ExoMars Mission Analysis and Design from Mars Arrival to Landing

Rodrigo Haya Ramos, Juan Luis Cano, Davide Bonetti,
Cristina Parigini, Francesco Cacciatore
DEIMOS Space, Spain

David Gittins, Dave Northey, David Riley
Tessella PLC, UK

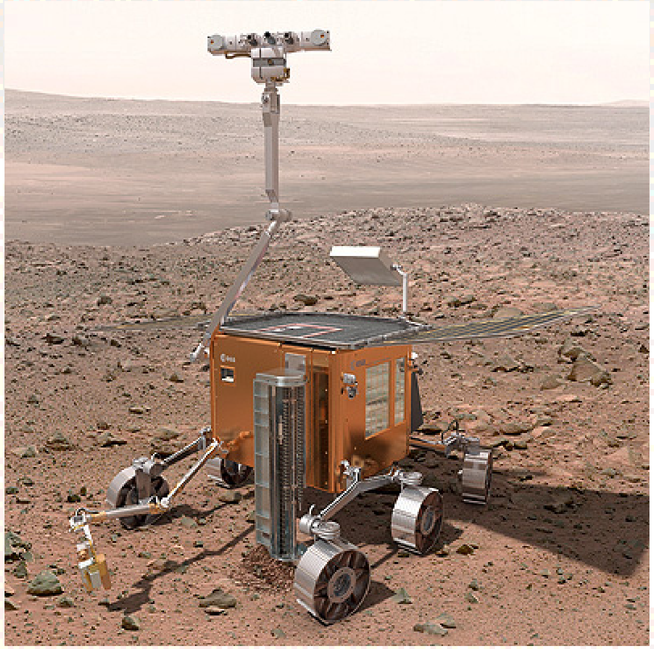
Stefano Portigliotti, Alberto Anselmi -
Thales Alenia Space, Italy

Agenda

- **ExoMars Mission**
- **Motivation and Objective**
- **Mission Scenario**
- **Arrival**
- **Global Entry Corridor**
- **Mission Performances**
- **Triggering Algorithms**
- **DLS performances**
- **Conclusions**

Exomars Mission

- **Scientific Objectives**
  - The search for traces of past & present life
  - To characterise the water/geochemical environment
  - To study the surface environment and identify hazards to future human missions
  - To investigate the planet's subsurface and deep interior
- **Technological objectives**
  - Entry, Descent and Landing (EDL) of a large payload on the surface of Mars,
  - Surface mobility via a Rover having several kilometres of mobility range,
  - Access to sub-surface via a Drill to acquire samples down to 2 meters,
  - Automatic sample preparation and distribution for analyses of scientific experiments.
- **The ExoMars Descent Module (DM) will deploy two science elements:**
  - a high-mobility Rover
  - a fixed station, the Geophysics/Environment Package (GEP).



Credits: ESA

Motivation and Objective

- **Project Motivations**
  - ExoMars is ESA's current mission to planet Mars aimed for launch in 2013 (baseline) or 2016 (back-up)
  - ExoMars is the first Aurora Flagship mission under assessment
  - Project is currently undergoing Phase B2 studies under ESA management and Thales Alenia Space Italia project leadership
  - DEIMOS Space provides support to TAS-I on interplanetary and in-orbit Mission Analysis and Design
  - DEIMOS Space is responsible for the Mission Analysis and Design for the Entry, Descent and Landing (EDL) activities. Within this contract, Tessella is responsible for the support to sizing and analysis of the Descent and Landing System
  - Current mission scenario is the so-called "Enhanced Baseline"
- **Presentation Objectives**
  - To present the methods, tools and results used to support the ExoMars Mission Analysis design during EDL phases to Mars

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Mission Constraints

- **Mission launched in 2013 as baseline. Back-up shall be possible in 2016**
- **Mission shall be launched by Ariane 5 (baseline) or Proton M (back-up)**
- **Transfer to Mars will be of type 2 with a large DSM**
- **Injection orbit in Mars will be a 4-sol orbit with a 500 km pericentre radius (trading-off delta-V needs and orbit stability)**
- **Descent to Mars such that the following complies:**
  - After MGDS (planet solar longitude of 340º) and 180 sols before next
  - No solar superior conjunction occurrence in 180 sols
  - Maximisation of the descent mass
- **Another constraint imposed by the launcher is:**
  - Escape trajectories with Ariane 5 constraint to always depart from Earth with an almost null declination

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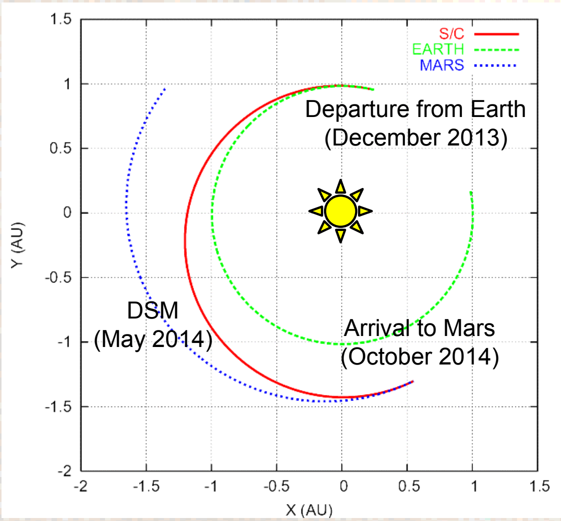
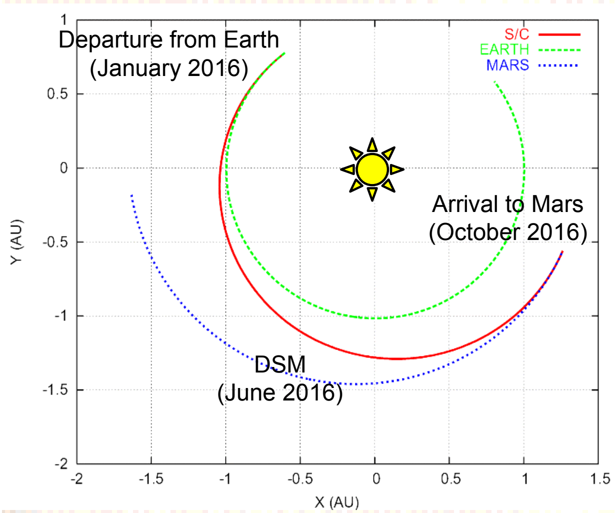
Mission Scenario

