Post Flight Analysis of the COMARS+ Data and Backcover Heating of the ExoMars Schiaparelli Capsule

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Outline

- Introduction
- COMARS+ set-up
- COMARS+ sensor features
- Flown trajectory points
- Flight data
- Concluding remarks
- Next steps

Motivation

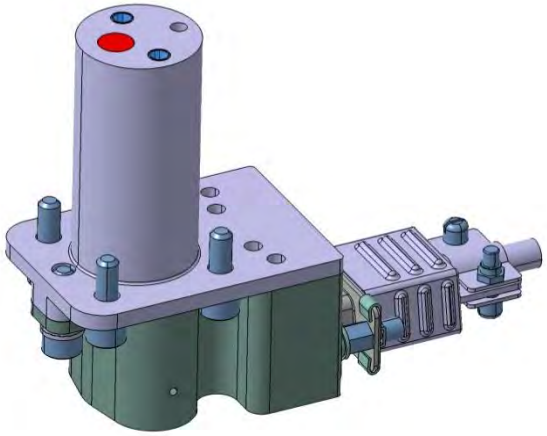
- Because of shortcomings of design tools and limited health monitoring data spacecraft design is carried out with high margings.
- Improvement of confidence in experimental data is only possible by using relaible new generation sensors.
- Decrease of the design margins and improvement of the strucure index by keeping the satisfacition all reliability requierements should be the main goal of future mission.
- Additional flight data should improve modelling of aerothermal loads on the rear surface of Martian entry capsules.
- Relaible data on the vehicle surface parameter would also help in the reconstruction of the atmospheric parameter in dependency on the altitude.

COMARS+ Flight Hardware integrated into the EXOMARS EDM 2016

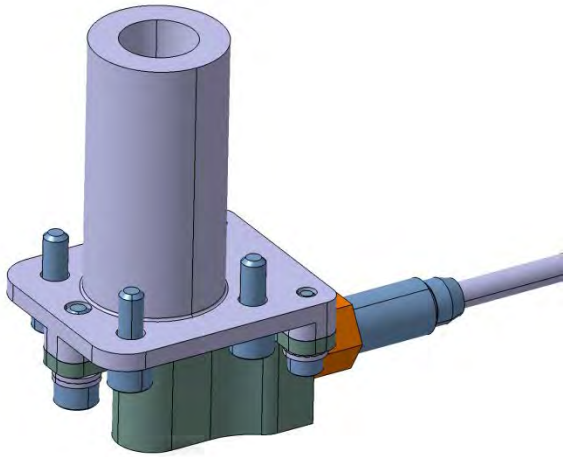
Fatures of the COMARS+ Sensor Package

- COMARS+ consists of three combined sensors (COMARS), one broadband radiometer (RAD) and an analogue electronic box.
- Each COMARS sensor measures the pressure, surface temperature, total heat flux rate and radiative heat flux at two selected wavelength range of approx. 2.9 micrometer and 4.6 micrometer. The narrow band radiometer sensors (called ICOTOM) were provided by CNES.
- A broad band radiometer measures the radiation of the high enthalpy gas heated by the bow shock close to the vehicle shoulder region.
- The electronic box allows processing the data of 24 sensor channels by means of a multiplexer. Additional sensors are mainly temperature sensors, which monitor the temperature of housing and detectors.

