



# Re-Entry Platform for Radiation Studies

11<sup>th</sup> International Planetary Probe Workshop  
- Pasadena, USA, 2014 -

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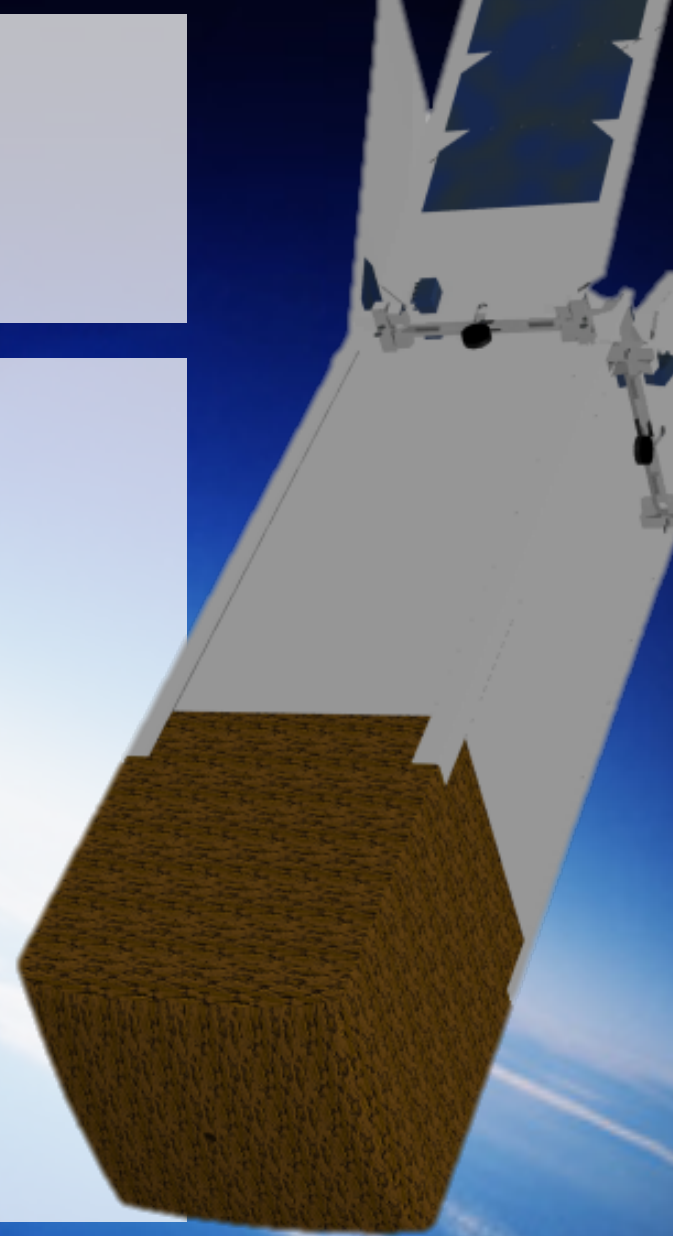
<sup>2</sup>Airbus Space and Defence, Les Mureaux, France

<sup>3</sup>Von Karman Institute, Rhodes-Saint-Genèse, Belgium



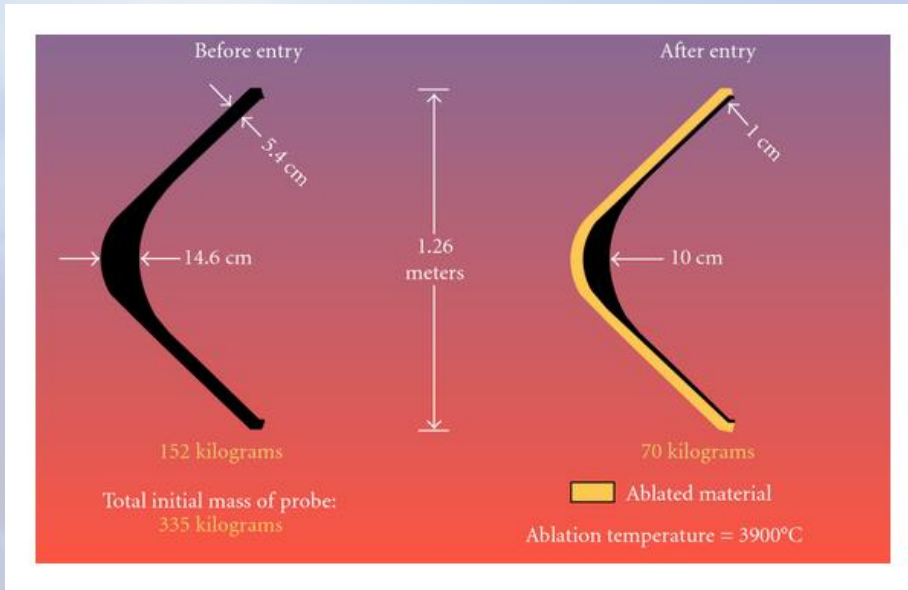
# Content

- Context
- QARMAN Platform
- Radiative Environment
- Spectrometer Payload
- Future Perspectives
- Conclusion



# Introduction

-Problematic-



## Galileo Probe

Reentered Jovian Atmosphere  
on December 7th 1995

## Mission conclusions:

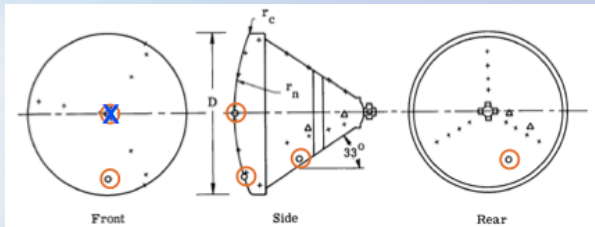
### High Uncertainties on:

- Radiative heat flux ( $\approx 20\%$ )
- Ablation product impacts on heat fluxes
- Ablation rate (no direct measurements, indirect measurement with velocity gradient and intrusive methods)
- TPS sizing ( $\geq 20\%$  margin)



# Introduction

-Problematic-



**Mission conclusions:**

Fire II architecture

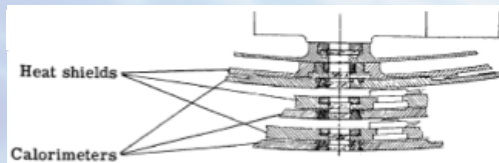
**High Uncertainties on:**

-Radiative heat flux ( $\approx 20\%$ )

-Ablation product impacts on heat fluxes

-Ablation rate (high signal/noise ratio, indirect measurement with velocity gradient)

-TPS sizing ( $\geq 20\%$  margin)



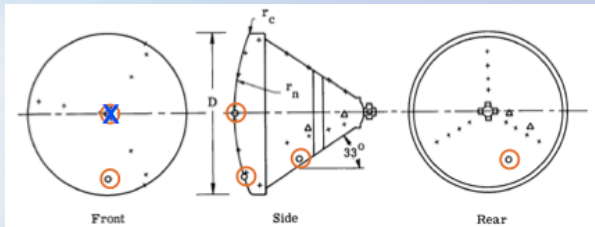
Cauchon, D. L., Radiative Heating Results from the FIRE II Flight Experiment at a Re-entry Velocity of 11.4 Kilometers per Second, TM X-1402, NASA, 1967.

Data Period	Altitude / km	Velocity / km/s
<b>Fire I</b>		
1	89.01 – 70.00	11.63 – 11.53
<b>Fire II</b>		
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

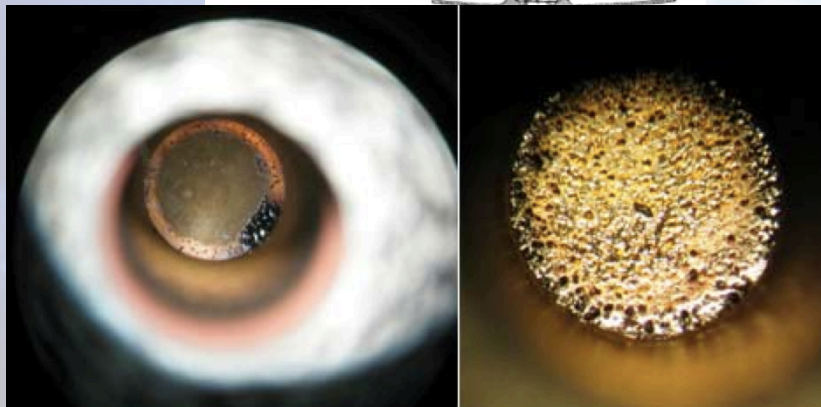


# Introduction

-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 ( $\approx 20\%$ )

➔ -Ablation product impacts on heat fluxes

-Ablation rate (high signal/noise ratio, indirect measurement with velocity gradient)

-TPS sizing ( $\geq 20\%$  margin)

# Introduction

-Problematic-

## Mission conclusions:

Fire II architecture



### High Uncertainties on:

-Radiative heat flux ( $\approx 20\%$ )

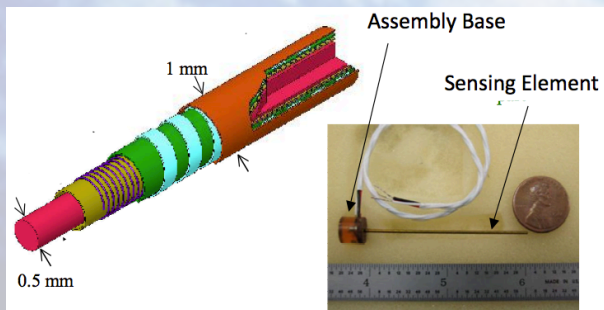
-Ablation product impacts on heat fluxes

ARAD probe (Galileo, MSL)



-Ablation rate (high signal/noise ratio, indirect measurement with velocity gradient)

-TPS sizing ( $\geq 20\%$  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 ( $\approx 20\%$ )

-Ablation product impacts on heat fluxes

ARAD probe (Galileo, MSL)



-Ablation rate (high signal/noise ratio, indirect measurement with velocity gradient)

-TPS sizing ( $\geq 20\%$  margin)



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



# Introduction

-What to do?-

Design criteria:

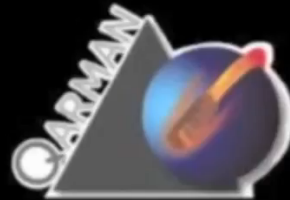
- Find an instrument with a small mass/form factor  
(multiple measurement on a reentry vehicle)
- Able to measure radiative flux and TPS recession rate at the same location and for the full duration of the reentry to correlate Radiation/Ablation coupling  
(resistant to optical access pollution by ablation 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

# QARMAN Platform

-Mission Scenario-



CubeSat for Aerothermodynamic Research and Measurements on Ablation

- Reentry Platform for Radiation Studies -

Supported by:

