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Ausgabe Issue	**Datum** Date	**Betroffener Abschnitt/Paragraph/Seite** Affected Section/Paragraph/Page	**Änderungsgrund/Kurze Änderungsbeschreibung** Reason for Change/Brief Description of Change
Draft	18. March 2005	All	New Document

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1. Introduction

The ATV development and its evolution is a further step of enhancement of orbital infrastructure w.r.t the ISS logistics and already for the visible first aspects of space exploration. The initial situation of the ATV evolution study has to be seen in combination with the intended and/or initiated studies of the "Human Space Transport Study" and the Study for "Man rating of AR5".
The ATV S/C as basic element of the vehicle allows different evolution steps in the context of the ISS logistics taking into account the announced traffic changes and shortages due to the retirement of the NASA space shuttle for 2010. In this context the ISS related transportation of pressurized and un-pressurized payload has to be considered.
. Based on the proposed and agreed scenarios which are:

- Payload transport scenario (PTV)
- Crew transport scenario (CTV)
- Un-pressurized logistic carrier (ULC)

the specific task of this phase of the study is to identify conceptual system configurations and architectures for the identified scenarios and to identify from the ATV point of view the necessary modification and their consequences for the major subsystem of ATV. In this context the specific interfaces to the system elements like ISS and return capsule has to be considered as part of the ATV evolution concept. Here the ISS adapter and the interface structure between the nominal ATV and the transported capsule has to be mentioned.

2. Scenarios and Mission Analysis

2.1 PTV Scenario

The following figure gives an overview about the PTV scenario:

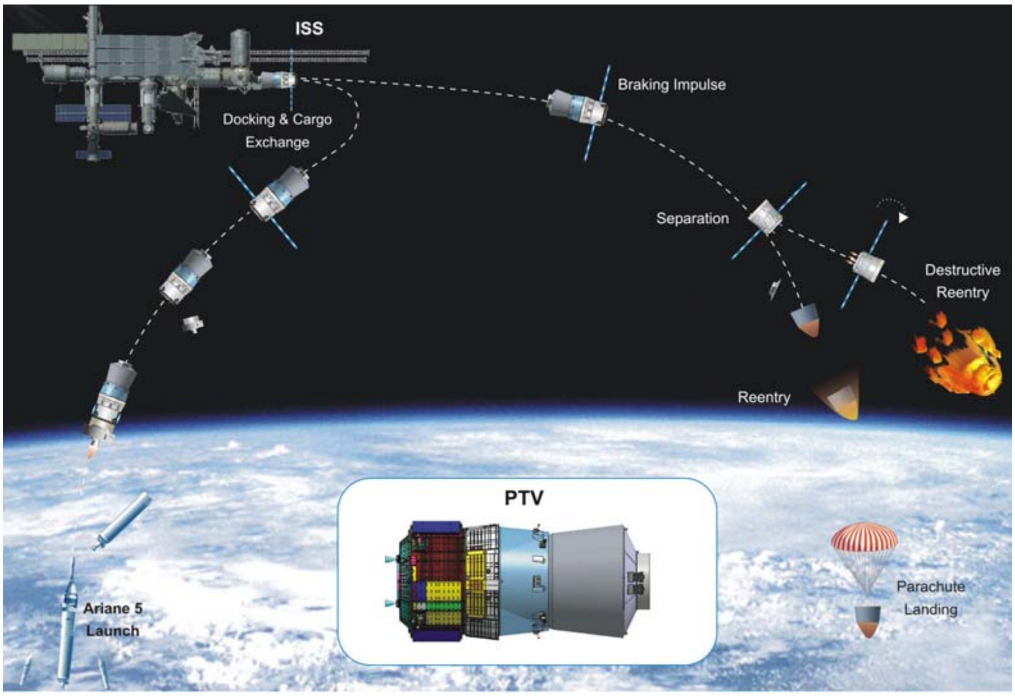

Figure 2.1-1: PTV Mission Scenario

The PTV mission consists of the following events:

- Launch and ascent as for ATV (AR5, 20,5 t)
- Proximity and RvD driven by USOS IBDM requirement
- Different docking port and approach scenario (V-bar at node 2)
- Common de-orbit to achieve precisely the separation box
- Bring return capsule on the right path (entry angle, re-entry point)
- Achieve sufficient distance between landing area and fall out zone of the modified ATV S/C

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2.2 CTV Scenario

The following figure gives an overview about the CTV scenario:

