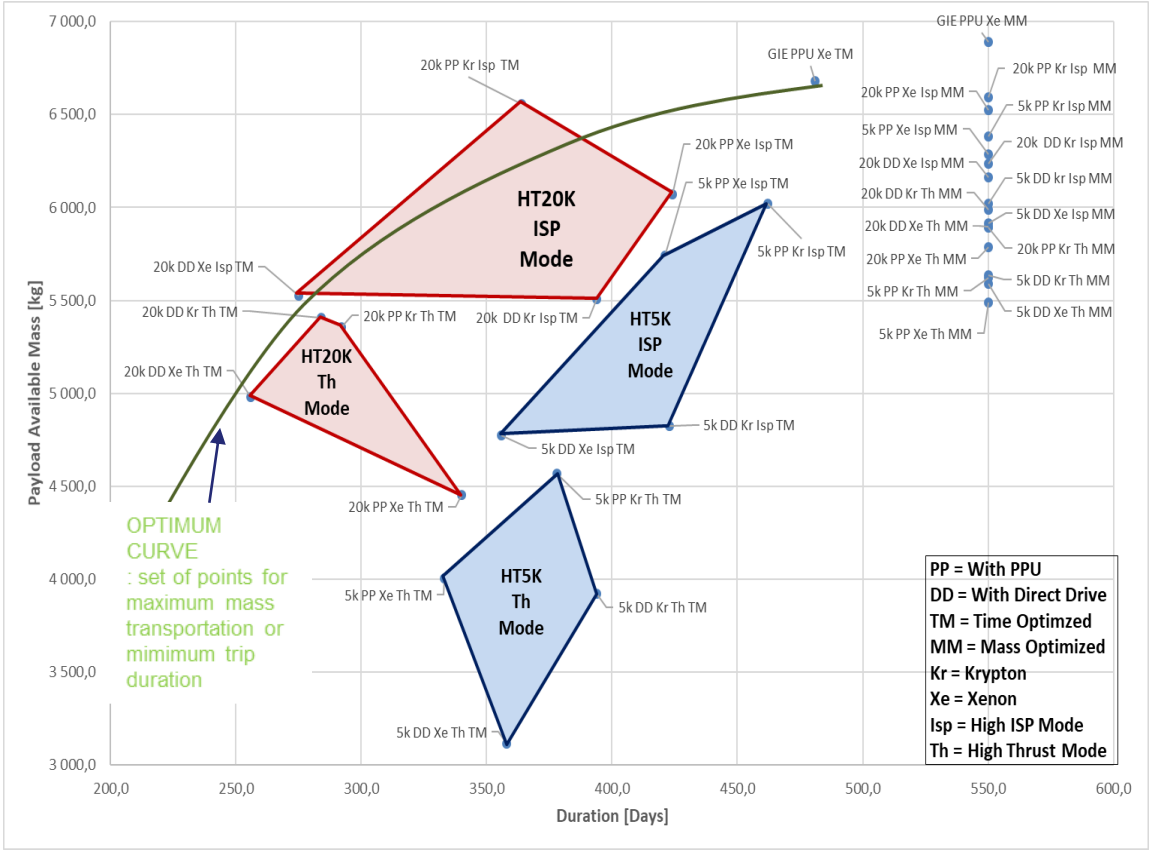
TRIP TO MARS IN VARIOUS CONFIGURATIONS

/// Hall Effect Thruster compatible with various Mars missions.

/// **General tendancy PPU vs DDU :**

- **Direct drive** for lower trip duration
- **PPU** for high Isp (and lower propellant mass and higher payload mass)

/// Similar shape for other missions (around Earth for instance)



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CONCLUSION

/// Thanks to several Building Block studies, Direct Drive is on the right track!

/// Large power range compatible with different Space transportation missions in inner solar system (around Earth, to/from Moon, to/from Mars).

/// Unique modular architecture and power unit.

/// Design for European thrusters (5-7kW or 20kW) in 250V-400V as HET and HEMPT.

/// Objective: in flight between 2027 and 2030.

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