

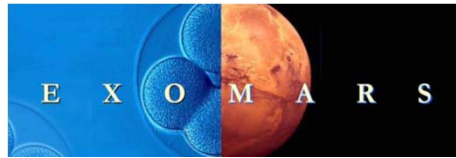
Reconstruction of the Mars Atmosphere with ExoMars Schiaparelli Flush Air Data System



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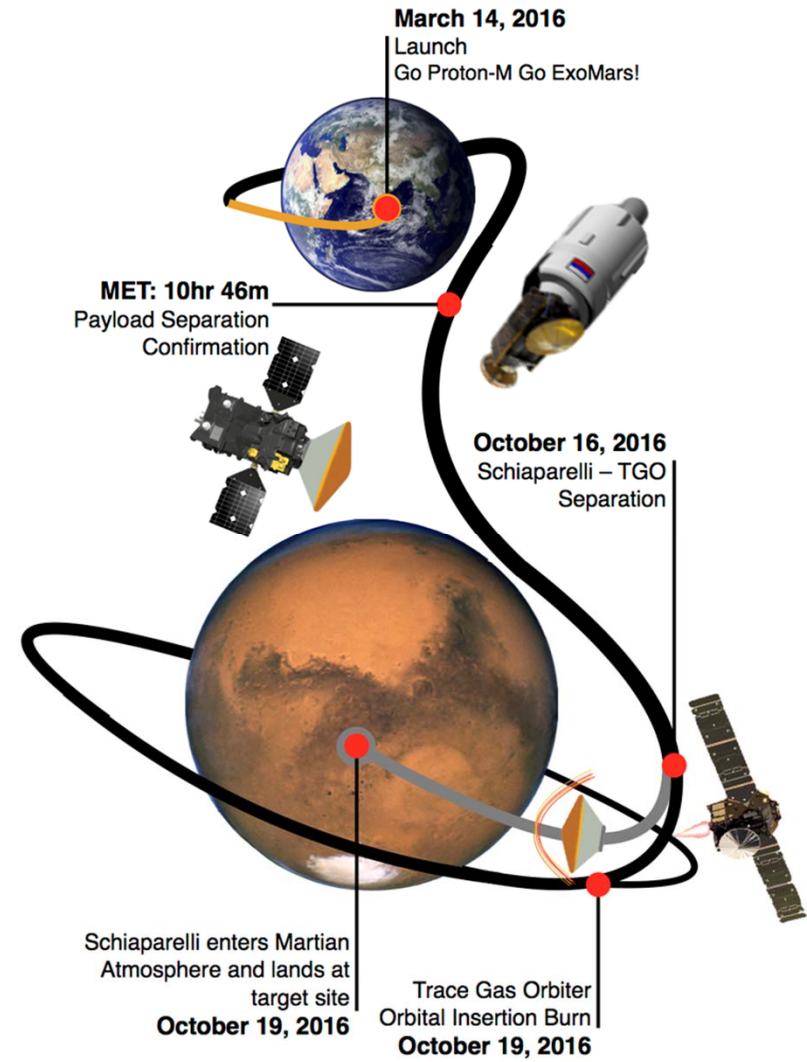
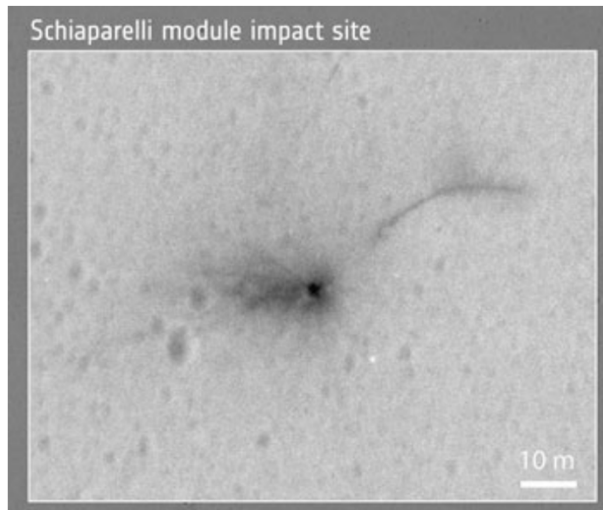
**Scientific workshop
“from Mars Express to ExoMars”
Madrid, 27 February 2018**

ExoMars Schiaparelli mission

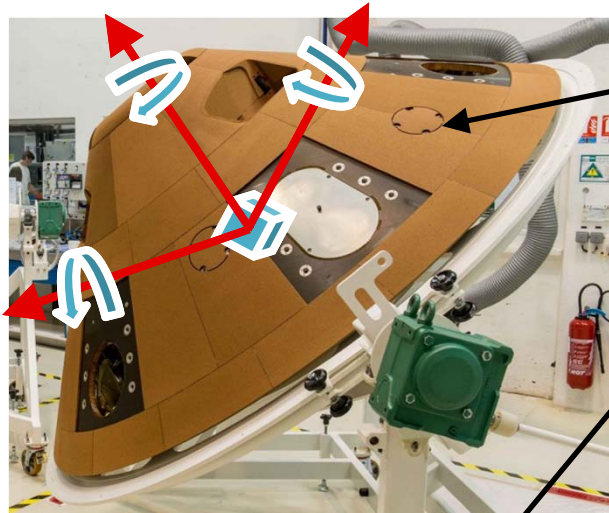


in a nutshell

- Successful launch, separation from TGO
- Successful atmospheric entry, parachute deployment... **crash landing!**
- Trajectory & atmospheric reconstruction still possible with **real-time flight data**