- **Trajectory profile characterised by:**
  a) Direct transfer to Mars with an intermediate DSM
  b) Insertion into a 4-sol Mars waiting orbit (WO)
  c) Avoidance of eclipses larger than 3 hours once in orbit
  d) Injection in Mars retrograde orbits to land in allowed LST time range after the waiting phase
  e) Composite descent from orbit, initiated by the Carrier
  f) Separation of CM-DM composite
  g) CM burns up in the Martian atmosphere
  h) DM goes on to complete the EDL

Baseline scenario



Back-up scenario



Targeting of EIP & Operational timeline

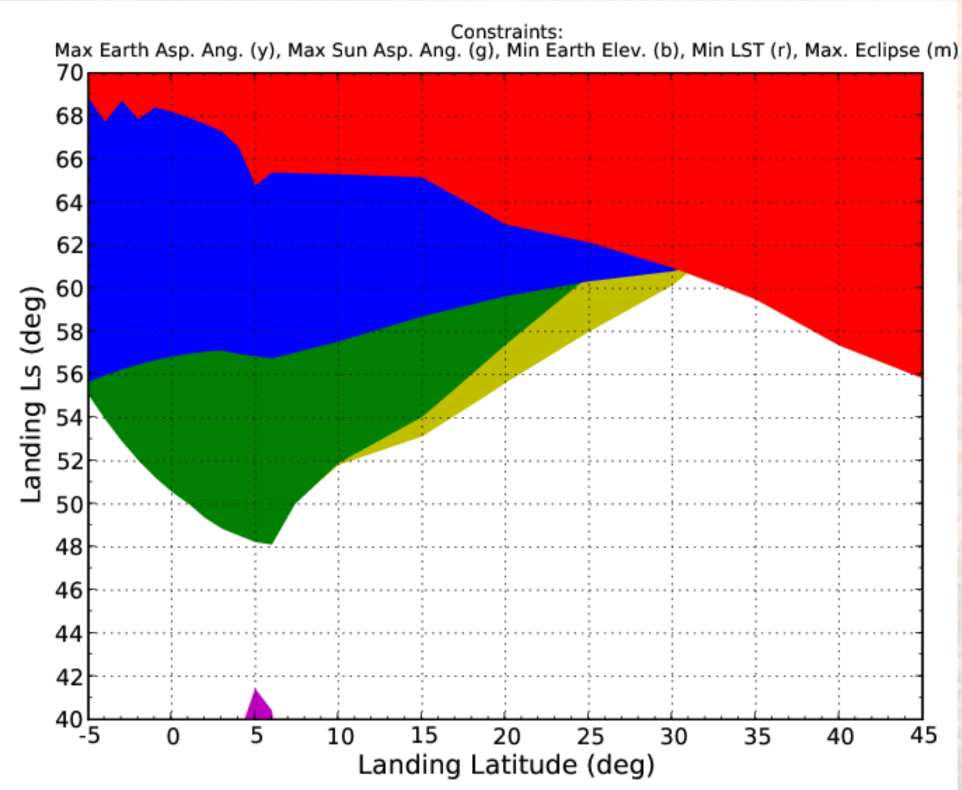
- **Targeting conditions at end of waiting phase shall ensure:**
  - Arrival to correct latitude and longitude at selected Ls
  - LST at landing point above 8:00 and below 12:00
  - Earth at landing point above 15º over the horizon (for DTE communications)
  - Other spacecraft constraints to be satisfied (maximum sun and earth aspect angle constraints at EIP)

- **Operational implementation:**
  - Injection in Mars orbit
  - Wait until 3 orbits before descent and perform target latitude correction (if needed) and pericentre reduction to 250 km
  - Perform DMTM at last apocentre
  - Perform DM-CM separation between 0.5-2 h from EIP
  - EDL phase

