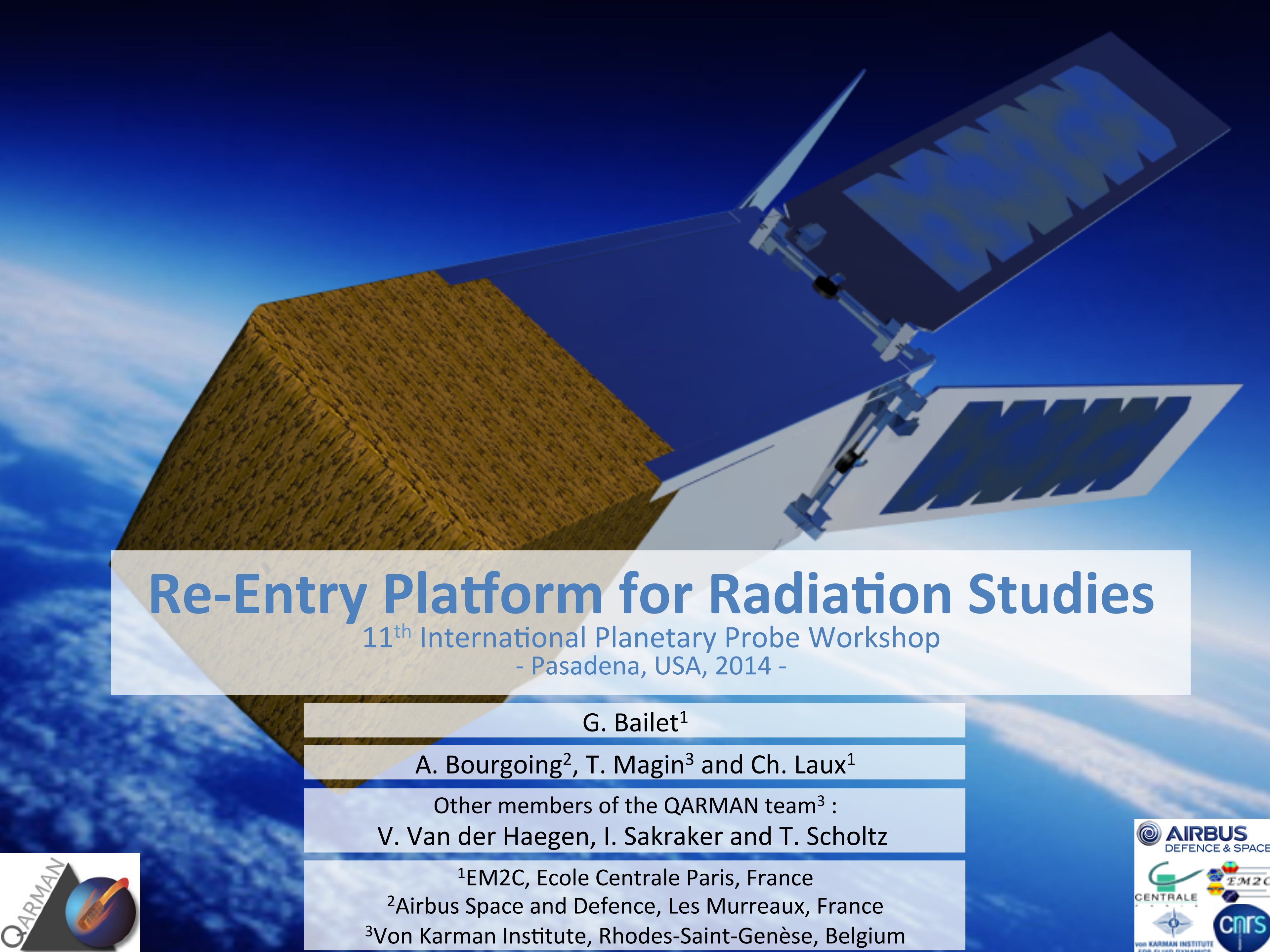


# Re-Entry Platform for Radiation Studies

$11^{th}$ International Planetary Probe Workshop

- Pasadena, USA, 2014 -


G. Bailet[1]

A. Bourgoing[2], T. Magin[3] and Ch. Laux[1]

Other members of the QARMAN team[3] :