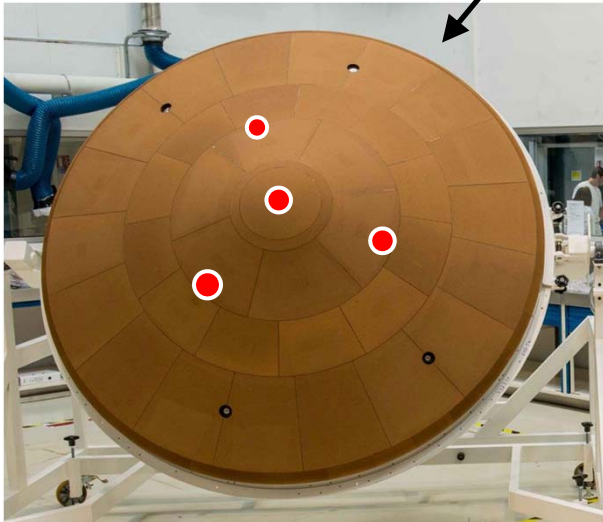


Flight instrumentation

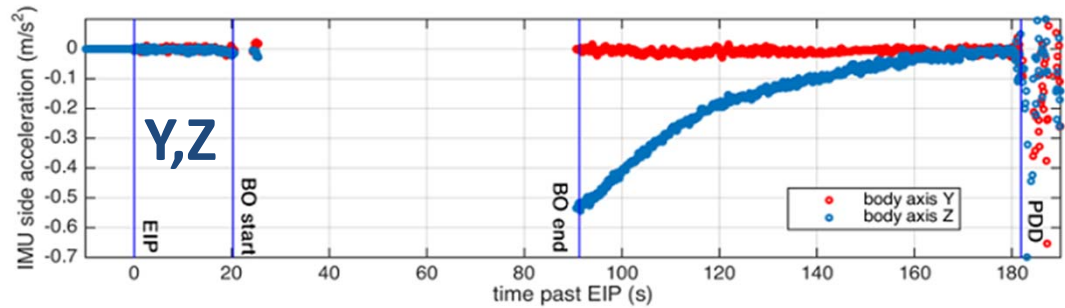
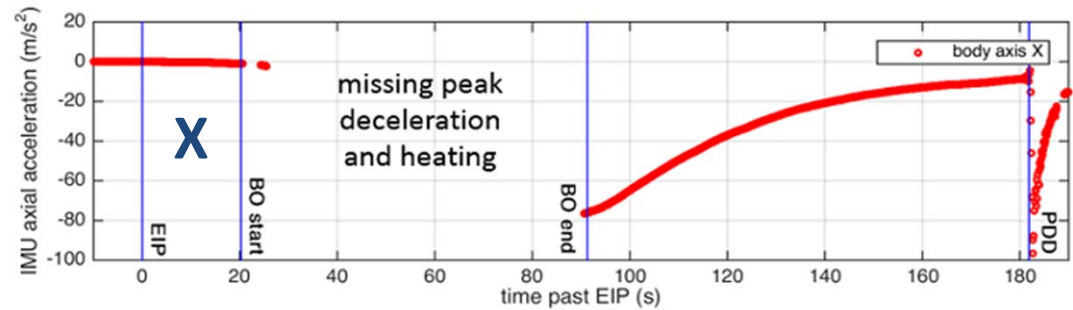


IMU: Inertial Measurement Unit
3-axis accelerometer & gyroscope

FADS: Flush Air Data System
4 heat shield pressure sensors



Real-time flight data (IMU acceleration)



27-10 km



Atmospheric reconstruction (2 approaches)

IMU + aerodynamic drag model

- Atmospheric density from acceleration and C_D = **drag coefficient**

$$\rho_{\infty} = 2 \frac{m \cdot |\vec{a}_{aero}|}{C_D \cdot A_{ref} \cdot V_{\infty}^2}$$

