Thermal Analysis for a Langmuir Probe to be used in a Re-entry CubeSat Mission

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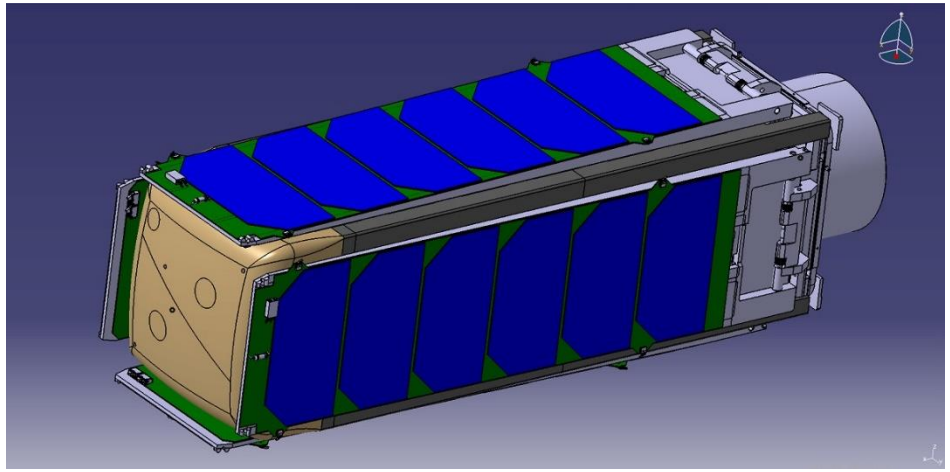
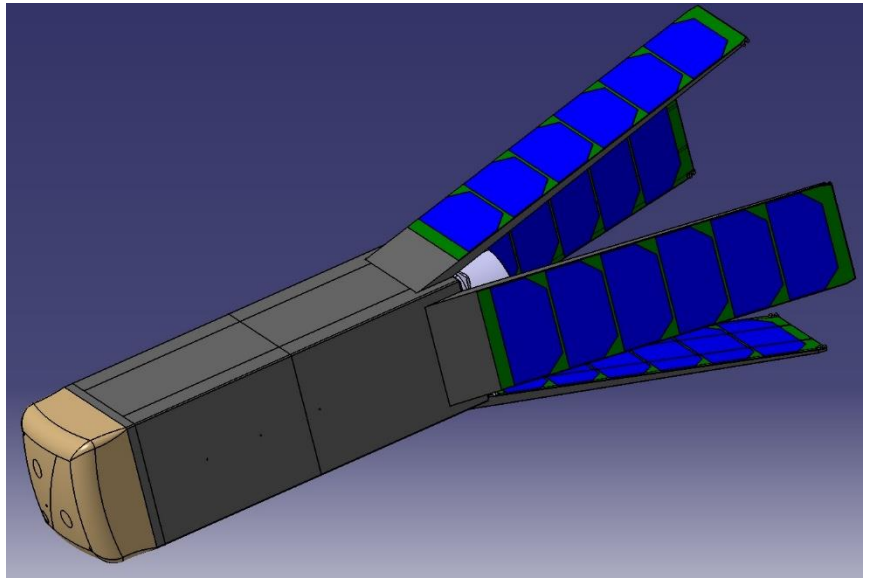
Outline

- Motivation
- Literature Review
- Designs of Langmuir Probes
- Results and Discussion
- Concluding Remarks

Motivation (1/2)

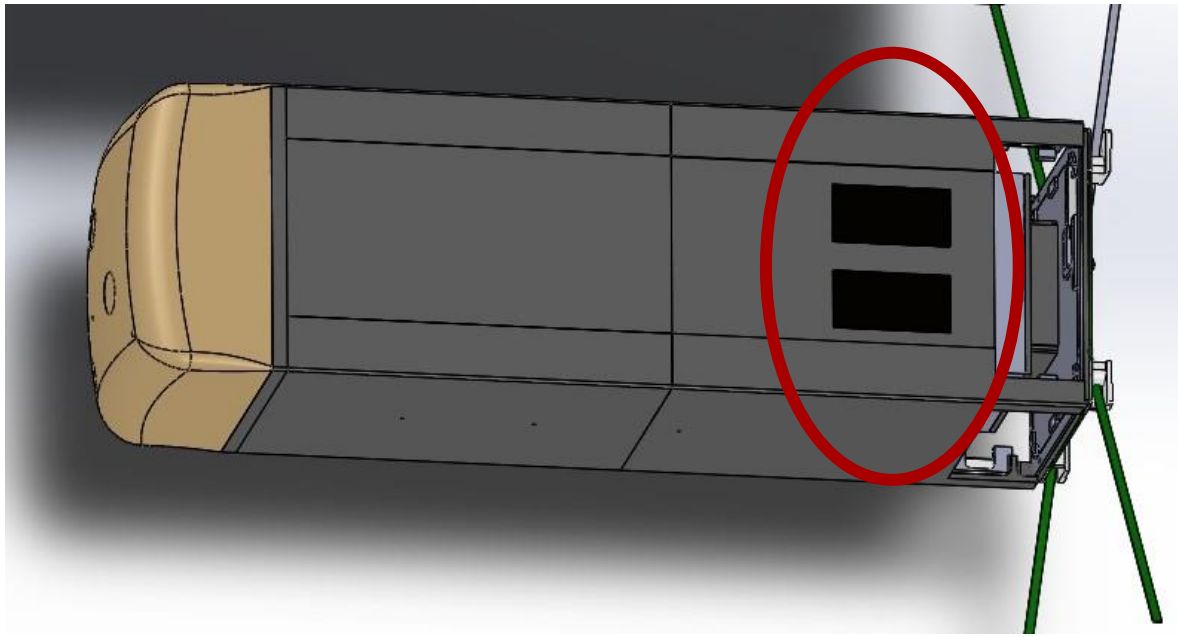
- Re-entry CubeSat (3U)
- Transmit data before impact
- Langmuir probe
- OBC thermally insulated from exterior





