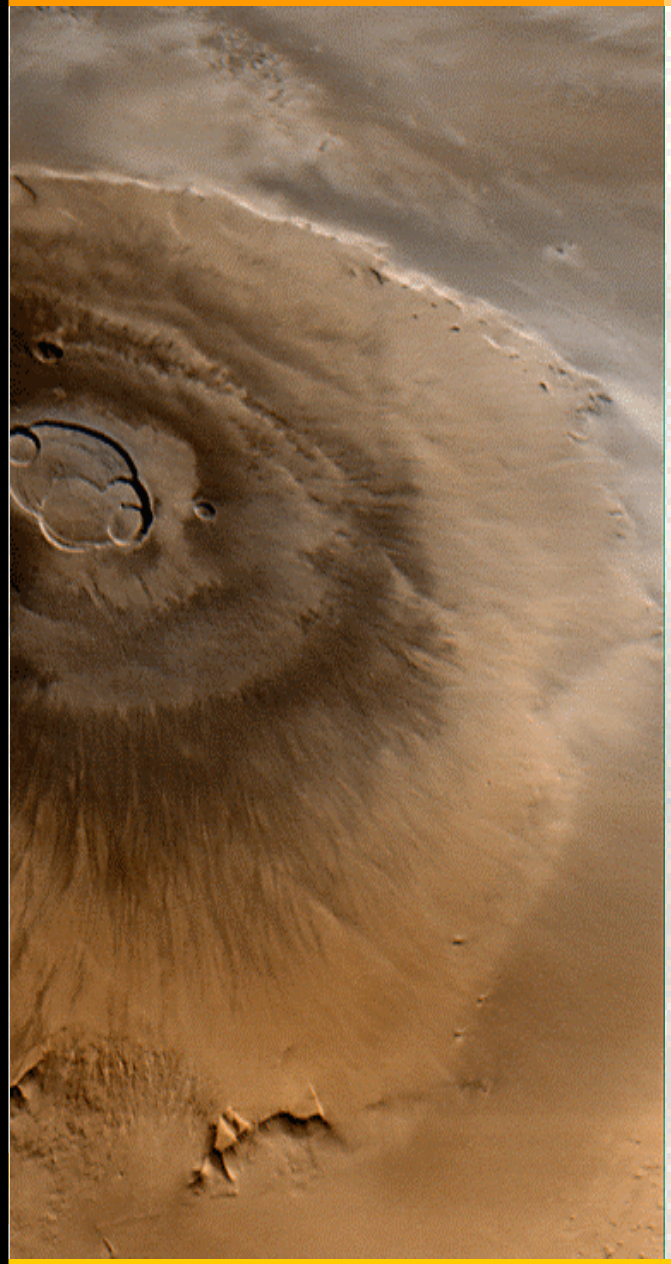

STATUS OF EXOMARS MISSION ANALYSIS AND DESIGN - ENTRY, DESCENT AND LANDING

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Bordeaux, 25-29 June 2007

Motivation and Objective

- **Motivations**
  - ExoMars is ESA's current mission to planet Mars aimed for launch between 2013 and 2015. The project is currently undergoing Phase B studies under ESA management and Thales Alenia Space Italia project leadership.
  - Deimos Space is responsible for the Mission Analysis and Design of the Entry, Descent and Landing (EDL) support to TAS-I. Within this contract, Analyticon Ltd. is responsible for the sizing and analysis of the Descent and Landing system.
  - Exomars is the first Aurora Flagship mission to be assessed.
  - The challenging requirements currently imposed to the mission need innovative analysis and design techniques to support system design trade-offs.
- **Objectives**
  - To present the methods and tools used to support the Exomars EDL design from a Flight mechanics and GNC standpoint.
  - To highlight the status of the Exomars EDL Mission design activities

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Approach

- **The Mission Analysis and Design covers:**
  - Identification of Design Driving Requirements and Constraints functions
    - Arrival conditions
    - Environment (atmosphere)
    - Entry Corridor
    - Sizing Trajectories
    - Landing Site Filtering
    - DLS sizing
    - Nominal conditions and ranges
    - …
  - EDL Trajectory
    - Nominal timeline
    - Sequence of events
    - Triggering algorithms

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Exomars Mission

- **Objectives**
  - search for traces of past and present life
  - characterize the Mars geochemistry and water distribution
  - improve the knowledge of the Mars environment geophysics
  - identify possible surface hazards to future human exploration missions
- **The ExoMars Descent Module (DM) will deploy two science elements:**
  - a high-mobility Rover
  - a fixed station, the Geophysics/Environment Package (GEP).