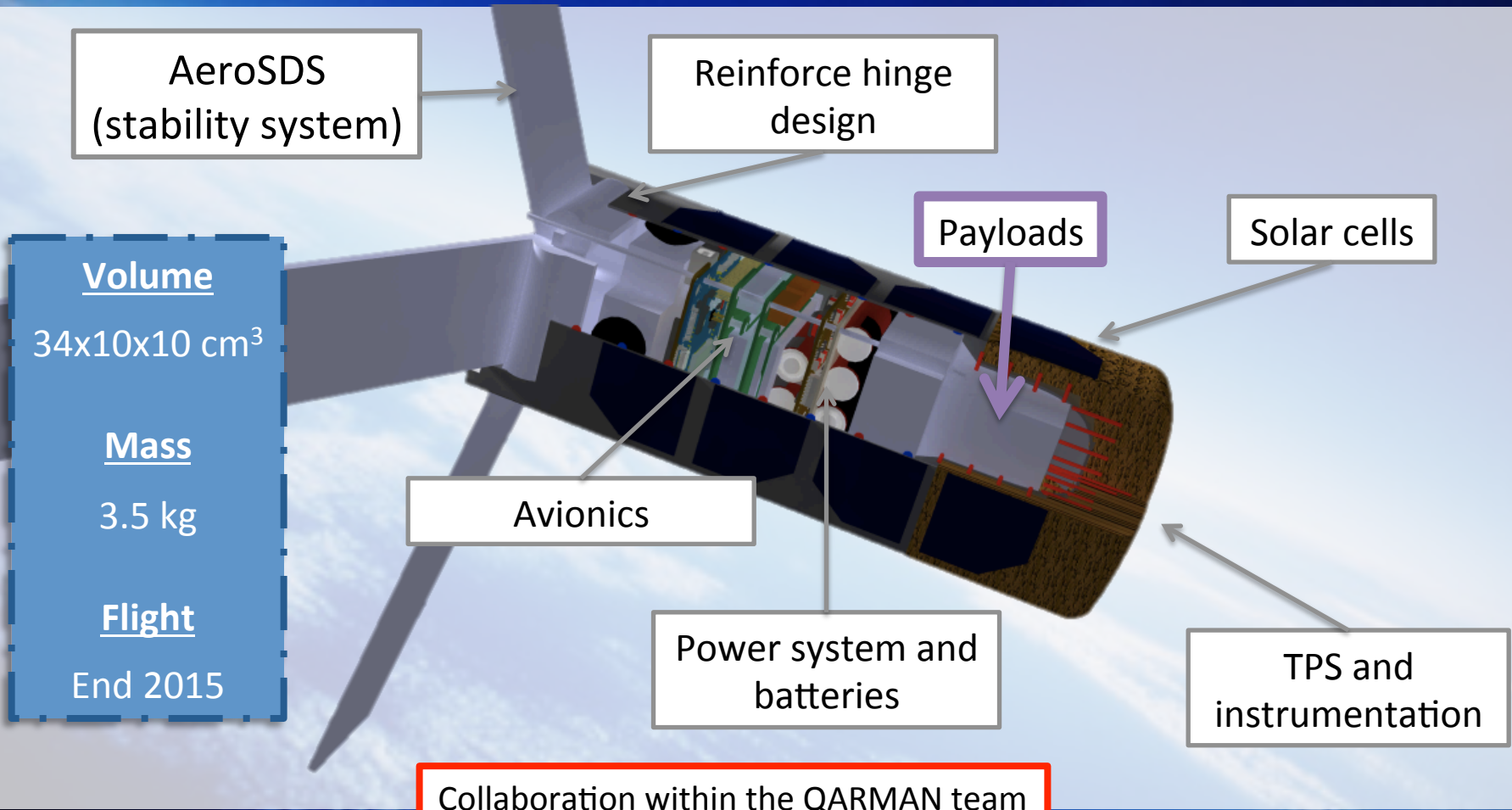


- IPPW 11, June 17<sup>th</sup> 2014 -



# QARMAN Platform

-System Design-





# QARMAN Platform

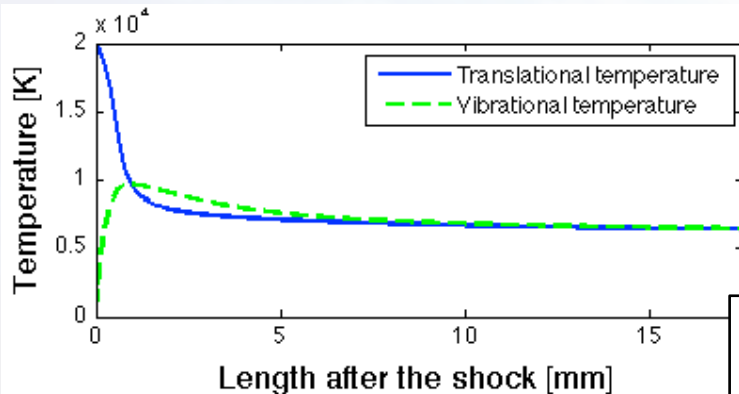
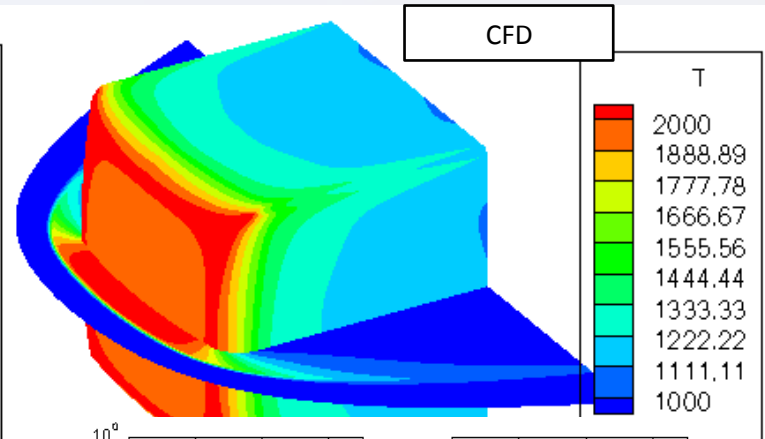
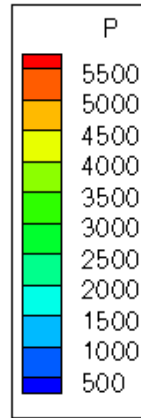
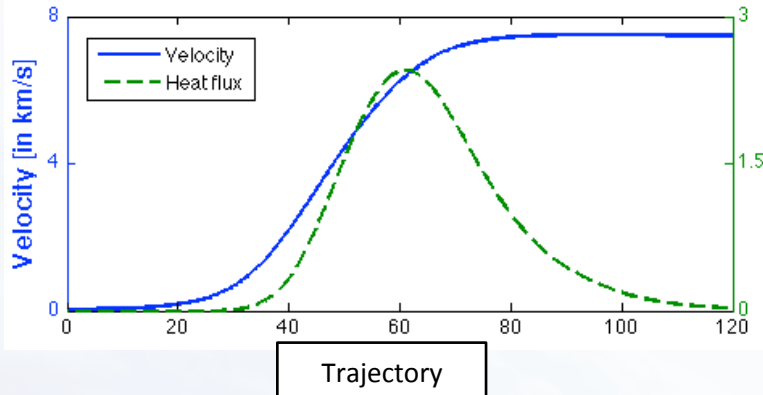
-Is QARMAN Platform Relevant?-