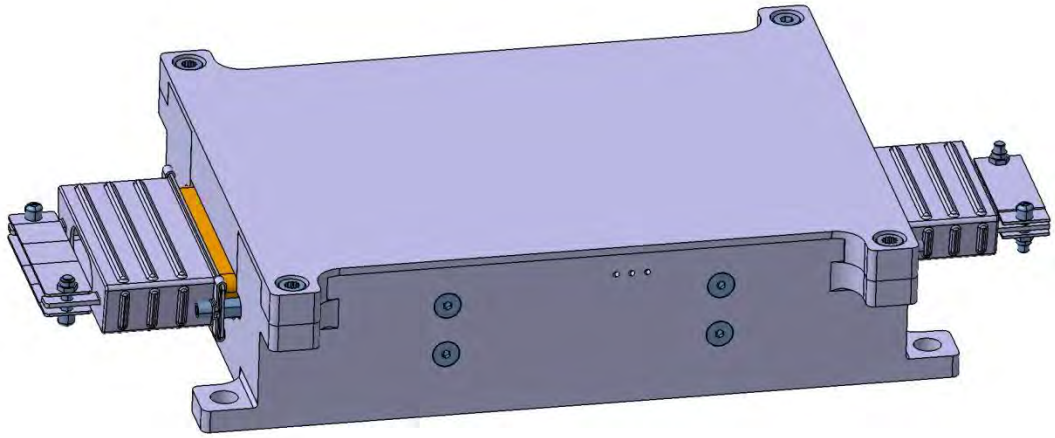
3D view of COMARS+ components



COMARS sensor

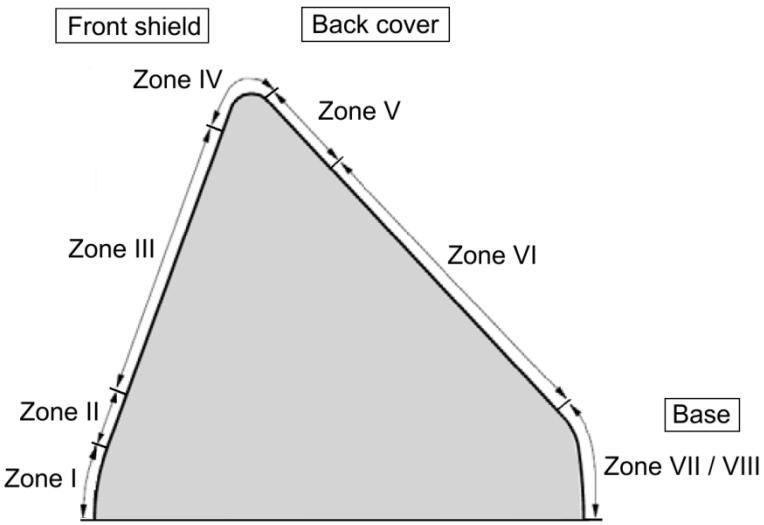


Radiometer

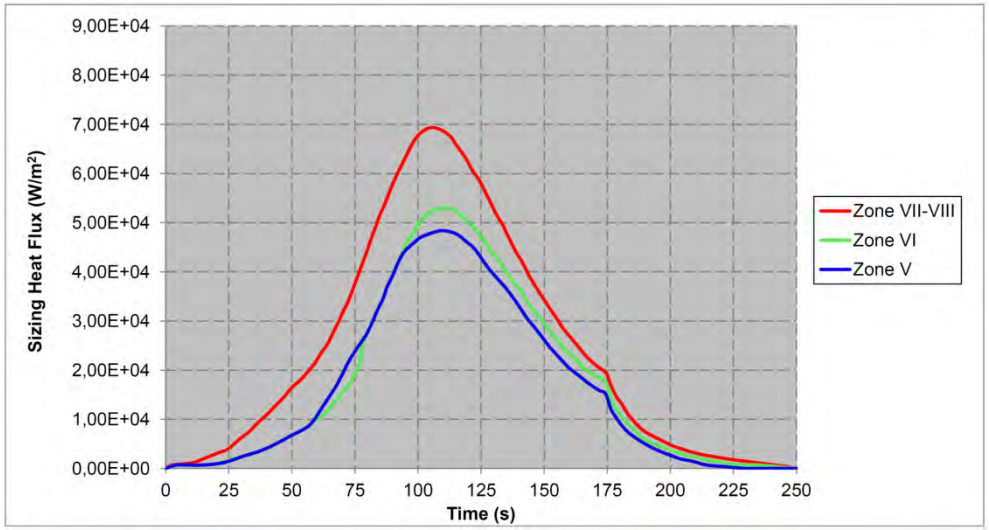


Electronic box

Sizing Heat Flux Profiles for EDM Back Cover TPS



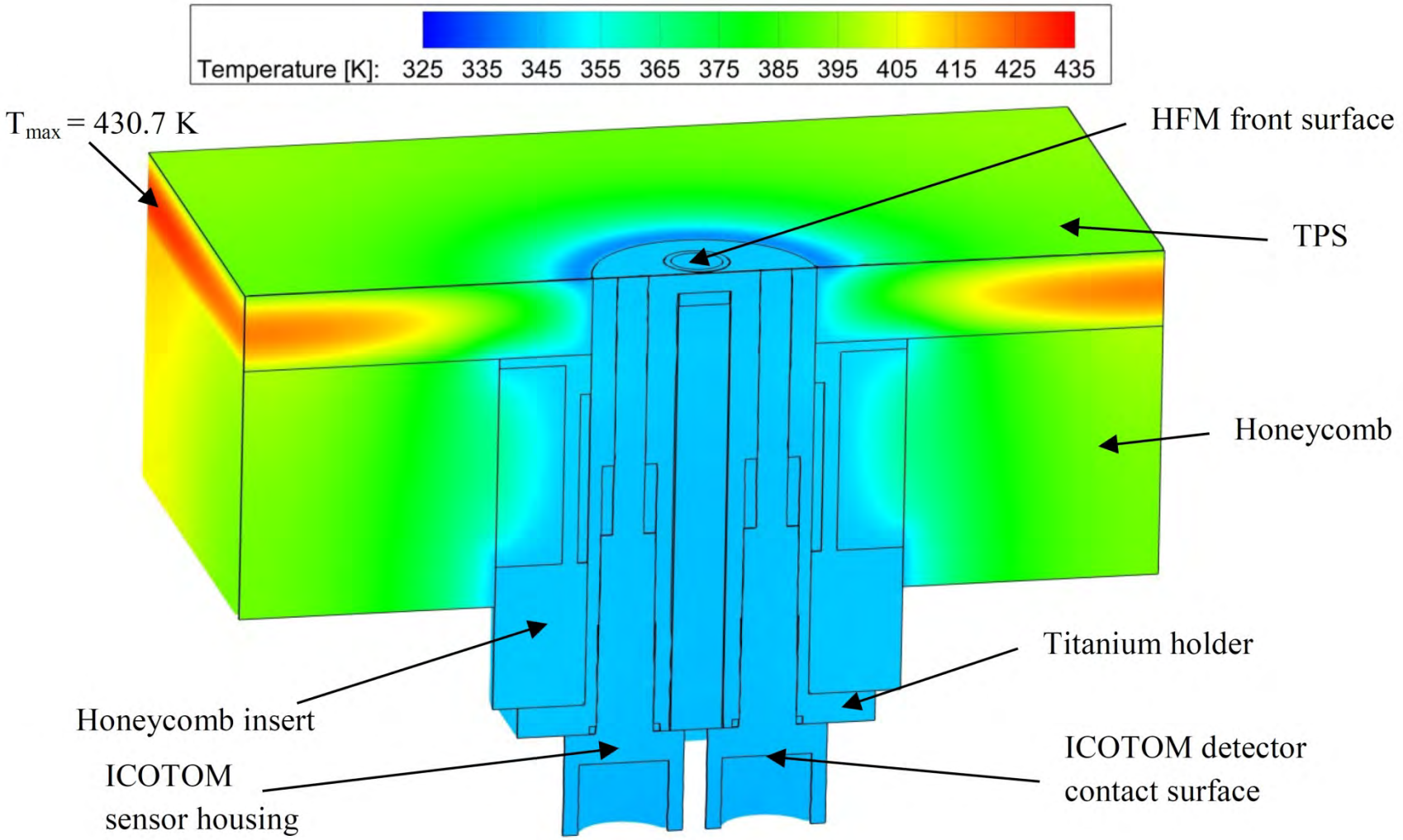