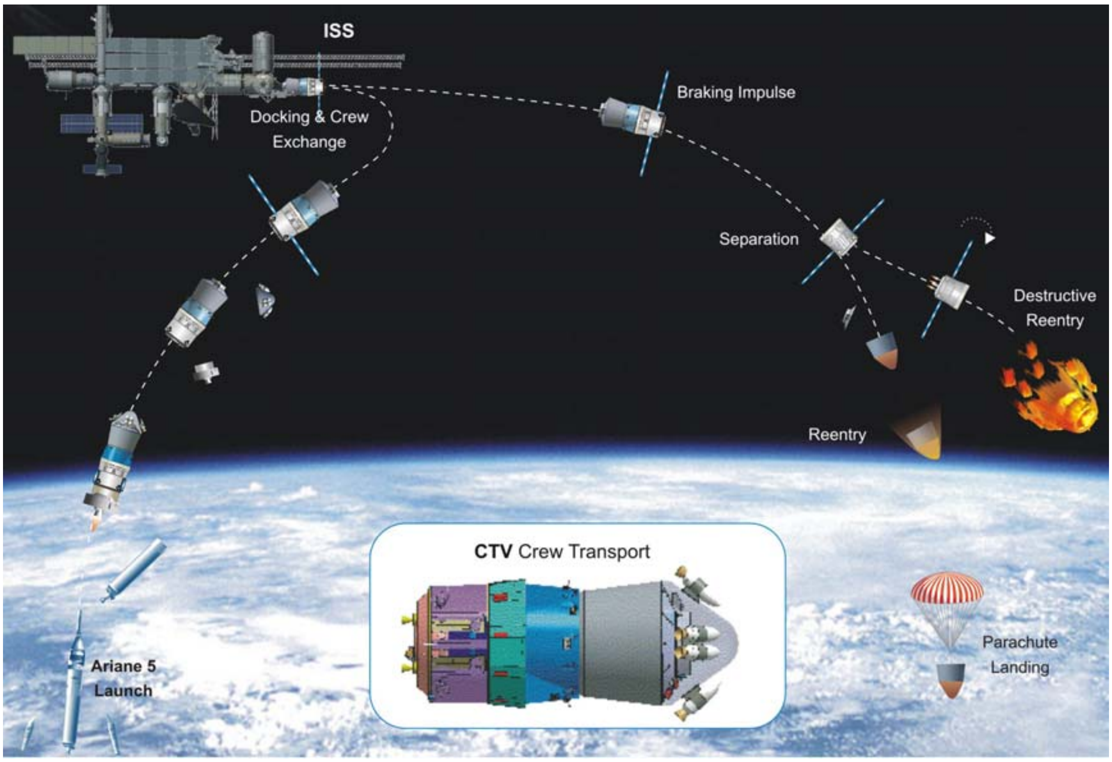


Figure 2.2-1: CTV Mission Scenario

The CTV mission comprises the following steps:

- Nominal launch and ascent as for PTV except
  - Launch without fairing and AR5 – ESC-B, 23 t cap.
  - Separation of launch escape system
  - Separation of ATV fairing

- Safeguard scenario in case of launcher failure
- Proximity and RvD as PTV

– No emergency separation from ISS required
– De-orbit and separation as PTV

2.3 ULC Scenario

The following figure gives an overview about the ULC scenario:

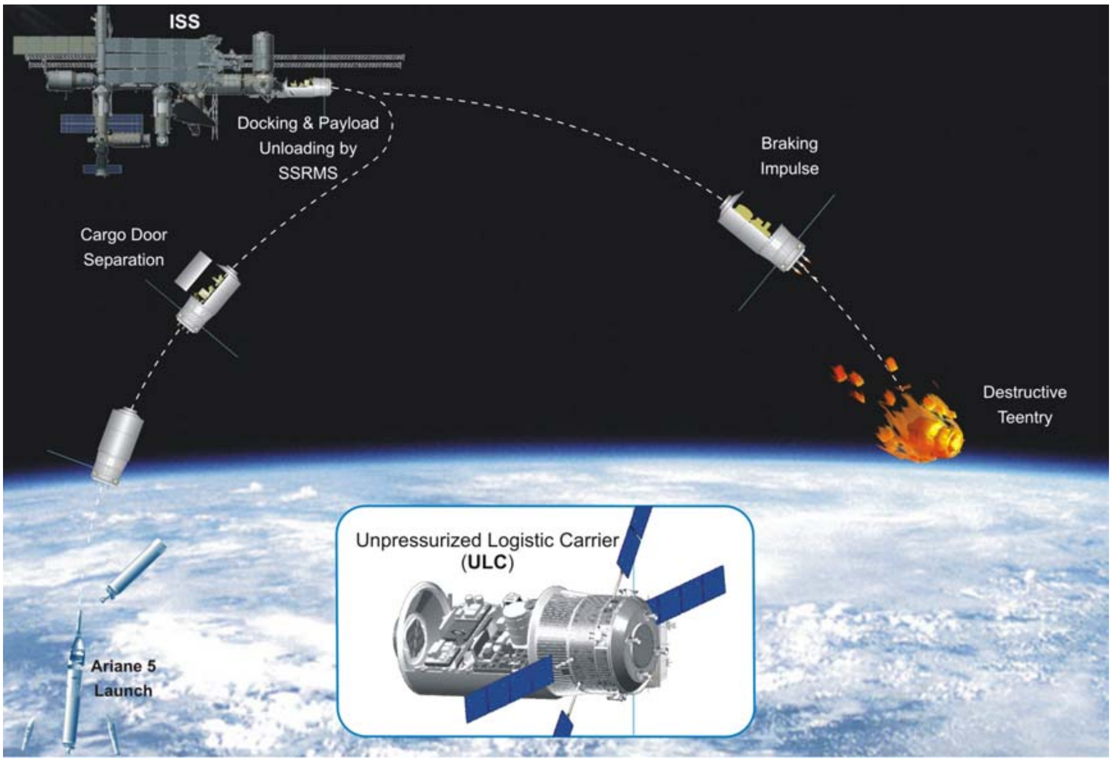


Figure 2.3-1: ULC Mission Scenario

The ULC mission is very similar to ATV nominal mission

– Launch and ascent as for ATV (AR5)

– Proximity and RvD as PTV

– De-orbit as ATV (destructive re-entry)

The figure below presents the changed approach to the +V-bar (US node 2) for all 3 vehicles.

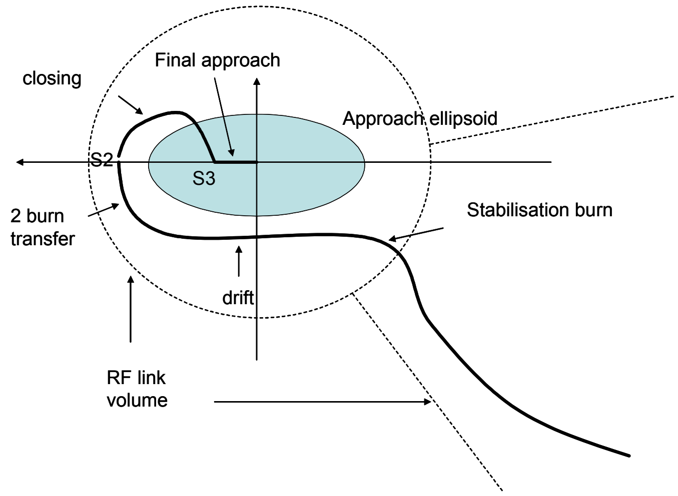


Figure 2.3-2 : PTV Approach to +V-bar

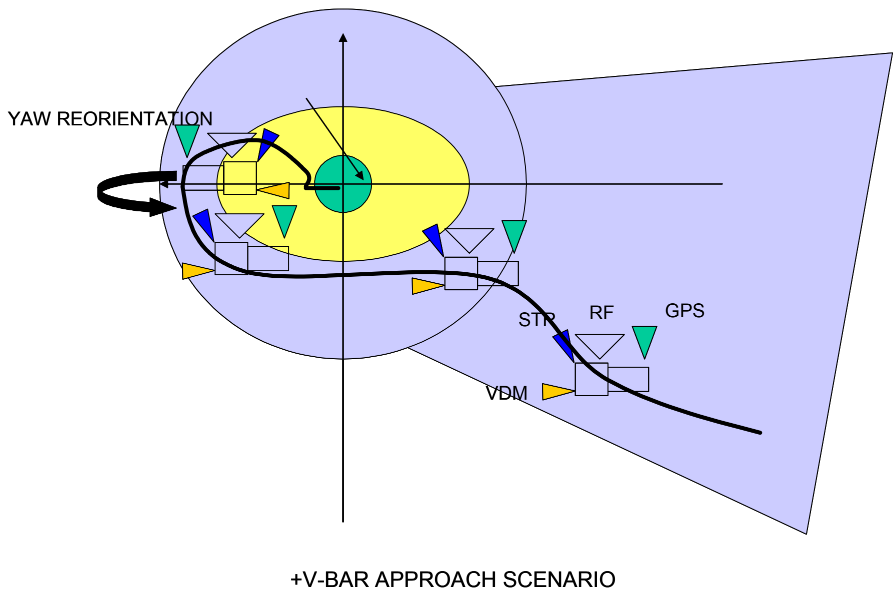


Figure 2.3-3 : PTV +V-bar Approach Scenario with Sensors

2.4 Safeguard scenario

The safeguard scenario for the manned CTV system shall consider the following aspects:

- Launch escape system shall cover launcher failures during the EPC phase (separation of the capsule only)

- After jettison of the LES a launcher failure to be covered by ATV S/C propulsion capability
  - Delay time for ATV propulsion system activation
  - Sufficient thrust level

The typical distancing requirement are (exo-atmospheric, TBC):
  - 200 m within 30 s and
  - 700 m within 100 s

The required thrust for 30-s case will be 8.89 kN for 0-s delay . There is no additional accelleration for 100-s requirement necessary.

The results of the abort scenarios analysis are:

- Nominal Launch to 260-km altitude
- Transfer arc perigee: 147 km
- 8-kN ATV thrust
- Earliest time for abort to orbit: 760 s

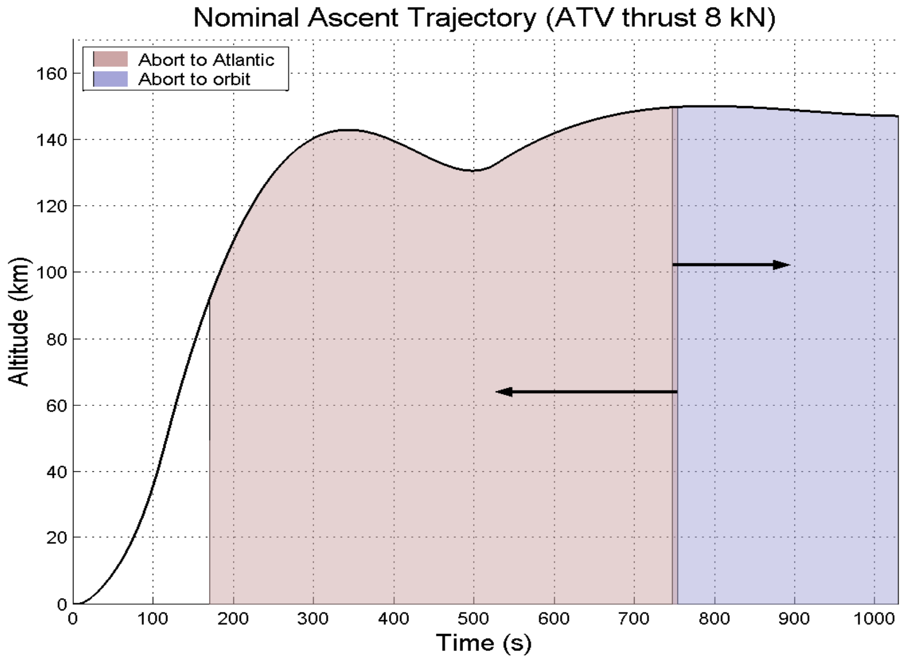


Figure 2.4-1: Launch Abort Scenario

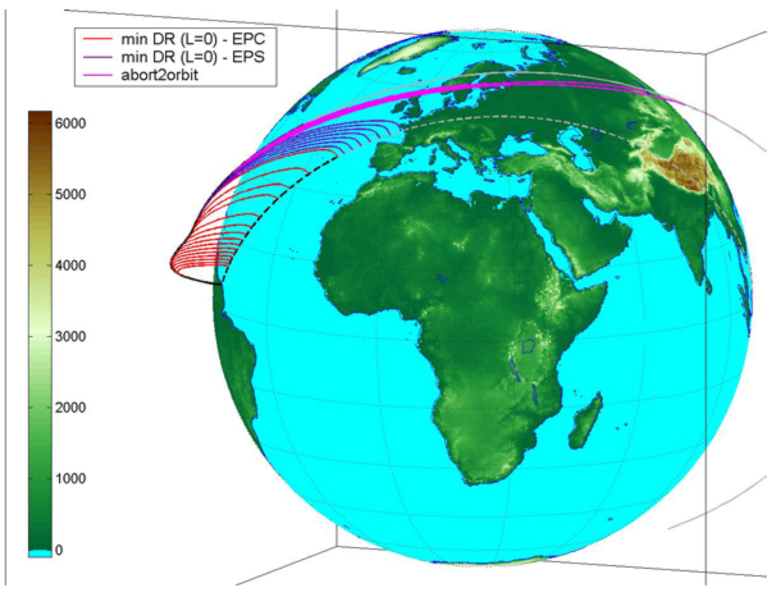


Figure 2.4-2: Abort to Atlantic

- The 2-kN ATV nominal propulsion exerts very little influence on the re-entry trajectory and the CTV atmospheric flight mostly controls the splashdown point.
- The EPS-V 2-burns ascent trajectory results in re-entry trajectories with lower peaks of load factor and higher downrange capability than the ESC-B 1-burn ascent trajectory.
- The peak load factor is above the tolerable human limit in many cases, so imposing restrictions in the attitude profile and, in consequence, on the downrange capability. Therefore, the splashdown point is very constrained near the maximum downrange (in particular at the times of failure around the culmination of the nominal ascent trajectory).