- Reconstruct pressure and temperature

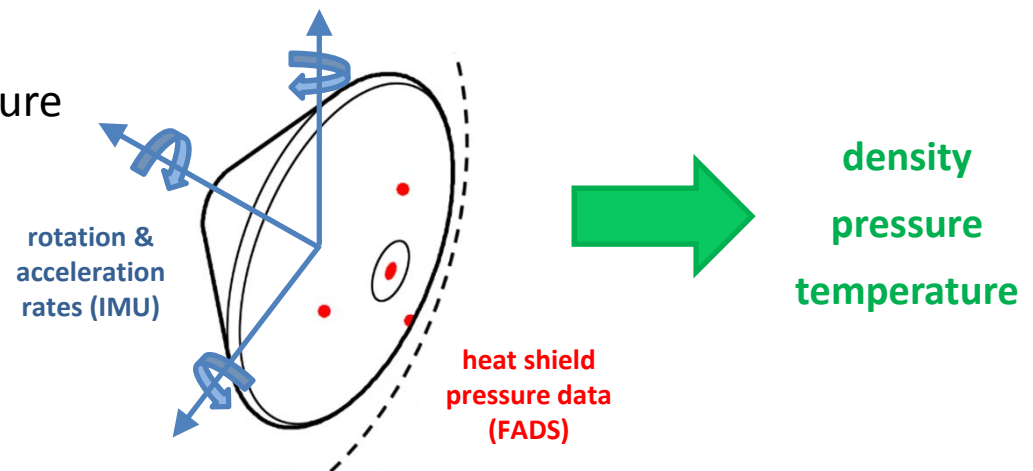
$$p_{\infty} = p_0 - \int g \rho_{\infty} dh$$

$$T_{\infty} = \frac{\mu p_{\infty}}{R \rho_{\infty}}$$

- Validated w/ 2008 Phoenix flight data

FADS + pressure model

- Atmospheric density by combining pressure data with **heat shield pressure model**
- Atmospheric pressure and temperature derived from density (see left)

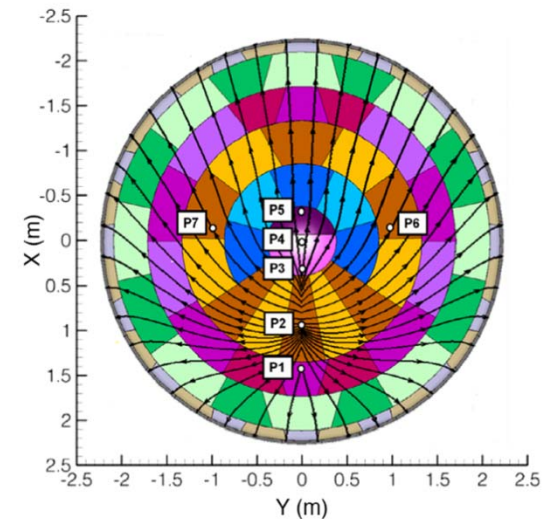
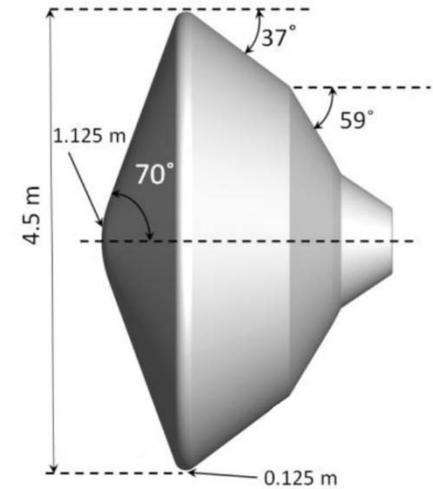
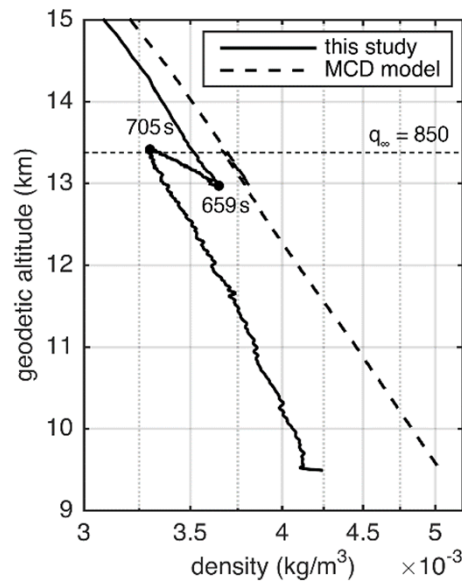
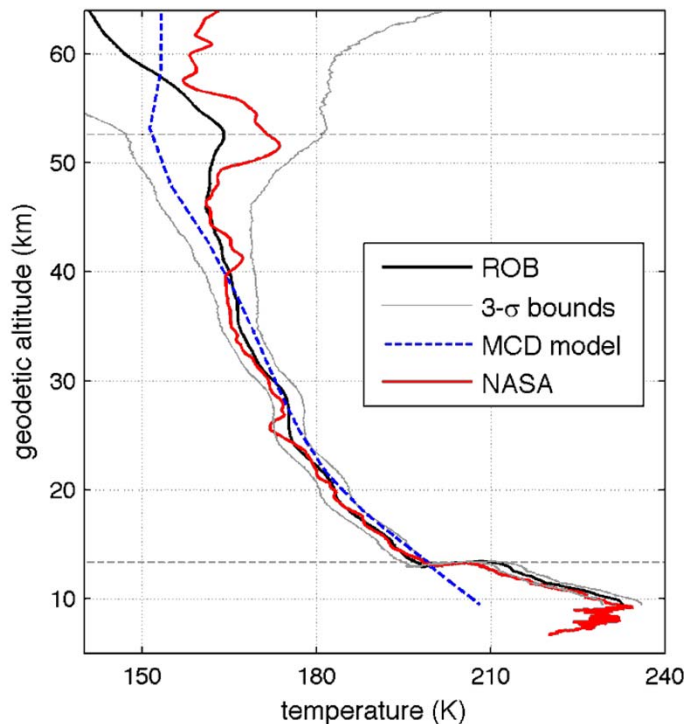