Zone definition of Schiaparelli



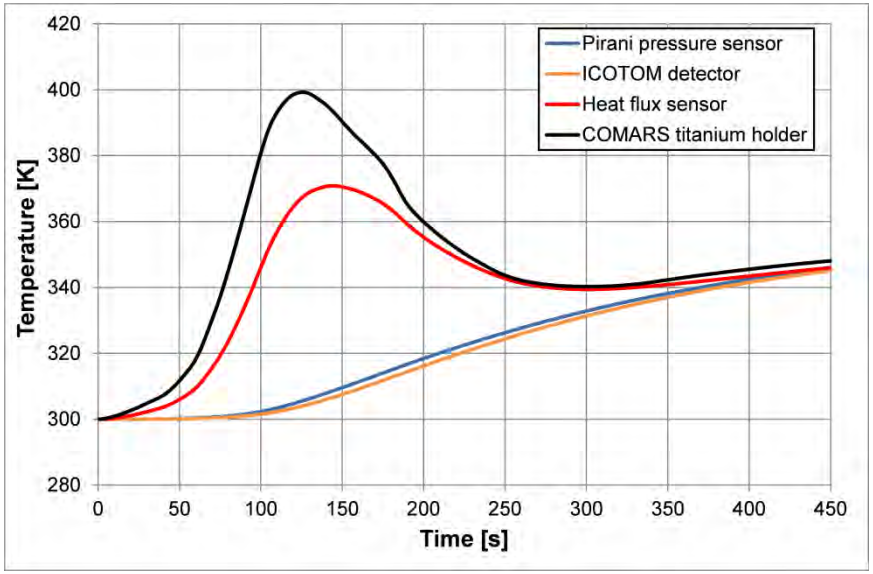
Ref.: EXM-DM-TNO-AI-0059:
ExoMars EDM Aerothermodynamic Database

Sizing heat flux profile for EDM back cover

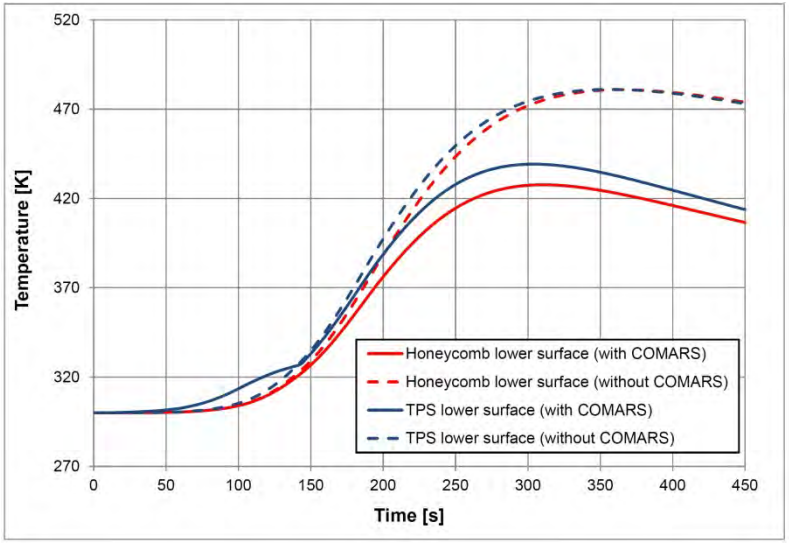
COMARS Sensor Thermal Simulation Results