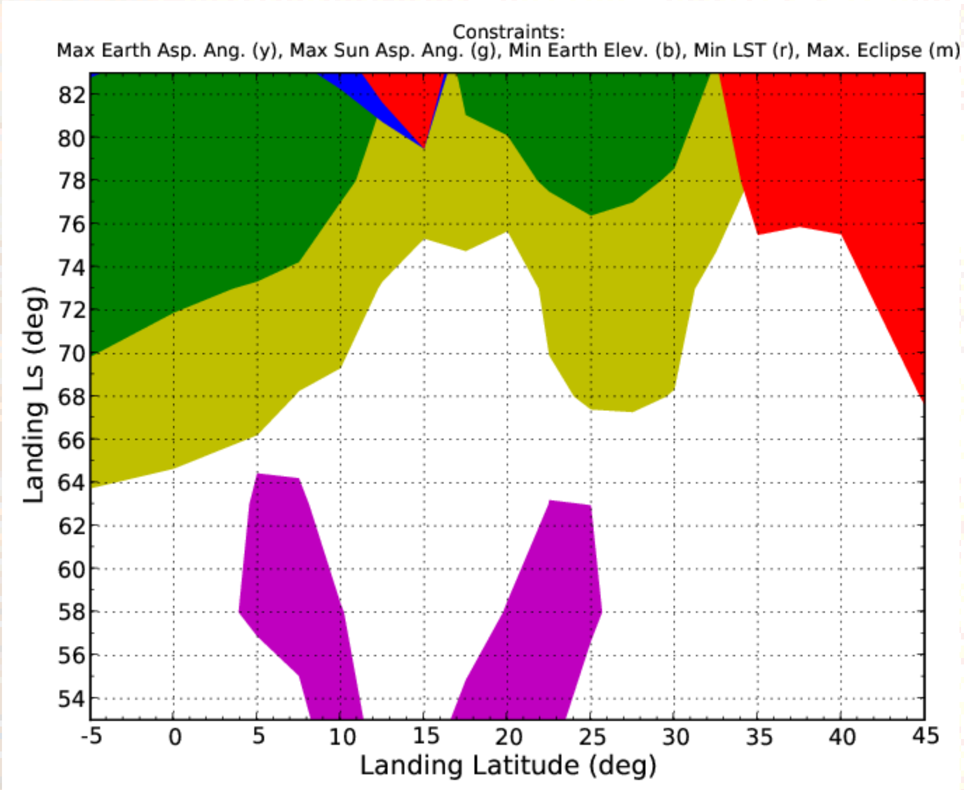
Landing constraint maps

- **Compliance to constraints produce the following landing Ls-Latitude maps:**
  - White areas represent allowed landing regions

Baseline scenario



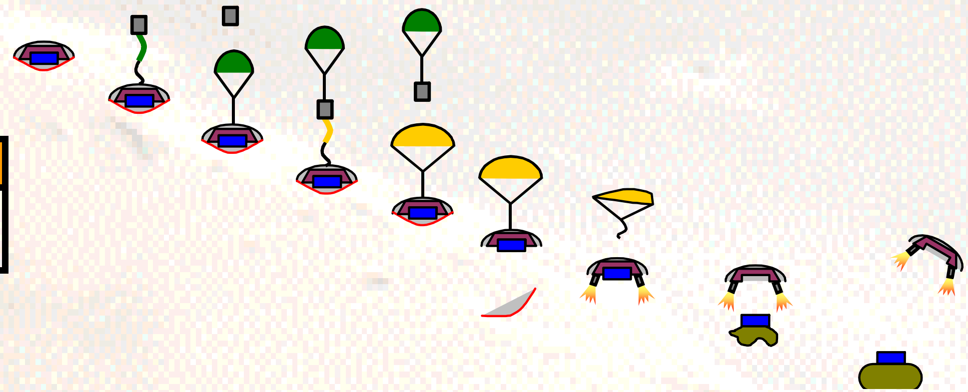
Back-up scenario



EDL Mission Requirements

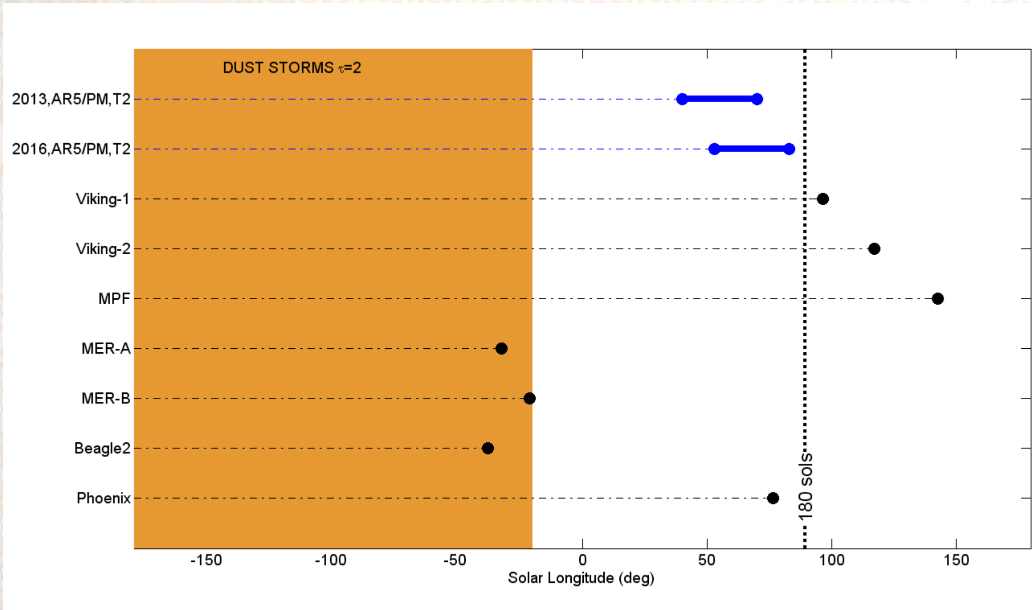
- **EDL architecture**

DM	Parachutes	Retro-rockets	Airbags
70º/47º aeroshell	Two Stages	Liquid rockets	Vented



