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company's strengths to help  
unlock hidden value.*



PI Solutions



## Disruptive Electric Propulsion Thruster Concepts for MPD Technology



**EPIC Workshop 2018 for Electric Propulsion Technologies**

**SESSION 6: EP Technologies and Capabilities**

**October 16<sup>th</sup>, 2018.**

PI INTEGRAL SOLUTIONS LIMITED - GERMANY

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Universität Stuttgart



**THEVA**

INDUCTIVE SOLUTIONS  
**ABSOLUT  
SYSTEM**



**Associated Partner:**



**AIRBUS**



**Pending:**



# Content

Technology Roadmap

Introduction

Previous Demonstrators (SX3)

Prototype Supreme RV-X1 (20 kW)

Fundamental Objectives

Consortium Partners

Project Diagram

Work Package Breakdown

Project Coordination Team



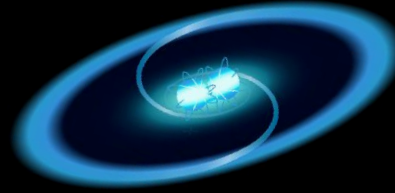
# Technology Roadmap

## DEVELOPMENT IN EUROPE

- Disruptive Technologies for Space Power and Propulsion (DiPoP) project: High temperature superconductors were listed as one of the technology enablers for non-fission space power propulsion.
- EU funded FP7 "High Power Electric Propulsion Roadmap" (HiPER): First large group of private companies, enterprises, research institutes and universities to define a roadmap for high-power electric propulsion. Two MPD thrusters were developed one with applied magnetic field, the other with sole self-induced magnetic field.
- Also in FP7 HiPER hollow cathodes for high power applications were developed with current capabilities up to 180 A.
- HiPER activities were aimed at designing and testing two 100 kW-class Applied-Field MPD thrusters. Activities carried out included, among others: characterization of plasma instabilities, identification of design solutions for instability control, development of high current cathodes.
- MPD thruster development activities were further pursued under the ESA/TRP scheme under the project "100-kW unsteady AF-MPDT" (ESTEC Contract N° 21797/08/ML/PA).



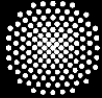
Proposed Project Title



**SUPREME**

**SUP**erconducting **R**eadiness **E**nhanced **M**agnetoplasmadynamic  
**E**lectric-propulsion

AN EPIC II PROJECT PROPOSAL FOR HORIZON 2020



Universität Stuttgart

**THEVA**

INNOVATIVE SOLUTIONS  
**ABSOLUT  
SYSTEM**



**uc3m**

Associated Partner:



**AIRBUS**



arianegroup

\*Pending



# Proposed Nomenclature

## **SUPREME**

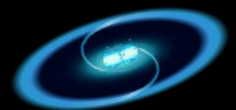
- Superconducting Readiness Enhanced Magnetoplasmadynamic Electric Propulsion