Credits: ESA

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Mission Requirements & Constraints

- **Baseline: single Soyuz 2b launch (from Kourou) of a Carrier spacecraft and a Descent Module (DM) between 2013 and 2015 with direct entry in Mars**

- **New scenarios added**
  - Dual launch
  - Ariane 5 launcher
  - Orbiter
  - Release from HEO
  - 2015 opportunity

- **Architectures:**
  - Non-vented/Vented airbag
  - Single/2 stages
  - Solid/Liquid RCS

Subject	Requirement
Landing Latitude	15ºS, 45ºN
Nominal Surface Mission	180 sols outside MGDS
Landing accuracy	25 km 3σ (15 km goal)
Landing time	Daylight
Landing altitude	< 0 m MOLA
Oscillations (parachute)	< 10º
Descent & Landing Loads	< 40 g
Entry Control concept	ballistic
Terrain Slopes	<10º(100m), <18º(10m)
Winds at landing	<20m/s (H), <5m/s (V)
DM geometry	70º/47º

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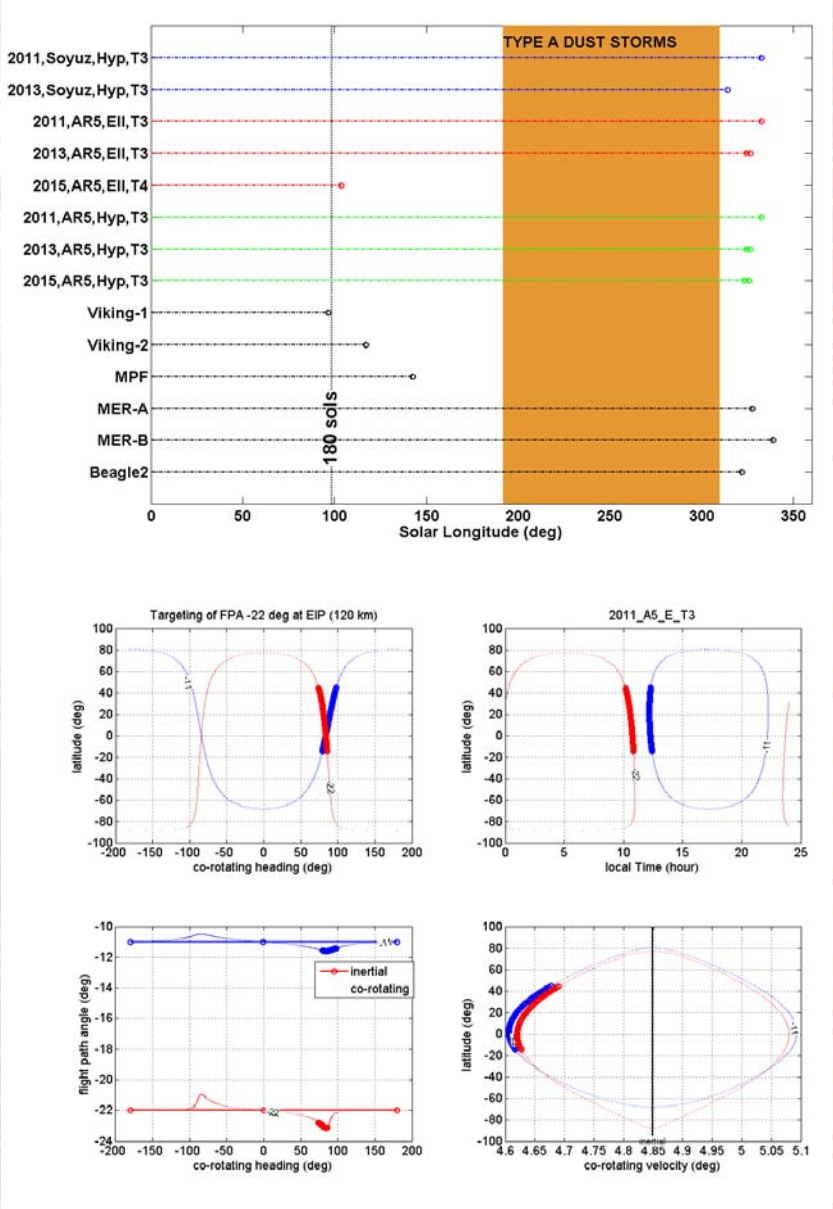
Arrival Conditions