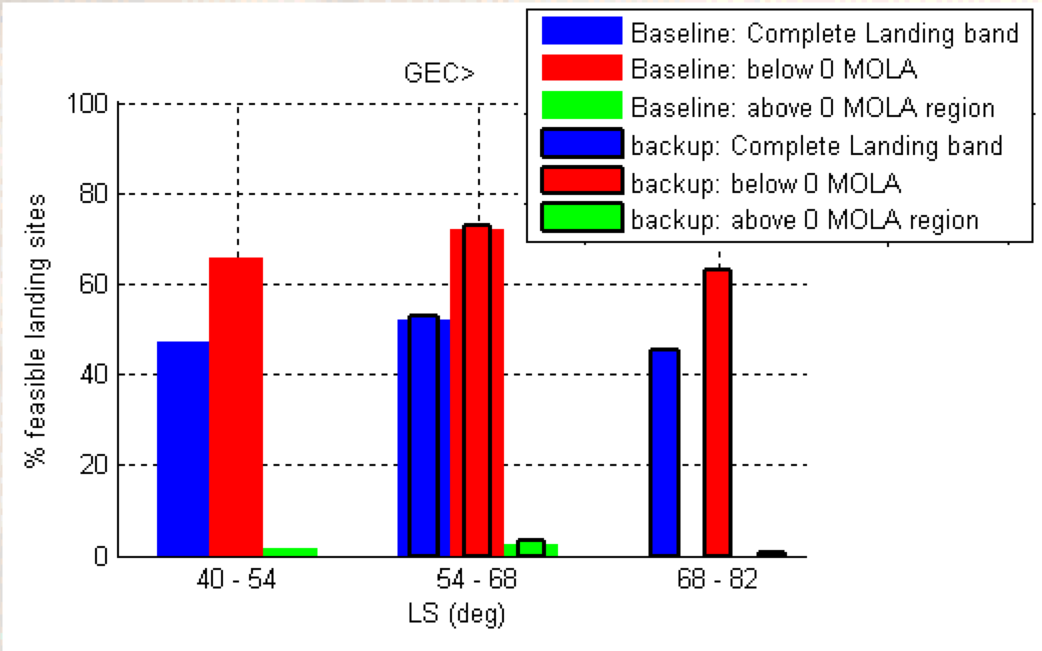
- **Main requirements applicable to EDL**

Subject	Requirement
Landing Latitude	5ºS to 45ºN
Nominal Rover Mission	180 sols, outside MGDS
Landing accuracy	50 km 3σ
Landing time	8:00 –12:00
Landing altitude	< 0 m MOLA
Oscillations under parachute	< 10º
Descent and Landing Loads	< 40 g
Entry Control concept	Ballistic
Terrain Slopes	<10º(100 m), <18º(10 m)
Winds at landing	< 20 m/s (horiz.), < 5 m/s (vert.)



Global Entry Corridors 1/2

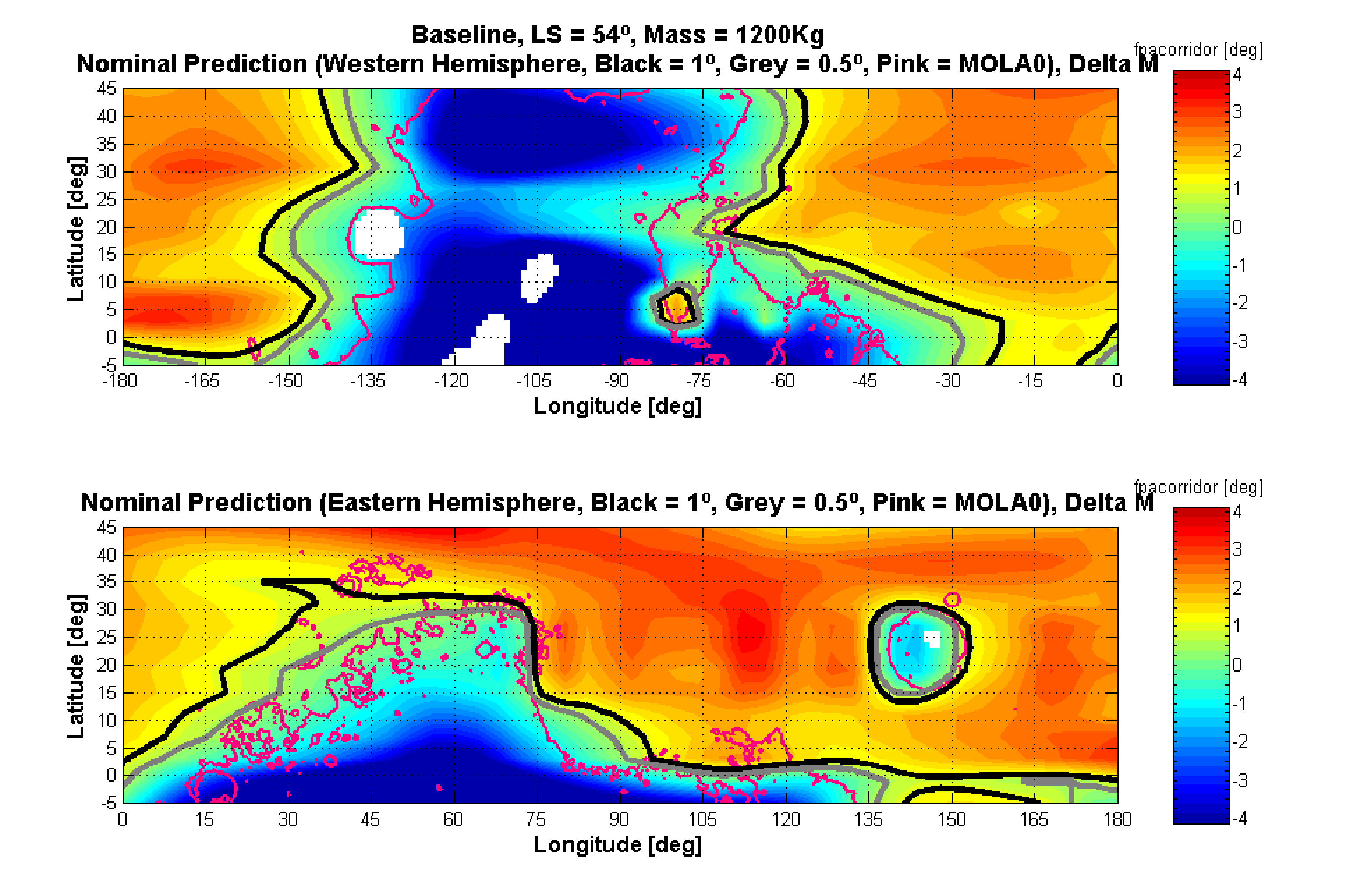
- **Global Entry Corridors (GEC) are an extension of the entry corridors to characterise the DM entry capability in every region of the required landing latitude band**
- **The combination of Global Entry Corridors, Engineering constraints on the terrain and Scientific requirements provides an overall view of the feasibility of a landing site**
- **Feasible sites above 0 MOLA identified**