Mission	Year	Entry speed [km.s <sup>-1</sup> ]	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 2008 2010	>12 7.8 >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	

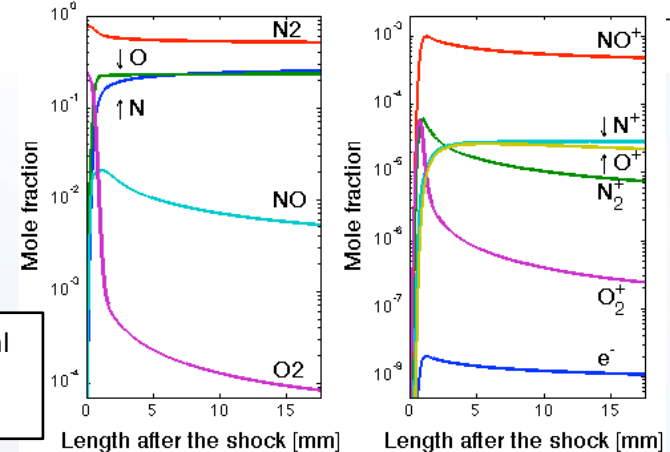


# Radiative Environment

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



Thermal and Chemical properties of the stagnation line



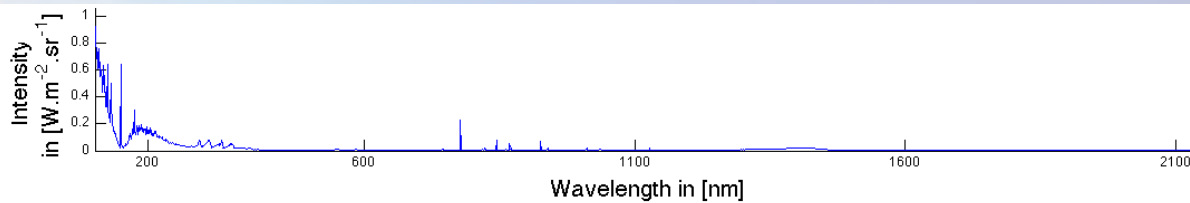
Steps leading to the calculus of Line-of-sight's radiations at a given altitude



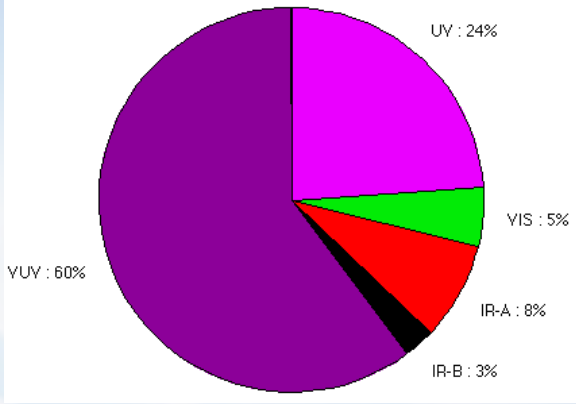
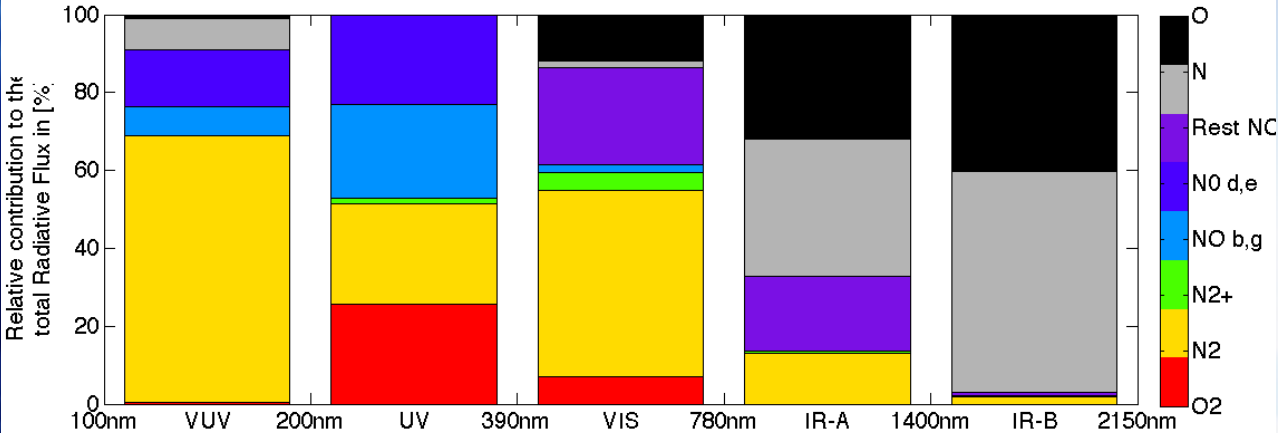
High 3d dependence on phenomena