## **SUPREME DD**

- Direct drive 100 – 160 V current regulated thruster

## **SUPREME RV**

- 300 – 750 V voltage regulated thruster



# Introduction

## SUPerconducting Readiness Enhanced Magnetoplasmadynamic Electric-propulsion

### SUPREME

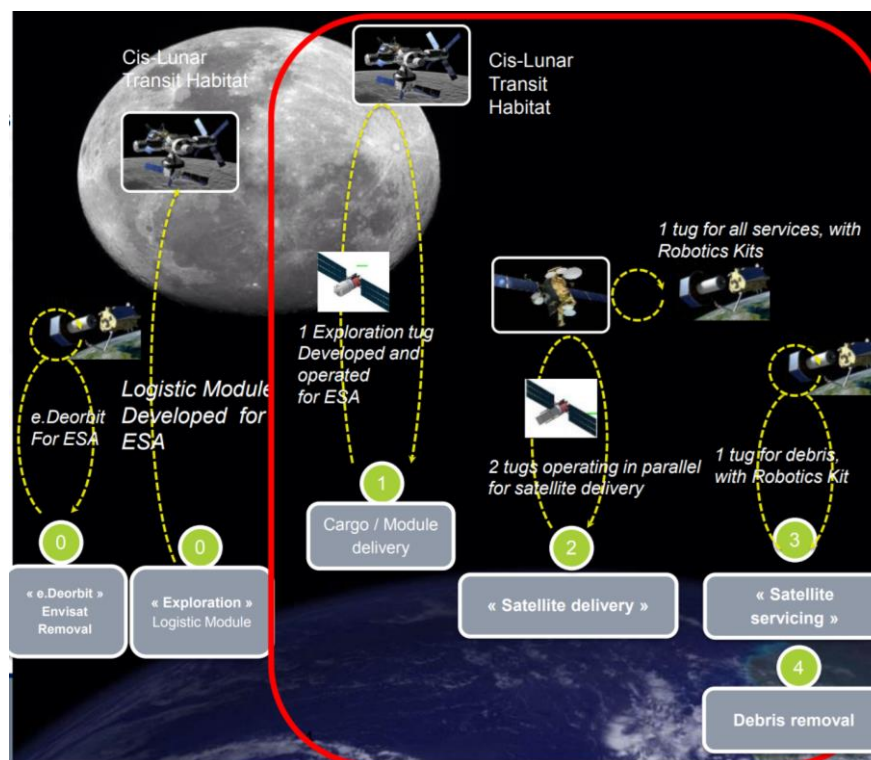
Applied Field MPD Thruster

Desired power range: from 20 kW to 500 kW

Specific impulses: 2000-4000s

Thrust range > 1N

- First of its class superconductor-based applied field magnetoplasmadynamic thruster (AFMPDT).



[1] Michel Frezet, Space Tug. Presentation for Clean Space Industrials days. May 24<sup>th</sup> 2016

- **SUPREME DD:** Direct drive 100 V DC (current regulated) for >150 kWe EP systems
- **SUPREME RV:** 300 – 750 V DC (voltage regulated) for >20 kWe EP systems



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# Introduction: Market

## From LEO to Mars and beyond

### SUPREME

Applied Field MPD  
Thruster

Desired power  
range: from 20 kW  
to 500 kW

Specific impuls:  
2000-4000s

Thrust range > 1N

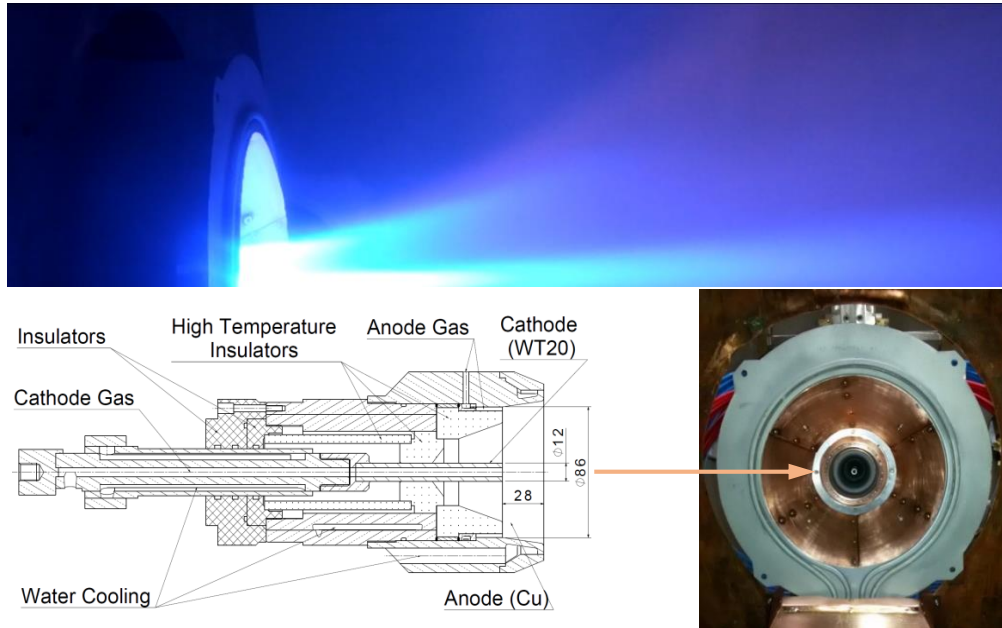
- **SUPREME 20 kW class:**
  - Satellite delivery: More payload and faster TTO (*20 missions/year*)
  - On orbit satellite servicing
  - Active debris removal (*15 missions/year for satellites >1ton*)
- **SUPREME > 20 kW class:**
  - Logistics and cargo delivery for human exploration (*1 mission/2years*)
  - Lunar transits require 60 – 100 kW EP systems.
  - Mars transits require > 200 kW EP systems.





