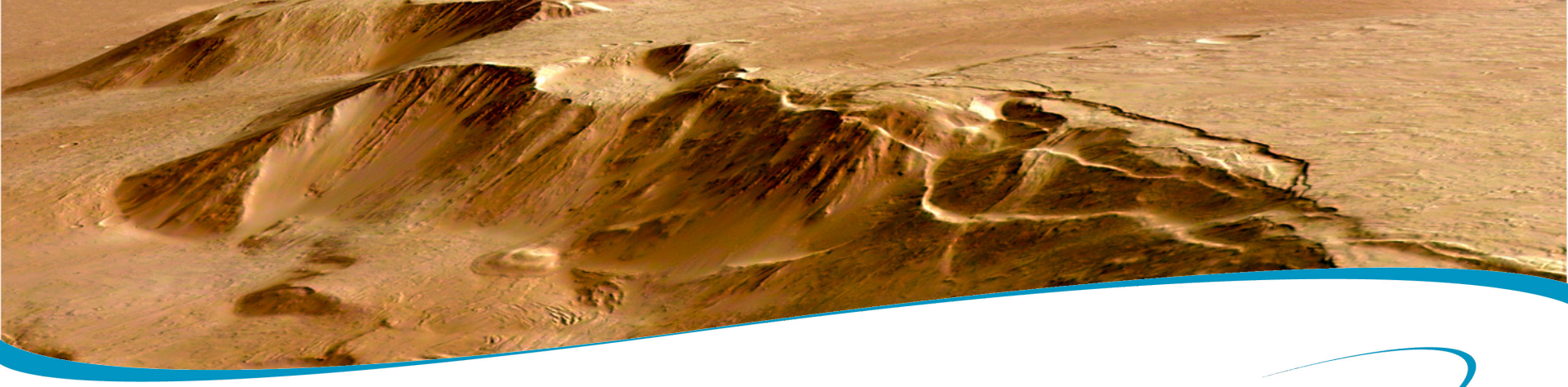

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A Robust Entry Descent and Landing System for the ExoMars Mission

by P.Arfi & F. Beziat
Thalès-Alenia Space - France, Cannes

THALES

Template reference : 100181708K-EN

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Mission objectives

- Framework
  - The first mission of the ESA Aurora Exploration Program
- Scientific objectives
  - Characterize the Mars geochemistry and water distribution
  - Improve the knowledge of the Mars environment and geophysics
  - Identify possible surface hazards
  - Establishing whether life ever existed or is still present on Mars
- Technological objectives
  - Demonstrate critical technology linked to Mars mission
  - Including the critical Entry Descent and Landing phases
  - Surface mobility and access to subsurface

Major Descent Module mission features

- Launch
  - 2013 (Ariane5 or Proton)
- Spacecraft
  - Orbiting Carrier Module (CM)
- Descent Module release
  - From Mars orbit
  - Ballistic entry
- Descent Module features
  - Mass range 1100-1350kg
  - DM is housing
    - A mobility Rover (exobiology PL)
    - A fixed station (Geophysics/ Environment PL)
    - “Descent science” payload