Global Entry Corridors 2/2

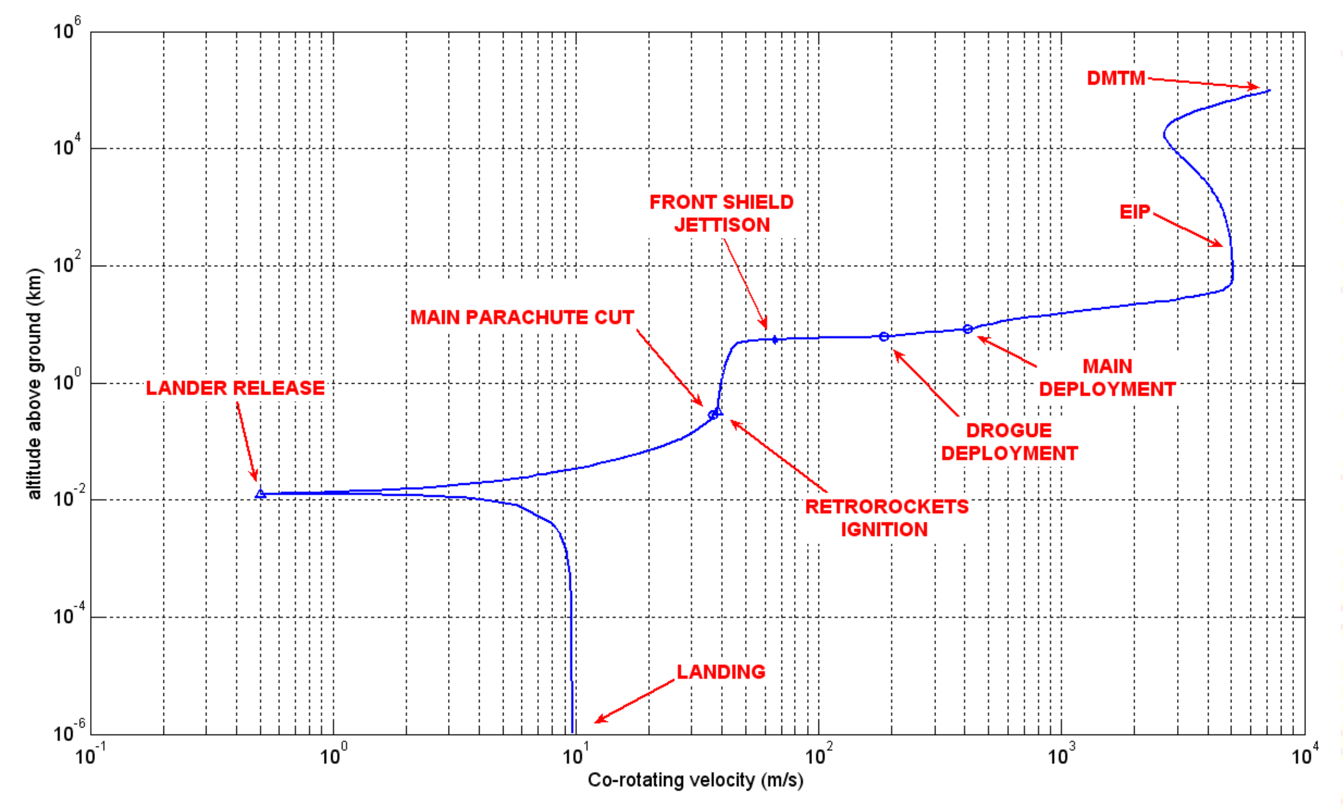
- **Sizing conditions are identified using GEC predictions**