V. Van der Haegen, I. Sakraker and T. Scholtz

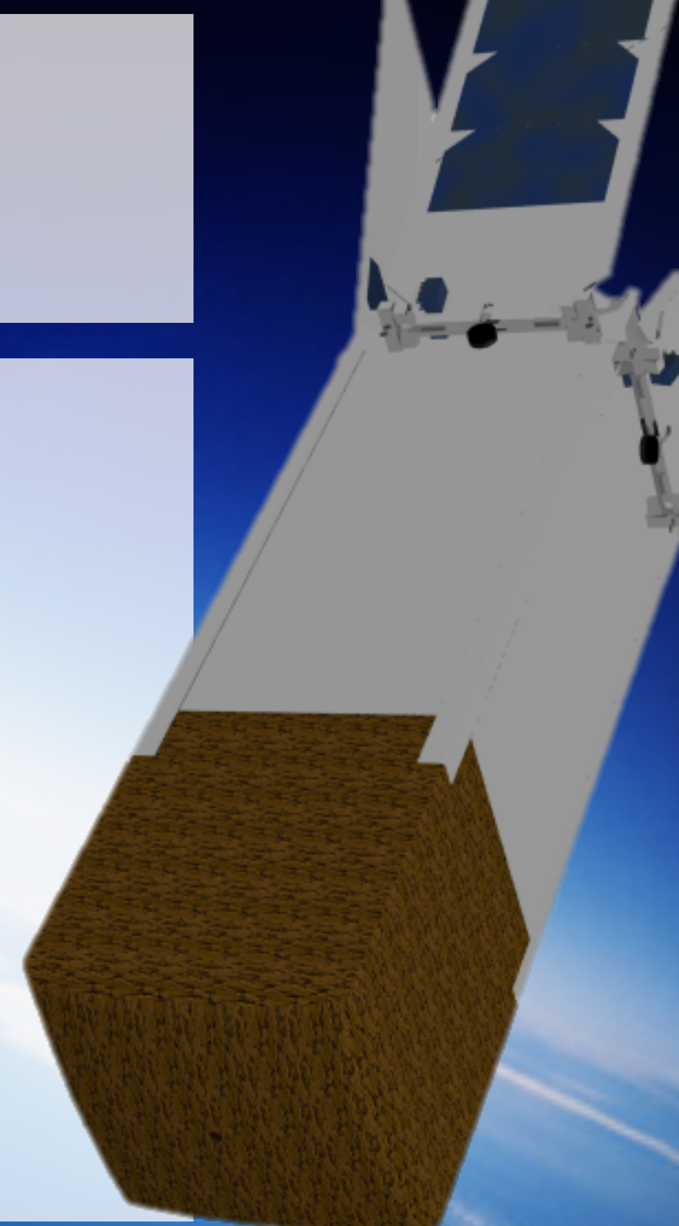
[1]EM2C, Ecole Centrale Paris, France

[2]Airbus Space and Defence, Les Murreaux, France

[3]Von Karman Institute, Rhodes-Saint-Genèse, Belgium

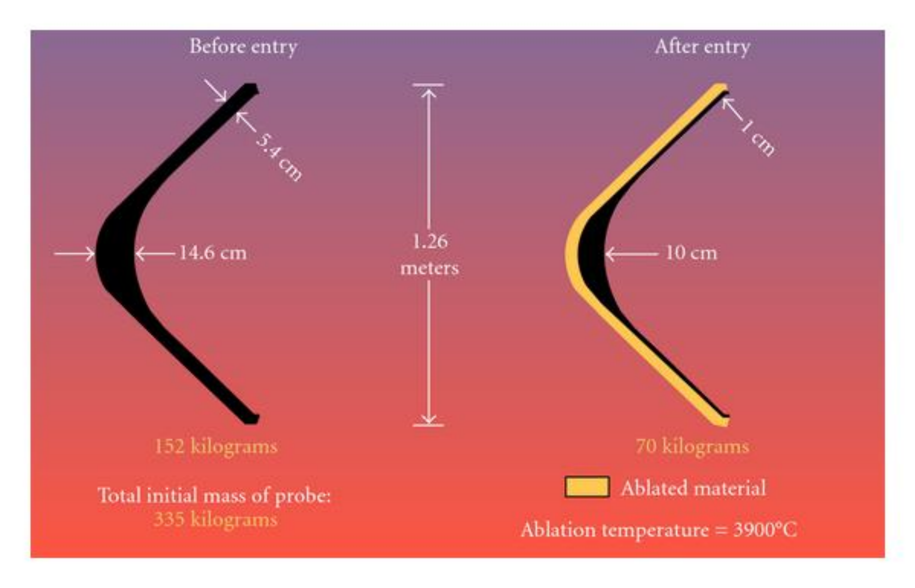
# Content

- ➢Context
- ➢QARMAN Platform
- ➢Radiative Environment
- ➢Spectrometer Payload
- ➢Future Prospectives
- ➢Conclusion



# Introduction

## -Problematic-




**Galileo Probe**
Reentered Jovian Atmosphere
on December 7th 1995

**Mission conclusions:**

**High Uncertainties on:**
-Radiative heat flux (≥20%)

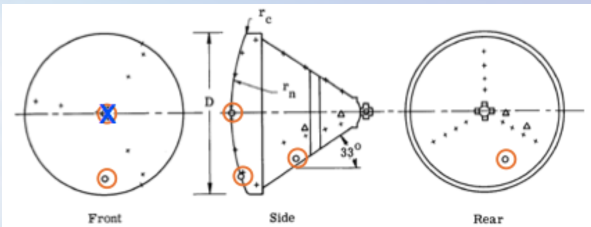
-Ablation product impacts on heat fluxes

-Ablation rate (intrusive methods or indirect measurement with velocity gradient)

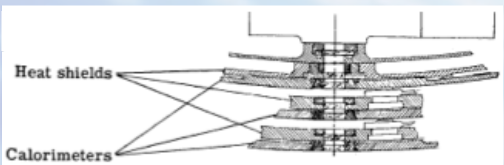
-TPS sizing (≥20% margin)

# Introduction

## -Problematic-




**Fire II architecture**




Cauchon, D. L., Radiative Heating Results from the FIRE II Flight Experiment at a Re-entry Velocity of 11.4 Kilometers per Second, TM X-1402, NASA, 1967.

| Data Period | Altitude / km | Velocity / km/s |
|---|---|---|
| **Fire I** | | |
| 1 | 89.01 – 70.00 | 11.63 – 11.53 |
| **Fire II** | | |
| 1 | 83.75 – 69.80 | 11.37 – 11.30 |
| 2 | 54.34 – 53.23 | 10.61 – 10.51 |
| 3 | 41.80 – 40.75 | 8.20 – 7.74 |

**Mission conclusions:**

**High Uncertainties on:**

-Radiative heat flux (≈20%)

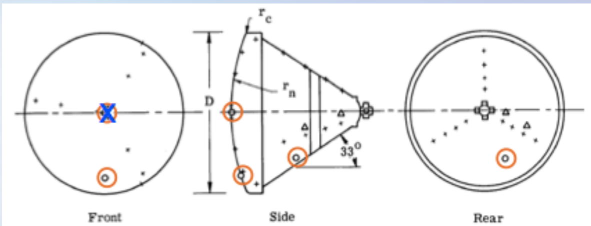
-Ablation product impacts on heat fluxes

-Ablation rate (intrusive methods or indirect measurement with velocity gradient)

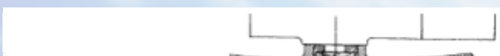
-TPS sizing (≥20% margin)

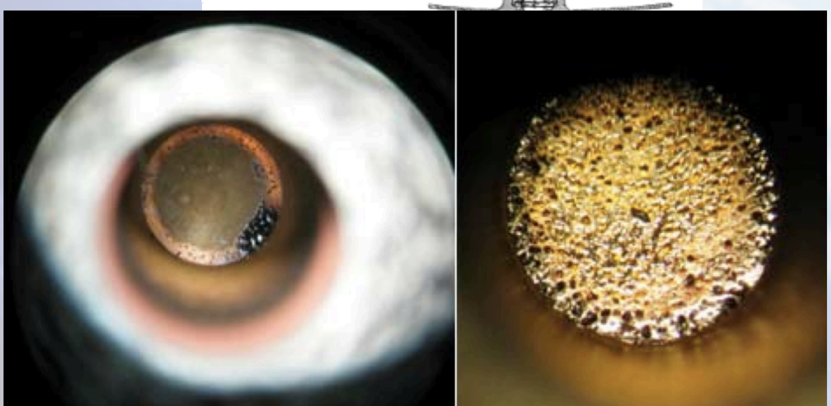
# Introduction

## -Problematic-




Fire II architecture





Preci, et Al., **Development of a Combined Sensor System for Atmospheric Entry Missions**, 7th European Symposium on Aerothermodynamics for Space Vehicles

**Mission conclusions:**

**High Uncertainties on:**

-Radiative heat flux (≈20%)

→ -Ablation product impacts on heat fluxes

-Ablation rate (intrusive methods or indirect measurement with velocity gradient)

-TPS sizing (≥20% margin)

# Introduction

-Problematic-

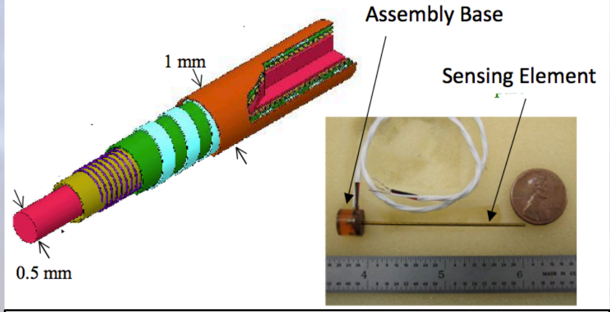
**Mission conclusions:**

Fire II architecture → **High Uncertainties on:**
-Radiative heat flux (≈20%)

-Ablation product impacts on heat fluxes

ARAD probe (Galileo, MSL) → -Ablation rate (intrusive methods or indirect measurement with velocity gradient)

-TPS sizing (≥20% margin)




D. M. Empey, et al., **NASA Application of TPS Instrumentation in Ground and Flight, IPPW 9**

# Introduction

-Problematic-

**Mission conclusions:**

Fire II architecture → **High Uncertainties on:**
-Radiative heat flux (≈20%)

-Ablation product impacts on heat fluxes

ARAD probe (Galileo, MSL) → -Ablation rate (intrusive methods or indirect measurement with velocity gradient)

-TPS sizing (≥20% margin)

→ Both systems impose strong design constrains on the mission and are considered as highly intrusive technics only suitable for a certain range of applications

# Introduction

## -What to do?-

Design criteria:

- Find an instrument with a small mass/form factor

  (multiple measurement on a reentry vehicle)

- Able to measure radiative flux and TPS recession rate a the same location and for the full duration of the reentry to correlate Radiation/Ablation coupling