- **Arrival epoch**
  - Several scenarios
  - Several Transfer Options
  - Arrival either after the end of the MGDS or 180 sols before onset

- **Arrival Conditions**
  - LT:
    - 10:00 – 15:00
  - Heading:
    - Hyperbolic: Eastwards
    - Elliptic: NorthEast & Eastwards
  - Inertial velocity
    - Hyperbolic: 5.6 km/s
    - Elliptic: 4.8 km/s



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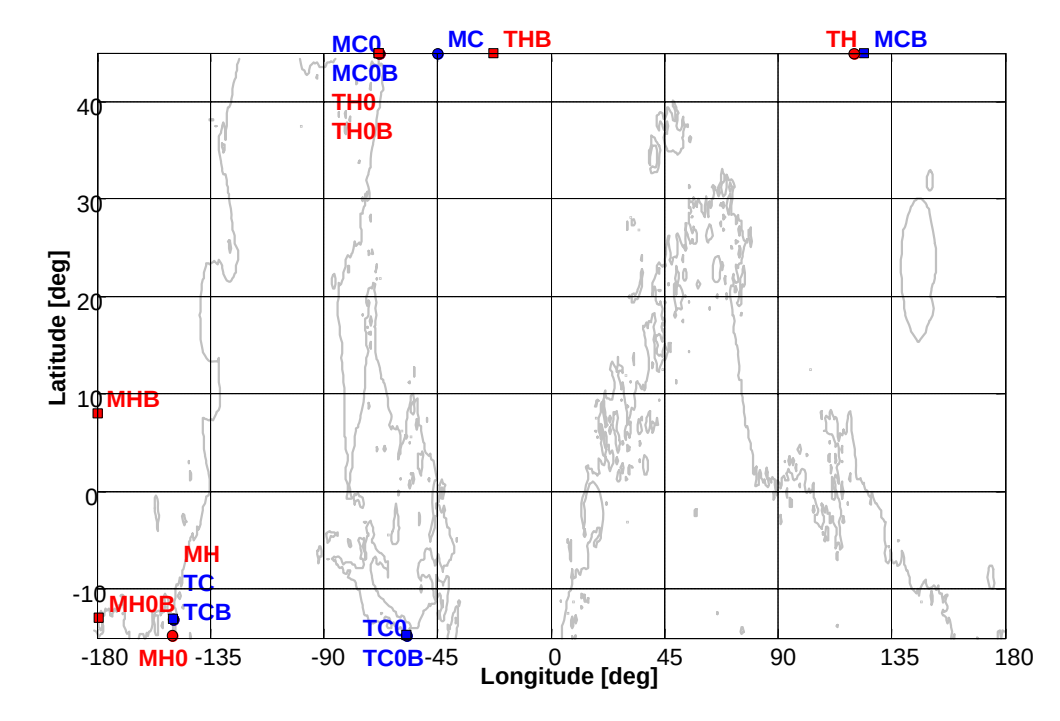
Atmosphere

- **Model: European Mars Climate Database (EMCD)**
  - Database derived from GCM simulations
  - Validated with observations
  - Several dust scenarios ranging from a clear atmosphere to Dust Storm (τ=4)
  - Depends on location, season and local time