Motivation (2/2)

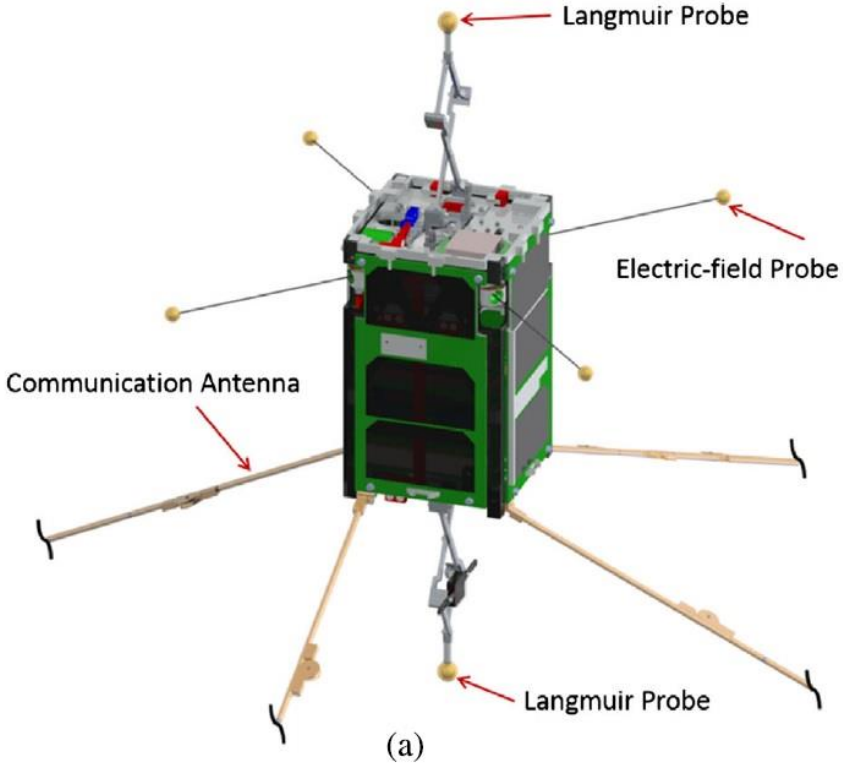
- FLP located on the exterior
- Electrically conductive and thermally conductive
- Spacial considerations for heat sink



Literature Review (1/3)

Fish, C.S., Swenson, C.M., Crowley, G. et al. 2014

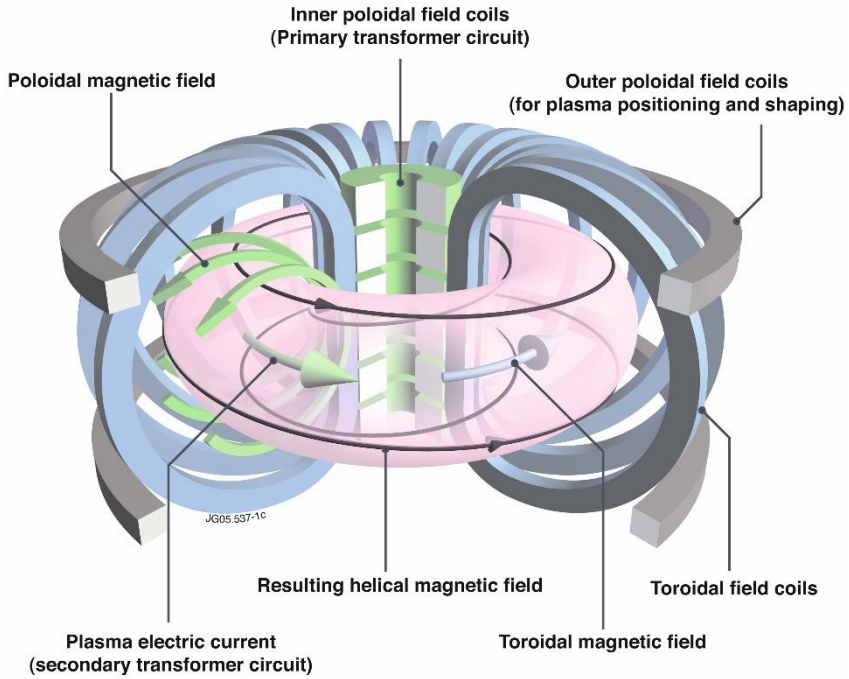
- Dynamic Ionosphere CubeSat Experiment (DICE) mission
- Two identical 1.5U CubeSats with two single Langmuir probes each for in situ measurements