- The latest times of failure allows greater control on the downrange.

Abort to orbit

- For the nominal 2-kN ATV thrust level, the abort to orbit is only possible if the time of failure is very close to the end of the nominal ascent first burn.
- For the nominal 2-kN ATV thrust level, there is a gap in the time of failure between the abort to Atlantic and the abort to orbit cases where the CTV will not reach the emergency orbit and cannot land in the Atlantic Ocean.
- For the high thrust levels, the lack of fuel prevents the abort to orbit for times of failure earlier than a limit.
- In the ESC-B 1-burn scenario the minimum time of failure for abort to orbit is less sensitive to the thrust level than in the EPS-V 2-burns case.
- In the EPS-V 2-burn mission, the minimum thrust level to overlap the two scenarii is 16 kN (considering the maximum ATV delta-V and ballistic re-entry in abort-to-Atlantic).
- In the ESC-B 1-burn mission, the minimum thrust level to overlap the two scenarii is above 16 kN.

2.5 Return scenarios

Targets:

- Safe and soft landing of crew / payload at the landing zone
- Sufficient distance between landing zone of the capsule and fall out zone of the ATV debris (ground population safety)

Three proposals:
Increase the apogee in order to have time after separation for:

- Further braking of the ATV S/C (use of residual propellant)
- Perigee raising of ATV S/C (elliptical orbit) to allow later de-orbit in the same hemisphere
- Perigee raising of ATV S/C (circular orbit) to allow later de-orbit in both hemispheres