# Radiative Environment

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



Prediction at 60 km



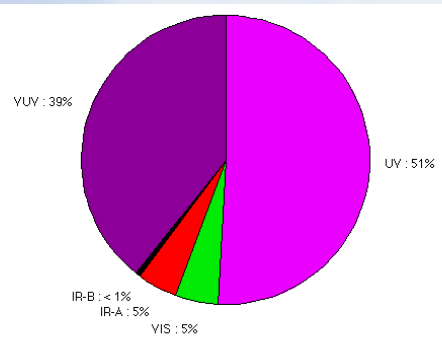
**N, O, N<sup>+</sup> and O<sup>+</sup>, N<sub>2</sub>, O<sub>2</sub>, NO, the molecular band systems, N<sub>2</sub> 1<sup>st</sup> Pos, N<sub>2</sub> 2<sup>nd</sup> Pos, N<sub>2</sub> Birge-Hopfield, O<sub>2</sub> Schumann-Runge, NO β, NO γ, NO δ, NO ε, N<sub>2</sub><sup>+</sup> 1<sup>st</sup> Neg and N<sub>2</sub><sup>+</sup>**



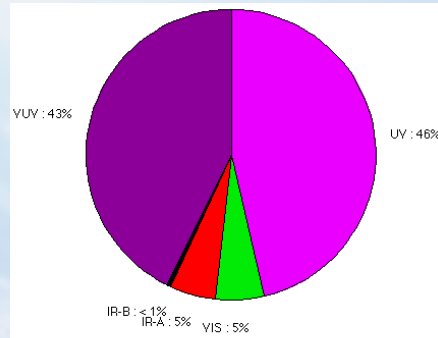
# Radiative Environment

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

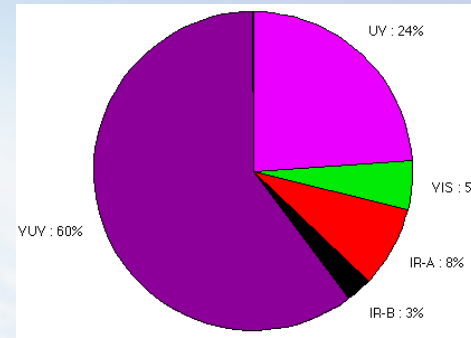
Prediction at 50 km



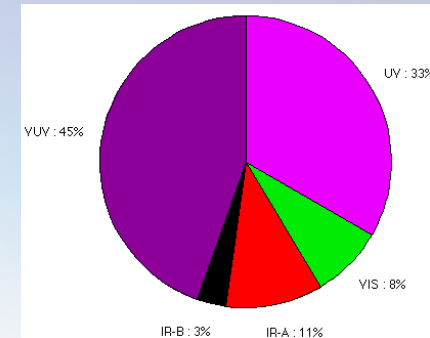
Prediction at 55 km



Prediction at 60 km



Prediction at 65 km



**N, O, N<sup>+</sup> and O<sup>+</sup>, N<sub>2</sub>, O<sub>2</sub>, NO, the molecular band systems, N<sub>2</sub> 1<sup>st</sup> Pos, N<sub>2</sub> 2<sup>nd</sup> Pos, N<sub>2</sub> Birge-Hopfield, O<sub>2</sub> Schumann-Runge, NO β, NO γ, NO δ, NO ε, N<sub>2</sub><sup>+</sup> 1<sup>st</sup> Neg and N<sub>2</sub><sup>+</sup>**

# Spectrometer Payload

-Hardware Selection-

## STS-Ocean Optics

Dimensions:

**40x42x24 cm<sup>3</sup>**

Weight:

**68 g**

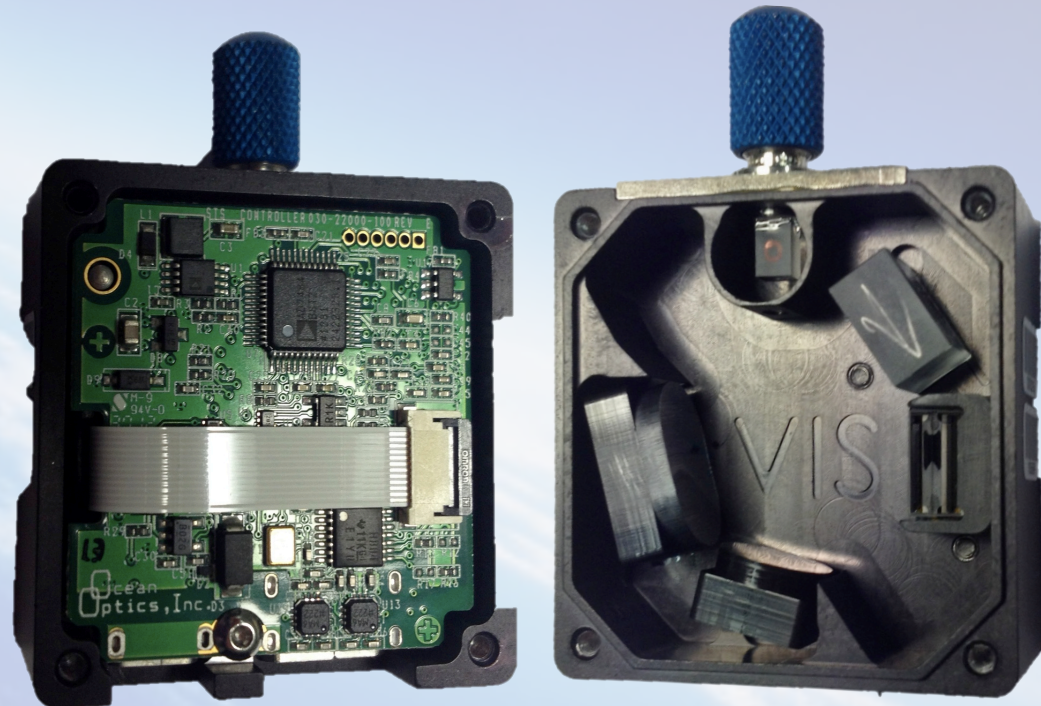
Wavelength range:

**~450 nm**

**over [190 1100]**

Spectral resolution:

**~1 nm**



Selected emission spectrometer for the QARMAN's platform

# Spectrometer Payload

-Solution-

Dimensions:  
81.2x40x32.8  
mm<sup>3</sup>

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



# Spectrometer Payload

-Solution-

Dimensions:  
81.2x40x32.8  
mm<sup>3</sup>

« 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-

## Test conditions:

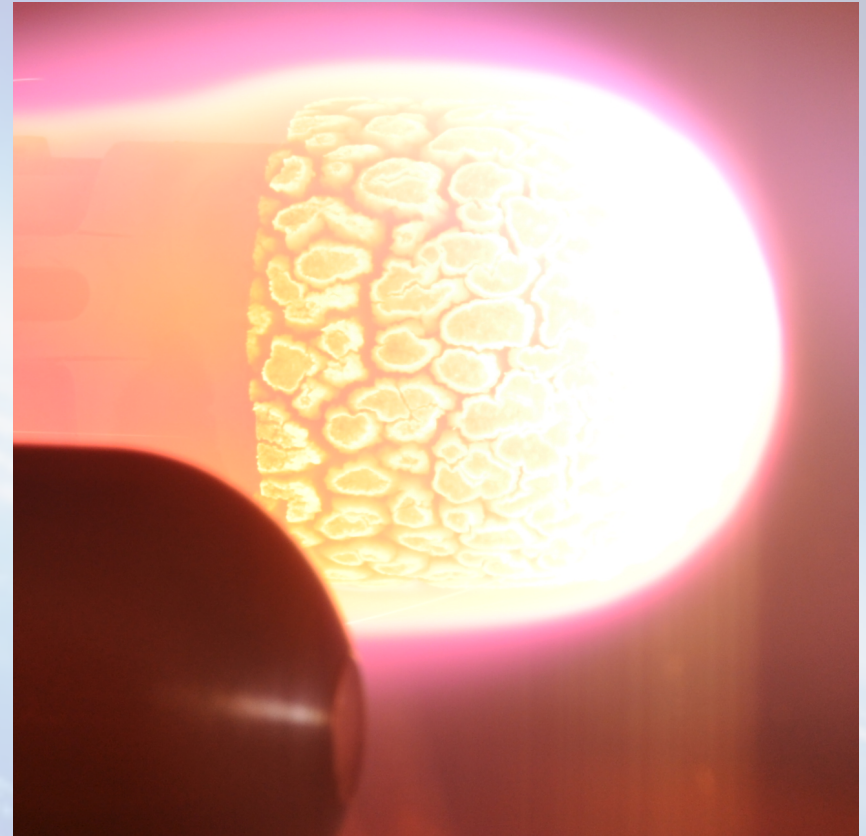
HeatFlux: 1.2 MW/m<sup>2</sup>

HeatLoad: 368 MJ/m<sup>2</sup>

Pressure: 100 mbar

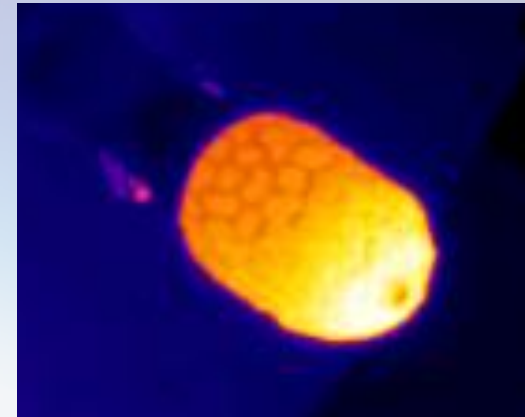
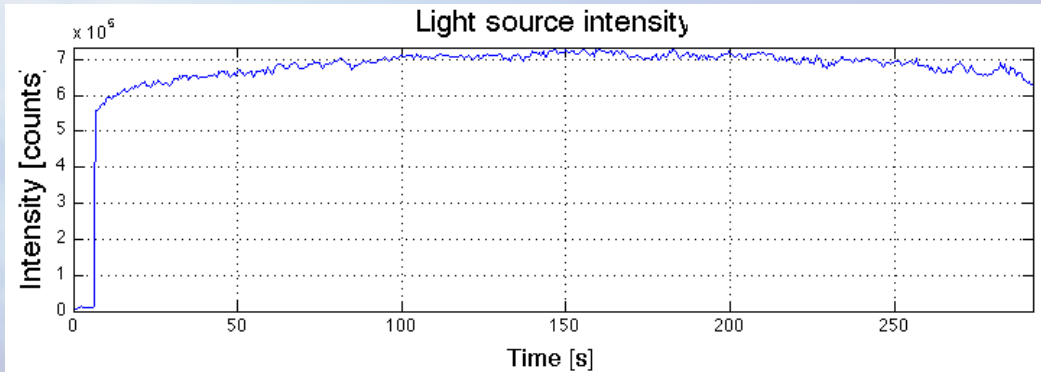
Quartz tube

