ATTACHABLE IRDT BASED STABILIZER FOR ARIANE-5/EAP RECOVERY

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1. Input data and requirements

1.1 The developed device should provide a stabilization of the side boosters of "Ariane-5" (EAP) LV on descending phase of the flight before the beginning of parachute leg of descent.
1.2 The device should be performed as attachable and not make significant modifications to the schedule and a technology of EAP boosters preparation on the launching site.
1.3 In a stowed configuration the device should be located in a tail part of EAP booster. Dimensions of accommodation zone of the device are shown on Fig. 1-1 below.

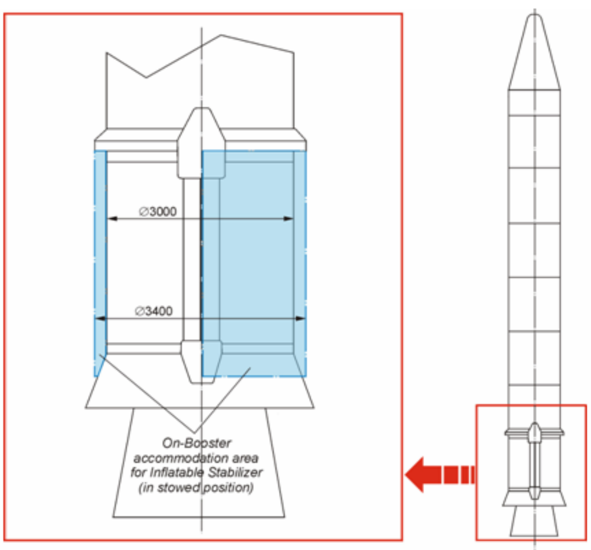


Fig. 1-1. Dimensions of AIS accommodation zone on EAP booster in a stowed position

1.4 In a deployed configuration the diameter of the device makes 6.278 mm.
1.5 The concept of the device should be based on IRDT technology.
1.6 In the filling system of the device the high-pressure gas balloons should not be used.
1.7 Time of inflation of device should be not more than 100 sec.
1.8 In order to provide requirements adopted for EAP splash-down, the pressure in the device should be dropped before the landing.
1.9 The proposed technical solutions should provide a minimum mass of the device (300-500 kg).
1.10 The device has the mechanical and command interface with EAP booster.

2. Purpose and composition of device

The attachable inflatable stabilizer (AIS) is intended for creation of the lifting power from an approach aerodynamic flow incident on the booster on which AIS is installed.
The stabilizer is installed on a booster bottom part on the launch site.
The stabilizer consists of the following main elements:
• a frame which is attached to the booster structure mechanically and on which an attachment and packing of the inflatable torous envelope and its thermal insulations and thermal protection is carrying out; along the frame perimeter the torous envelope

filling system gas generators are located uniformly;

• a torous envelope attached on the frame, encased in a thermal insulation and thermal protection; the lines going from the filling system (from the gas generators) are connected to the envelope;

• thermal insulations and thermal protections which are installed on the torous envelope and which ensure a structure protection from effect of the heat flows at an aerodynamic braking;

• the filling system consisting of quantity of gas generators and lines connecting them with the torous envelope.

3. AIS options analysis

Main part determining the parameters and configuration of the whole device is the pneumatic structure. Therefore as the first step the trade-off was carried out and the optimal configuration of this part of the device has been chosen. Then for the chosen concept the main parameters of the mechanical part and the filling system have been determined.

During the present study the trade-off of two following concepts of the pneumatic frame has been carried out:

1. Single-toroidal frame
2. Multi-toroidal frame

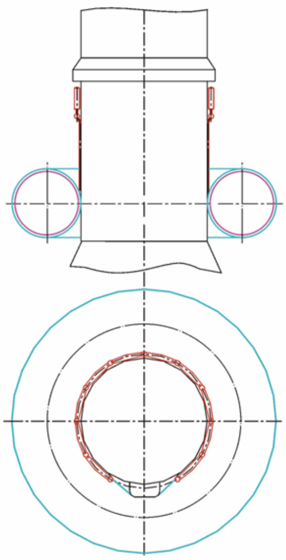
In one's part each of these concept have various options of performance. For the single-toroidal frame the following two options were considered:

3. Single-Toroidal Concept (Common Volume Design)
4. Single-Toroidal Concept (Sectionalized Volume Design) with the spherical shape of sections

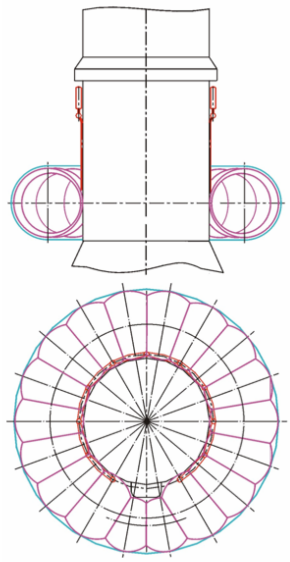
For the multi-toroidal frame three options differing by number of toruses, and also by the shape of the structure formed by them in the inflated configuration were considered.