- Validated w/ 2012 Mars Science Laboratory flight data

FADS approach: validation with MSL

Atmospheric reconstruction with MSL pressure data

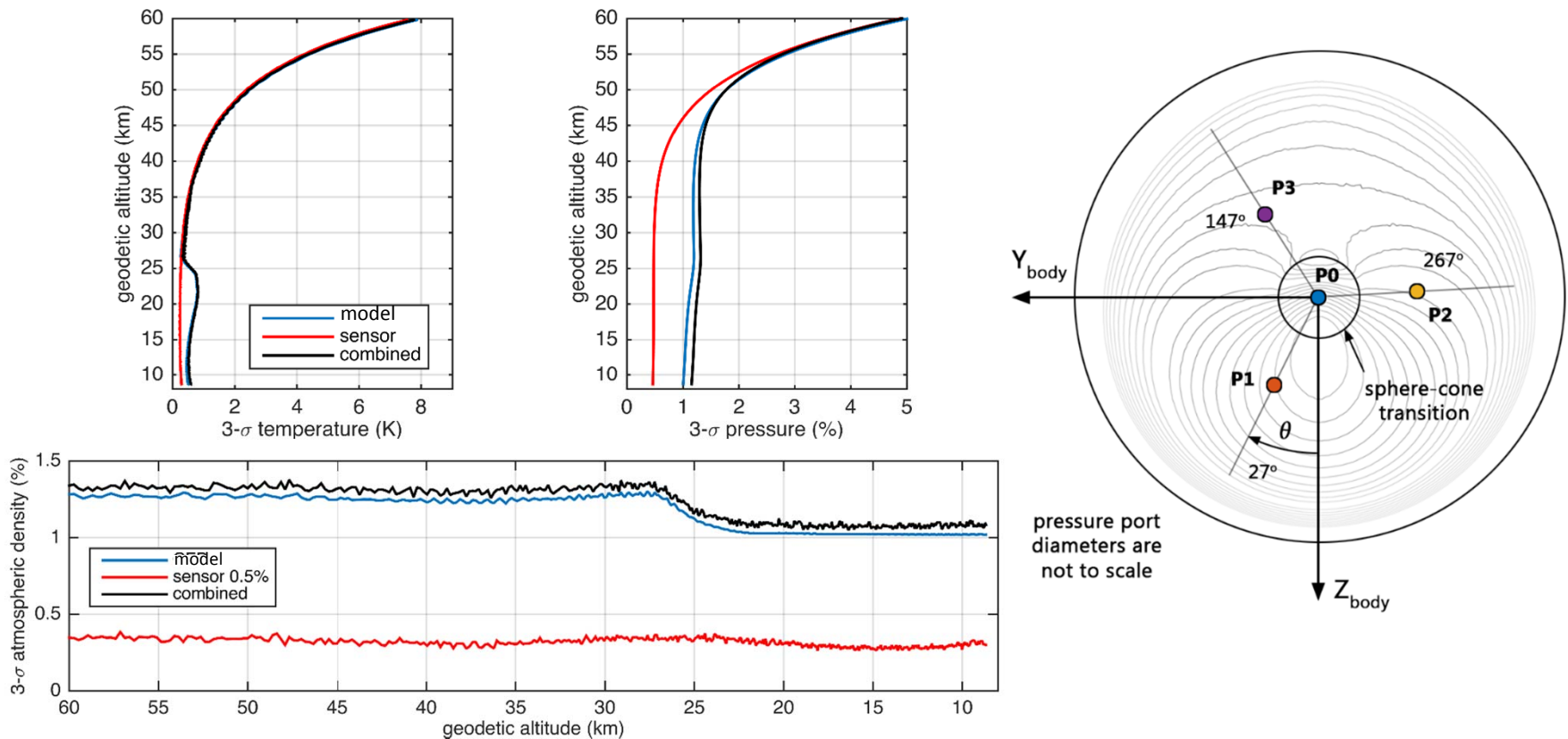
- Successful validation of basic FADS approach
- Accurate atmospheric reconstruction using 1-D pressure model with 1 pressure sensor (P2 near stagnation point)
- Confirmed indirect wind observation at 13 km
- UPWARDS: archived results on Planetary Data System