TPS sizing **PAS/RCS** **Structure** **Margins**



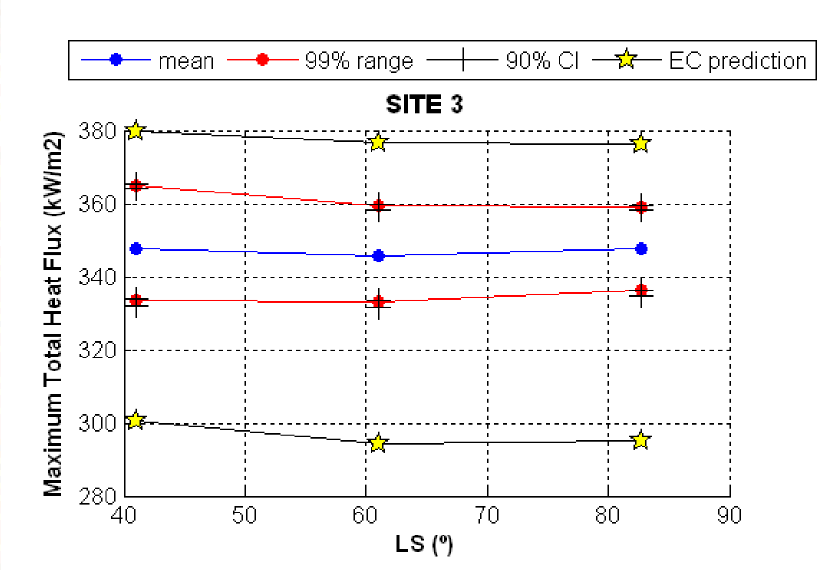
Mission Performances 1/2

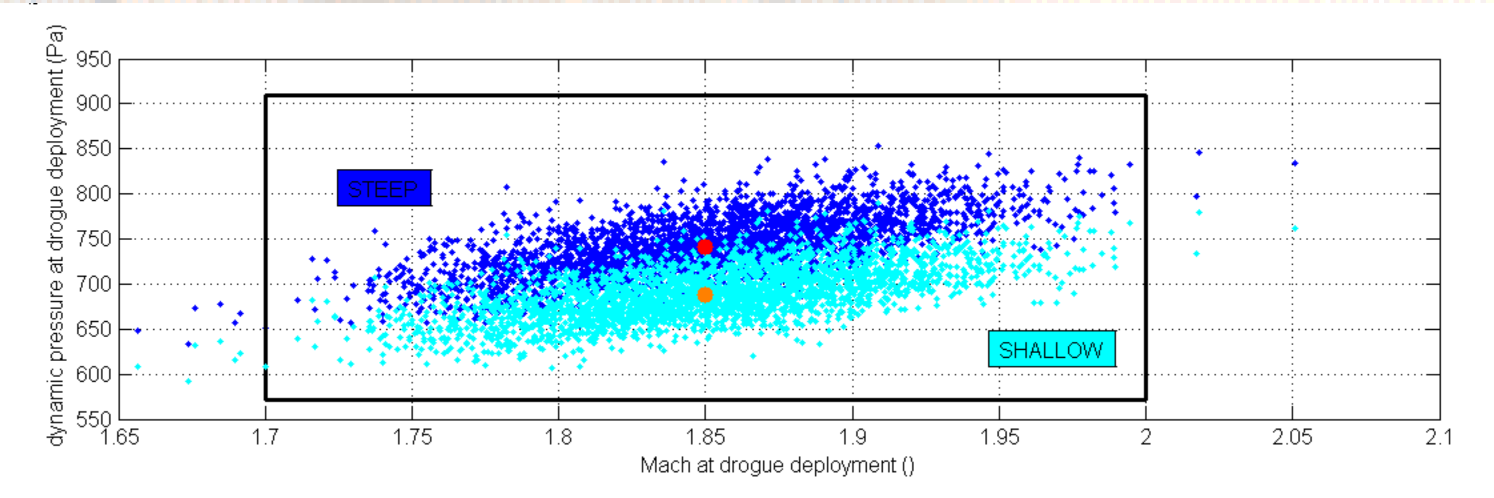
- **Reference Scenario defined as an End-2-End trajectory**
  - From MOI to landing
  - Linked to Arrival conditions
  - Close-loop guidance during retro-rockets phase.



Mission Performances 2/2

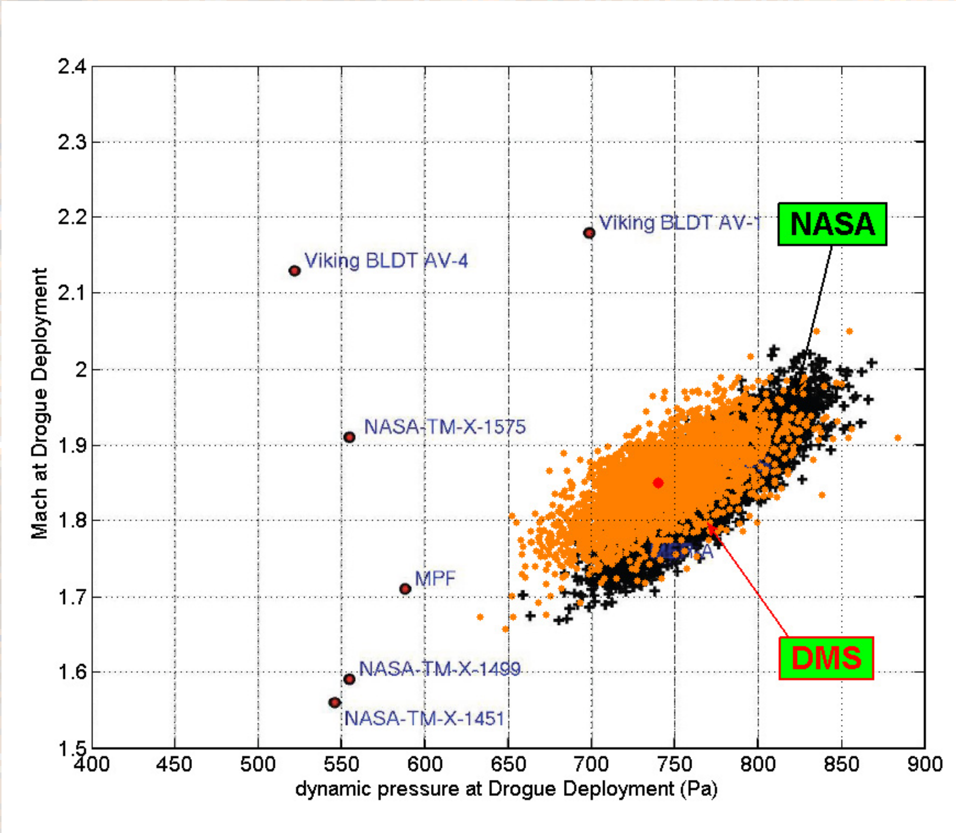
- **An intensive Monte Carlo campaign has been carried out in selected sites & dates to assess the mission performances (uncertainties)**
- **The GEC predictions correctly reproduce the Monte Carlo variability in all parameters**