COMARS thermal simulation maximum temperatures

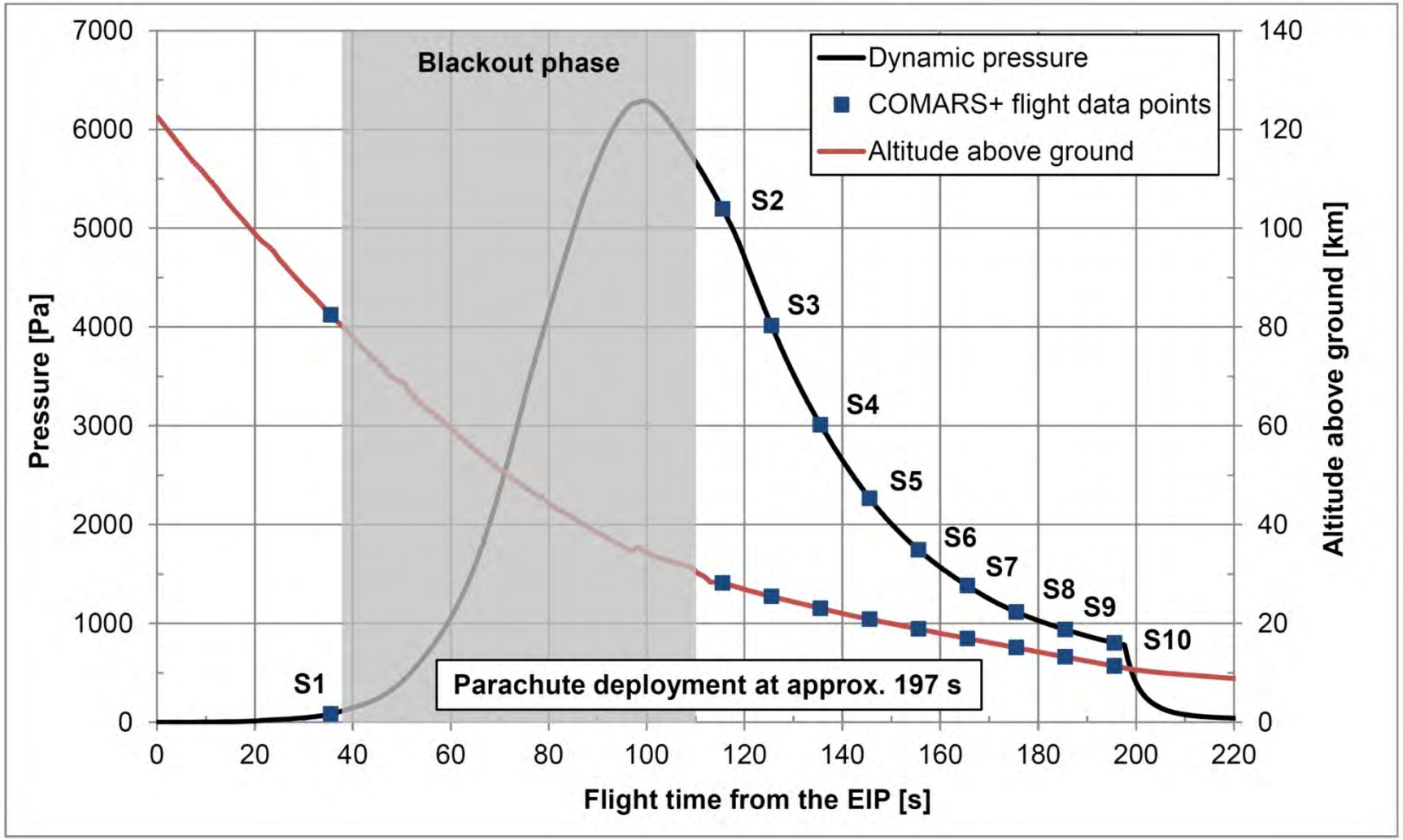


COMARS sensor simulation maximum temperatures



TPS maxiumum temperatures with and without COMARS+ sensors

Schiaparelli trajectory points with COMARS+ data



Ref.: A. Gülhan, T. Thiele, F. Siebe, R. Kronen, T. Schleutker; Aerothermal Measurements from the ExoMars Schiaparelli Capsule Entry, Journal of Spacecraft and Rockets, DOI: 10.2514/1.A34228, 2018.

Main parameters of the trajectory with COMARS+ data

	Flight time from EIP [s]	Altitude above ground [km]	Speed [m/s]	Atmospheric density [kg/m^3]	Atmospheric pressure [Pa]	Atmospheric temperature [K]	Mach number [-]	Dynamic pressure [Pa]
EIP	0	122.6	6001.39	3.306E-08	0.0008	126.27	32.320	0.595
S1	35.553	82.467	5829.38	5.092E-06	0.16	165.50	27.946	86.53
				Communication blackout				
S2	115.553	28.202	2595.41	1.542E-03	56.56	191.58	11.665	5193.40
S3	125.551	25.477	2013.84	1.979E-03	74.13	195.38	8.967	4013.02
S4	135.552	23.064	1570.58	2.440E-03	93.15	199.13	6.935	3009.56
S5	145.551	20.862	1236.92	2.962E-03	114.57	202.28	5.431	2265.92
S6	155.551	18.887	1001.92	3.478E-03	137.21	205.79	4.360	1745.64
S7	165.553	16.959	823.09	4.078E-03	163.84	209.69	3.553	1381.21
S8	175.551	15.099	685.40	4.751E-03	194.15	213.67	2.937	1115.89
S9	185.552	13.227	584.38	5.496E-03	228.85	217.40	2.483	938.40
S10	195.551	11.379	503.09	6.355E-03	269.55	221.63	2.120	804.24