Since a simple commom toroidal envelope unambiguously does not provide the required parameters of the device, it is not considered hereinafter.

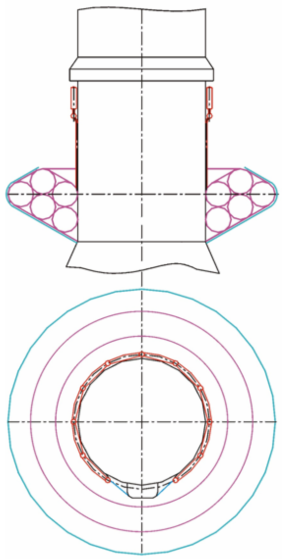
The results of trade off, performed taking into account of the various trade-off drivers are given in Table 3-1 below.



Single-Toroidal Concept (Common Volume Design) STC-1

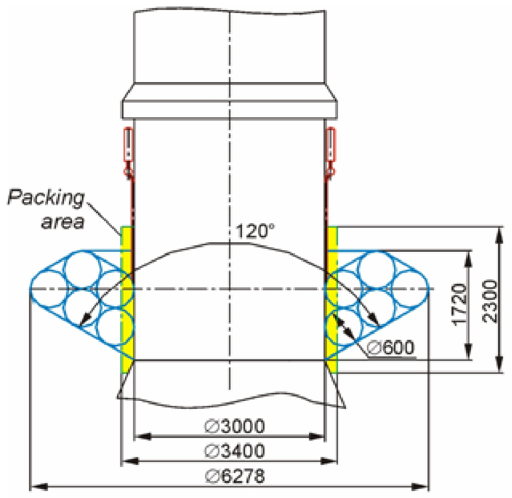


Single-Toroidal Concept (Sectionalized Volume Design) STC-2

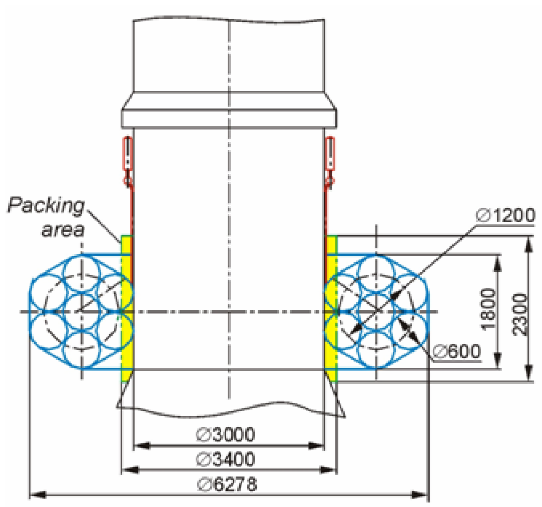


Multi-Toroidal Concept MTC-1 – MTC-3

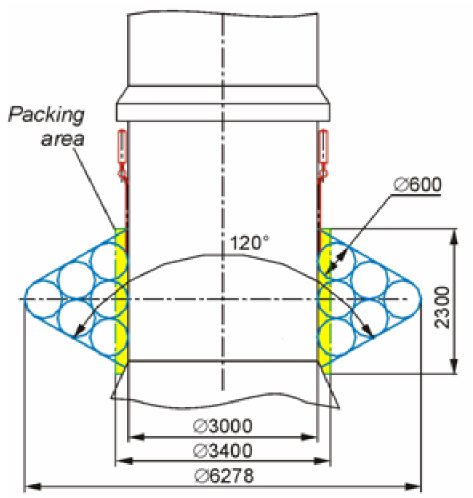
Fig. 3-1. AIS options



MTC-1 Option



MTC-2 Option



MTC-3 Option

*Table 3**Ошибка! Текст указанного стиля в документе отсутствует.**-1 Mass budget of pneumatic part for the considered options*