Literature Review (2/3)

Cacace, M., Batal, T., Corre, Y., et al. 2015

- Plasma measurements in bigger apparatus include actively cooling systems
- WEST project (W-Environment in Steady-State Tokamak)



Tokamak example
www.euro-fusion.org

Literature Review (3/3)

Field, E.S. 2011

- Arrays of individually addressable probes with 600µm-diameter tips
- Up to 25 probes per 1cm-square tile

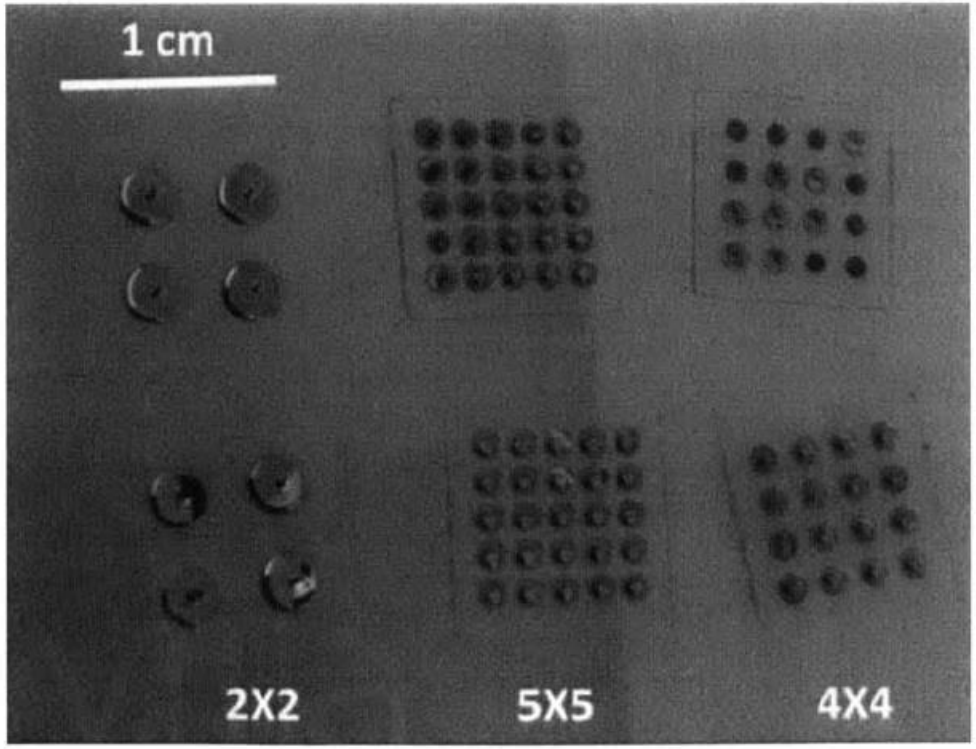


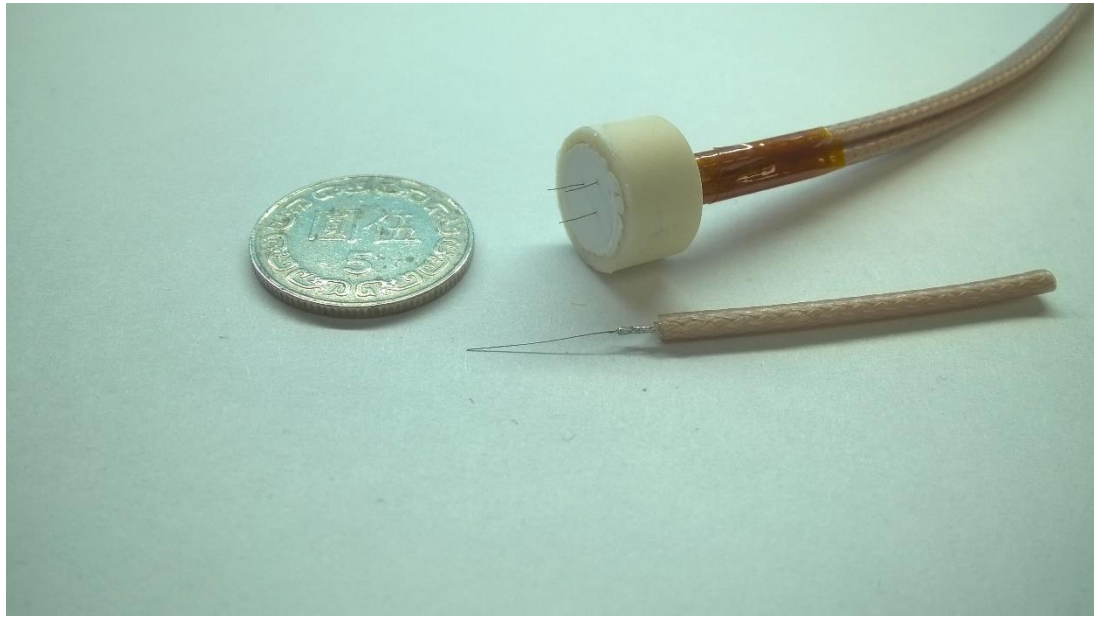
Figure 4.14: Various array sizes of MEMS Langmuir probes.