inner diameter: 300 mm



# Spectrometer Payload

-Performences-



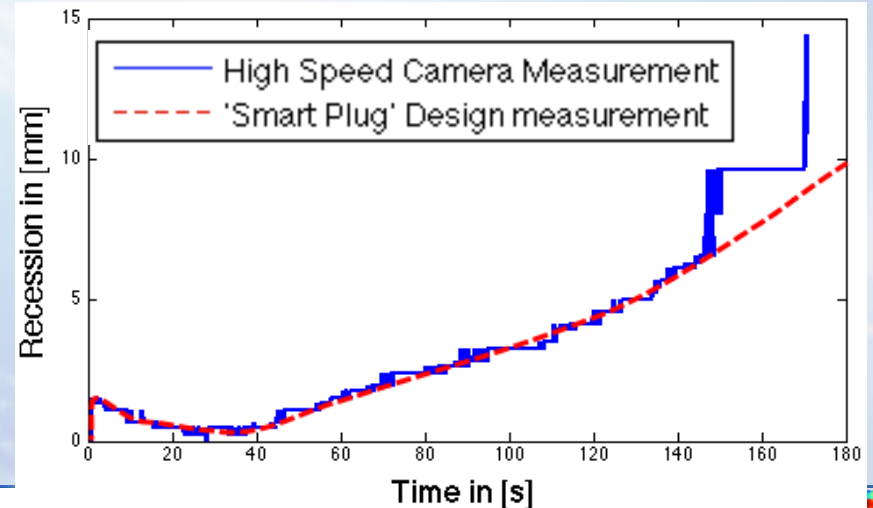
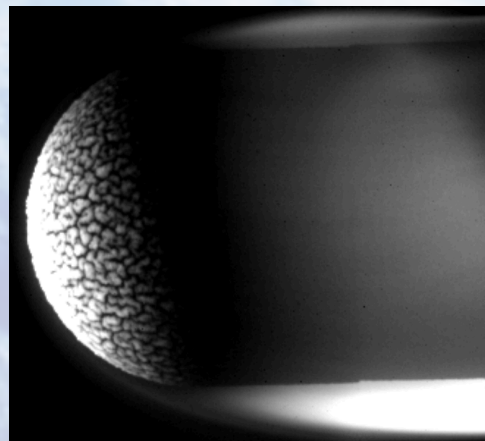
## Test conditions:

HeatFlux: 1.2 MW/m<sup>2</sup>

HeatLoad: 368 MJ/m<sup>2</sup>

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 (3<sup>rd</sup> trimester 2014)

## Planned

- Qualification with different TPS materials and at high heat flux (Asternm at 10 MW/m<sup>2</sup>)
- Qualification for other atmospheres (Mars, Titan, Gas 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?)