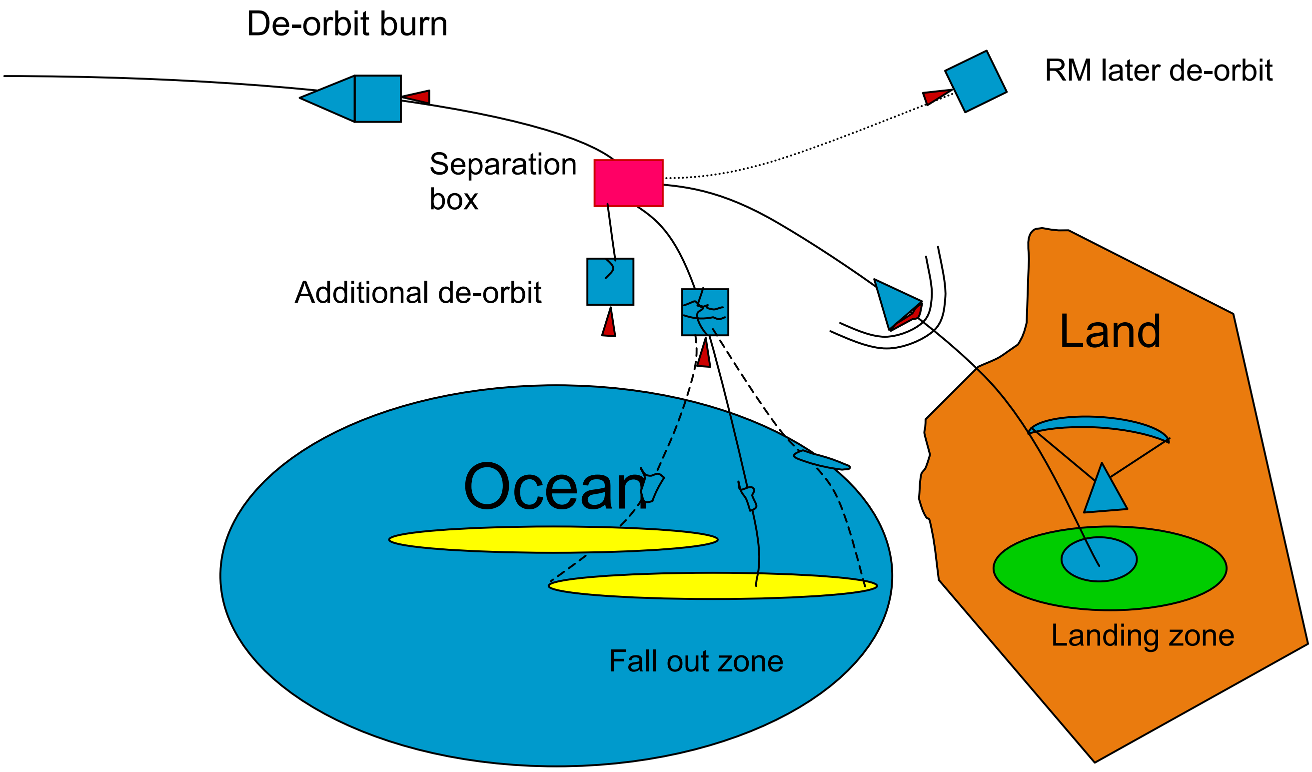


Figure 2.5-1 : Return Scenario

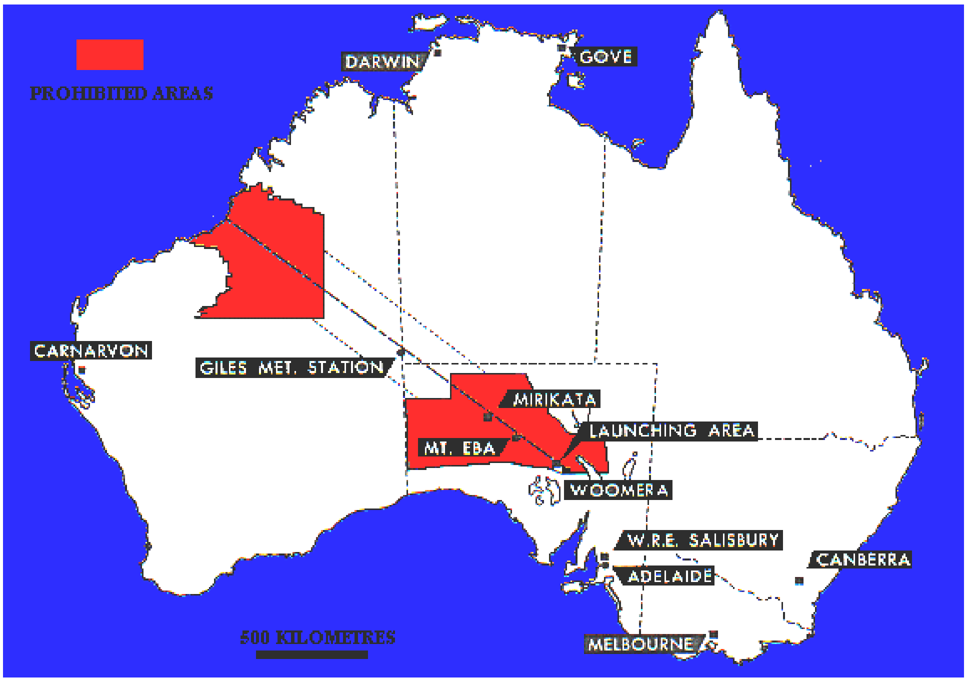


Figure 2.5-2 : Possible Landing Area

Return Alternative Phases	Nominal ATV mission	Re-entry at same time	Re-entry on same Hemi-sphere	Re-entry on different Hemisphere
Injection to ISS (460Km)	796	796	796	796
Correction maneuvers	200	200	200	200
RVD maneu-vers	504	504	504	504
De-orbit Ma-neuvers	820	1018	1221	1611
Total	2320	2518	2721	3111
Additional propellant	1.	200	400	800

Figure 2.5-3 : Propellant Budget (kg)

Return scenario 2 (same hemisphere)
Initial Orbit Altitude = 350 km circular /51,6 °
- Capsule mass = 8000 kg
- Thrust level = 980 N
- Specific Impulse = 310 s => Δ prop = 400 kg