- **Extreme atmospheric conditions**
  - Density & winds
  - Low & High altitude
  - Large variability:
    - Wide landing site area
    - range of arrival epochs



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Entry Corridor (1)

- **Lower upper bounds expressed in terms of flight path angle at EIP and Ballistic Coefficient**
- **Atmosphere variability considered**
- **Landing accuracy**
  - model validated with Monte-Carlo simulations
  - Trade-off with navigation performances

Constraint	Limit
Heat Flux (kw/m^2)	< 670
	< 513
Heat load (MJ/m^2)	< 26
Load factor (Earth g)	< 20
Altitude at parachute opening (km)	> 5
Dynamic pressure at parachute opening (Pa)	< 950
	< 1450
Mach number at parachute opening	[1.8 2.1]
DM mass (kg)	Soyuz < 1000
	Ariane < 1150
Landing accuracy (3σ) (km)	25

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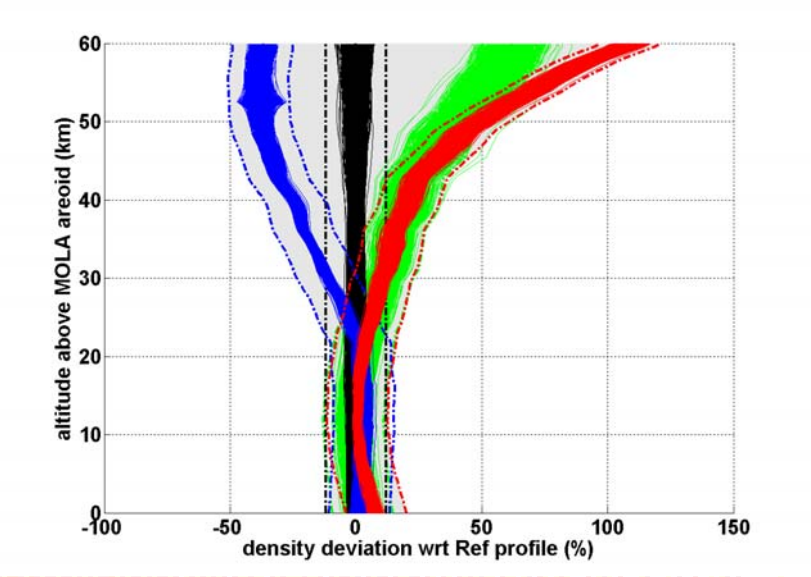
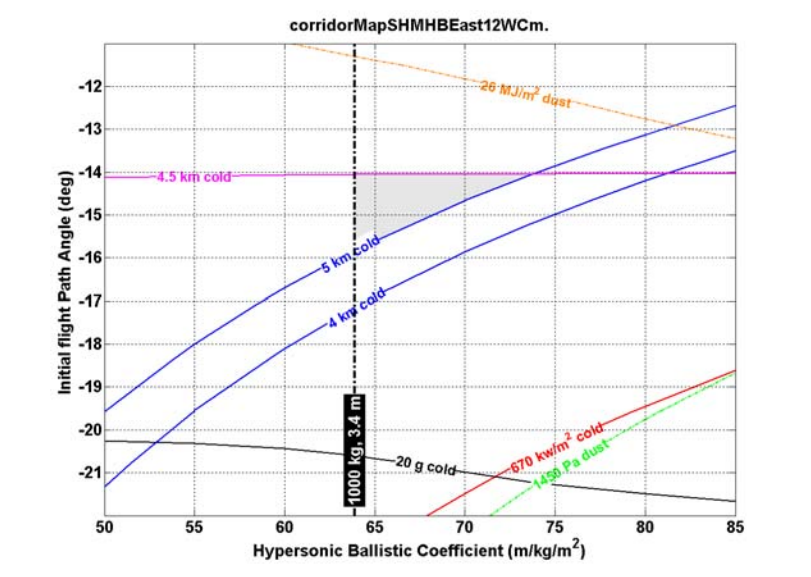
Entry Corridor (2)