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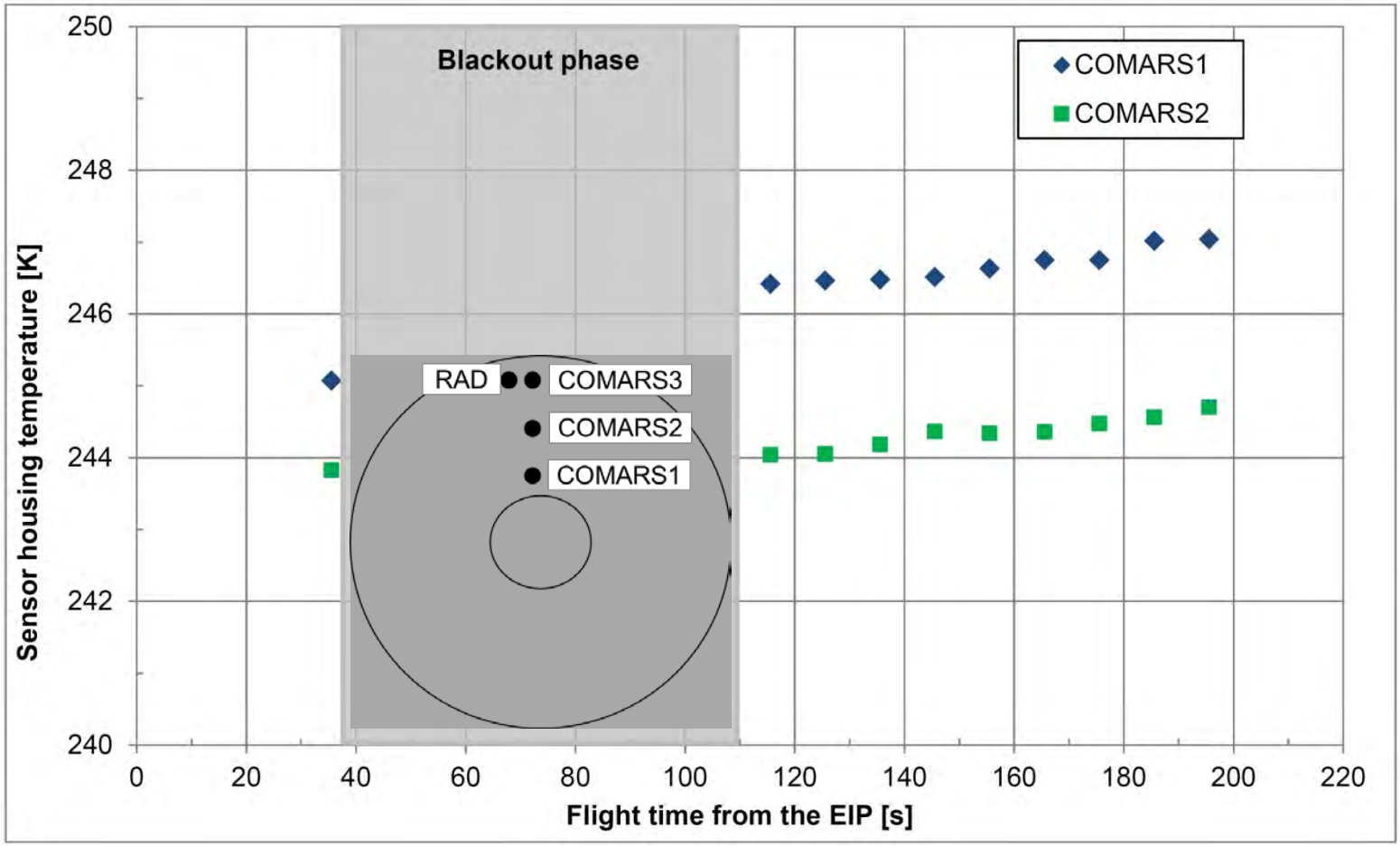
Measured housing temperature of COMARS



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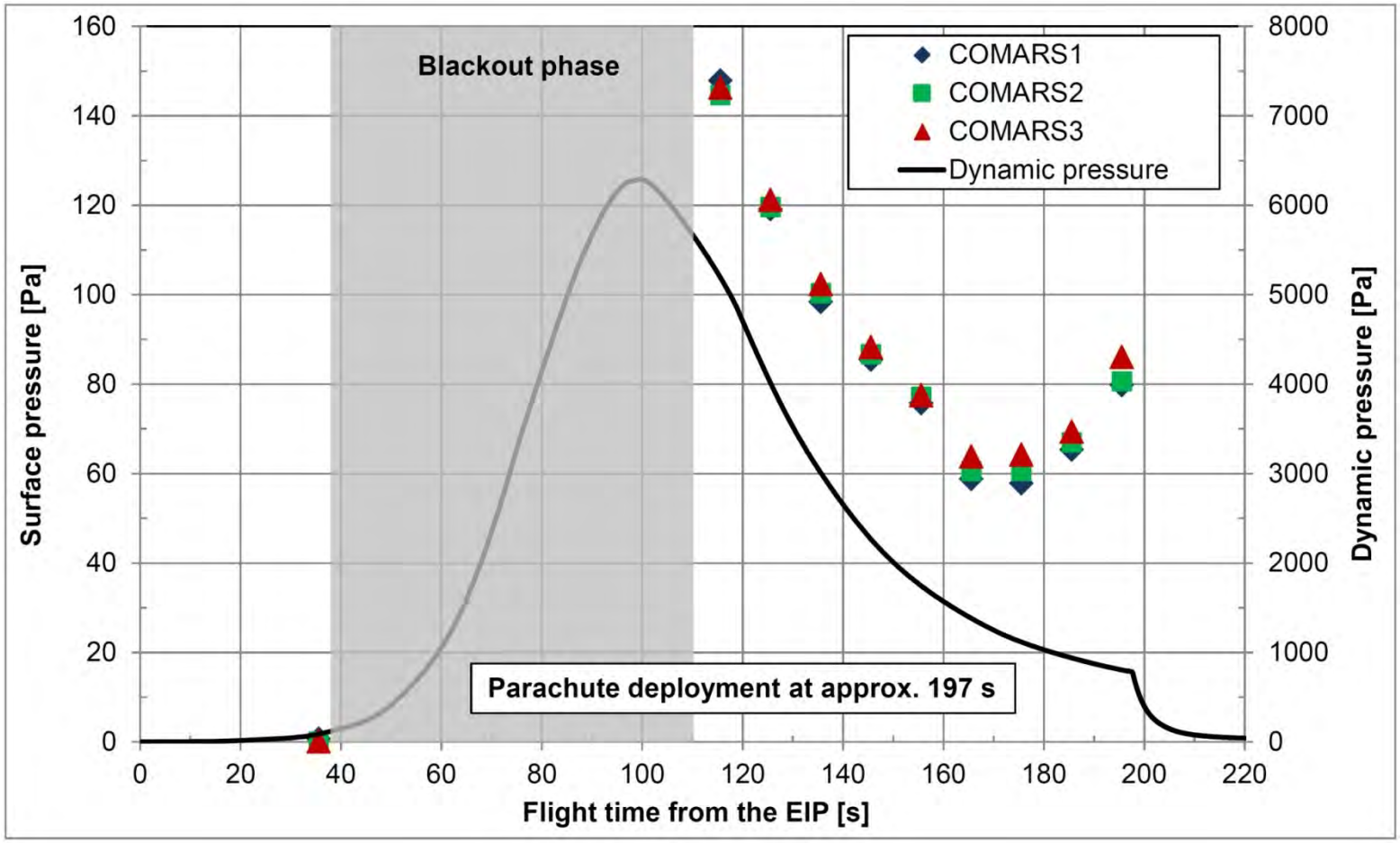
Measured back cover surface pressure during entry