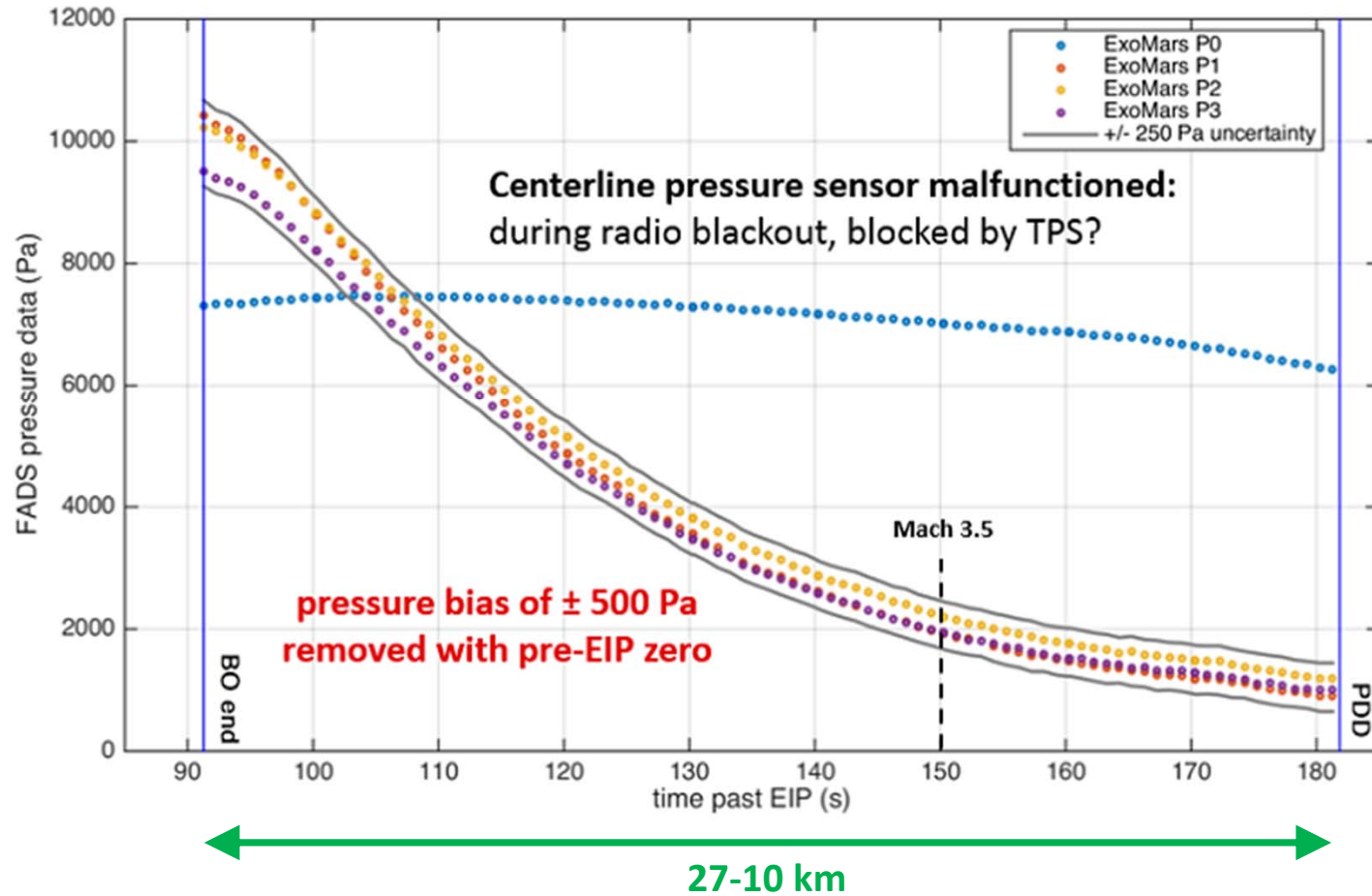
FADS approach for ExoMars

Pre-flight uncertainty quantification

- **Theoretical performance** of ExoMars FADS: developed 3-D pressure model (combine all sensors)
- Reconstructed atmospheric density 1-1.3%, pressure-temperature 1-5% and 0.5-8 K (3- σ)
- Actual FADS flight data has a sensor malfunction and higher than expected uncertainty

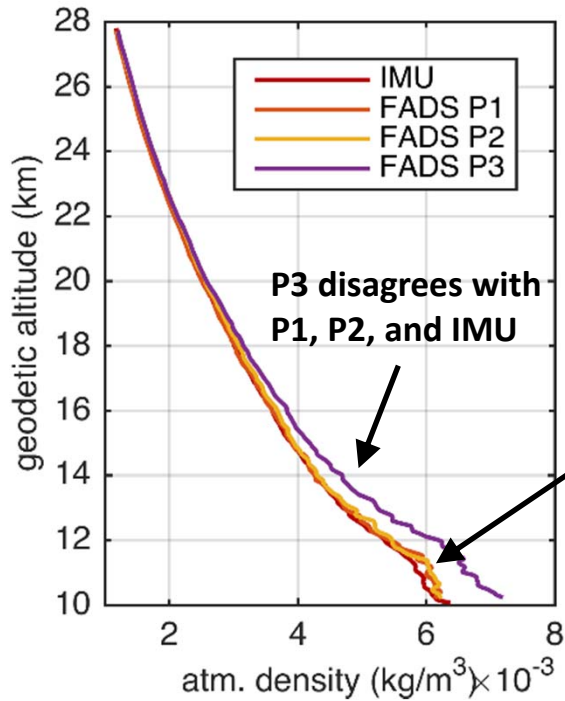


FADS data from ExoMars Schiaparelli



Atmospheric reconstruction (preliminary)