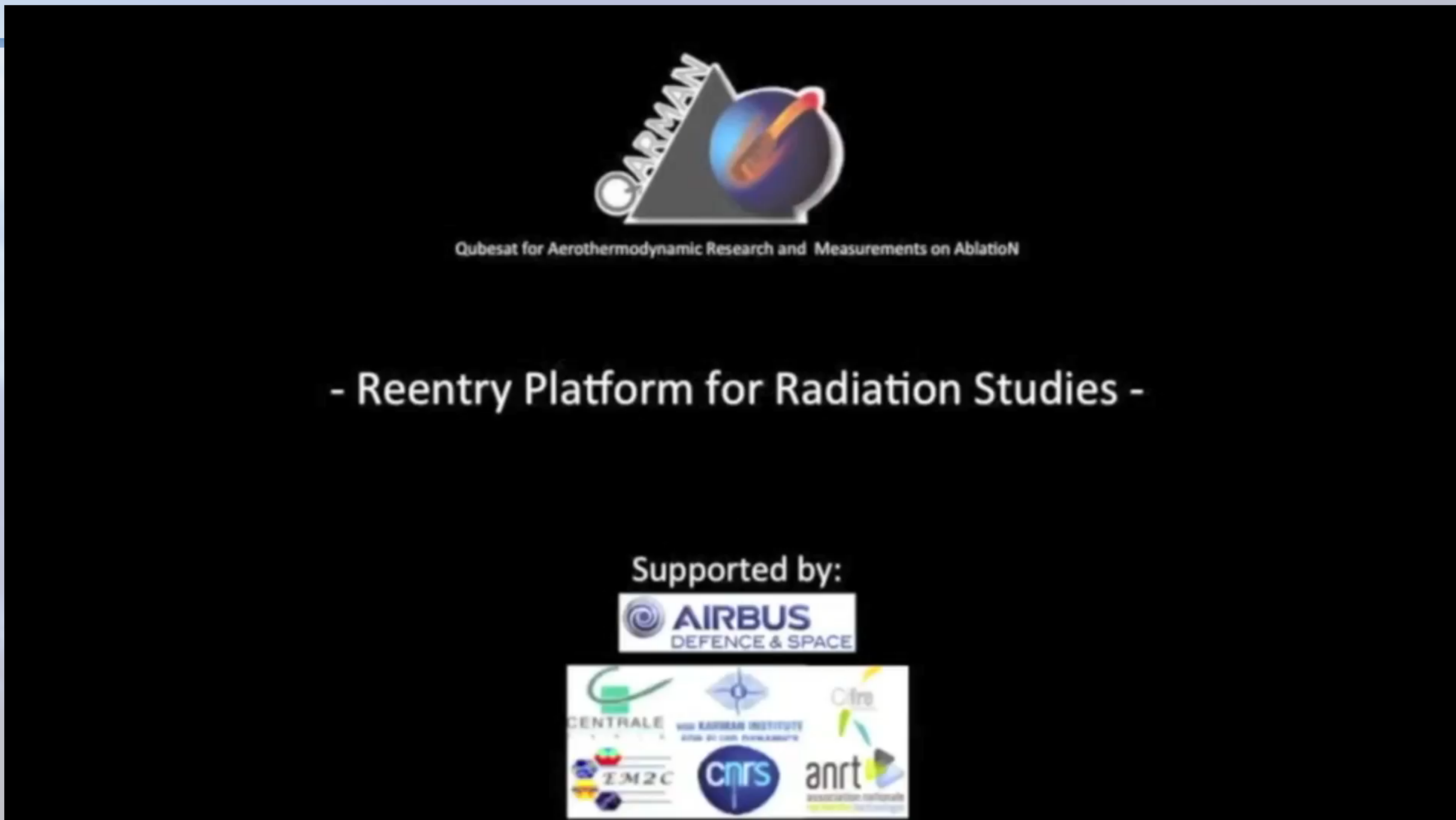
  (resistant to optical access pollution by ablation products)

- Minimal impact on the platform and highly flexible to mission/TPS materials

→ Necessity of in-flight qualification ASAP in order to be considered suitable for the coming mission proposals