# Previous Demonstrators (SX3)

## 100 kW class AFMPDT demonstrator



	MAX. THRUST	MAX. ISP	MOST EFFICIENT	
Anode current, A	750	320	428	Control Parameters
Applied field, mT	400	400	400	
Mass flow, mg/s	180	30	60	
Arc power, kW	114	50	65.7	
Arc voltage, V	152	156	153	
Thrust, mN	<b>3390</b>	1183	2167	
Isp, s	1916	<b>4000</b>	3670	
Thrust efficiency, %	28	46	<b>59</b>	
TTPR, mN/kW	29.8	23.0	<b>32.9</b>	

[2] A. Boxberger y G. Herdrich, «Integral Measurements of 100 kW Class Steady State Applied-Field Magnetoplasmdynamic Thruster SX3 and Perspectives of AF-MPD Technology,» de International Electric Propulsion Conference, Atlanta, Georgia, USA, 2017.



# Prototype Supreme RV-X1 (20 kW)

## PPU modules:

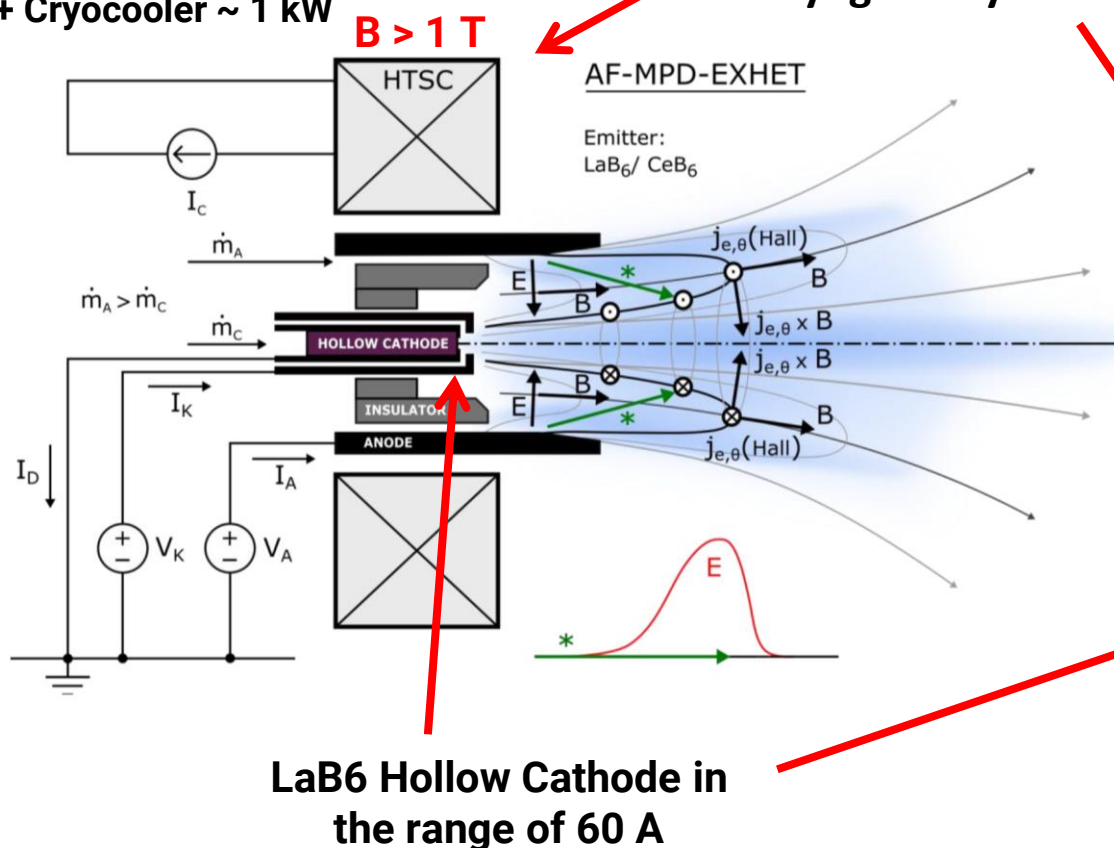
Discharge (voltage regulated) ~ 18 kW

Cathode + Keeper ~ 1 kW

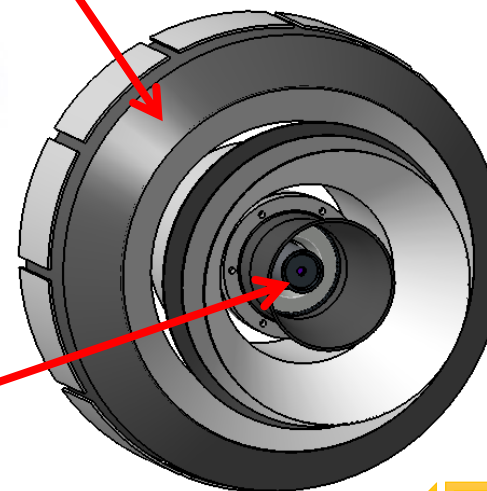
HTSC + Cryocooler ~ 1 kW

High-temperature  
superconductor coil

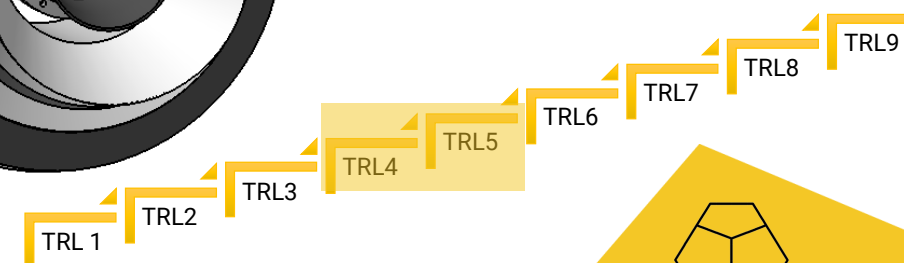
+  
Cryogenic system



- **Testing in relevant environment** all subsystems (cathode, HTSC, cryogenic system, etc.)
- Assess the **thrust performance** (max. thrust, max. Isp, max. efficiency) and define the **laws of scalability** for SUPREME at higher powers.