- **Navigation at last TCM key issue for landing accuracy**
  - HEO release: requirement is feasible
  - Direct entry: precise navigation techniques needed
    - single beam interferometry
    - direct link between the composite s/c and an orbiter
- **No corridor in regions with thin atmosphere**
  - Landing accuracy & deployment altitude/heat flux as main constraints





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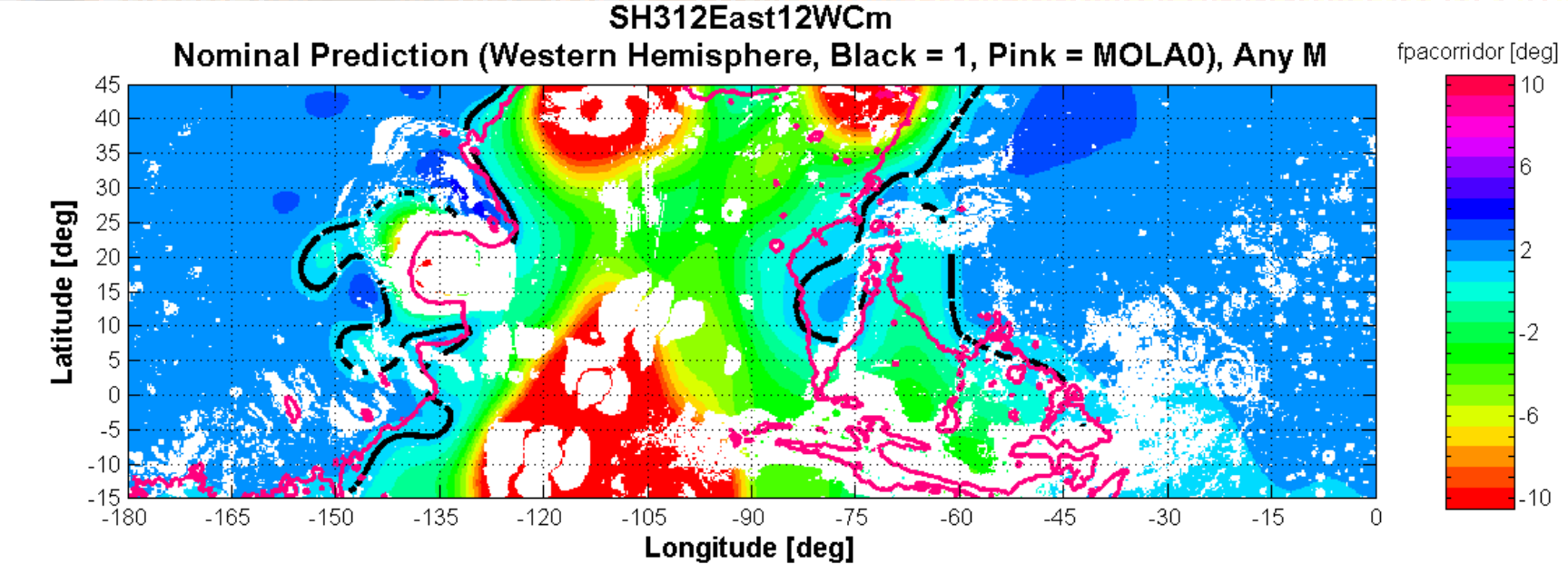
Global Entry Corridors

- **Worst-case design based on a single entry corridor requires a worst-of-the-worst approach that is not realistic due to the large variability in environmental conditions**

- **Global Entry Corridors are an extension of the entry corridors to characterise the DM entry capability in every region of the landing latitude band**



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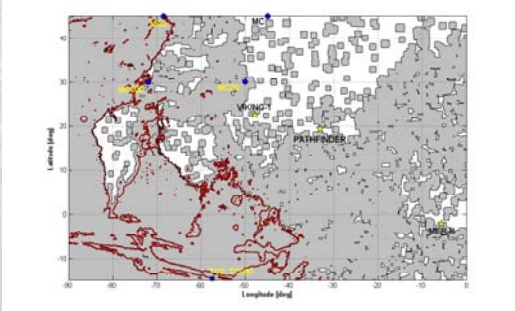
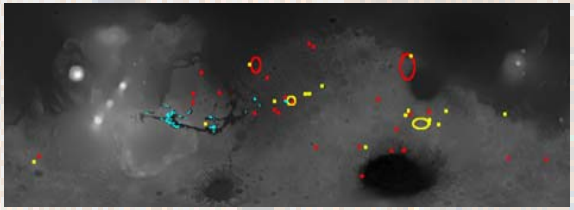
Support to Landing Site Selection

