RITD Re-entry: Inflatable Technology Development in Russian Collaboration

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A new generation of inflatable Entry, Descent and Landing System (EDLS) for Mars has been developed. It is used in both the initial atmospheric entry and atmospheric descent before the semi-hard impact of the penetrator into Martian surface. The EDLS applicability to Earth's atmosphere is studied by the EU/RITD project. It focuses on the analysis and tests of the transonic behaviour of this compact and light weight payload entry system under Earth re-entry conditions.

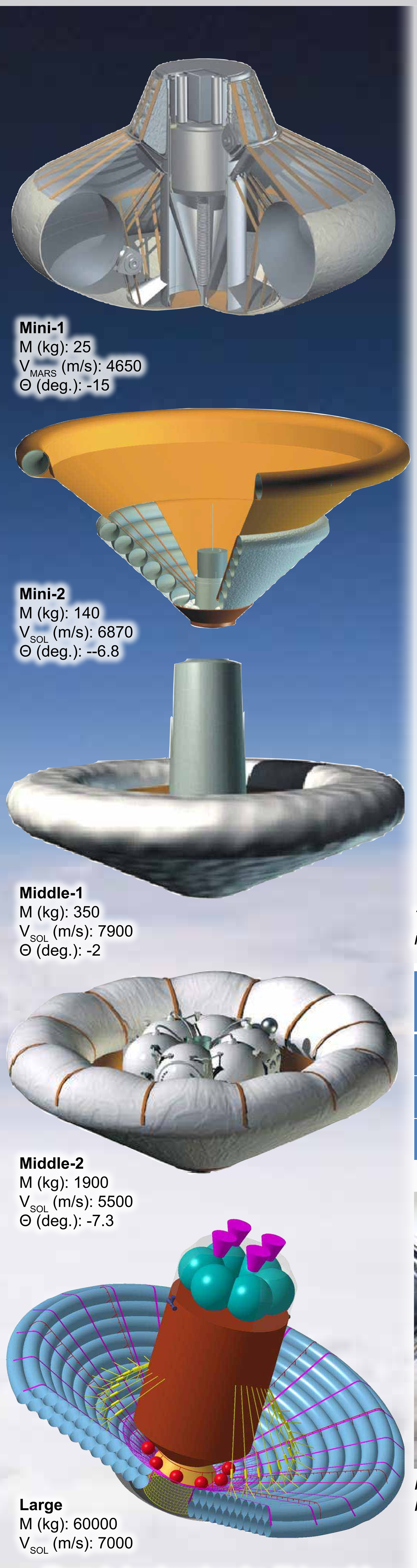

Figure 1: Lander categories. Pictures: LA.

EDLS for Earth

The dynamical stability of the craft is analysed, concentrating on the most critical part of the atmospheric re-entry, the transonic phase. In Martian atmosphere the MetNet vehicle stability during the transonic phase is understood. However, in the more dense Earth's atmosphere, the transonic phase is shorter and turbulence more violent. Therefore, the EDLS has to be sufficiently dynamically stable to overcome the forces tending to deflect the craft from its nominal trajectory and attitude. The preliminary design of the EDLS for Earth will be commenced once the scaling of the re-entry system and the dynamical stability analysis have been performed. The RITD-project concentrates on the current MetNet-type (i.e. Mini-1 category) of landers, and on requirements posed by other types Earth re-entry concepts (figure 1).

Wind Tunnel Tests

The aim of the wind tunnel test was an experimental determination of the Mini-1 -lander damping factors in the Earth atmosphere and recalculation of the results for the case of the vehicle's descent in the Martian atmosphere.

Mini-1 wind tunnel tests were performed by the method of oscillation process analysis at air flow of the model fixed to the holder through a free-oscillation mechanism (FOM).

The program of the performed wind tunnel tests and realized parameters of the flow at chosen wind tunnels are shown in Table 2. Figure 2 shows the Mini-1 EDLS wind tunnel mock-up model that is in scale of 1:15. The mock-up model is manufactured in a single copy and it was tested at all the values of Mach numbers, provided in Table 2.