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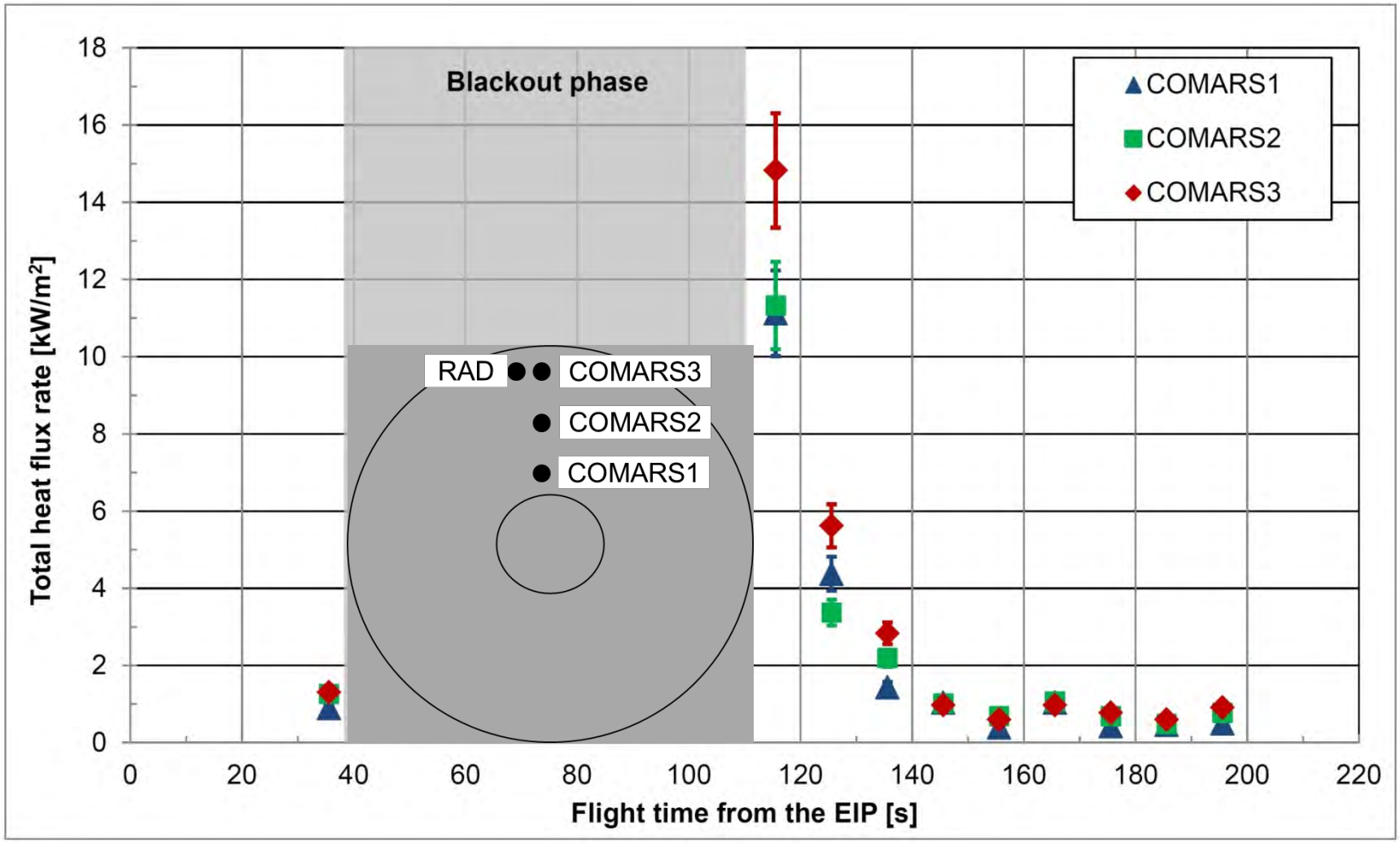
Measured back cover heat flux during entry