1-D FADS compared to IMU:

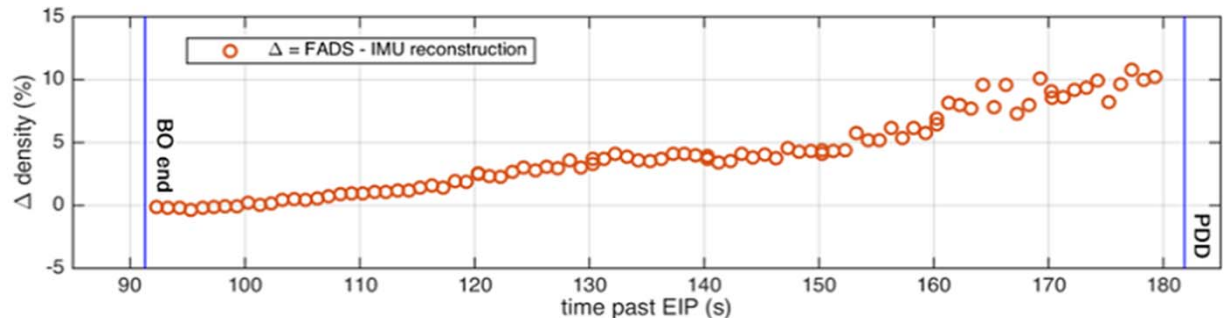
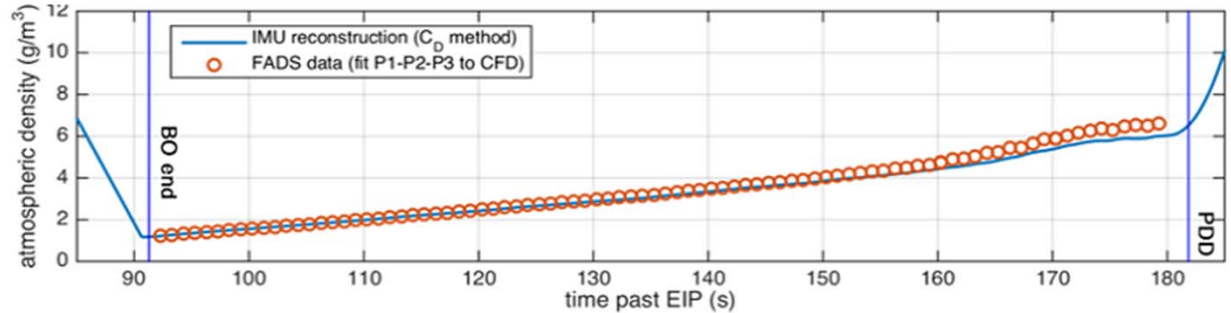


IMU & FADS method

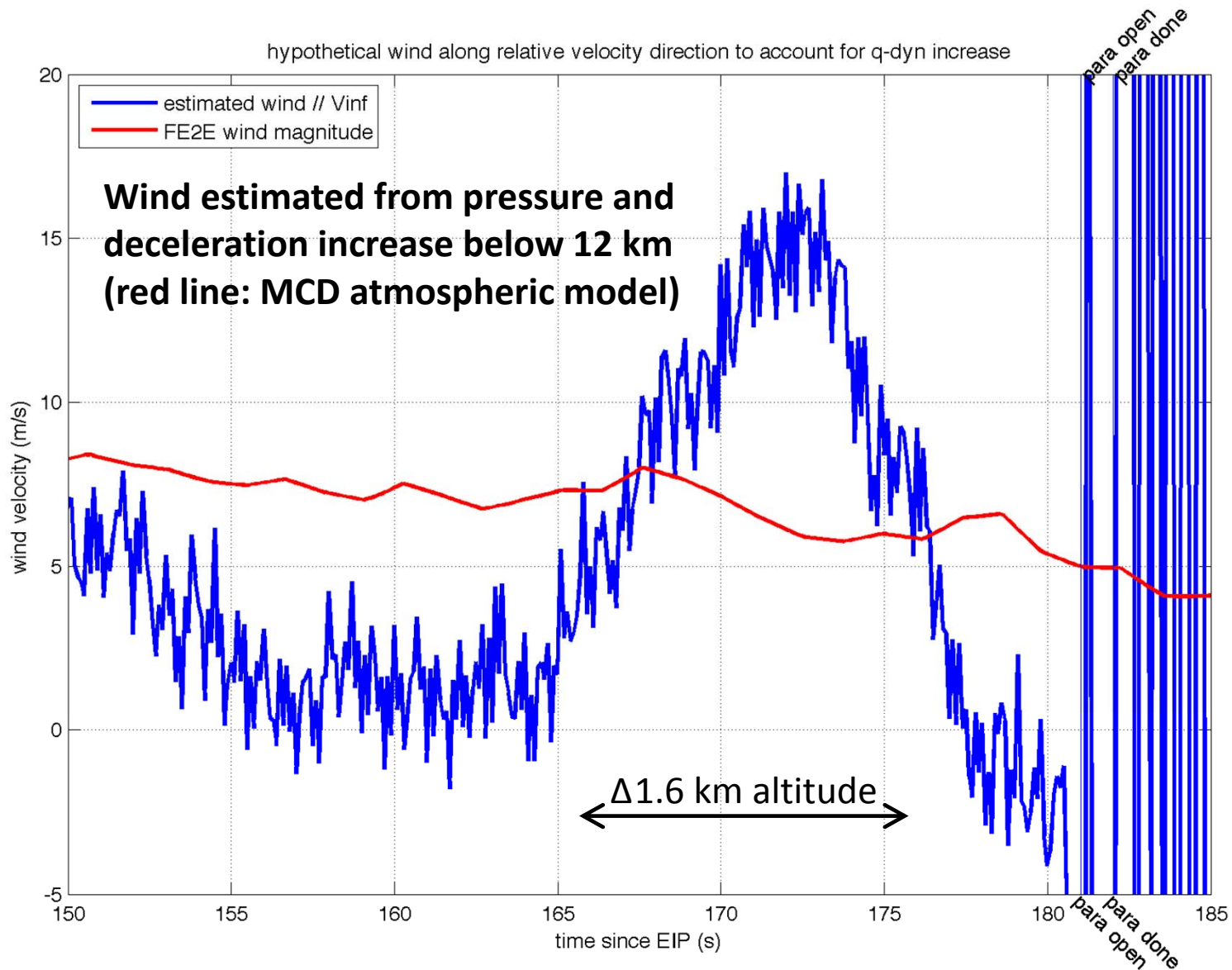
- Good agreement between 1-D FADS and IMU, but pressure sensor P3 in poor agreement
- Good agreement between 3-D FADS and IMU above 20 km, but not below: due to P3 data?
- IMU and FADS both suggest wind below 12 km