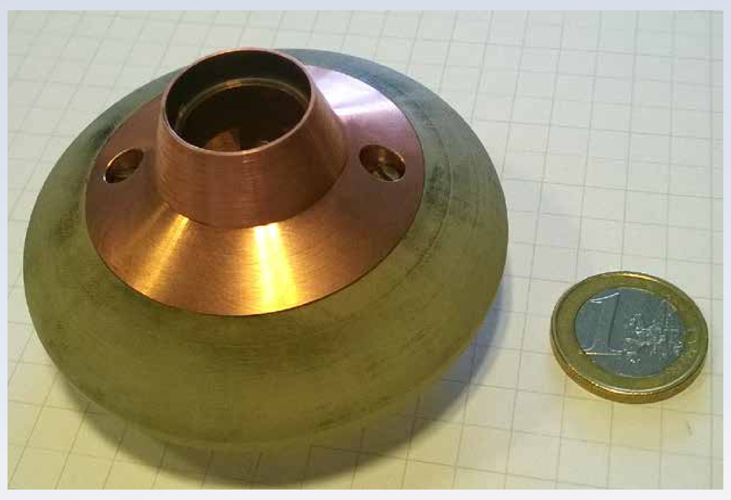

Figure 2: Wind tunnel test mock-up. Picture: FMI.

At the wind tunnel tests (see figure 3), the FOM was adjusted in such a way that the model became free depending on the expected character of oscillations at zero angle of attack (A_H) or equal to 5° and 10°. If an oscillating process was expected in damping conditions, the angle of attack was set as nonzero, but if antidamping of the model oscillation was expected the angle $A_H = 0$ was set.

Table 2: Conditions of test performance in wind tunnel tests. ($Re_{\infty D}$ in the table is Reynolds number).

Condition number	1	2	3	4	5	6	7
M_∞	0.85	0.96	1.05	1.19	1.25	1.30	1.55
$Re_{\infty D}\cdot 10^{-5}$	1.17	1.26	1.31	1.42	2.35	4.30	6.40
q_∞[kg/m²]	3427	4164	4782	5442	8013	9320	6477

Figure 3: Mini-1 mock-up inside wind test chamber. Picture: Lavochkin.

In case of lander unstable motion, the lander is exposed to the action of a damping moment which prevents it from the rotation that is explained by the angular rate of rotation ω_Z and by a downwash delay. As a rule, during the landing both of these factors take place and therefore the total moment of damping is equal to their sum and the damping factor is determined by the expression $C_{mq} = C_m^{\bar{\alpha}} + C_m^{\bar{\omega}_Z}$. This factor of damping moment can either prevent the lander from rotation if its value is negative ($C_{mq} < 0$) or lead to increase of the amplitude of its oscillations if its value is positive ($C_{mq} > 0$).