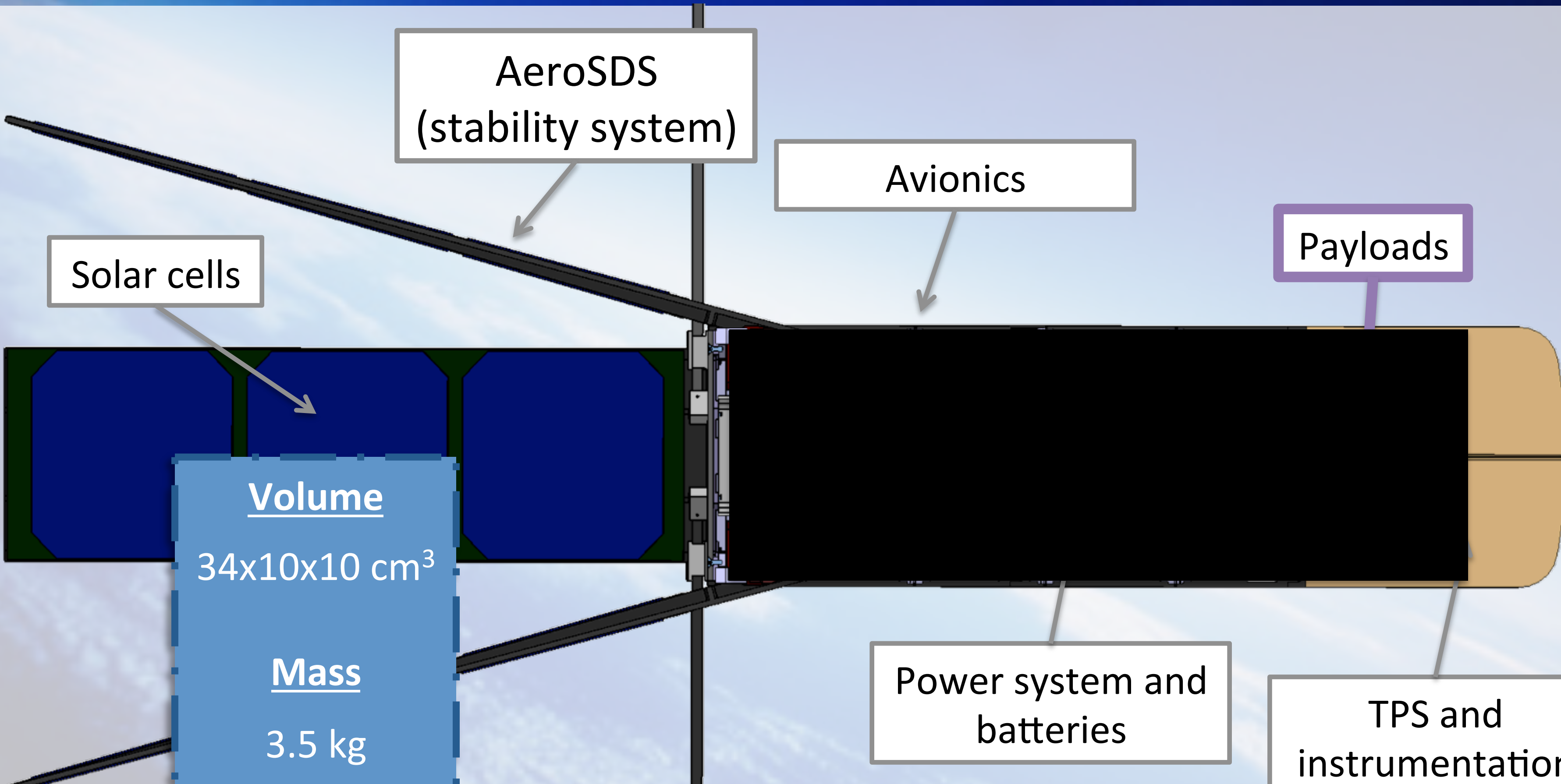
# QARMAN Platform

-Mission Scenario-



# QARMAN Platform

-System Design-




**Volume**

34x10x10 $cm^3$

**Mass**

3.5 kg

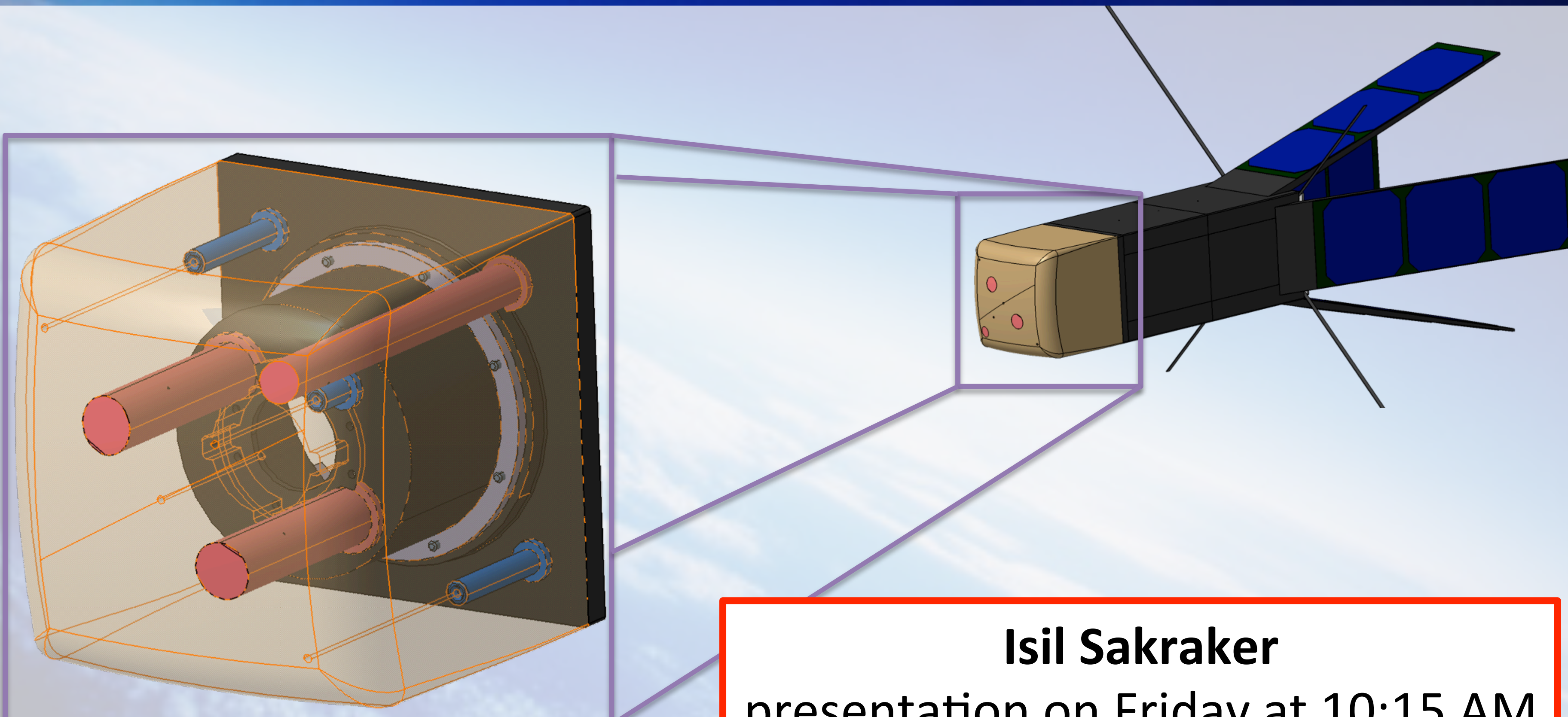
**Flight**

End 2015

Collaboration within the QARMAN team

# QARMAN Platform

-Want to know more?-



**Isil Sakraker**
presentation on Friday at 10:15 AM

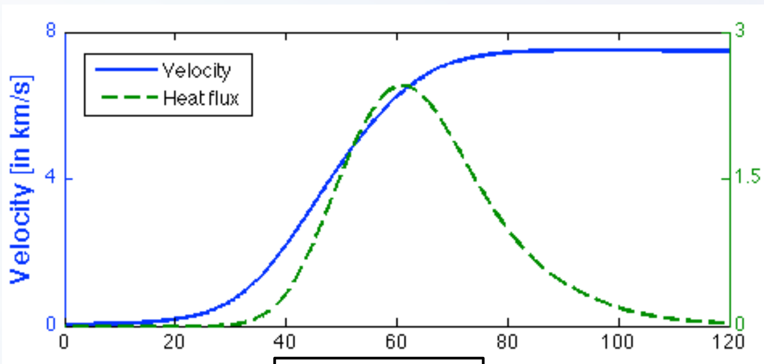
# QARMAN Platform

-Is QARMAN Platform Relevant?-

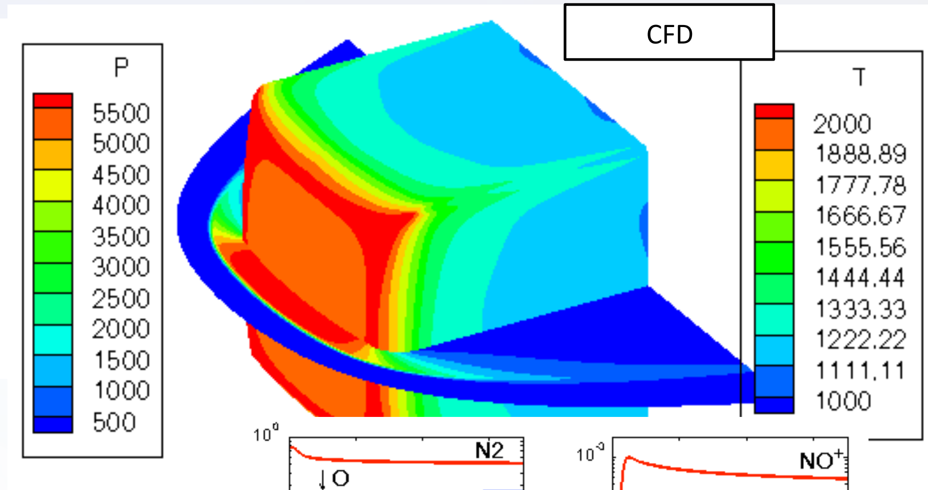
| Mission | Year | Entry speed [km.s$^{-1}$] | Altitude range [km] | Spectral range [nm] | Spectral resolution [nm] | Focus |
|---|---|---|---|---|---|---|
| FIRE I | 1964 | 11.5 | 70-89 | 300-600 | 4 | Coupled ablation/ radiation |
| FIRE II | 1965 | 11.5 | 40-83 | 300-600 | 4 | Coupled ablation/ radiation |
| BSUV I | 1990 | 3.5 | 38-70 | 200-400 | 1 | UV diagnostic |
| BSUV II (UVDE) | 1991 | 5.1 | 62-110 | 200-400 | 1 | UV diagnostic |
| Ground observations (Stardust, ATV 1 and Hayabusa) | 2006<br>2008<br>2010 | >12<br>7.8<br>>12 | ? | 300-2000 | 0.1-20 | Global observation |
| EXPERT | 2013? | 5 | ? | 200-850 | 1.5 | Build a database |
| QARMAN | 2015 | 7.6-7.8 | 50-120 | 200-1100 | 0.8-1.5 | |

# Radiative Environment

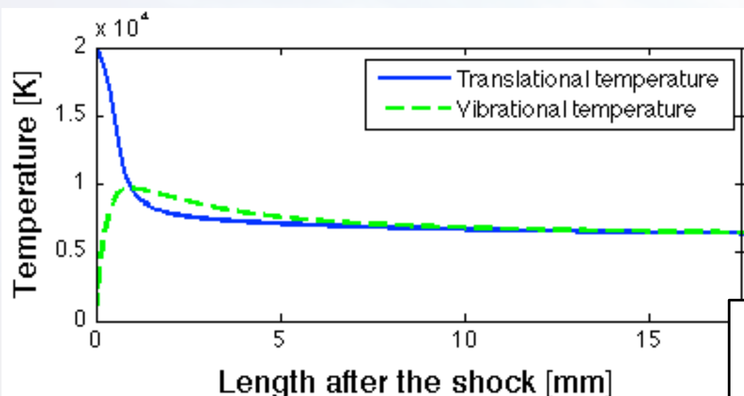
## -Prediction of the Line-of-Sight's Radiation-