- Investigate the **lifetime** of the critical components, in particular the cathode.
- Impact of the AF to efficiency and lifetime.



➤ Increase TRL from 4 to 5



[2] A. Boxberger y G. Herdrich, «Integral Measurements of 100 kW Class Steady State Applied-Field Magnetoplasma-dynamic Thruster SX3 and Perspectives of AF-MPD Technology,» de International Electric Propulsion Conference, Atlanta, Georgia, USA, 2017.


# Fundamental Objectives



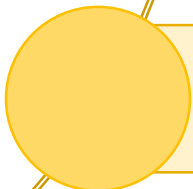
INCREASE OF FLIGHT PROFICIENCY FOR MPD TECHNOLOGY (TRL 4 TO TRL 5) BY INTEGRATING AND TESTING ALL THRUSTER SUBSYSTEMS AT RELEVANT CONDITIONS



REDUCE GAP FOR MPD TECHNOLOGY DEVELOPMENT COMPARED TO OTHER EPS



DEVELOPMENT OF HIGH-TEMPERATURE SUPERCONDUCTING SUBSYSTEMS FOR ELECTRIC SPACE PROPULSION



DEVELOP ROADMAP FOR HIGH-POWER AF-MPD THRUSTERS



# Consortium



## UNIVERSITY OF STUTTGART, INSTITUTE OF SPACE SYSTEMS IRS

Offers wide research in the field of Space Technology and Astronautic Appliances. It has contributed to atmospheric entry experiments: HERMES; EXPRESS; MIRKA; X-38, HUYGENS, EXPERT; Miriam 2, REXUS. As well, as the development of space propulsion systems such as AF-MPD, TITUS.