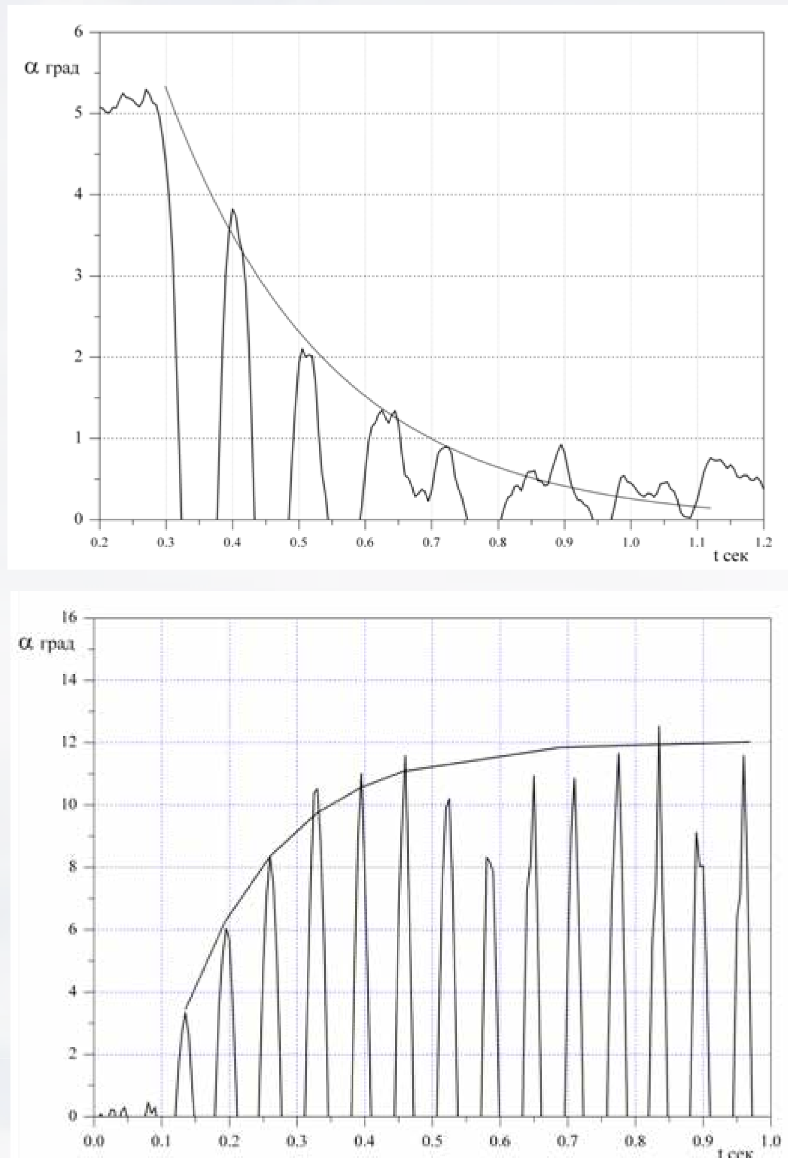

Figure 4: Dynamic stability of the Mini-1 in wind tunnel tests. Above with factors: $M_\infty = 0.85$ and $A_H = 5$ deg. Below with factors: $M_\infty = 1.25$ and $A_H = 0$ deg. Graphs: Lavochkin.

According to the wind tunnel test results (figure 4), within the range of Mach numbers $M_\infty = 1.1 – 1.53$ and angles of attack 0° – 10° the self-excitation of oscillation and increase of oscillation amplitude took place up to the value A_H = 9° – 11.5°. In this case, the antidamping factor varied within the limits 0.01 to 0.25 ($C_{mq} > 0$).

Within the range of Mach numbers M_∞=0.85 – 0.95 and angles of attacks A_H = 5° – 10° the damping of oscillations was observed. In this case, the aerodynamic factor of damping moment varied within the limits -0.07 to -0.12 ($C_{mq} < 0$) and the lander was stable.

Table 1: Possible applications for category 1 to 5 landers. Table: Lavochkin / FMI.

Category	Application	Key technical requirements
Mini-1	Technology demonstration	- Safety of science devices
	Science mission	- Safety of landing (accuracy)
	Planetary exploration	- Aerodynamics
	Sample return mission	- Flight quality of inflatable technology
Mini-2	Technology demonstration	- Safety of science devices
	Science mission	- Safety of landing (accuracy)
	Planetary exploration	- Aerodynamics
	Down-mass mission	
	Sample return mission	
Middle-1	Down-mass mission	- Safety of landing (accuracy)
	Space laboratory mission	- Aerodynamics
	Science mission	- Safety of science devices
	Planetary exploration	- Safety of science experiments
	Sample return mission	
Middle-2	Space laboratory mission	- Safety of landing (accuracy)
	Planetary exploration	- Aerodynamics
	Sample return mission	- Safety of science devices
		- Safety of science experiments
Large	Manned mission (emergency)	- Safety of landing (accuracy)
	Planetary exploration	- Aerodynamics
		- Crew safety (life-support system)

Application Opportunities

Table 1 presents applications that can be realized with the landers categorized in the figure 1 (Mini-1 highlighted). Proposed applications are given only as an example and other similar type of applications can be realized also.

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More information from the RITD website http://ritd.fmi.fi

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