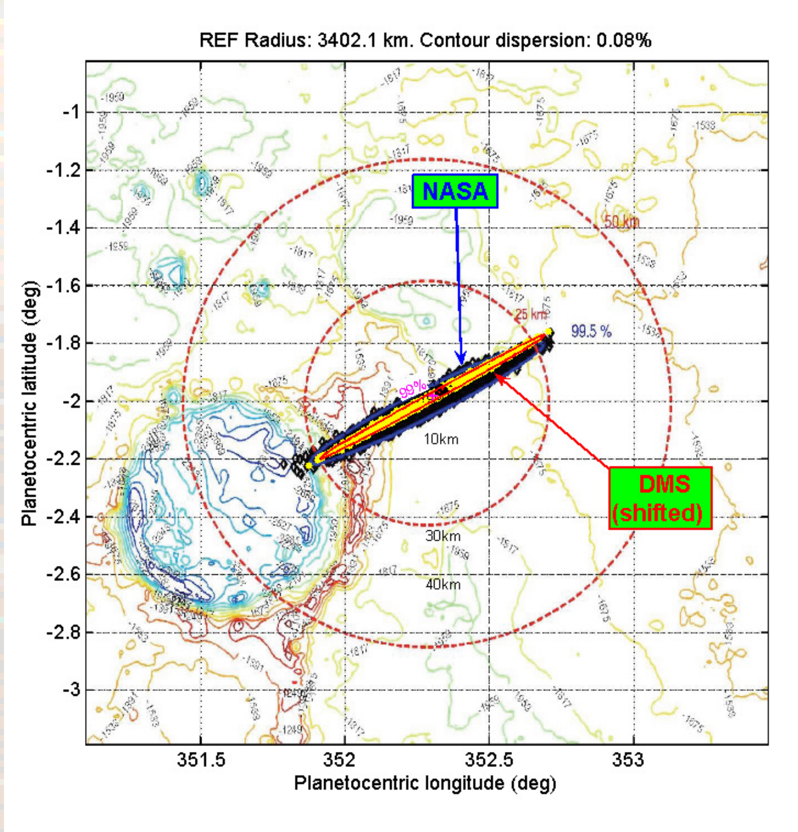




NASA Cross Check

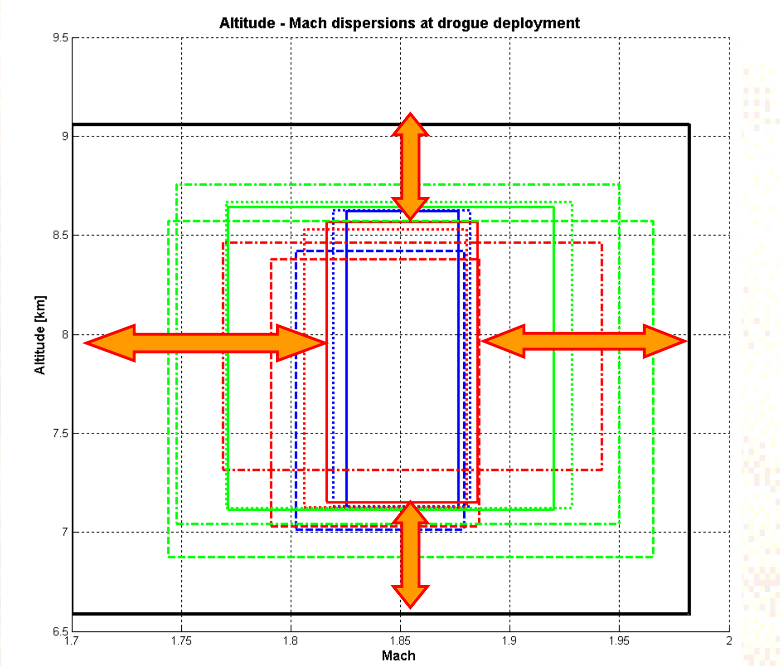
- **An independent verification of the performances has been performed by NASA**
  - Different aerodynamics & atmosphere models
- **Good agreement**