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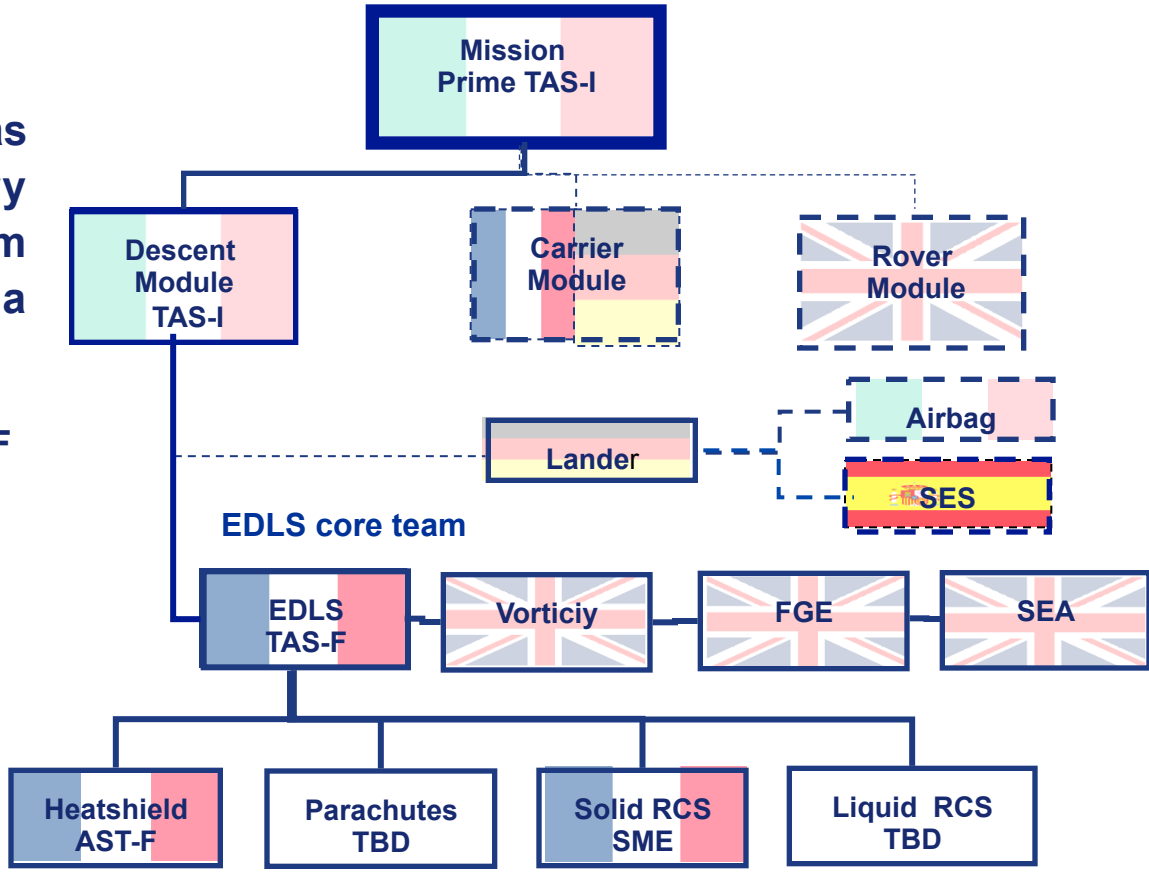
EDLS: a fruitful European cooperation

ExoMars EDLS activities

- Thalès Alenia Space-France was awarded the PhaseB1 Entry Descent and Landing System study under Thalès Alenia Space-Italy mission prime
- EDLS industrial team under TAS-F leadership
  - Core team supported for
    - Parachute: Vorticiy (UK)
    - TPS definition: FGE (UK)
    - Planetary protection: SEA (UK)
  - Heatshield: AST-F (Fr)
  - Parachute (selection in progress)
  - Reaction control system
    - Solid SME (Fr)
    - Liquid (ITT process)



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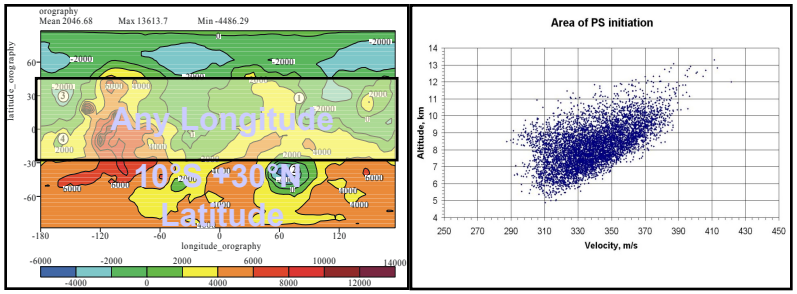
Taking up the challenge

EDLS main functions

- Safely deliver the payload on the Mars surface.
  - Perform necessary operations within a limited sequence (typ. below 3min)
  - Relying on an autonomous sequence
  - Decelerate the probe in a rarefied atmosphere, in a stable and controlled manner
- Ensure integrity of the DM in severe environment
  - Aero-thermodynamic fluxes and loads (1,500 kW/m², 20-40MJ/m²)
  - Peak deceleration (up to15g)
  - Stringent Martian atmospheric environment (CO_2, Dust, Wind & gusts),…
  - Induced environments (deployment shocks, …)

Provide robustness wrt

- Specification evolutions and potential mass snowball effects
- Large range of requirements: FPA (13.5+/-1°), landing sites (10°S to 30°N) and atmospheric conditions
- Dispersions along the trajectory due to EIP conditions, atmospheric, physical properties, aero-dynamical properties, sensor triggering dispersions



Typical landing site range & Altitude/velocity ellipse dispersions at descent phase init.