Design of Langmuir Probes (1/2)

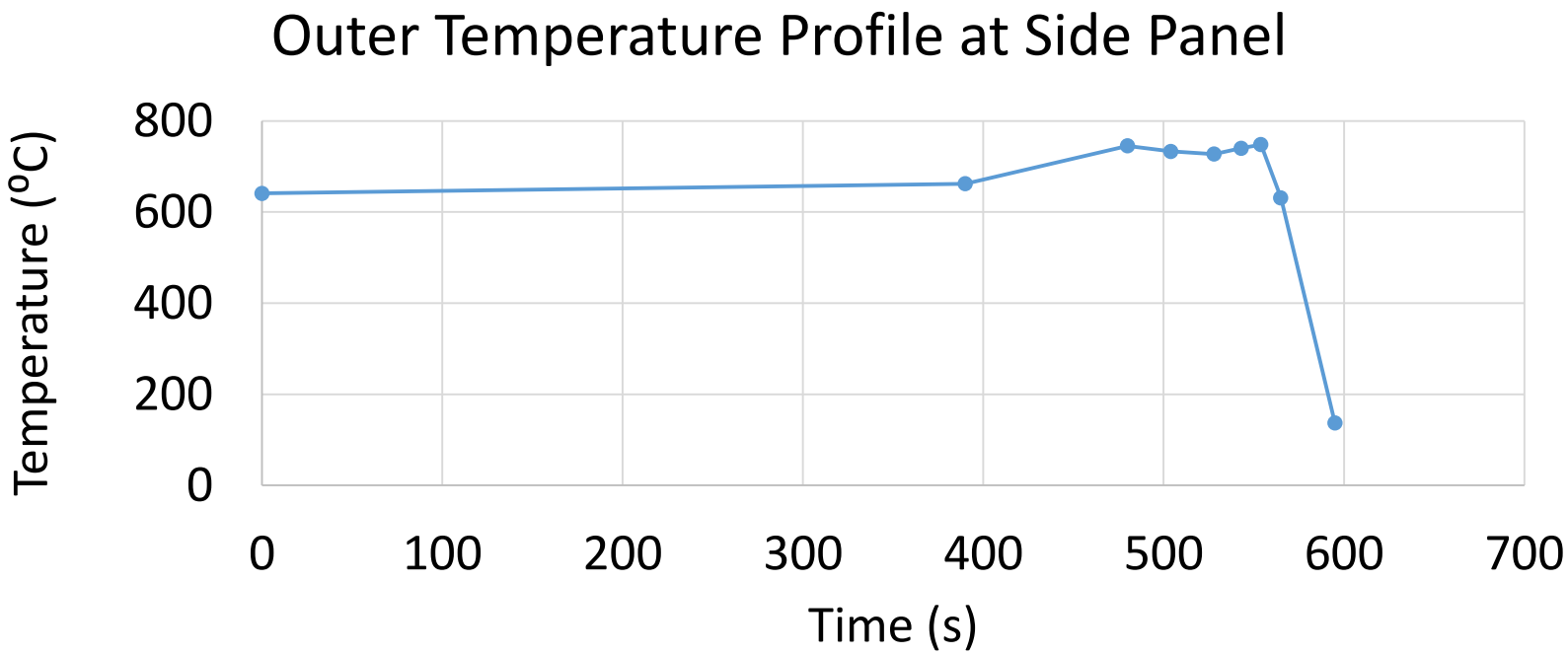
- Flush mounted double probe
- Graphite head and harness
- No aerodynamic interference
- Measurement subject to CubeSat boundary

Design of Langmuir Probes (2/2)

- Needle tip triple probe
- Stainless steel, tungsten tips and harness
- Ceramic head and heat resistant adhesive filling