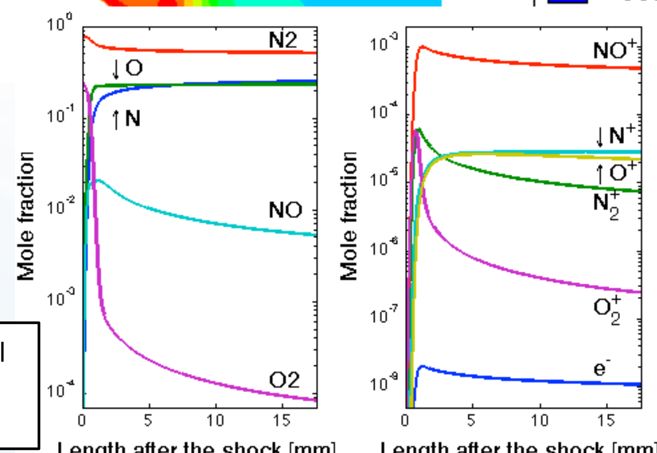

Trajectory




CFD




Thermal and Chemical properties of the stagnation line

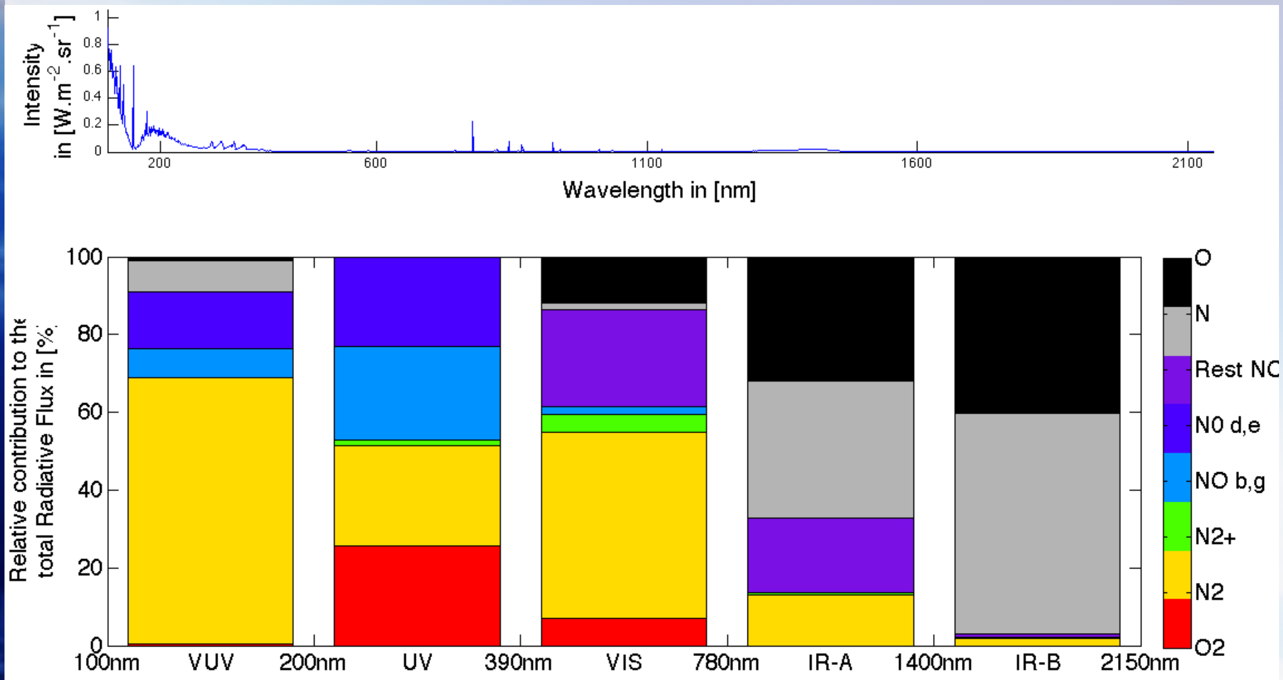



Steps leading to the calculus of Line-of-sight's radiations at a given altitude

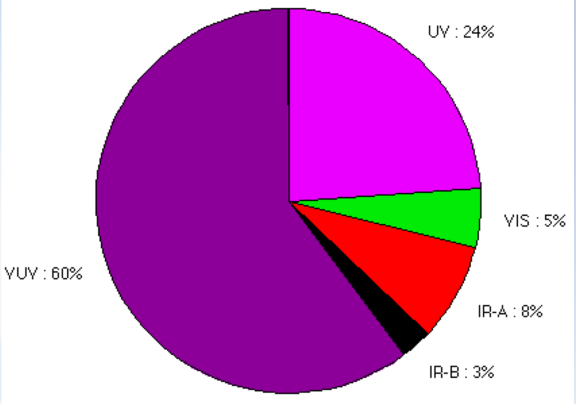
➡ High 3d dependence on phenomena

# Radiative Environment

-Prediction of the Line-of-Sight's Radiation-




**Prediction at 60 km**

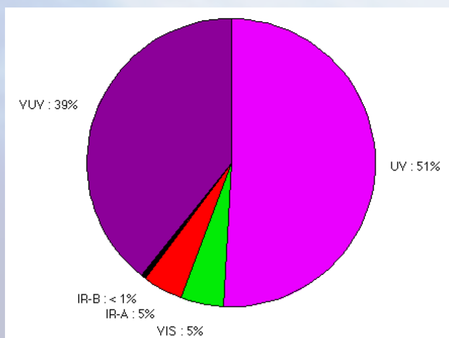



**N, O, $N^+$ and $O^+$, $N_2$, $O_2$, NO, the molecular band systems, $N_2$ 1st Pos, $N_2$ 2nd Pos, $N_2$ Birge-Hopfield, $O_2$ Schumann-Runge, NO β, NO γ, NO δ, NO ε, $N_2^+$ 1st Neg and $N_2^+$**

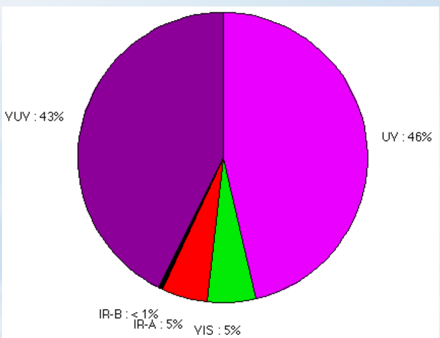
# Radiative Environment

## -Prediction of the Line-of-Sight's Radiation-

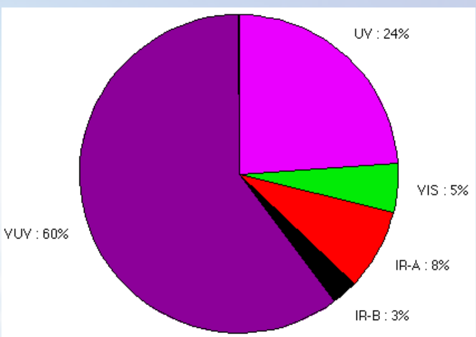
**Prediction at 50 km**



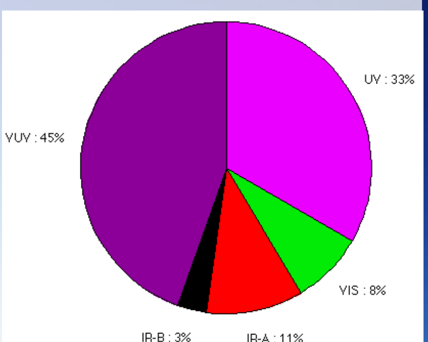

**Prediction at 55 km**




**Prediction at 60 km**




**Prediction at 65 km**




VUV UV VIS IR-A IR-B

**N, O, $N^+$ and $O^+$, $N_2$, $O_2$, NO, the molecular band systems, $N_2$ 1st Pos, $N_2$ 2nd Pos, $N_2$ Birge-Hopfield, $O_2$ Schumann-Runge, NO β, NO γ, NO δ, NO ε, $N_2^+$ 1st Neg and $N_2^+$**