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EDLS operational sequence

Entry Phase

- Start at EIP 120km
- Peak deceleration 15g
- Peak heat flux 1,500 kW/m²
- Max heat load 20-40 MJ/m²

Heatshield

- Withstand aerodynamic loads
- Provide aerodynamic shape and stability
- Accommodate « descent science » instrumentation

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EDLS operational sequence

Descent phase

Parachute sub-phase

•Pilot Chute deployment

At Mach 1.9

Altitude 5.5km

Max dyn pressure 850Pa

•Main Parachute deployment

At Mach 0,8

Altitude 3.5km

Max dyn pressure 180Pa

•T0+10s FrontShield jettison

Two stage parachute

•Pilot Chute

•Provide stable transonic deceleration

•Allow Main parachute deployment

Main Chute

•Provide subsonic deceleration and a vertical trajectory for terminal descent phase

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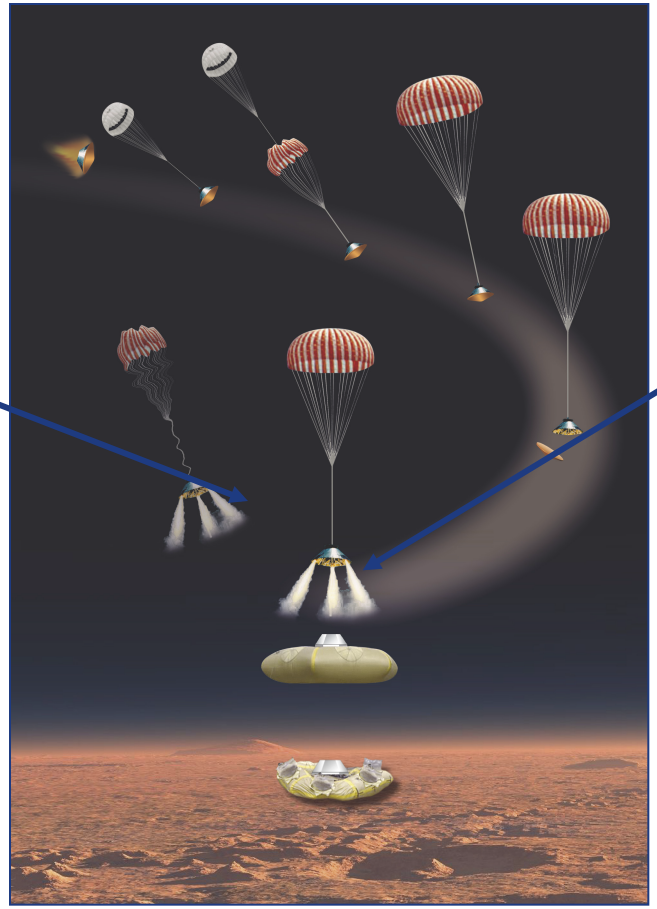
EDLS operational sequence

Descent phase

Reaction control sub-phase

Activated at ~700m above ground

Provide 45m/s to 0m/s deceleration



Reaction Control System

- **Provide terminal deceleration**
- **Control release conditions compatible with Airbag System**
- **Provide fly-away manoeuvre for re-contact avoidance**