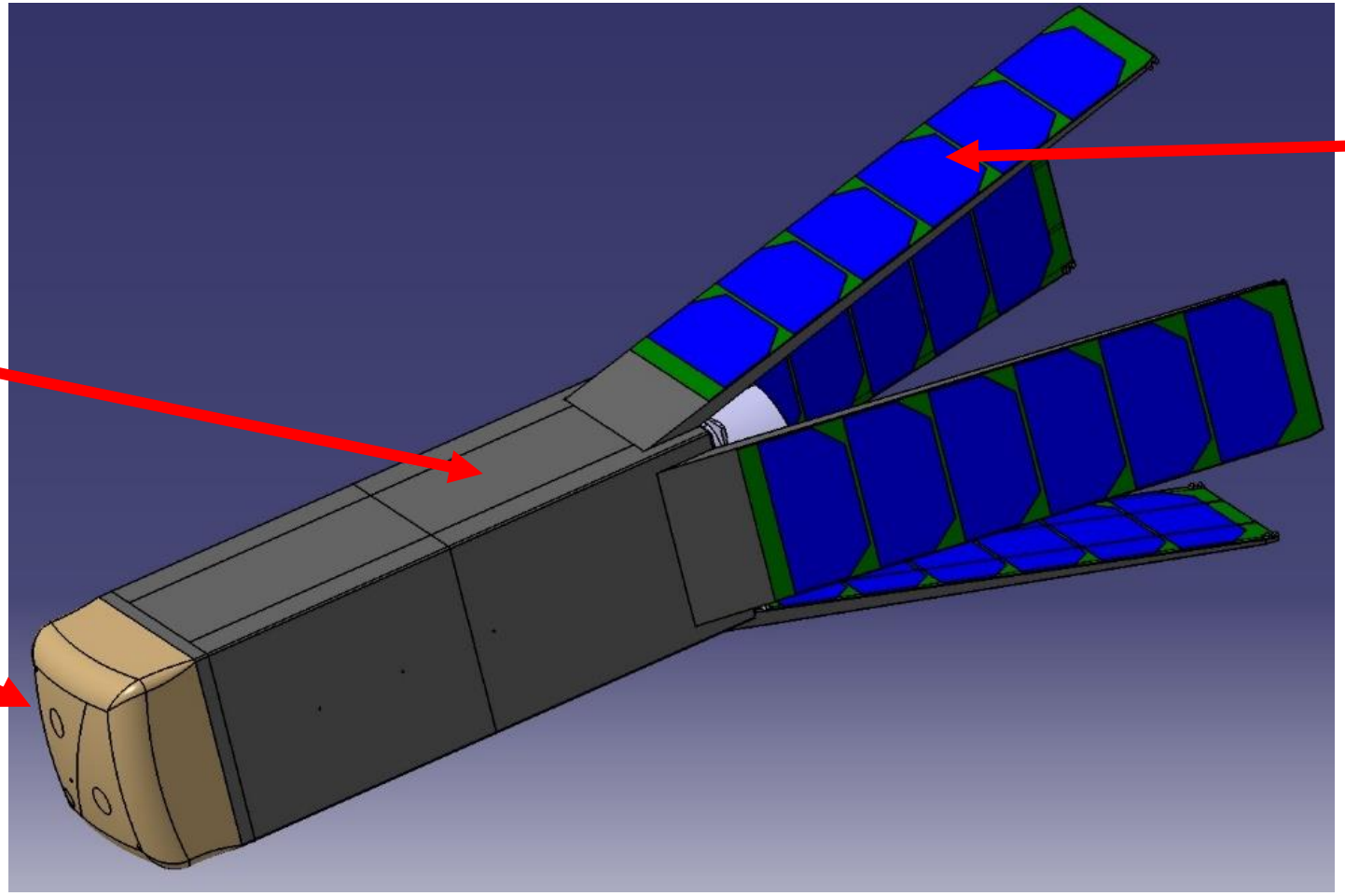
TPS Re-entry Temperature



*Data provided by von Karman Institute of Fluid Dynamics

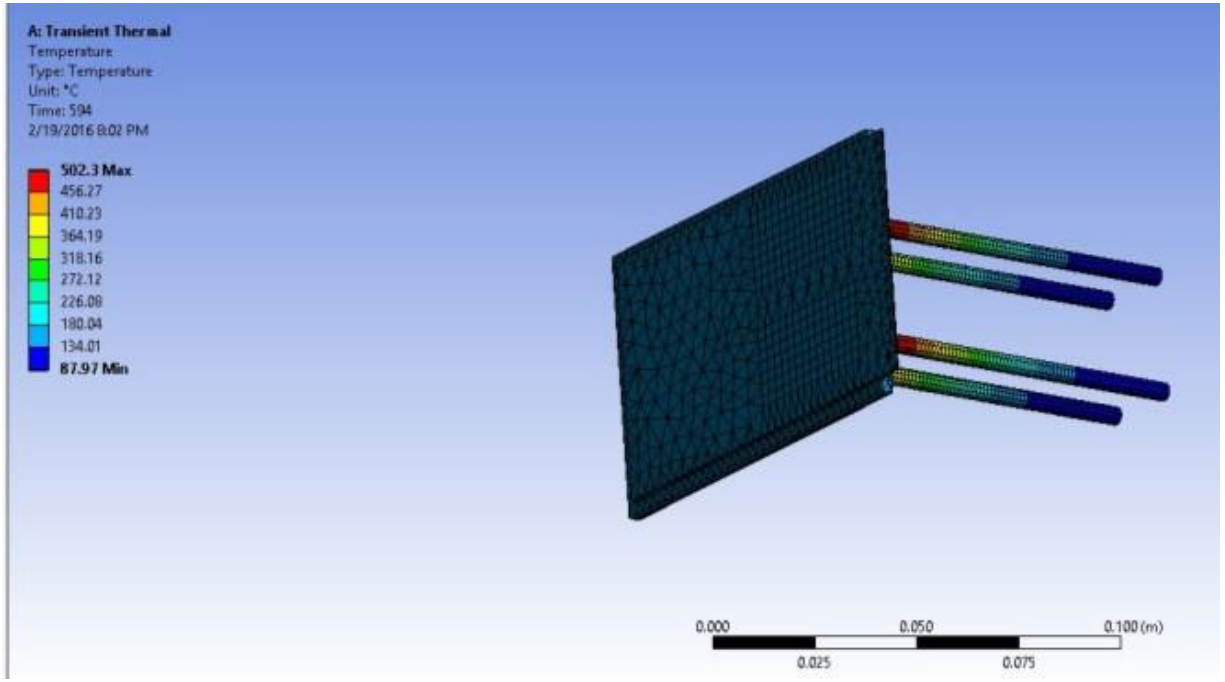