- **Example of site selection**

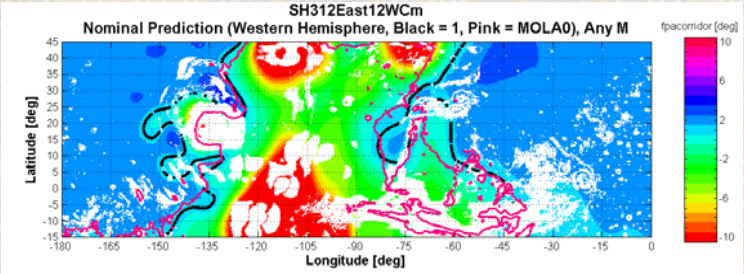
Engineering Constraints



Scientific Goals

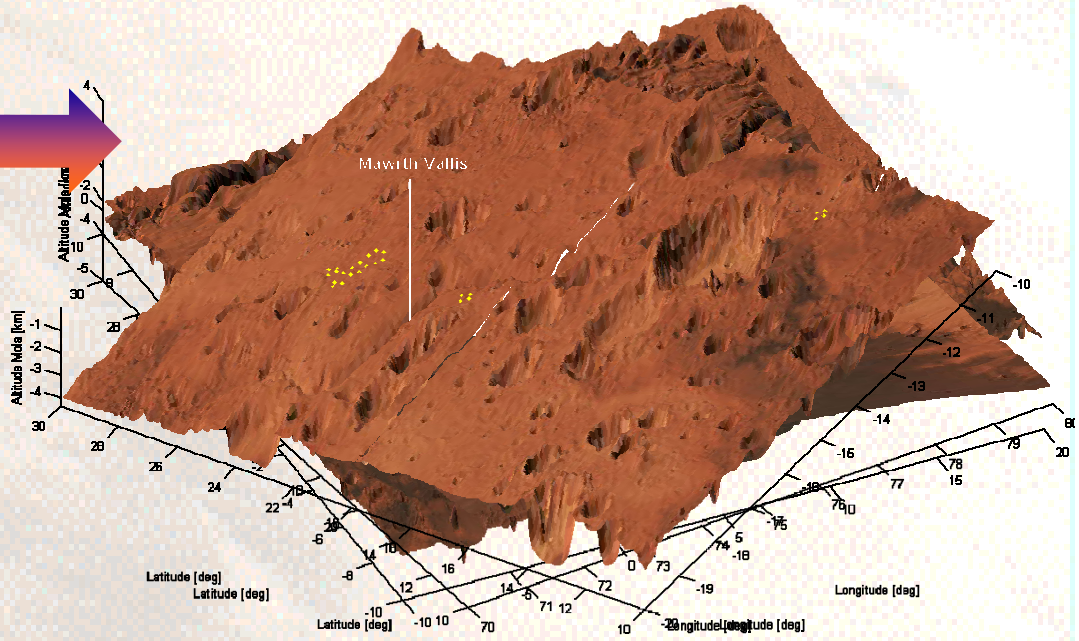


Global Entry Corridor



Site Selection

Area 3
Mawrth Vallis



(Some MSL Top sites within these regions)