# Spectrometer Payload

## -Hardware Selection-

**<u>STS-Ocean Optics</u>**

Dimensions:

**40x42x24 $cm^3$**

Weight:

**68 g**

Wavelength range:

**~450 nm**

**over [190 1100]**

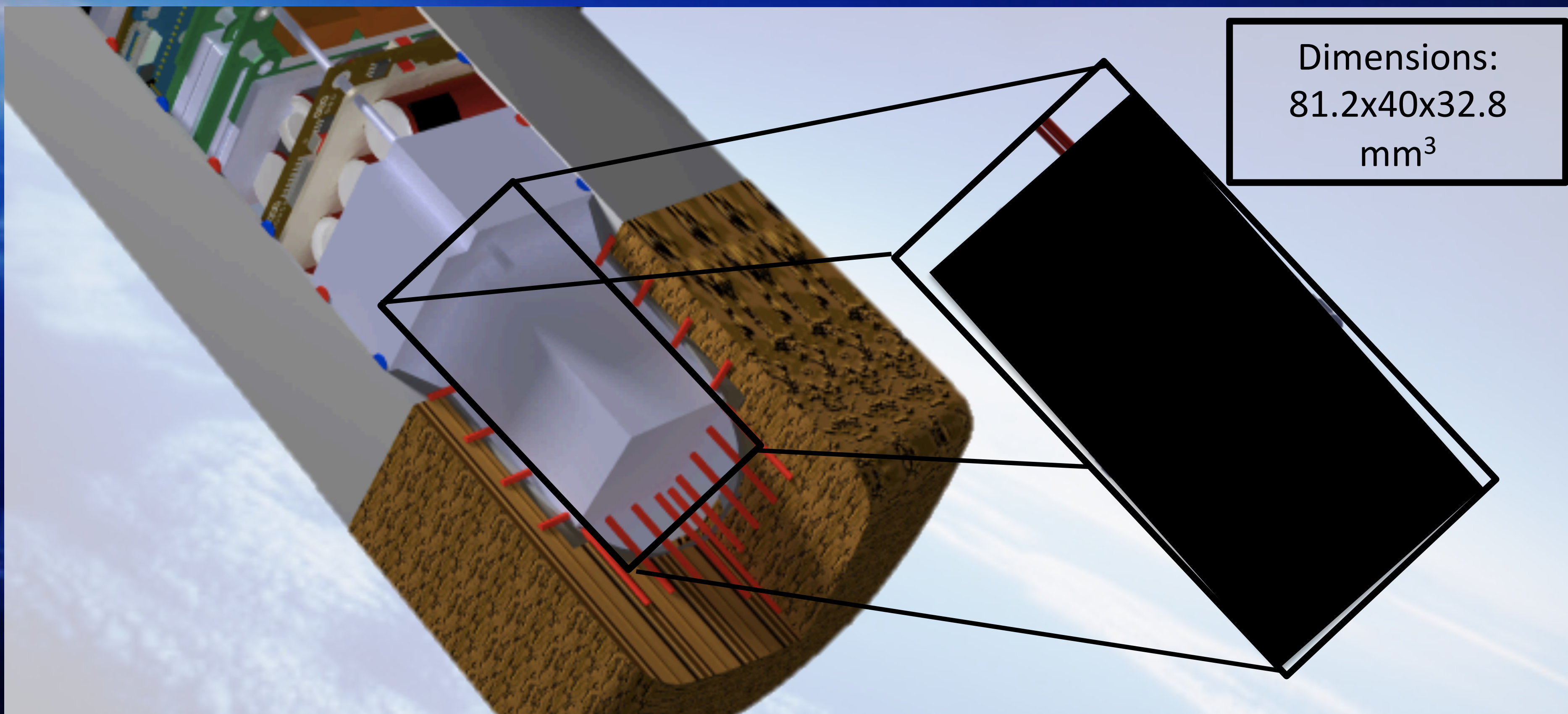
Spectral resolution:

**~1 nm**

Selected emission spectrometer for the QARMAN's platform

# Spectrometer Payload

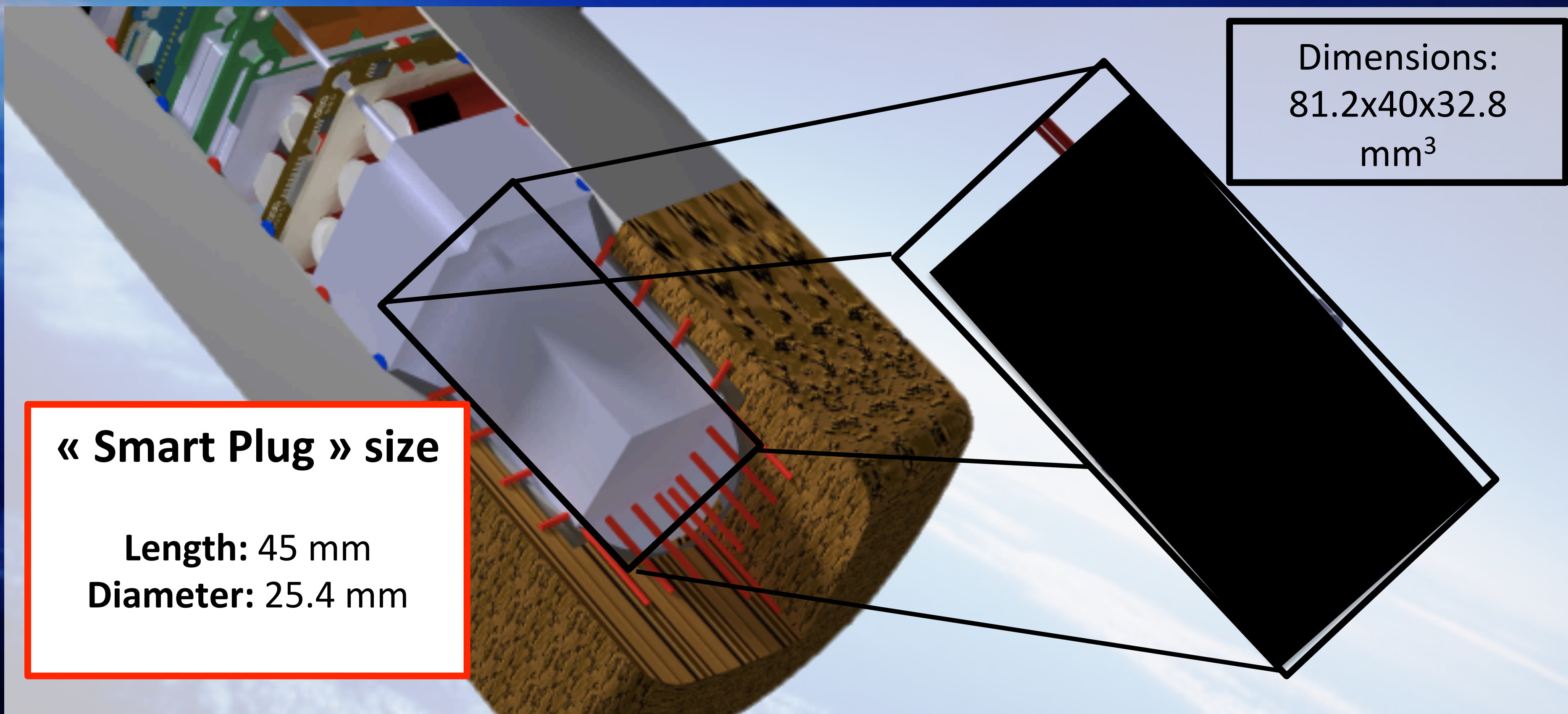
-Solution-




Integrated view of the Imbedded Nano-size Emission Spectrometer within the QARMAN's platform