## AIRBUS

A commercial aircraft manufacturer, with Space and Defence as well as Helicopters Divisions, Airbus is the largest aeronautics and space company in Europe and a worldwide leader.

Associated partner



## THEVA

Represents a unique approach to superconductor production. Theva superconductor tape pro line transport 200 times more current of copper with practically no power loss. Currently is working on Fast Grid and EcoSwing projects.

## UNIVERSIDAD CARLOS III

Founded in 1989, it has 128 investigation groups. The group that will participate in this consortium is focused on aerospace engineering.

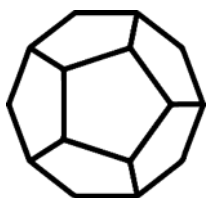


## INFLPR

Conducts basic and applied research in the fields of lasers, interaction of light with matter and plasma and electron accelerators.

## ABSOLUT SYSTEMS

Offer standardised and tailor-made superconducting and cryogenic solutions. For Space Applications.



## PI Integral Solutions

SME expert in integrating and coordinating R&D teams through long-term projects, performing workshops and intensive R&D exercises in tandem with internal teams.

## ARIANE Group

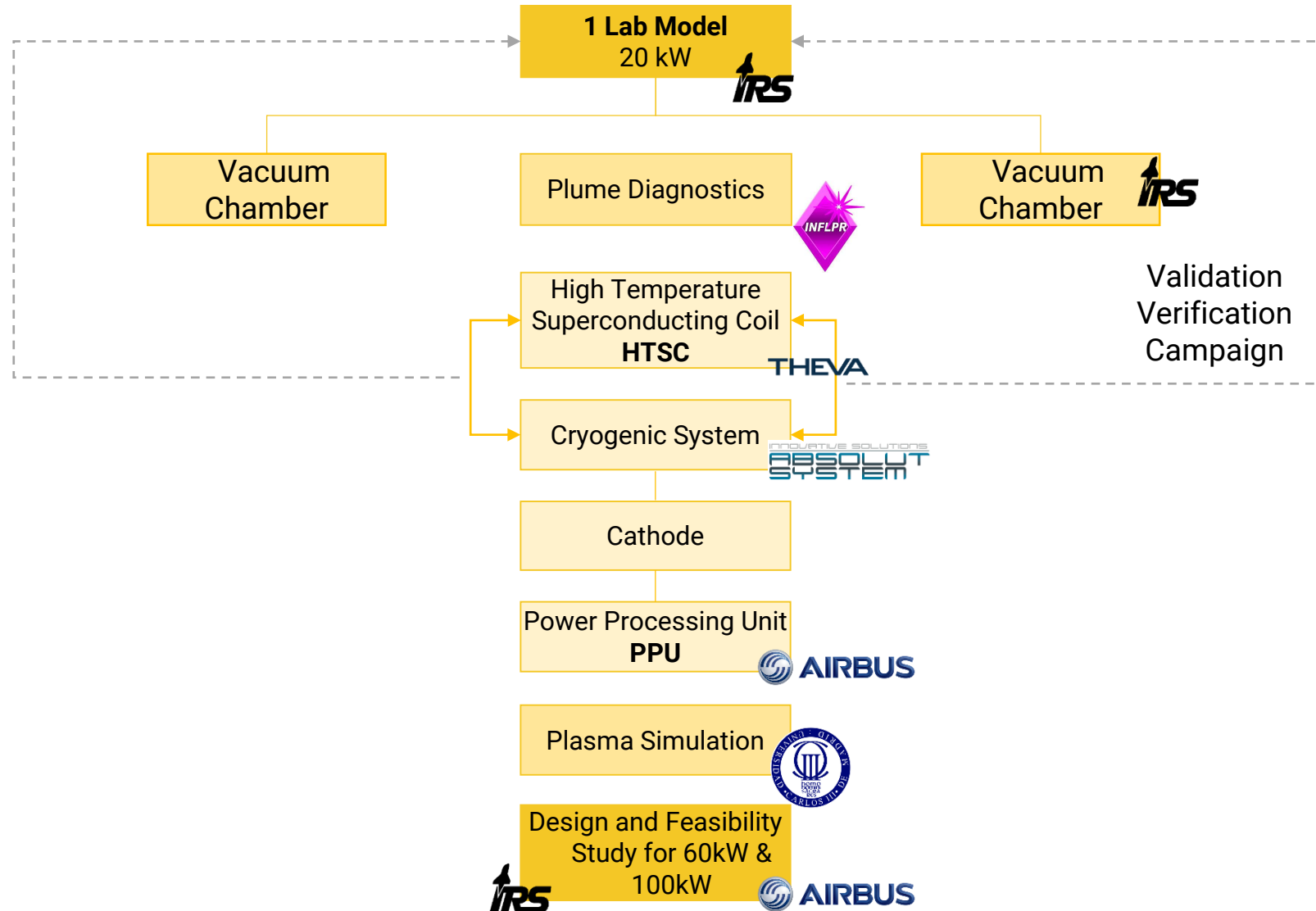
A commercial launchers and electric propulsion thrusters manufacturer with large heritage in the aerospace sector in Europe.