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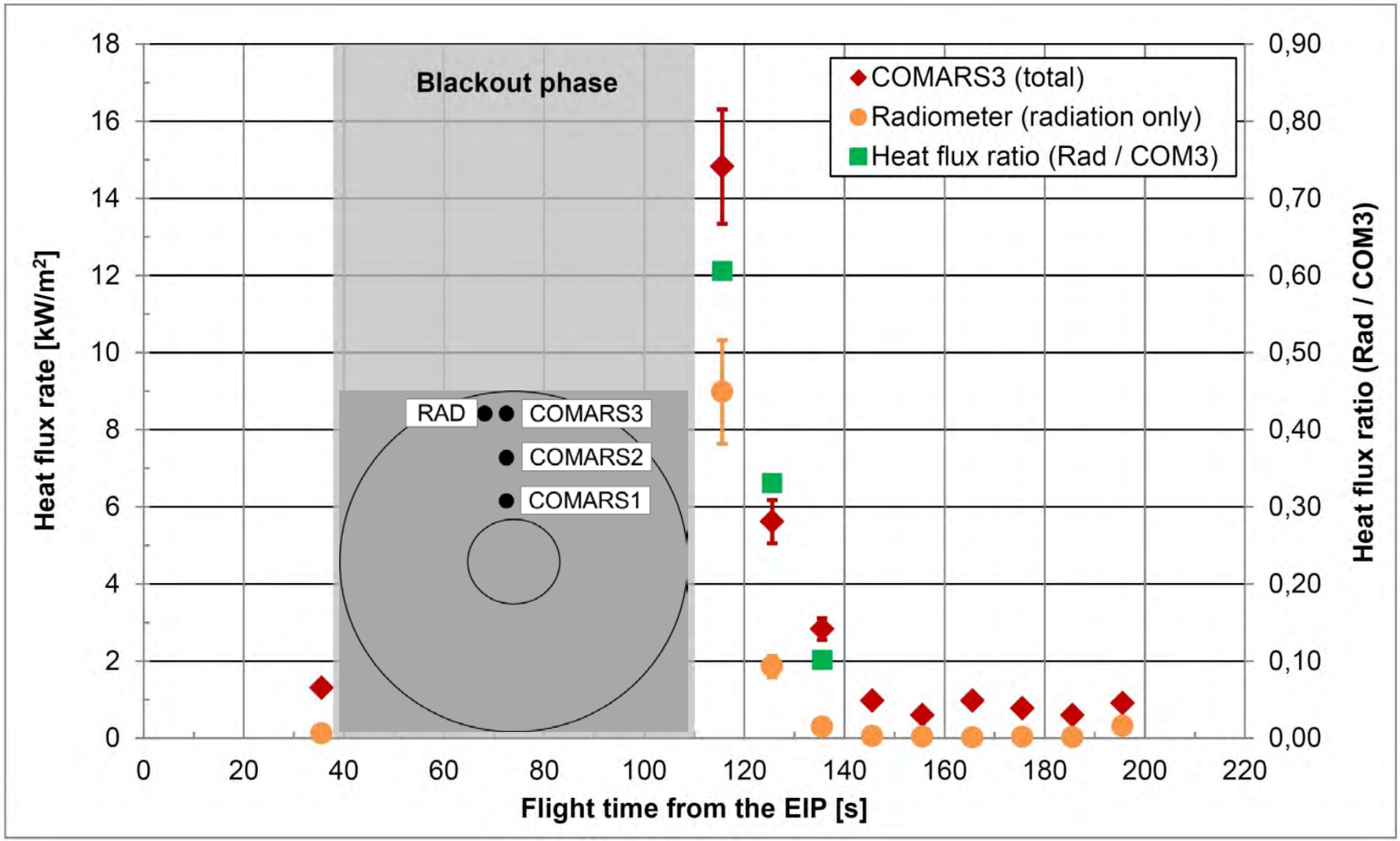
Measured total and radiative heat fluxes



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Ratio of the back cover heat flux to the stagnation point heat flux

Trajectory point	$\dot{q}_{meas}/\dot{q}_s$		
	COMARS3	COMARS2	COMARS1
S2	0.09	0.07	0.07
S3	0.06	0.04	0.05
S4	0.06	0.05	0.03

Stagnation point heat flux ($\dot{q}_s$) is predicted using Sutton-Graves relation

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Pressure coefficients on the back cover

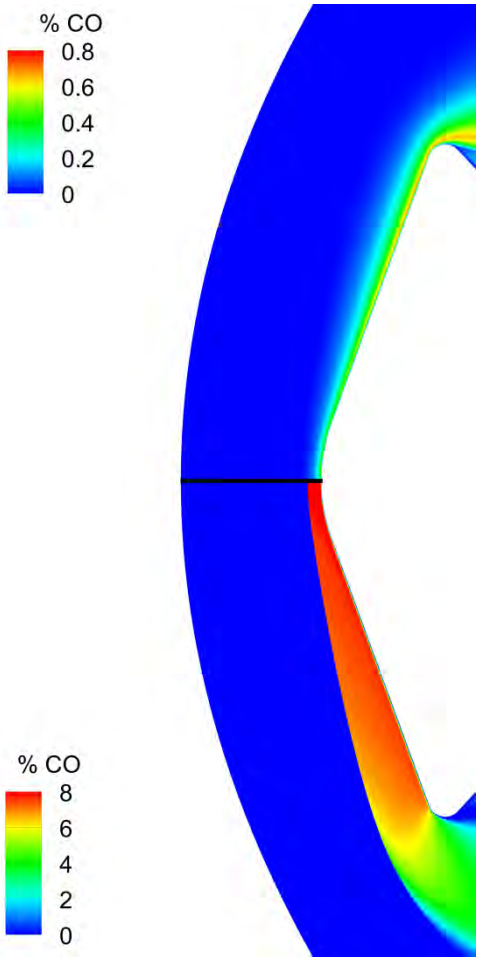
Trajectory point	Pressure coefficient c_p		
	COMARS3	COMARS2	COMARS1
S2	0.0172	0.0170	0.0176
S3	0.0117	0.0112	0.0129
S4	0.0029	0.0023	0.0016

Ref.: A. Gülhan, T. Thiele, F. Siebe, R. Kronen, T. Schleutker; Aerothermal Measurements from the ExoMars Schiaparelli Capsule Entry, Journal of Spacecraft and Rockets, DOI: 10.2514/1.A34228, 2018.