**Descent ranging from 100Km-30Km

Maximum Temperatures During Re-entry



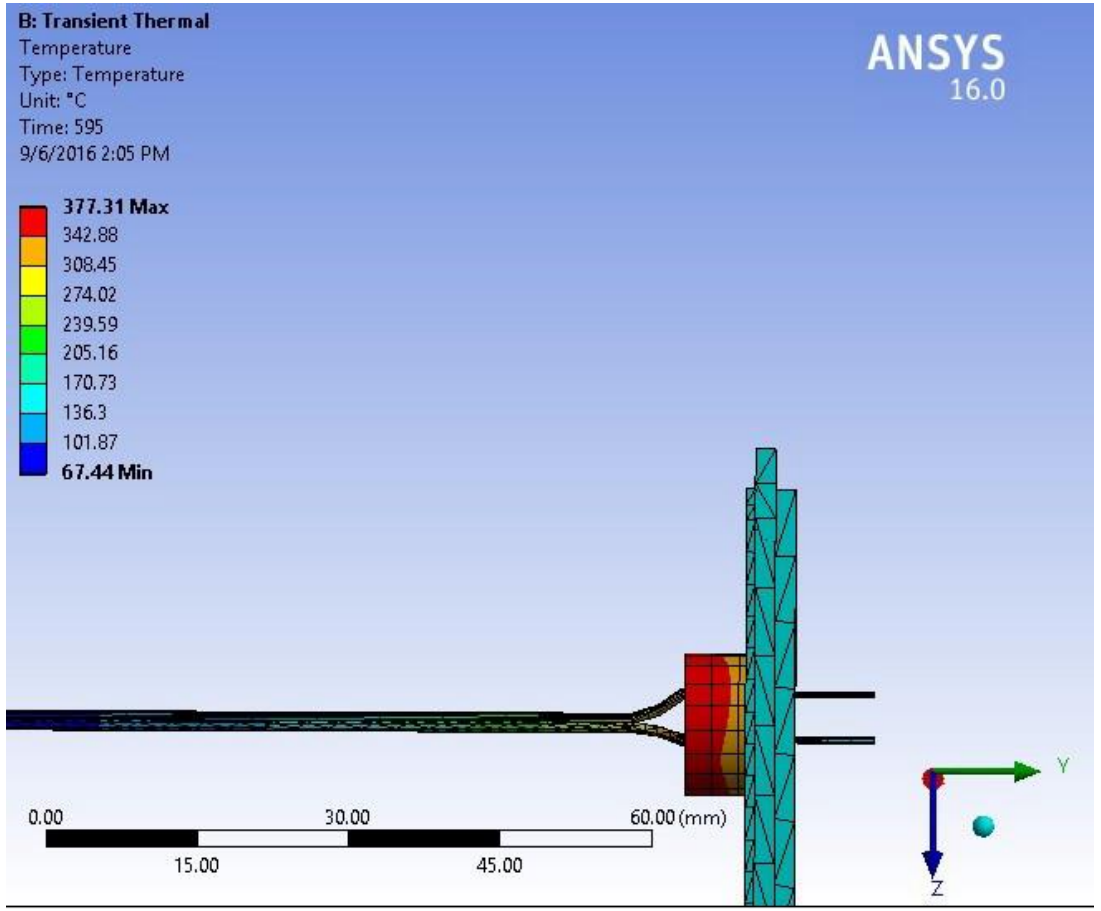
Results and Discussion (1/3)