# Spectrometer Payload

-Solution-



Dimensions:
81.2x40x32.8
$mm^3$

**« Smart Plug » size**

**Length:** 45 mm
**Diameter:** 25.4 mm

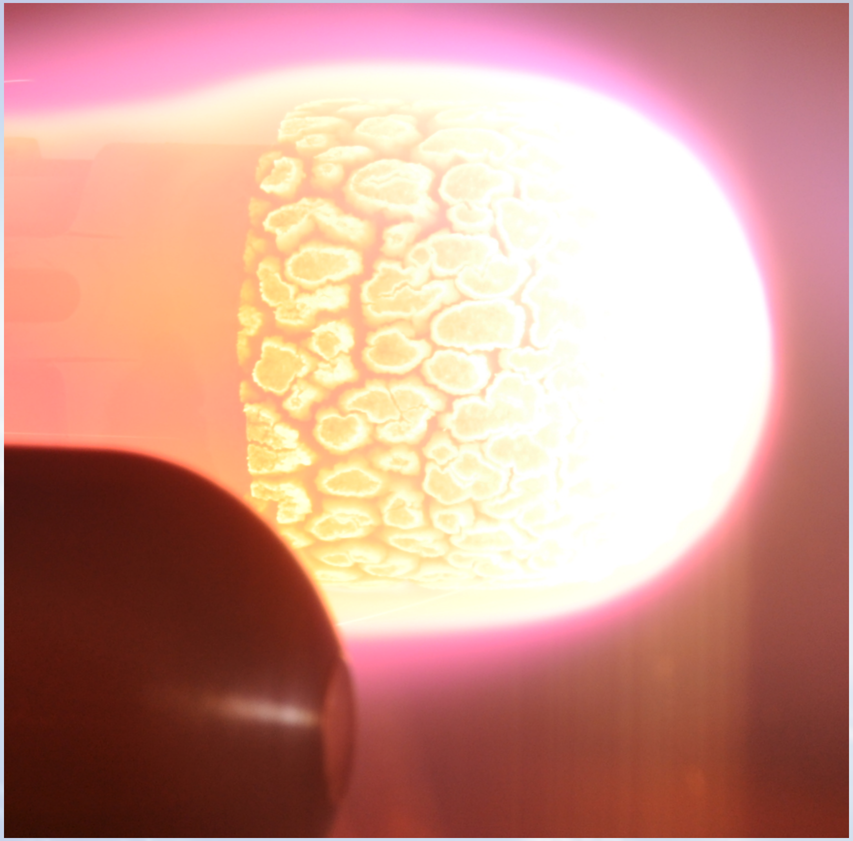
Integrated view of the Imbedded Nano-size Emission Spectrometer within the QARMAN's platform

# Spectrometer Payload

-Performences-

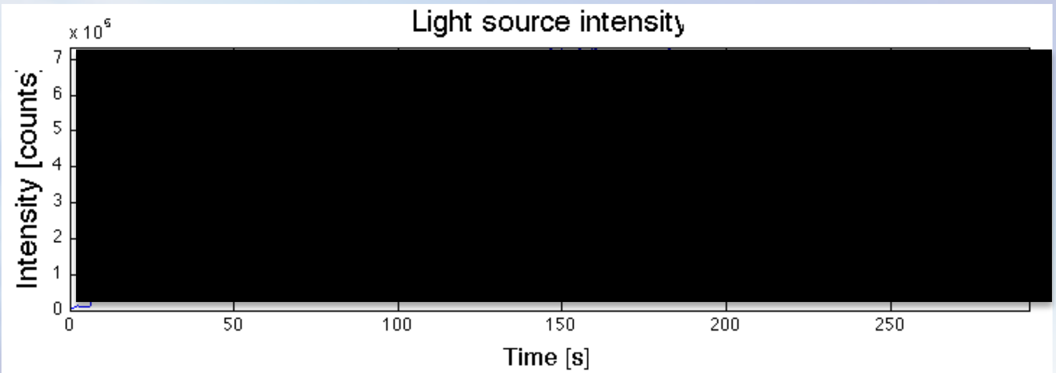
**<u>Test conditions</u>:**

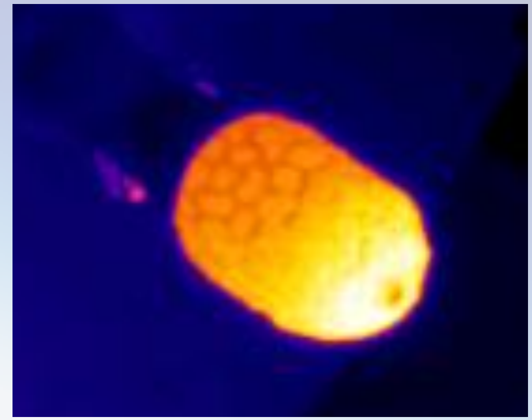
| | |
|---|---|
| HeatFlux: | 1.2 $MW/m^2$ |
| HeatLoad: | 368 $MJ/m^2$ (~5 minutes) |
| Pressure: | 100 mbar |
| Quartz tube inner diameter: | 300 mm |



# Spectrometer Payload

## -Performences-



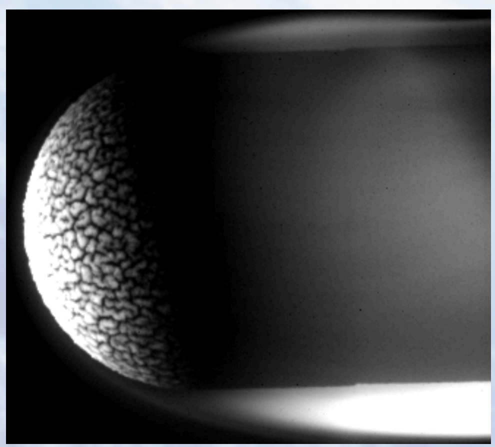
**Test conditions:**

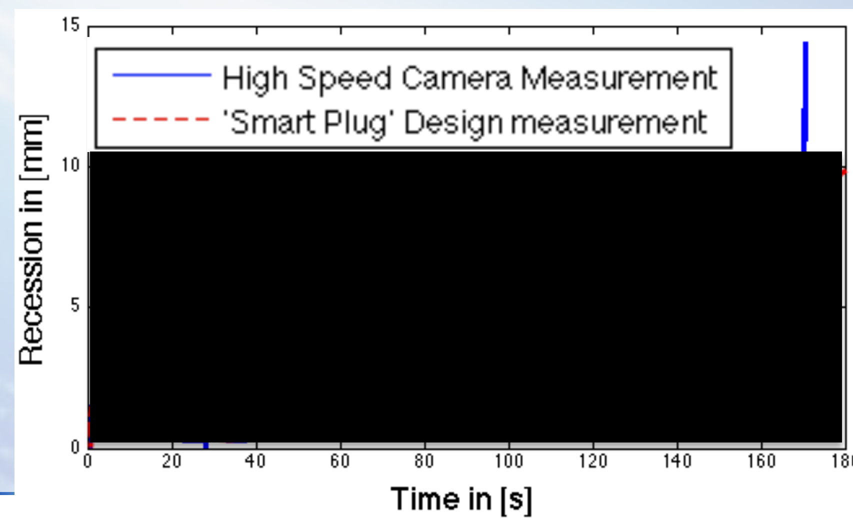
HeatFlux: 1.2 $MW/m^2$

HeatLoad: 368 $MJ/m^2$

Pressure: 100 mbar

Quartz tube inner diameter: 30 cm





# Future Prospectives

**Ongoing**

- Radiative flux prediction including ablation products with top notch tools
- Application for two patents
- Qualification Test for TRL 7 (3rd trimester 2014)