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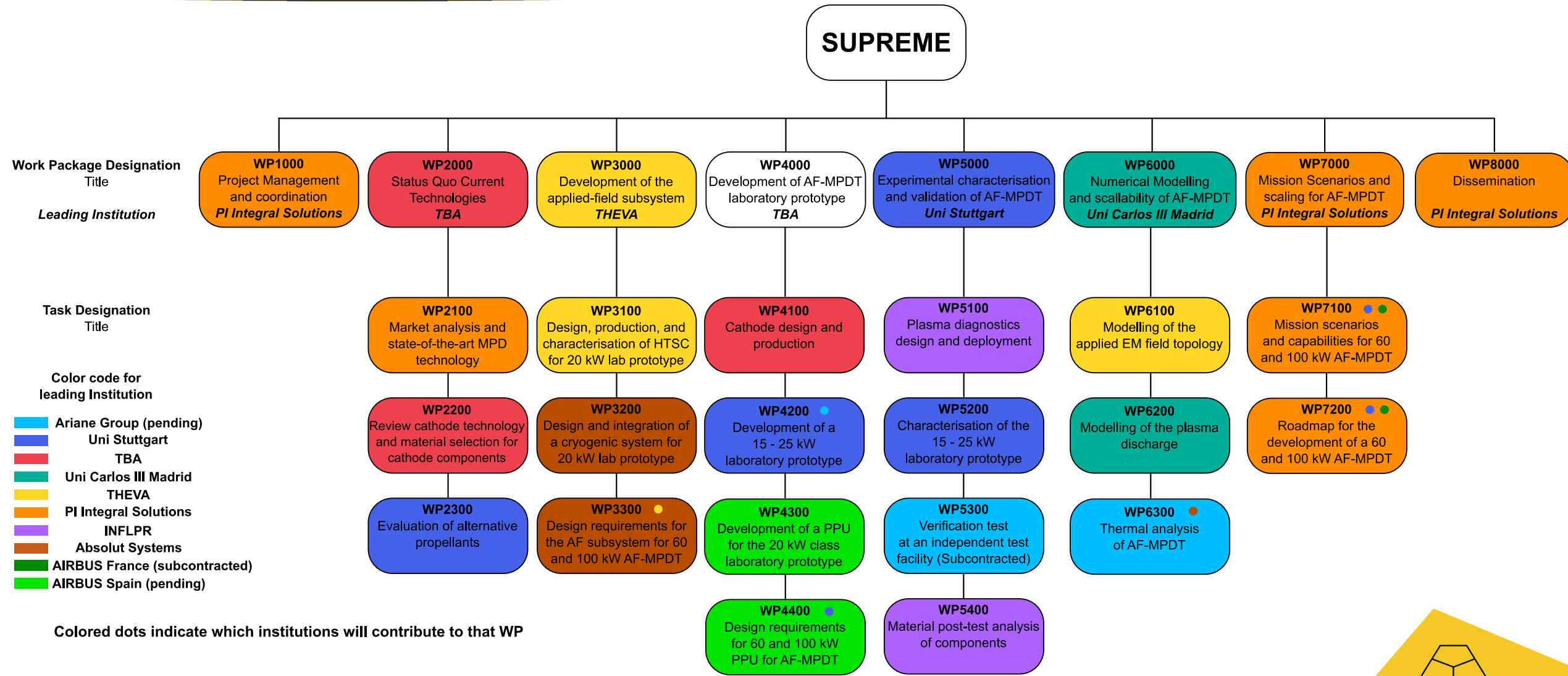