Subsyst.	**Single-Toroidal Concept**	**Multi-Toroidal options**		
		MTC -1	**MTC -2**	**MTC -3**
Flexible Thermal Protection	168.0 kg	160.0 kg	160.0 kg	160.0 kg
Inner Tubes	23.5 kg	18.0 kg	28.3 kg	20.8 kg
External Load-Carrying Envelope	31.5 kg	23.1 kg	33.0 kg	25.4 kg
Gas Generator	90.0 kg	91.0 kg	126.0 kg	100.0 kg
Inflation System	40.0 kg	50.0 kg	50.0 kg	50.0 kg
Total	353.0 kg	342.1 kg	397.3 kg	356.2 kg

As follows from the given above table the Single-Toroidal Concept STC-2 (Sectionalized Volume Design) has the following principal advantages:

• lower mass and internal pressure of the envelope (in comparison with STC-1 option);

• lower mass of the thermal protection (in comparison with STC-1 option);

• simplicity of integration and mounting of the device on the booster body (in comparison with the multi-toroidal options).

Therefore as a baseline concept STC-2 option was chosen.

4. AIS baseline concept

4.1. Layout scheme

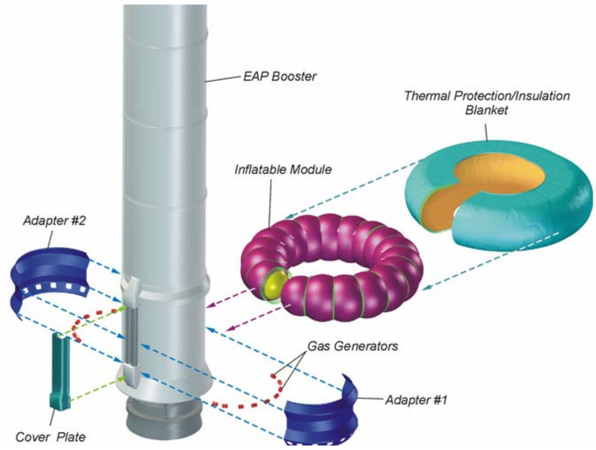


Fig. 4-2. AIS composition (baseline concept)

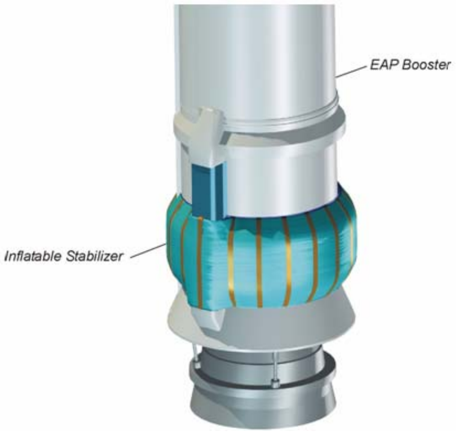


Fig. 4-3. AIS launch configuration (baseline concept)

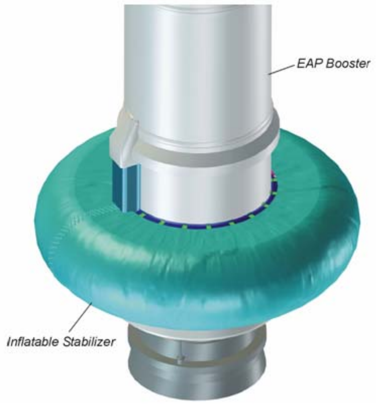


Fig. 4-4. AIS flight configuration (baseline concept)