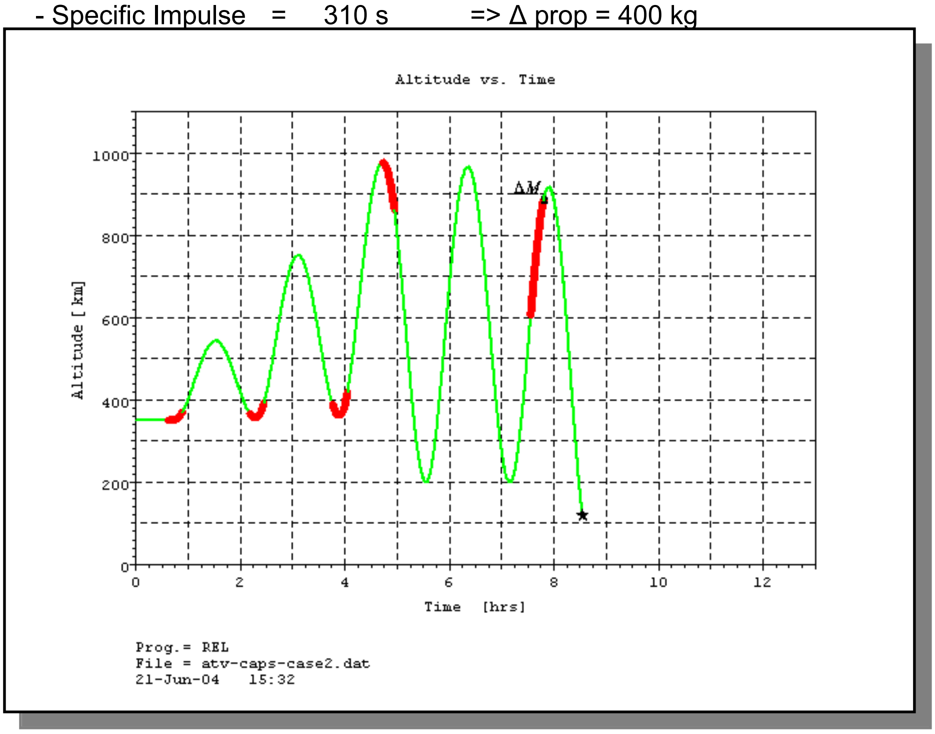


Figure 2.5-4 : Landing on different Areas (Manoeuvres in red)

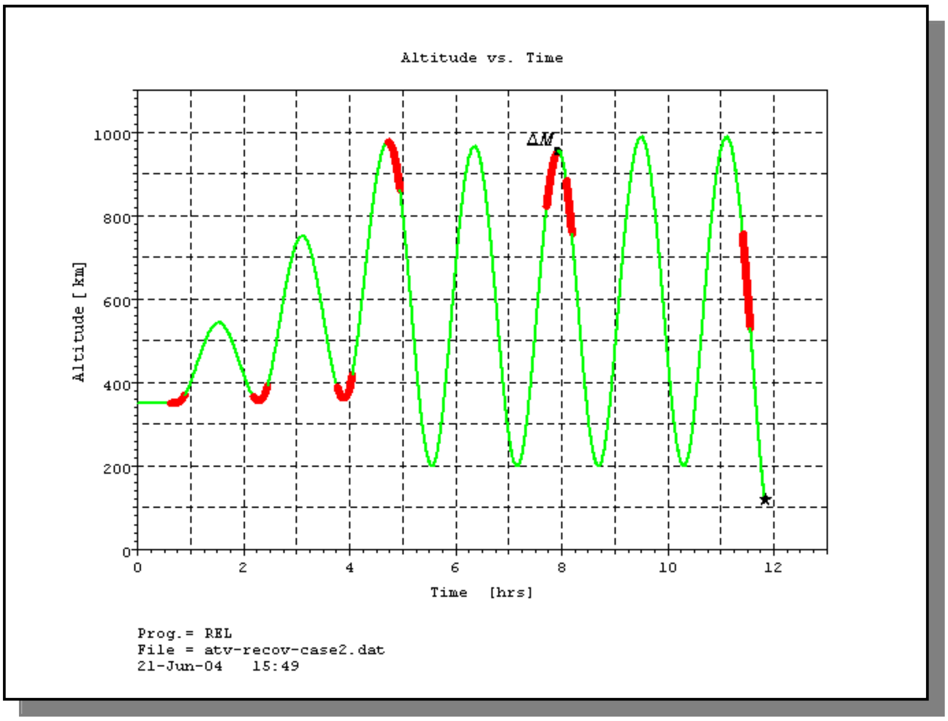


Figure 2.5-5 : Landing on different areas in different Hemispheres

Mission Profile down to Capsule Entry and ATV entry

- Nearly all elements of the nominal ATV mission scenario are transferable to the three scenarios (PTV,CTV and ULC)
- CTV safe guard support by ATV S/C only possible with an additional thruster /or module with thrust level > 8 kN
- Separation of landing zone and fall out area depends on the long range capability of the capsule (L/D):

Biconic > Viking > 1000km

The results of the analysis are the propellant needs in case that the landing area of the capsule should be in more distance to the fall-out zone as it would be without additional manoeuvres. The distance between both areas without any additional manoeuvre would be between 1000 km and about 2000 km depending of the capsule type and its lift-to-drag ratio. If it seems more useful to enhance both areas much more e.g. to land the capsule in Woomera and to locate the fall-out zone in the South Pacific the additional propellant need could be seen in the figure above. A decision about the most useful methode could be performed in a later project phase.