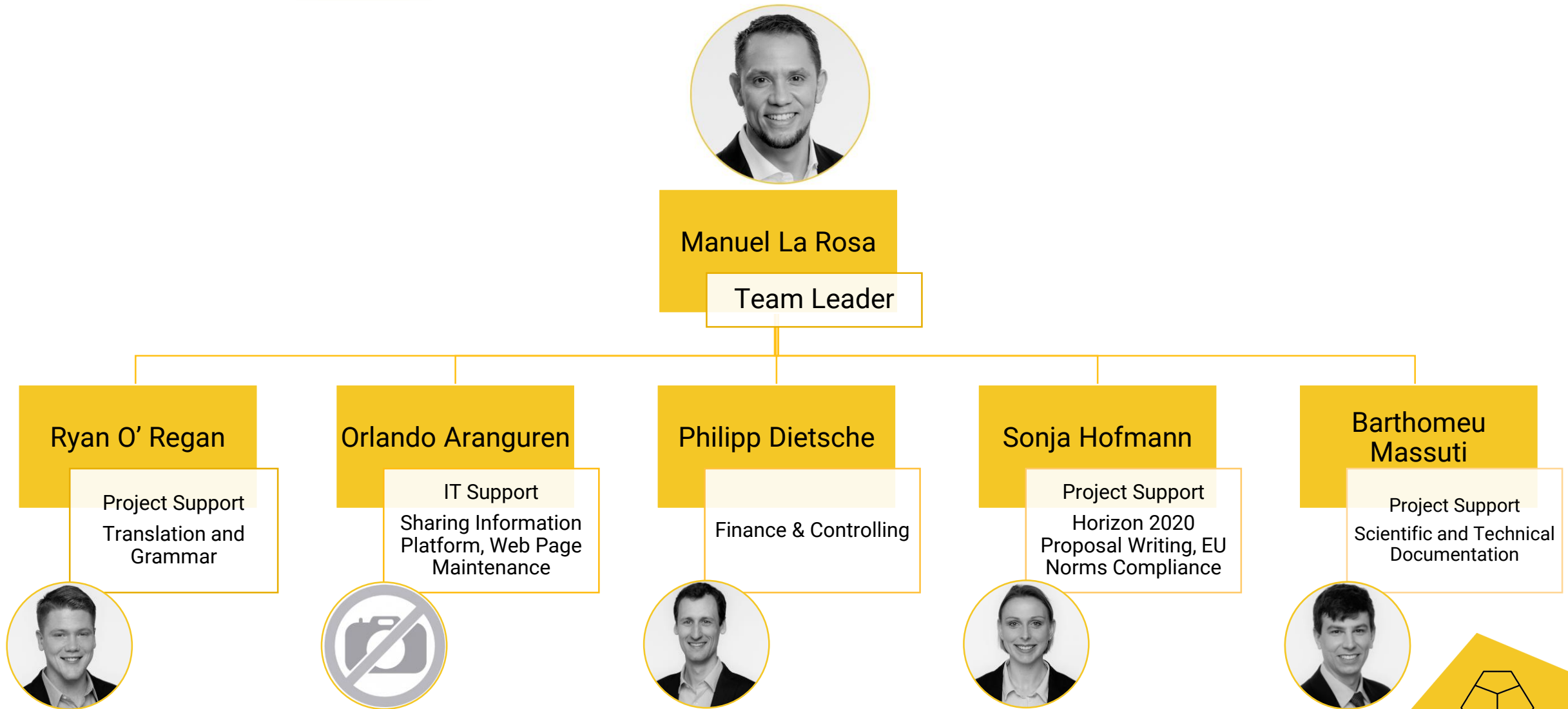
# Project Diagram



# Work Package Breakdown



# Project Coordination Team





# PI Solutions

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