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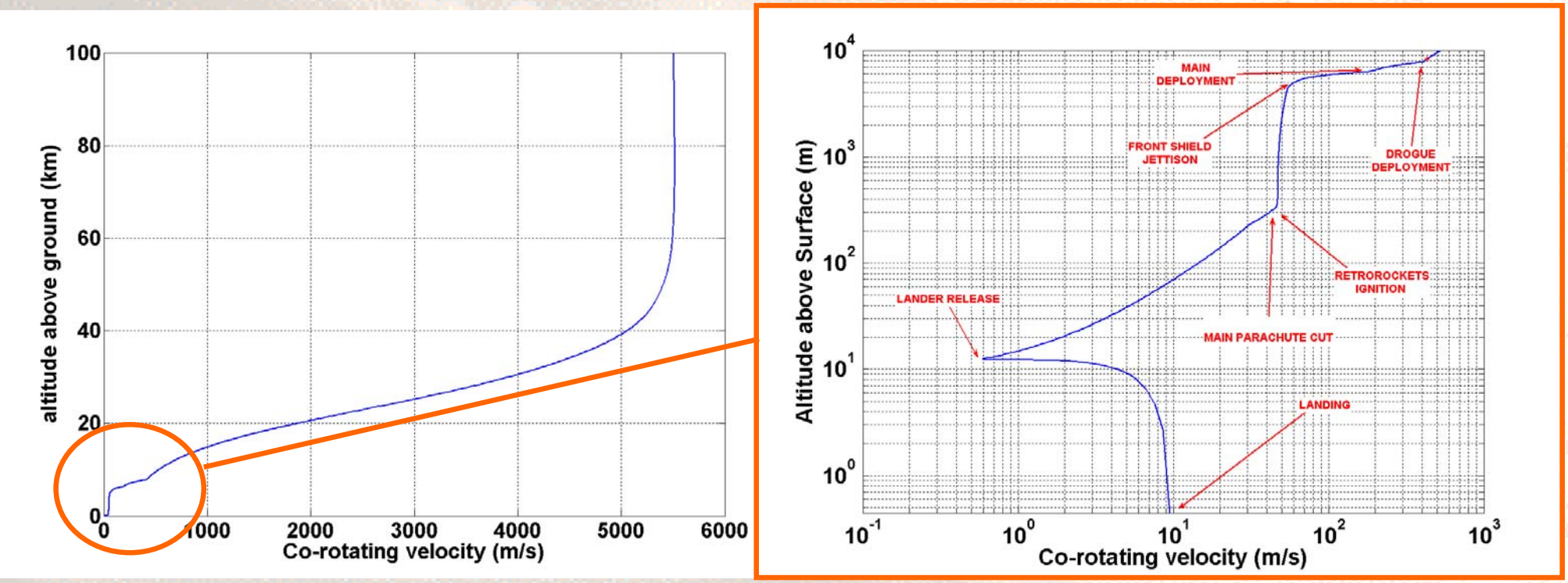
Sizing trajectories

- **Sizing trajectories result from the combination of Global Entry Corridors and terrain filtering**
- **Selected with a steep & shallow philosophy**



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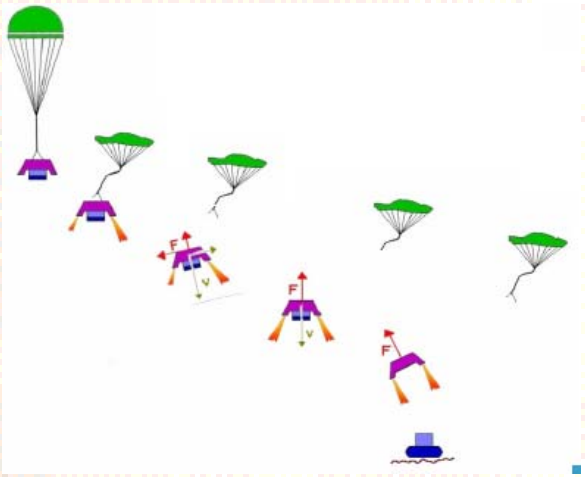
Sizing of the DLS (1)

- **Drivers:**
  - Lander mass (< 520 kg) & size
  - Limited overall mass budget
  - Safe separation of front shield
- **Parachute selection for DLS sizing activity (proven technology):**
  - Drogue parachute: Disk Gap Band (DGB)
  - Main Parachute: ringsail
- **Configuration options**
  - Single (possibly with reefing) or 2 stage systems
  - Solid or Liquid throttleable retrorockets
  - Non-vented and vented airbag
- **Key parameters**
  - Ballistic coefficient ratio at jettison
  - Parachute main material
  - Drogue-main balancing
  - Release conditions for airbag
  - Mass margin philosophy
- **Preferred concept:**
  - Two stage system with vented airbag