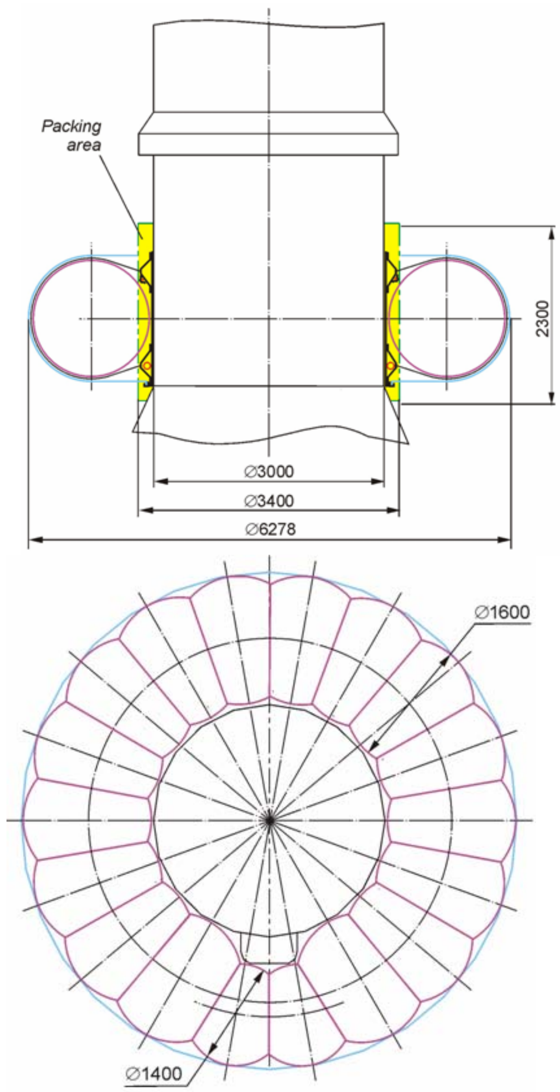


Fig. 4-5. AIS dimensions (baseline concept)

4.2. Mass budget

Subsystems	Mass, kg
Pneumatic Frame	55.0
Filling System (including gas generators)	130.0
Thermal Insulation and Thermal Protection	168.0
AIS Attachment Elements	283.0
Control Unit	2.0
Total:	638.0

4.3. Pneumatic frame (torus envelope)

The torous envelope structure is a number of spheres which are connected with each other along a circle. In a connection plane diaphragms are installed, which significantly improve strength properties of the device at its loading by the aerodynamic forces which occur at the booster drop.

The torous has a cross-sectional connector (mechanical), which allows to fix it on a frame and to install it on the booster on the launch site.

After the installation on the booster, the cross-sectional connector is laced and forms thereby the closed structure.

The envelope has a two-layer structure:

- external load-carrying layer (cover) is manufactured from the high-strength material SVM (such as Kevlar) by sewing; the cover is reinforced by the straps from SVM, to the cover the straps by means of which the envelope is attached to the frame are sewn.
- internal envelope, which forms a pressurized cavity is made from a rubberized film material; the internal shell is glued, after that the gluing places are exposed to a heat sealing.

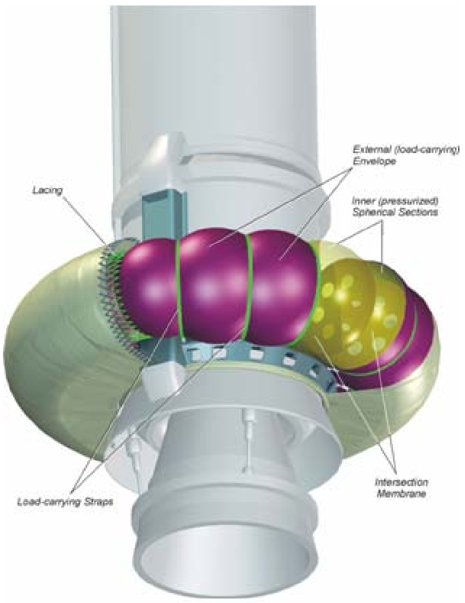


Fig. 4-6. Configuration of the AIS pneumatic frame (baseline concept)

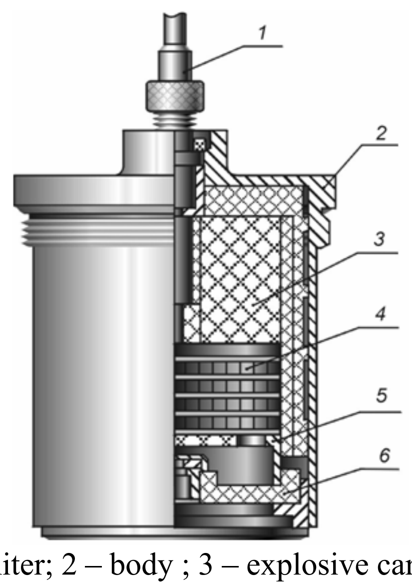
The cover has a hole through which the internal envelope is mounted in it. After mounting the hole is laced by the load-carrying lacing.

The torous envelope is attached on a frame. In a stowed position it is torous-shaped packed and its packing width is not more than 200 mm in a radial direction.

4.4. Filling system

The filling system of the torous envelope is a set of a quantity of gas generators, through which actuation product the internal cavity is pressurized up to a design pressure, allowing to realize the required geometrical form and to react a load from the aerodynamic loading.