- Maximum operational temperature of OBC 85°C
- Temperature at 7cm harness 87.97 °C
- Plasma contact area too big

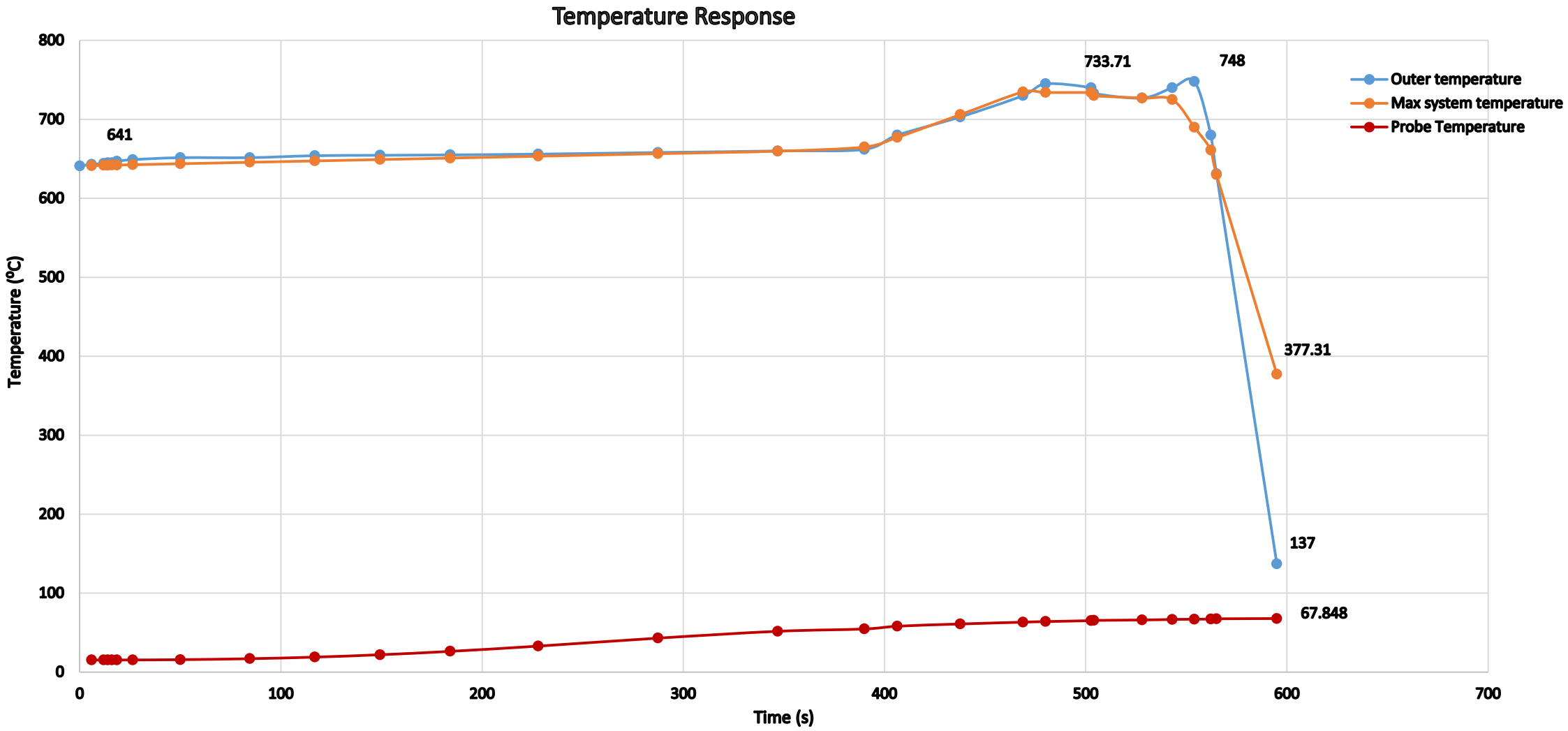


Results and Discussion (2/3)

- Harness length of 10cm selected for testing
- At 6cm, temperature dropped from 89^{o}C to 67^{o}C by placing directly and behind TPS
- Minimized exposure area



Results and Discussion (3/3)