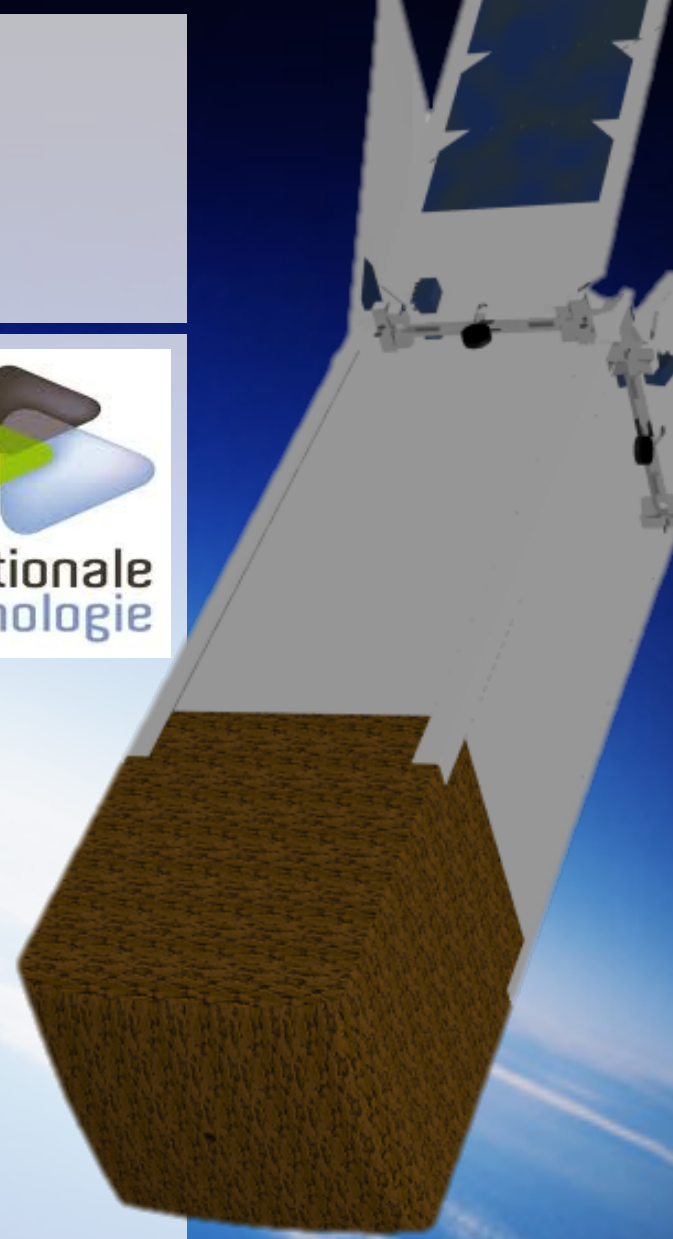
# Acknowledgements



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, Marc Dormieux and Coumar Oudea

Thanks to the QARMA? Team members for their help and support

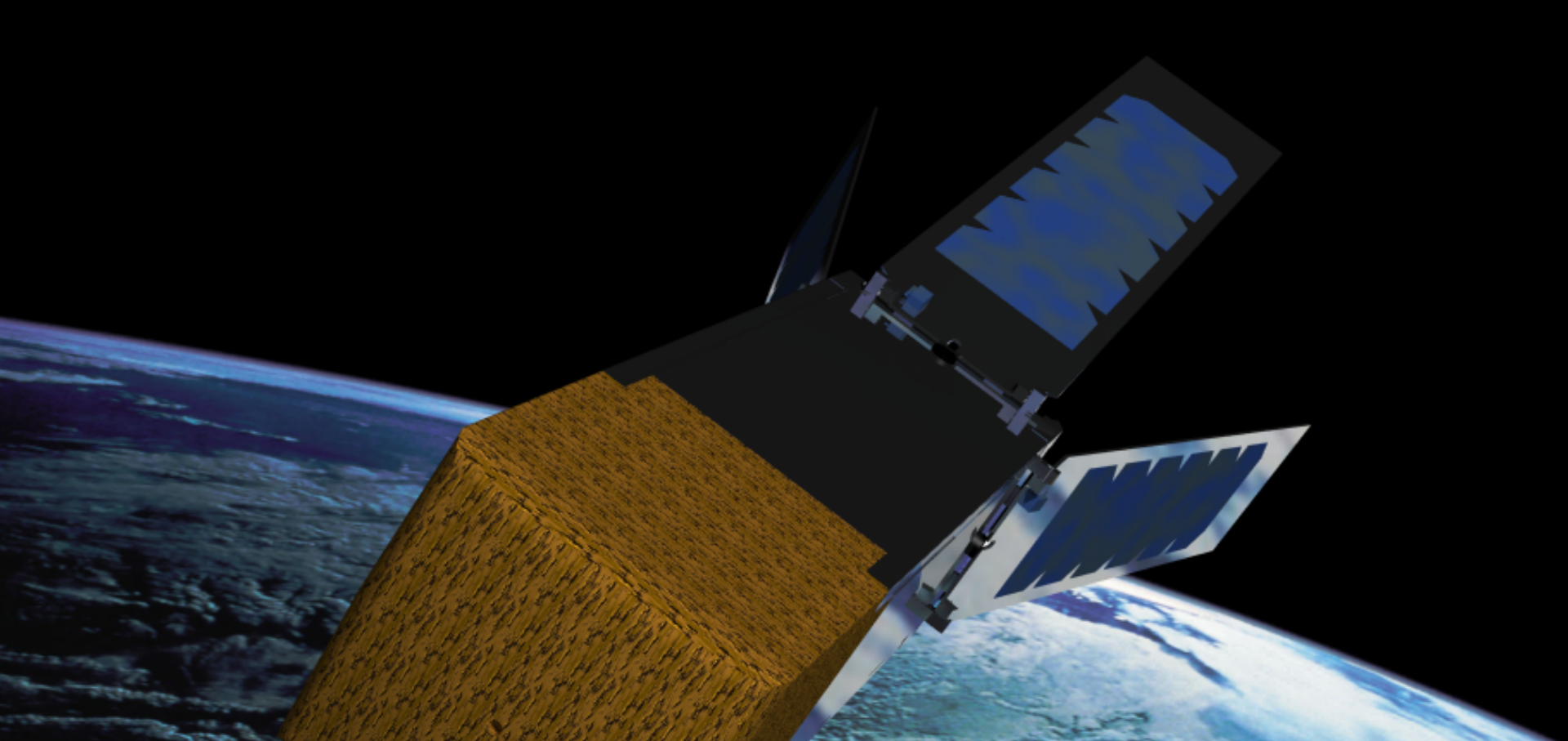


# Acknowledgments



**AIRBUS**  
DEFENCE & SPACE





Thank you  
for your attention

-gilles.bailet@ecp.fr-



# QARMAN Platform

-Preliminary design-

Reference: QARMAN proposal for QB50 call

Subsystem	Mass [g], [%]		Volume [10cm], [%]	
<b>Heat Shield</b>				
Front surface	360	20	0.63	25
Side-Panels	217	20	n/a	0
<b>Functional Unit</b>				
Structure (2U)	468	20	n/a	
OBC	161	10	0.17	10
EPS + Batteries	248	10	0.33	25
Solar Panels	336	5	n/a	
Communication	263	10	0.46	10
<b>Payloads</b>				
Acquisition PCB	240	20	0.25	25
Sensors	469	20	0.25	25
AeroSDS	300	20	0.5	25
<b>Total</b>	<b>3062</b>		<b>2.59</b>	