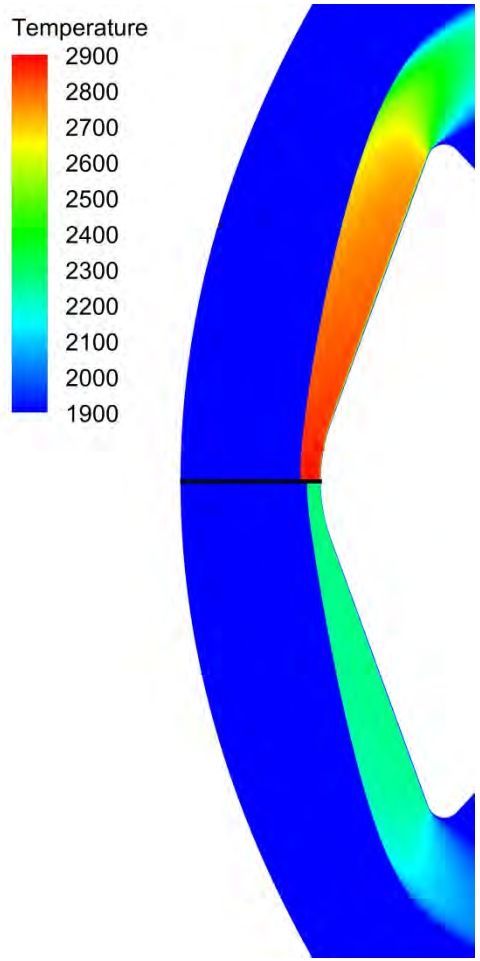
Concluding remarks

- The radiative heat flux on the back cover near the vehicle shoulder was measured successfully. At the first trajectory point after communication blackout the measured radiative heat flux is 9.0 kW/m^2, or 61% of the total heat flux.
- The highest ratio of the measured total heat flux of 15 kW/m^2 to the calculated front cover stagnation point heat flux occurred close to the vehicle shoulder (COMARS3) immediately after the communication blackout with a value of approximately 0.09.
- Pressure measured at three back cover locations showed almost no dependence on measurement location, as the pressures were very similar in magnitude and temporal behavior. This finding is believed to be the result of separated aftbody flowfield at the measurement locations.
- Measured back cover total heat fluxes are below the sizing total heat flux level of the back cover TPS. This very important result suggests that the design margins of the back cover TPS design can be reduced.

CFD analysis: NEQ (top) und EQ (bottom) @S2

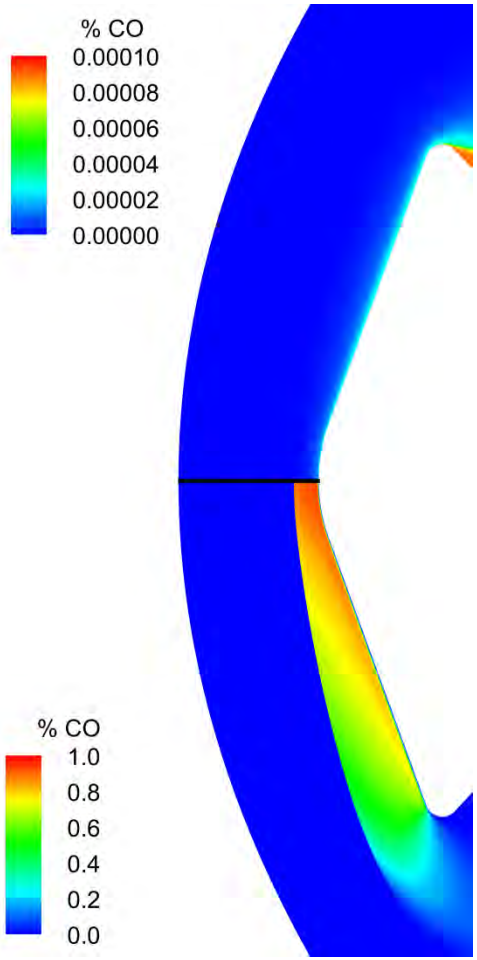


NEQ vs EQ:
CO concentration

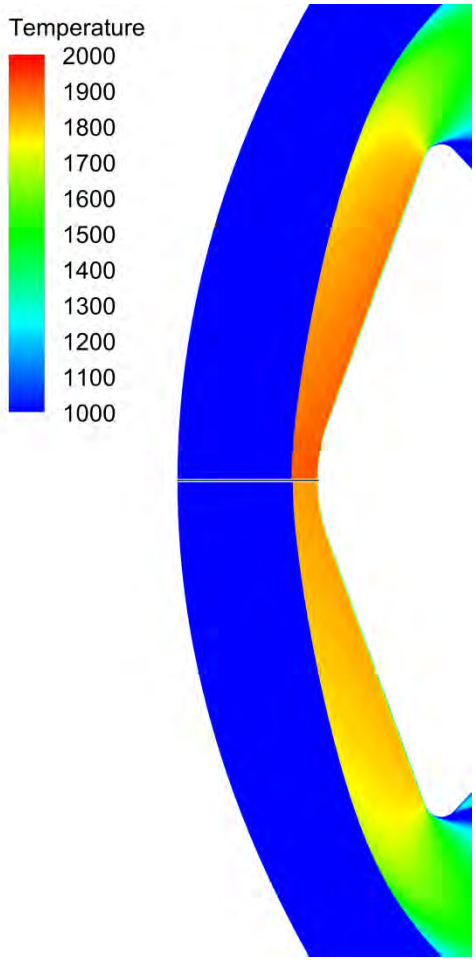


NEQ vs EQ:
temperature

CFD analysis: NEQ (top) und EQ (bottom) @S3



NEQ vs EQ:
CO concentration



NEQ vs EQ:
temperature