Gas generators are installed on the frame on which the envelope is mounted. The gas generators are connected with the envelope by the lines.



1 – igniter; 2 – body ; 3 – explosive cartridge;
4 – filter-cooler; 5 – fire-bar;
6 – nozzle block

Fig. 4-7. Principal configuration of Gas Generator (baseline concept)

Gas generators are ignited by the electric igniter which is installed on the upper end.

As the gas generators for filling of the

inflatable device the gas generators are proposed to be used generating nitrogen at some content in a structure of products of actuation of a condensed medium.
It is supposed to include in the filling system structure a cooling system of products of actuation before their intake in the inflatable device and the condensed phase filter.
As a nitrogen-generating composition for manufacturing of a pyrotechnical cartridge it is proposed to use a composition 62-15 which provides a combustion rate ≈ 2.3 mm/s at the pressure of 25 kg/cm2 and initial temperature +50°C. Thus the required combustion time and gas temperature in the inflatable device can be provided through the selection of the checker and the cooling system.

Table 4-2 Filling system base parameters (baseline concept)

Time of filling	120 s
Mass part of the condensed phase for 62-15 composition	0.43
Temperature of nitrogen in the inflatable device envelope	+ 50°C (323K)
Temperature of combustion materials in the chamber of gas generator pyrotechnical cartridge	750K
Mass of gas generator pyrotechnical cartridge (charge)	4.4 kg
Mass of nitrogen, generated by the gas generator	2.5 kg
Number of gas generators	18
Mass of filling system	130 kg

4.5. Thermal protection and thermal insulation

While descending in the atmosphere the AIS is affected by heat loading from an incident gas flow.
The device is made from inflatable elements manufactured from a gas-tight woven material. An allowable temperature of this material is 150°C.
In order to provide packing of stabilizer in non-operation condition into a compact volume thermo-protection of the inflatable envelope is made flexible using the IRDT technology.
A flexible thermal protection is a multi-layer structure containing two packages:
- thermo-protective;
- thermo-insulating.
The external thermo-protective package consists of two layers of silica fabric, impregnated with a sublimating substance. The internal thermo-insulating package consists 15 layers of a multi-layer insulation (MLI) coated by an arimid fabric.

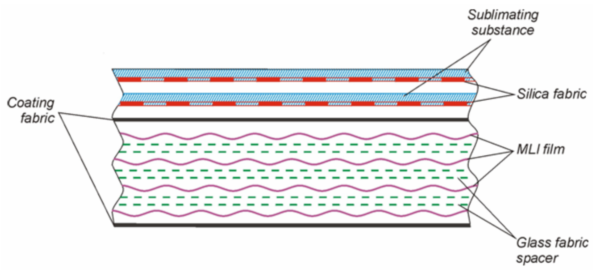


Fig. 4-8. General scheme of Flexible Thermal Protection

Allowable temperature of a coating fabric is 600°C. Temperature of destruction of MLI films is 500°C. Calculation of parameters of flexible thermal protection is carried out proceeding from the fact that maximal level of a heat flow changing along the descent trajectory in a critical point is 200 kW/m2. Duration of the heat floe effect is 180 s. Integral heat flow is 18 MJ/m2 to the critical point.
The chosen parameters of the Flexible Thermal Protection provide integrity of the hermetic envelop of the device within the whole duration of the booster descent. Thus the temperature of the external layer of MLI of the thermal-insulating package will not exceed 460°C, and of hermetic envelope – 110°C.
Flexible thermal protection is attached on the device with the help of two clamping frames to the bottom (structural supporting element) of the device along the whole perimeter of the

thermal protection, at the non pressurized condition of the hermetical envelope.
After pressurization of the hermetical envelope the thermal protection is stretched and remains in the stretched position, covering tightly a surface of the envelope.

4.6. Unreefing system

Purpose and composition of the base means of cutting of the load-carrying links are given in Table below.

Purpose	Composition
AIS activation	Pyroknife of cutting of cord of unreefing of the load-carrying links of packing of envelope and flexible thermal protection
AIS pre-landing depressurization	Extended hollow charge for the envelope depressurization

Fig. 4-9. General view of Pyroknife of cutting of load-carrying cords

4.7. Elements of AIS attachment to the booster

AIS is attached to the booster with the help of the special ring-shaped adapter consisting of two dissymmetrical parts.
Each of these parts includes the following:
- two frames;
- shell;
- clamping elements for attachment (fixation) of the thermal protective cover.