Triggering algorithms

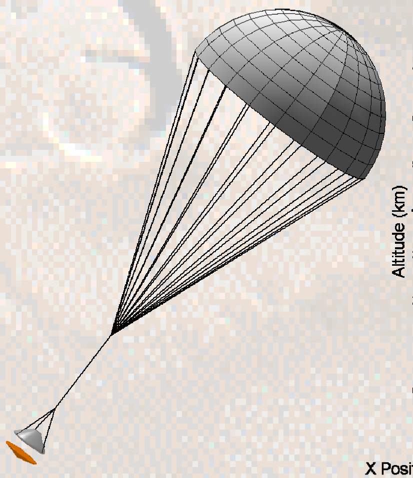
- **Drogue Deployment algorithms**
  - Based on accelerometer measurements
  - Tuning for each site
- **Reqs at drogue:**
  - Mach dispersion < 0.15
- **Performances assessed with Monte Carlo analyses**
- **All algorithms within specifications for all variables**
- **G-switch as back-up**

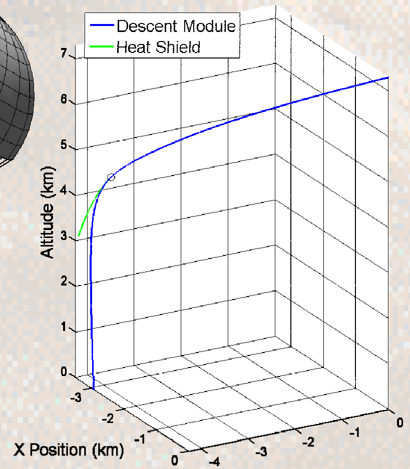


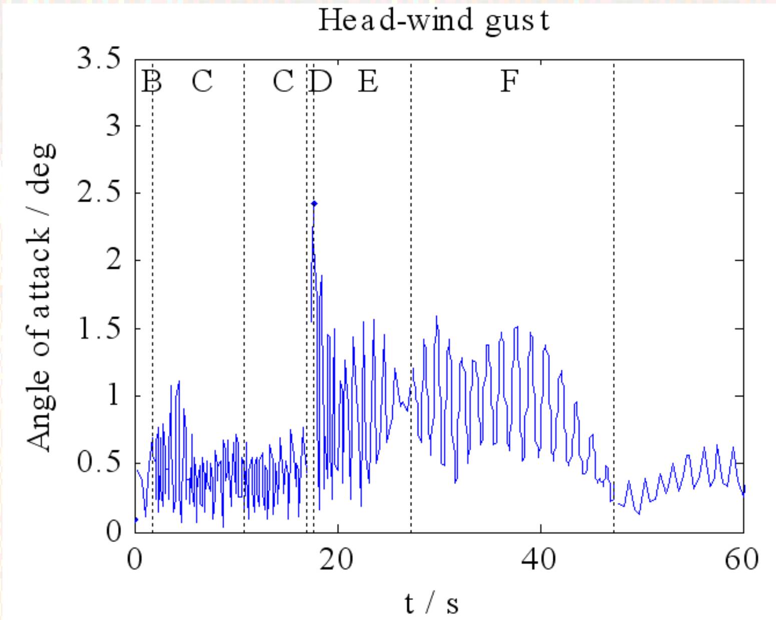
Multibody Simulations

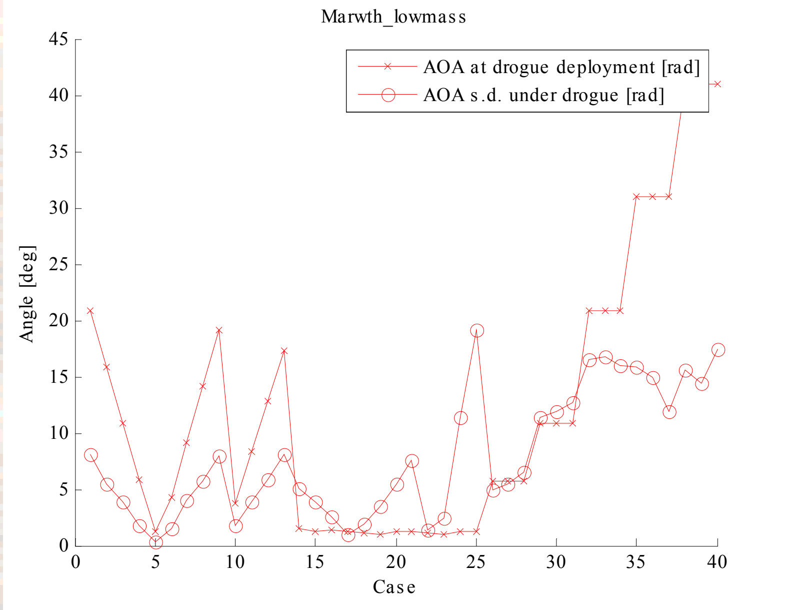
- **Descent sequence simulations:**
  - Multi-body 6-dof (using PASDA)
  - Drogue deployment through to thruster ignition
  - Deployment, inflation, frontshield (FS) separation included

- **Major objectives**
  - Assess oscillations
  - Preliminary gust responses
  - PAS offloading
  - FS separation









Conclusions

- **A comprehensive set of Mission Analysis results has been delivered to the mission Prime for Mission and System design**
- **New approach conceived by DEIMOS Space for worst-case analysis, mission capabilities assessment, landing site filtering and sizing trajectories selection based on Global Entry Corridors has continuing evolving.**
- **The detailed evaluation mission performances have validated the design tools.**
- **The increase in the fidelity of the models (ex: triggering algorithms, 6DOF+Multibody) as well as the independent cross checks are increasing the confidence in the design trades**
- **Parametric maps of DLS components combined with optimisation techniques allow the identification of optimum designs to support System trade offs.**