Non vented airbag

Vented airbag



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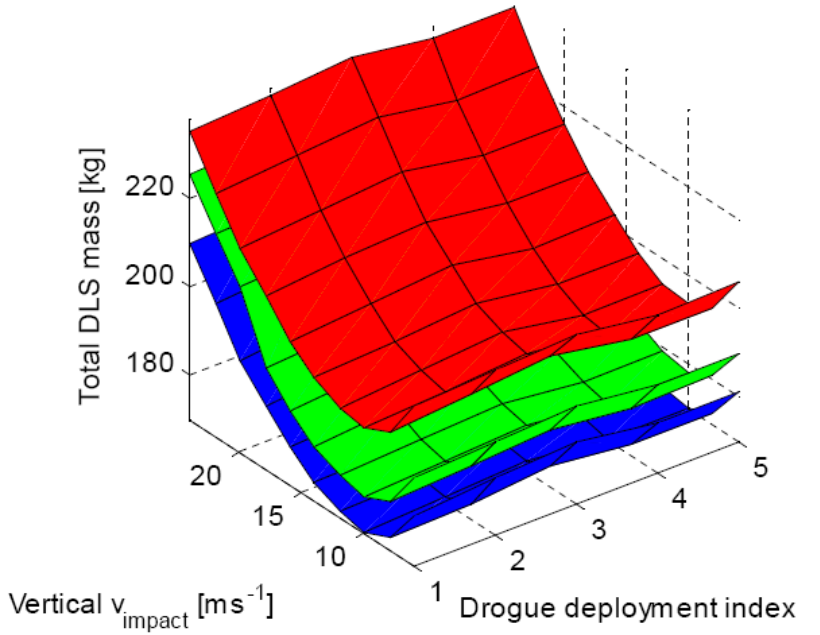
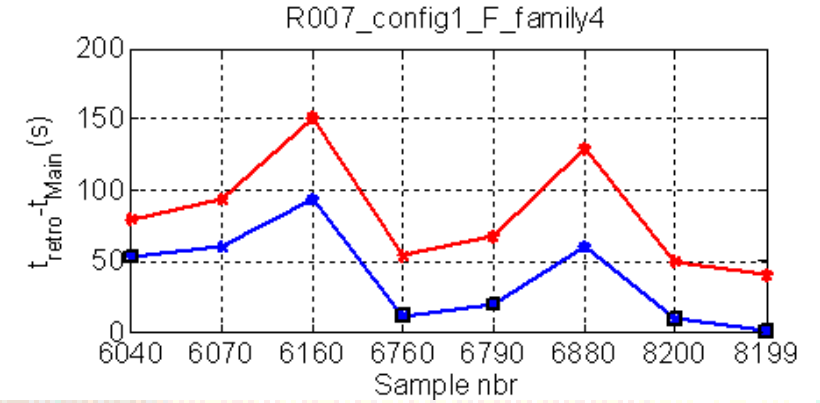
Sizing of the DLS (2)

- **Parameterisation of DLS sizing needed to support system design**
  - Non-vented: high sensitivity to impact velocity
  - Vented: horizontal impact velocities limit minimum vertical velocity
  - Relevant trade-off between system mass and height loss
    - Drogue-Main parachute balancing
  - Transonic main parachute deployment needed in some designs
  - Optimum designs can be selected from the pool of feasible designs.

- **Trajectory verifications used to validate designs**
  - height loss and timeline as figures of merit

Vented airbag





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Conclusions

- **Large variability in terms of landing site, arrival date and entry conditions associated to the scenarios Soyuz Hyperbolic, Ariane Elliptic & Hyperbolic.**
- **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 been successfully applied.**
- **Parametric maps of DLS components combined with optimisation techniques allow the identification of optimum designs to support System trade offs.**
- **Identification of key areas for next phases has been carried out.**

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