actual density increase or wind?

3-D FADS compared to IMU:



Atmospheric reconstruction (preliminary)



Conclusions

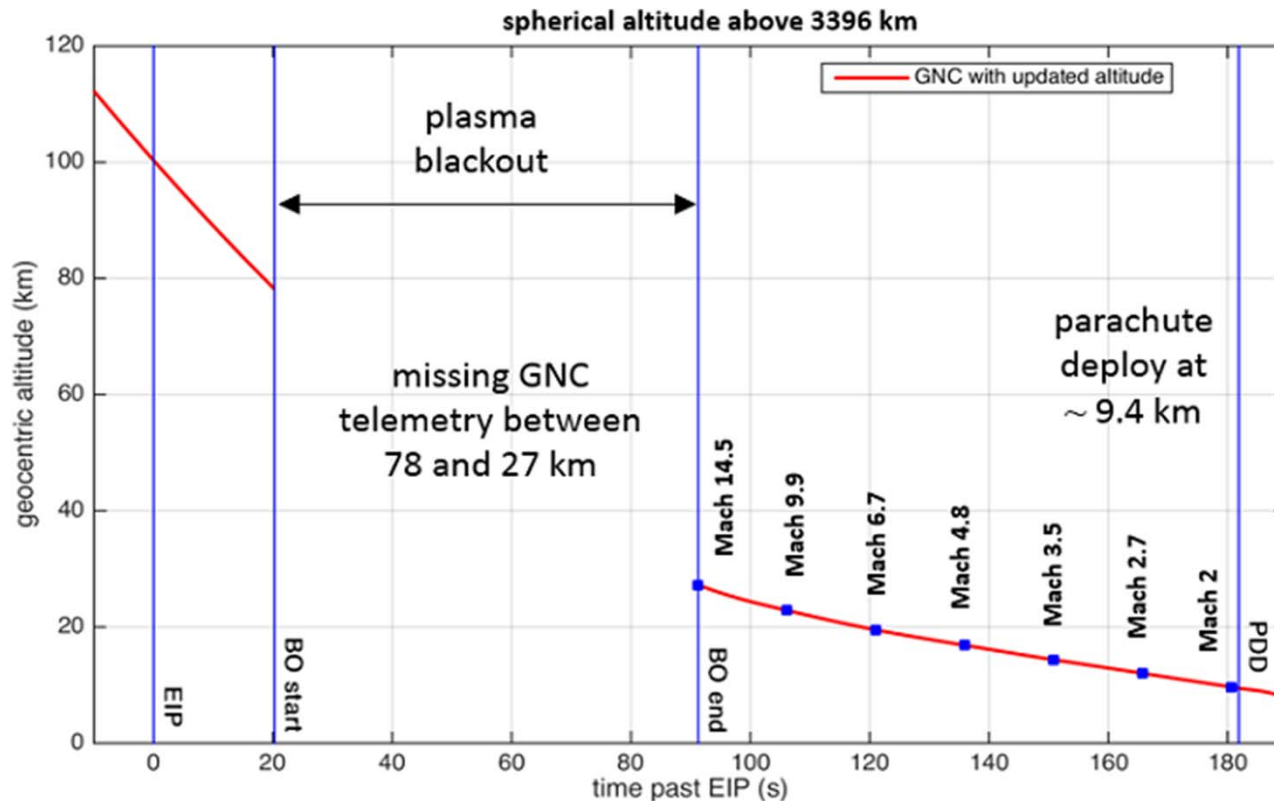
- FADS method validated with MSL flight data (1-D: one pressure sensor)
- FADS method extended for ExoMars (3-D: every pressure sensor)
- Pre-flight ExoMars uncertainty study: being updated to account for P0 sensor malfunction and outlying data from sensor P3