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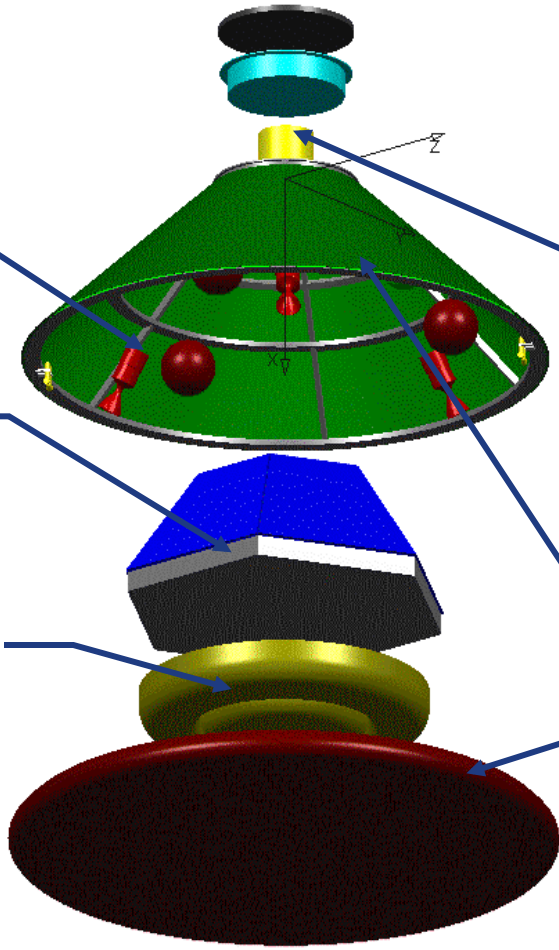
EDLS architectures



Reaction Control System

SES
Not part of EDLS
housing rover and fixed station

Airbags Systems
Not part of EDLS

Parachute system
Packed PAS
Canister

Heatshield
Backshield
Frontshield

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Heatshield

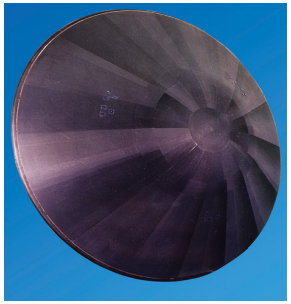
- Insulation performance
- Capacity to sustain loads
- Predictable aerodynamic shape evolution
- Mass
- Heritage

Instrumentation

- Thermistors
- Pressure
- Surface recession
- Spectrometer
- Flux meter

Frontshield

•Structure:
Honeycomb & carbon skin
Huygens heritage



Backshield

•Support structure:
Carbon skin
(backshell main structure is not part of EDLS)

Thermal Protection

•Ablative
Norcoat Liege
(up to 11mm thickness)
Netlander, Beagle2
and ARD heritage
•Internal
Foam

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Parachutes

- Inflation performance
- Loads
- Drag & Mass performance
- Aerodynamic stability
- Heritage

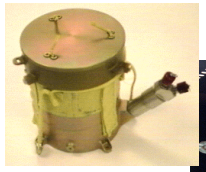
Mortar

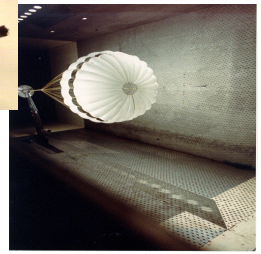
- Reliability
- Rapid deployment
- Heritage

■Pilot Chute & Mortar

Ø11m Disk-Gap-Band

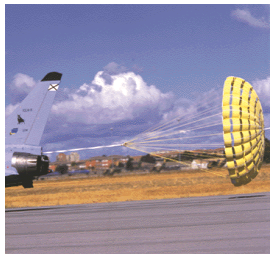
Huygens heritage





■Main Parachute

Ø24m RingIslot

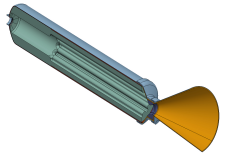


RCS

- Predictability and stability of thrust
- Thrust modulation capability
- Dynamic behaviour (response)
- Mass & Heritage

Solid engines

- **Solid fixed thrust**
  - 3 vertical engines (60.000Ns)
  - 3 lateral engines (3x1.000Ns)
- **Modulated solid thrust**
  - N20 injection based
  - Short response time
  - Thrust ratio down to 20%



Liquid engines

- **Ongoing process**

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Rationale for EDLS robustness

EDLS Specification

EDLS Design

No

Verification that EDLS engineering constraints are met

Yes

OK

EDLS engineering constraints:

-Heat load (st)	<20MJ/m²
-Flux (st)	<51W/cm²
-Deceleration	<15g
-Mach at PC deployt	<2,1
-Pdyn (PC)	<850Pa
-Mach at MP deployt	<0,8
-Pdyn at MP deployt	<180Pa
-Mach at FS jettison	<0,6
-FPA at VER firing	85°
-Velocity at VER firing	<45m/s

EDLS dispersed variables Covariance matrice
-MCI
-Entry state vector
-Aerodatabase
-Atmospheric data
-Terrain data

MonteCarlo analyses

EDLS parameters

Entry
-Peak heating rate
-Attitude & rates
-Total eat load

Pilot Chute deployt
- Mach
-Pdyn
-Altitude & rates
-Velocity
-FPA

Main Parachute deployt
- Mach
-Pdyn
-Altitude & rates
-Velocity
-FPA

Fronstshield jettison
- Mach
-Pdyn
-Altitude & rates
-Velocity
-FPA

Reaction Control System initiation
-Altitude & rates
-Velocity lateral / vertical

Lander release
- Normal and tangential velocities
- Attiude and rates

EDLS Robustness assessment

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Requires an EDL System engineering tool capability

- Provide EDLS system budgets wrt aerodynamic, MCI, atmospheric, terrain and sensor, propulsion activator dispersions to:
  - Specify the EDLS boundary conditions
  - Define the necessary margins to apply to EDLS subsystems ensuring the required success probability
- 6 DoF x per body– Multiple bodies capability to :
  - Define the stability of the trajectory, account for wind gust effects….
  - Attitude needed to define the needed performance of sensors, thruster firing, …
- Monte-Carlo analyses capability
  - EDLS performance and robustness assessment on landing sites other than the reference sizing site

A software developed from merged inherited validated subsystem models

- Aurora Robust Control heritage for Entry, Huygens for Descent, NetLander for D&L

SAFETO-MARS: Simulation Adapted For End To End Trajectory Optimisation Mars

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SafetoMars: Major Inputs/Outputs

Major Inputs

Geometry, MCI

Design parameters (surface area of chutes, bridle length…)

Entry state vector

Aero-database

Sequence triggering events (Mach, timer, altitude..)

Environnement
-Martian Atmosphere Model
- Martian gravity field

Major Outputs

Overall trajectory – Video visualisation tool

Aerodynamic attitudes FPA, AoA profiles

Trajectory Parameters (altitude, Mach, velocity, distance)

Multi-body attitude (pitch, yaw, roll) angle and rates

External loads: fluxes, dynamic pressure, accelerations

Initial and final conditions for each phases

Internal loads: Stress, snatch forces, lander lowering tension, bridle forces

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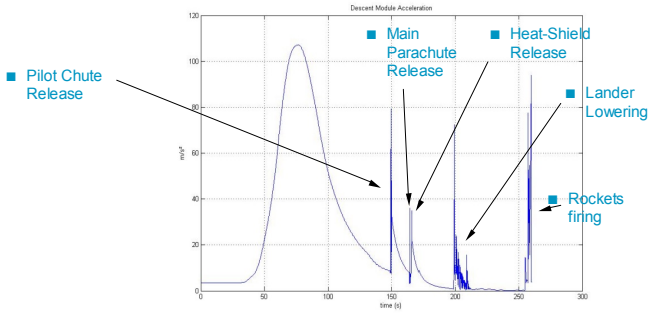
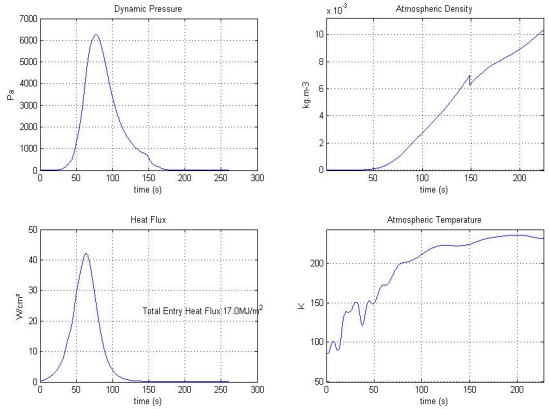
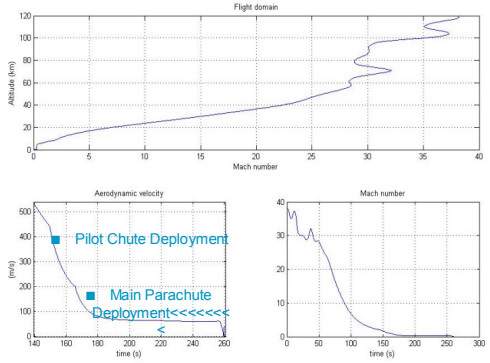
Typical simulation results