On the frame also the filling system gas generators and brackets of attachment of the load-carrying straps of the envelope and thermal protective cover are installed.
Adapter is attached to the booster structure mechanically, for example by bolts. Two parts of adapter are connected among themselves by brackets through which a bolt is passed. On the opposite side after completion of mounting on the booster these two parts are stacked by bolts.
Except the frame a special strap is attached on the booster which is installed on the block of tanks with the working fluid of the system of the booster thrust vector control.

4.8. Control unit

Two options of the control unit performance are possible:
- Option 1 – on a base of the pyrotechnical current source
- Option 2 – on a base of the chemical current source

In Option 1 the control system includes two identical units – main and reserve, each of them consists of the pyrotechnical current source and control-pulse generator. Time of the system operation - 2 sec after «START OF WORK» command generation. Power supply is not required.
In Option 2 the timing unit performs an ignition of the pyro-elements sequentially in the interval 0,1 sec. Each pyro-element includes two pyro filaments. Time from the moment of command generation from LV up to the control system actuation – 2 sec. Approximate mass of the power supply elements in Option 2 is about 300 g. Approximate total mass of the control unit is not more than 2 kg.

4.9. Device assembling and mounting on the booster

Mounting of the device is carried out on technical position of EAP booster (BIP). For this purpose the end joint of the torous envelope and the load-carrying frame is disconnected. The frame is opened on a necessary distance and is brought close to the booster.
The end of the frame envelopes the booster and closed with the other end. The frame is fixed on the booster. End of the frame are connected by bolts, ends of the envelope are laced up to each other with the help of the load-carrying cord. On the joint a thermo-insulating and thermal protective coating is applied.

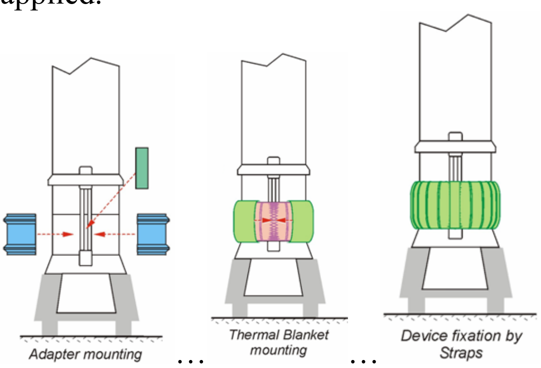


Fig. 4-15. Scheme of AIS mounting on the booster body (baseline concept)

Conclusion

On the base of carried out analysis it is possible to make the following main conclusions:
- application of IRDT technology allows to develop an inflatable attachable stabilizer;
- the proposed technical solutions would not cause significant changes in preparation of the EAP booster at the launch site;
- application of the already existing (available) elements in the structure allows significantly to decrease terms and cost of development.

A matrix of conformity of parameters of the chosen option to the main technical requirements is listed below.

Reference

"Input for feasibility study of an inflatable device implementable on EAP document n. LR 145/03".
"Preliminary Input Data For The More Precise Estimation Of The EAP Attachable Inflatable Stabilizer Design"
1. Trajectory data: velocity and altitude versus time.
(T0 = separation of EAP, time dispersion are given to take into account all possible trajectories)
Main quality events like:
- intensive nutation / rotation (from maximum dynamic pressure to parachute deployment)
- preferable period of stabilizer inflation from T0+50 s to T0+150S
- moment of entering into atmosphere ? depending on the definition
- parachute deployment T0+330s+/-30S
- deflation of stabilizer T0+360s+/-35s

2. Legs with maximal aerodynamic and thermal loads. More accurate data on aerodynamic and thermal loads versus time
Maximum dynamic pressure
TM = T0+230s +/-20s
Maximum flux TM = T0+230s+/-20s

3. Launch loads: (what is the influence on the mass of AIS?)
These data are needed for definition of design of folded AIS and volume of tests.
- character of aerodynamic flow in bottom part of EAP - it is enough to indicate only one parameter Pa – see fig. below.
- dispersion of temperature on the EAP's body in zone of stabilizer
- thermal flow from the EAP engine's air-blast during launch and time of its acting
- vibration

4. Possible mechanical docking points: quantity, arrangement and character of loads on them (character of loads they can stand). – this preliminary information permits to define the design of mechanical interface and reduce its mass (now it is 283 kg)