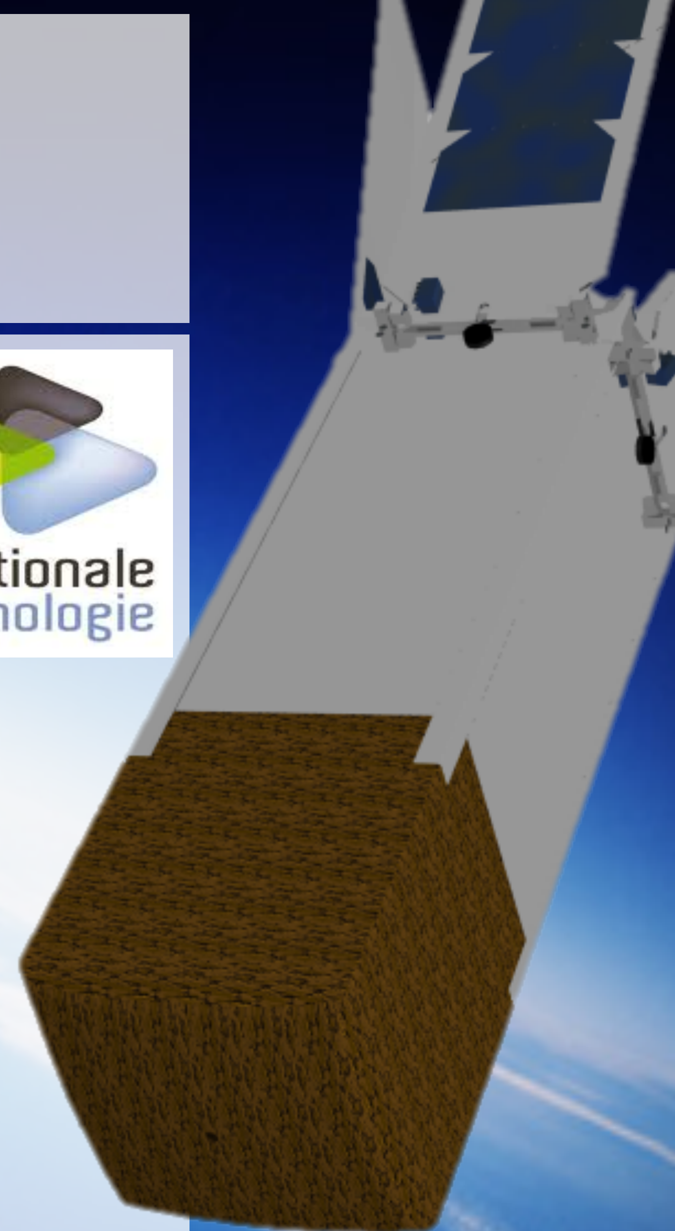
**Planned**

- Qualification with different TPS materials and at high heat flux (Asterm at 10 $MW/m^2$)
- Qualification for other atmospheres (Mars, Titan, Gas & Ice giants?)

# Conclusion

- **Efficient payload** able to measure recession rate and radiative flux in a small mass/form factor
- Equipped with photometers, **3 to 5 instruments** will enable data gathering for **validating radiation/ablation coupling** with only **few hundred grams** of payload mass with minimal bulkiness
- Will be Space Qualified (**TRL 9**) by Beginning 2016
- Will be qualified (**TRL 7**) for other atmospheres (Mars, Titan, Gas giants?)

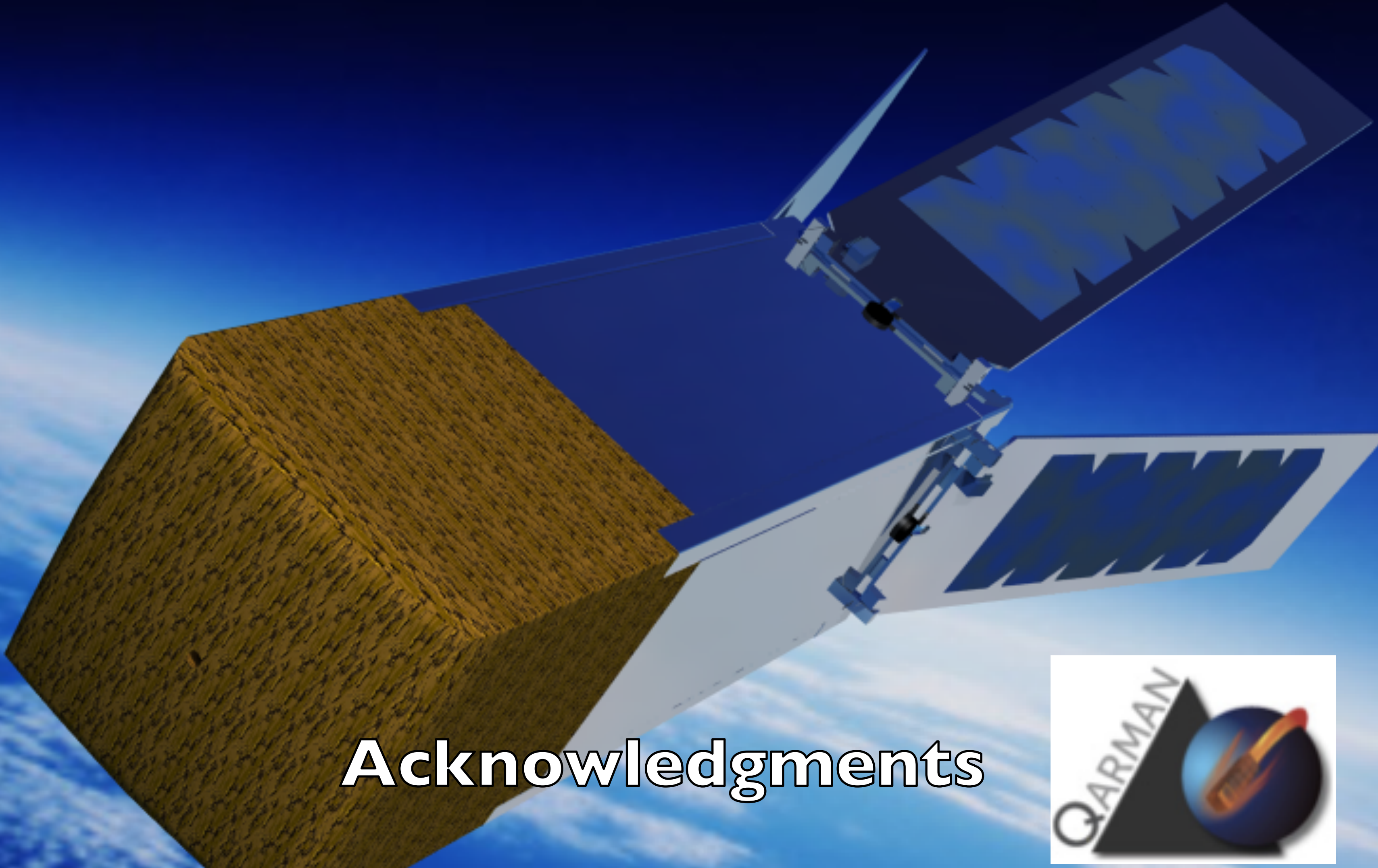
# Acknowledgements



The research leading to these results has received funding and support from AIRBUS defence & space through the ANRT's CIFRE program

Special thanks to Mr. Alexis Bourgoing, Franck Delattre, Jean-Marc Bouilly and Coumar Oudea

Thanks to the QARMAN Team members for their help and support



# Acknowledgments

# Thank you for your attention

-gilles.bailet@ecp.fr-