Concluding Remarks

- Needle tip triple probe selected
- Tungsten tips and harness selected
- 4mm diameter fiberglass cover for harness as heat sink
- 6cm long harness enough
- Place probe head behind Fiberfrax and SiC TPS

Thank you for your attention

Questions

Cacace, M., Batal, T., Corre, Y., et al. 2015

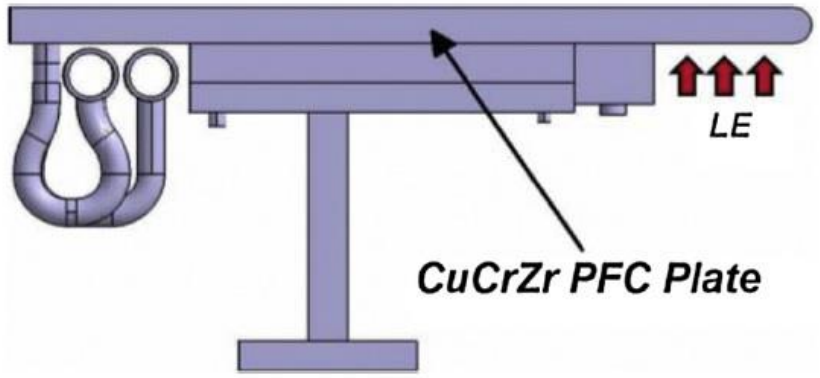
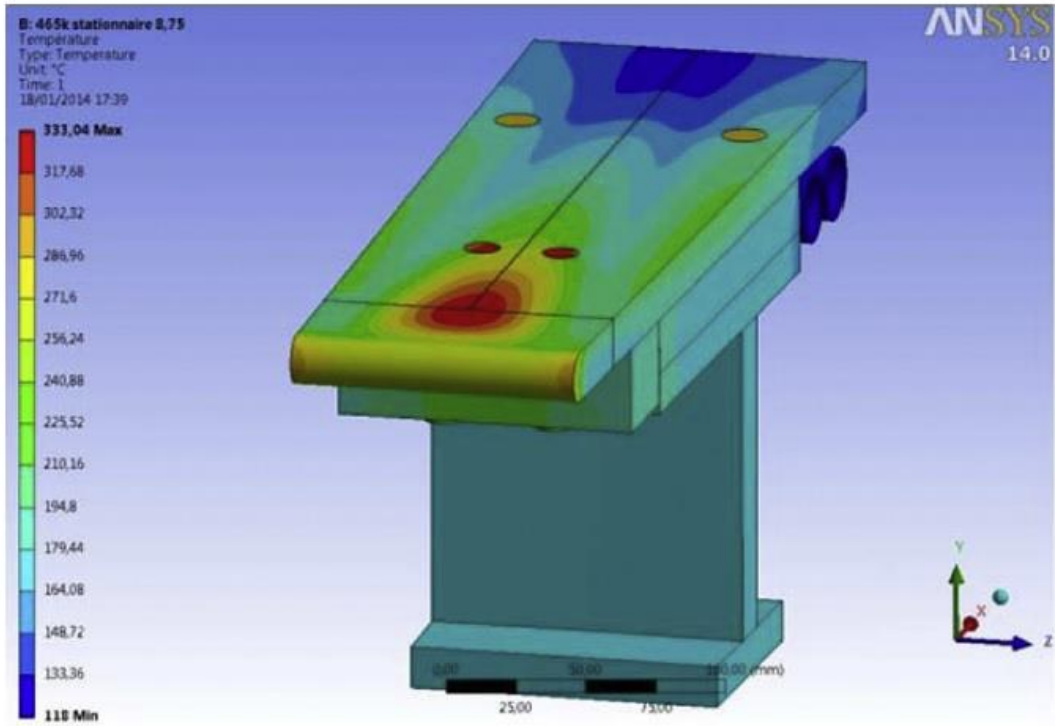


Fig. 1. Leading edge of the baffle will host the Langmuir probes. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



Exterior reference temperature profiles

The boundary conditions for the re-entry phase are presented in the table below.

Table 2-7: temperature boundary conditions during re-entry phase vs time and altitude, corresponding to a satellite mass of 4kg.

Altitude [km]	**100**	**80**	**66**	**60**	**53**	**48**	**44**	**40**	**30**
Time [s]	579,4	969,2	1059,2	1083,8	1107,0	1122,0	1133,1	1144,0	1174,0
Front Cork T [°C]	1099	1596	1816	1911	1925	1698	1692	1369	222
Side Cork T [°C]	801	1000	991	996	1002	1013	1018	858	153
TPS Sidewalls T [°C]	641	662	745	733	727	740	748	631	137
TPS Back T [°C]	138	194	144	267	283	274	273	216	117
Solar Panel Front T [°C]	640	830	887	873	886	832	830	696	168
Solar Panel Back T [°C]	445	537	525	482	462	455	463	412	141

This conditions are derived from CFD computations.