MARS ENTRY, DESCENT AND LANDING RISK MODELLING FOR LANDING SITE SELECTION ASSESSMENT M. Castillo and P. D. Martin, ESA - European Space and Astronomy Centre, PO Box 78, E-28691 Villanueva de la Cañada (Madrid), Spain; manuel.castillo@esa.int.

Introduction: The selection of landing sites for Mars missions implies a required number of iterations that must conciliate the Entry, Descend and Landing (EDL) risk and the in-situ operational constraints with the scientifically-driven selection process, and lead to the identification of prime and backup landing sites. The main goal of this work is to implement an EDL risk evaluation procedure to support the selection process of candidate landing sites for future European Mars missions.

Methodology: Conventional EDL risk evaluation methods operate on the assumption that all the EDL engineering constraints and environmental hazards can be parameterized and combined in a simple cost function [1]. However, this type of methods present two important inconveniences: It is very difficult to define the parameters for each contributing hazard or constraint and it does not represent properly the dynamics involved in a multidimensional complex procedure like the EDL.

An alternative approach can be based in Probabilistic Risk Assessment (PRA) techniques [2]. They involve a systematic methodology designed to evaluate the risk associated with complex sequences of technological events similar to the EDL. It makes use of event sequence diagrams to analyse the chain of events likely to happen following a system failure. In this approach the risk is defined as a feasible detrimental outcome of the EDL sequence and it is characterized by two quantities: the severity (magnitude) of the possible adverse consequences and the likelihood (probability) of occurrence of each consequence. Again, the main difficulties of this approach rely on the absence of a dynamical EDL description to define both magnitudes and probabilities. Apart from the binary application of the engineering constraints, typically the probabilities of the different sequence events come from historical data, test data or expert opinion.

In order to deal with the described difficulties, this work approach is based on the dynamical modelling of the complete EDL system sequence, including a detailed evaluation of the effects of the environmental hazards associated to the atmospheric conditions and the characteristics of each potential landing site. Two EDL concepts have been considered for this analysis. Both concepts are illustrated in Figure 1 together with the EDL events and the environmental hazards affecting them. One is the MER-like concept [3] where the landing phase is performed with an airbag envelope and a final free-fall. The other concept is the hybrid configuration under study for Exomars [4] where the final part of the landing uses a combination of vented airbags with an active autoguided soft landing. A two-stage descent phase is also under analysis.

Results: The dynamical modelling of the analysed EDL concepts is represented in the functional diagram of Figure 2A. It shows the required processing modules and I/O data illustrating the influence of the environmental hazards in the different EDL model modules. The atmospheric conditions, density and wind profiles, are extracted from the European Mars Climate Database Global Circulation Model [5, 6] and the landing region characteristics are obtained from available consolidated mapping products (MGS/MOLA, Viking/TES and MGS/Themis data). Using this model, the landing risk is evaluated following the functional diagram depicted in Figure 2B. In this diagram, for each possible landing site, the optimal entry corridor, nominal EDL trajectory and initial state vector is first calculated by using iteratively the EDL model. Then, a statistically significant number of Monte Carlo simulations of the complete EDL sequence is performed including all expected environmental variability. Finally, the landing risk is naturally defined as the percentage of times that the EDL system exceeds its capability performances (e.g., entry thermal constraints, touchdown velocity and attitude, etc…). Repeating the complete process for all possible landing sites leads to an EDL Risk Map obtained as main output of the procedure. However, an EDL accuracy map can also be obtained as a secondary output via performing a dispersion analysis of the successful landing simulations in order to evaluate the landing ellipses associated to each site.

Conclusion: The described modelling is mainly oriented toward the risk evaluation of the operation of a defined EDL system configuration to support the selection process of candidate landing sites. But, once this selection process has been completed, the same modelling can be applied to refine the candidate landing sites by means of the use of high-resolution mapping products resulting from recent and ongoing Mars orbiter missions. Additionally, the same procedure can be used together with optimisation techniques that enhance the design of the different EDL system elements for the purpose of extending its capabilities to high-priority candidate sites.

References:
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EDL Sequence

Phase	Events	Hazards
De-orbiting	De-orbit manoeuvres:Direct Insertion or release from orbiter	
Entry	Attitude actuators Aeroshell Atmospheric Drag	Atmosphere Density
1st Stage Descent	Drogue Parachute Deployment	Atmosphere Density
2on Stage Descent	Main Parachute Deployment	Atmosphere Density & Region Mean Altitude Horizontal Winds
	Heatshell Jettison Backshell & Lander Separation Altitude Adquisition Horizontal Velocity Actuators Airbags Deployment	Terrain Slope & roughness Horizontal Winds
Landing	Main Parachute Separation	
	Free Fall for MER-like Concept	Rock Distribution
	Controlled Fall & Surface Sensing for Soft landing concept	Rock & Dust Distribution
	Touchdown Payload Deployment	Rock & Dust Distribution

Figure 1: Mars Entry, Descent and Landing Sequence phases, events and environmental hazards.

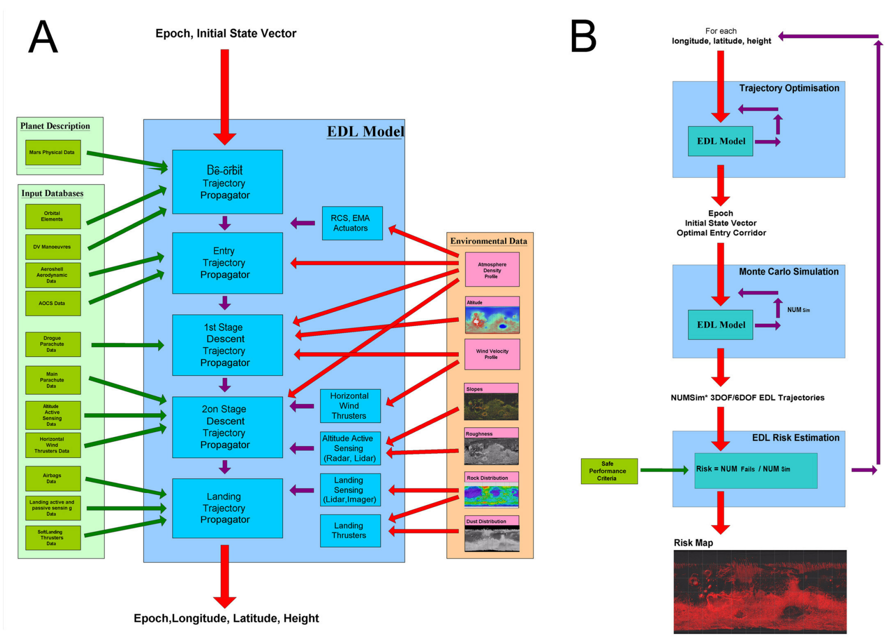

Figure 2: A - EDL Model. **B -** EDL Risk Estimation.