Induced environment

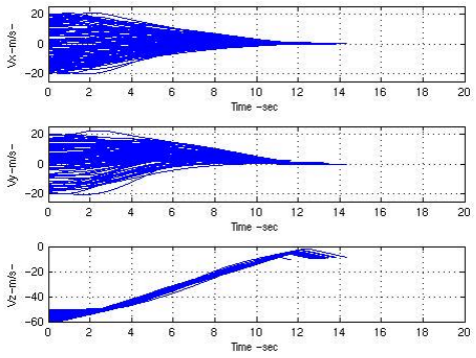


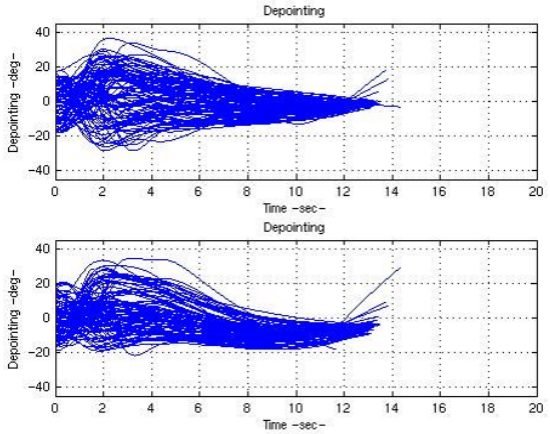


Trajectory



Body attitudes (here controlled loop)





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Visualisation tool

Configuration:

- Heatshield (3.4mø)
- Two-stage PAS system

Init taget. Mach1,9 & 0,8

- Fronstshield

Jettison MP +10s

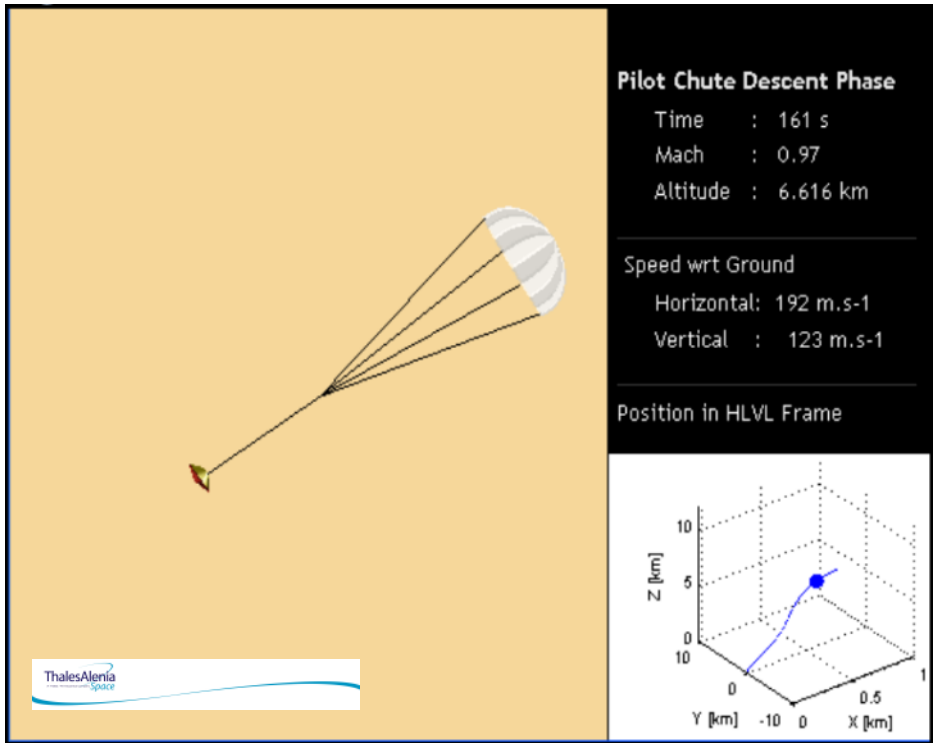
- Lander lowering

FS jettison +10s

- Solid fixed RCS

LAT and VER firing

- Lander release



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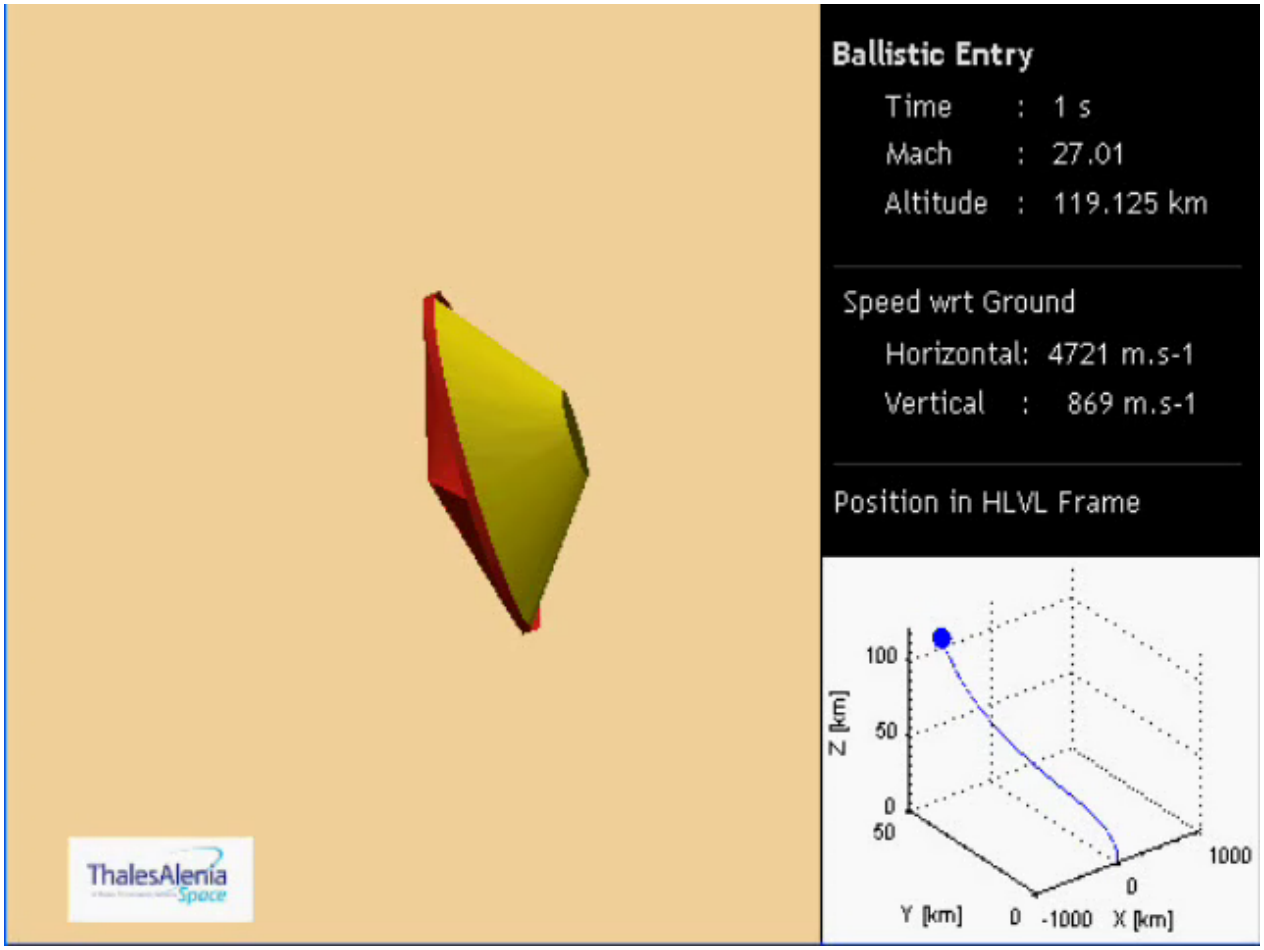

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