- Successful demonstration with flight data from ExoMars Schiaparelli
- Atmospheric density between 10-27 km: IMU and FADS methods in reasonable agreement, suspicious data from P3 sensor
- Consolidated IMU and FADS reconstruction will include atmospheric pressure and temperature, and (dis)confirm wind observation

Acknowledgements: UPWARDS consortium, ESA ExoMars 2016, AMELIA team, DLR aerospace center



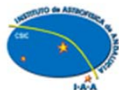
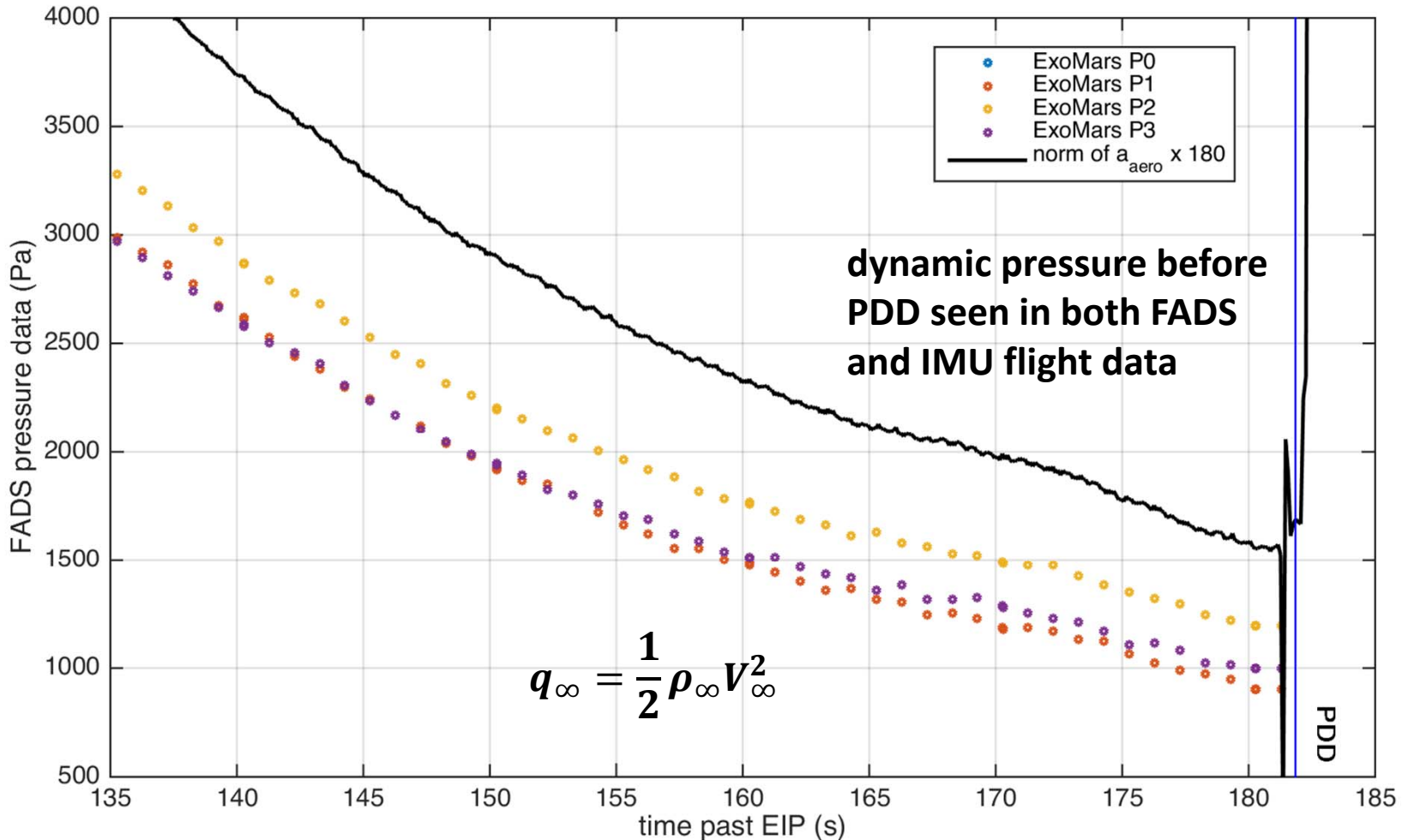
APPENDIX: ExoMars altitude profile



- **Schiaparelli crash landed on Mars:** but 'essential' flight data were transmitted and useful
- **Compared to nominal mission:** no data in radio blackout, reduced sampling frequencies, more uncertainty, we could reverse-calculated IMU flight data from GNC navigation

APPENDIX: Dynamic pressure increase before PDD

Local increase in atmospheric density or head wind?



Question for the Audience



UPWARDS
UNDERSTANDING PLANET MARS



ORB - KSB