3. PTV - Architectural and System Design

The following aspects have to be considered:

- Vehicle launch with Ariane5 ESC-A (20.5 tons capacity)
- US-port (V-bar as baseline, -R-bar as back-up treated by delta compared to V-bar)
- IBDM device
- 2 ISPRs capability → Bi-conic shape reentry vehicle
- Autonomous reentry capsule (no power, thermal regulation, … deliveries)
- No refuel, no reboost

- 1 month docking phase

3.1 International Berthing and docking mechanisms

This device is a docking system currently under development which will enable to connect spacecraft vehicles without significant extrusion (as for the Russian docking system) and without robotic arms (as for the Common Berthing Mechanism).
The IBDM is composed of a 2 subparts,

- "Soft" docking system driven by 6 linear actuators which enable to pilote an upper ring with 6 degrees of freedom
- "Hard" docking system including all the equipments and the hatch access.

The layout of a typical IBDM is the following one,

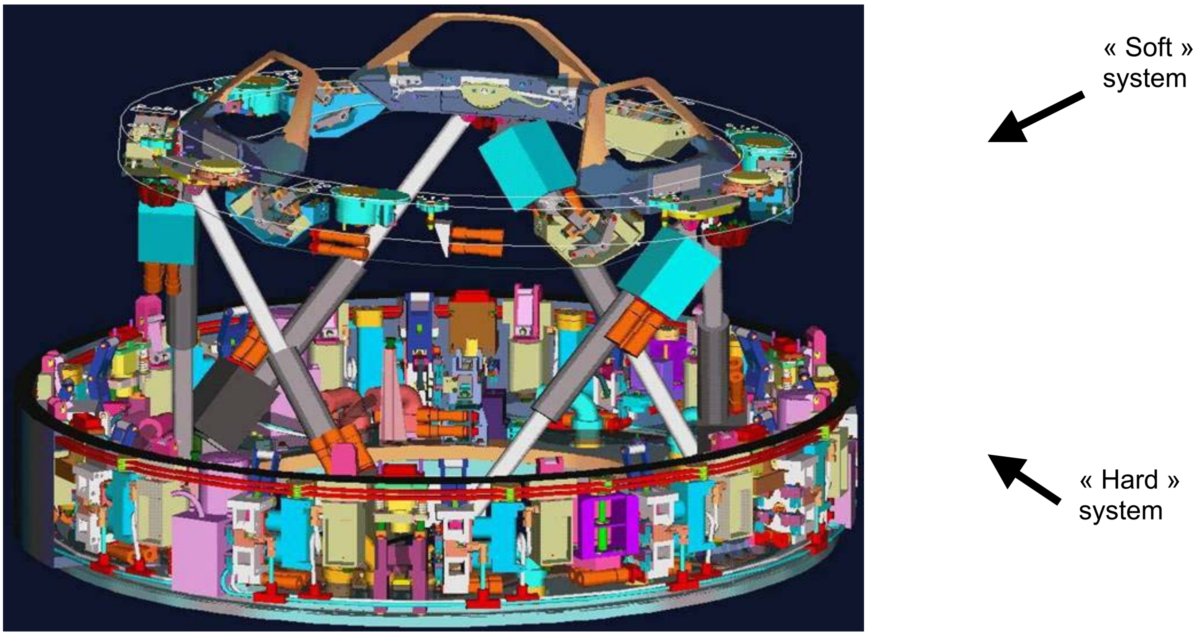


Figure 3.1-1: BDM configuration

To be compatible with the possibility to load ISPRs inside the reentry capsule, the inner diameter of that concept would be 1.6 meters.
The other geometrical characteristics are the following ones,

- Outer diameter = 2.2 meters
- Mass = 600 Kg excluding the rendez-vous equipments and the back-up structures
- Height = 500 mm

3.2 Selected biconic shape reentry capsule

The selected capsule from the preliminary trade-off activities is the updated one with the following characteristics,

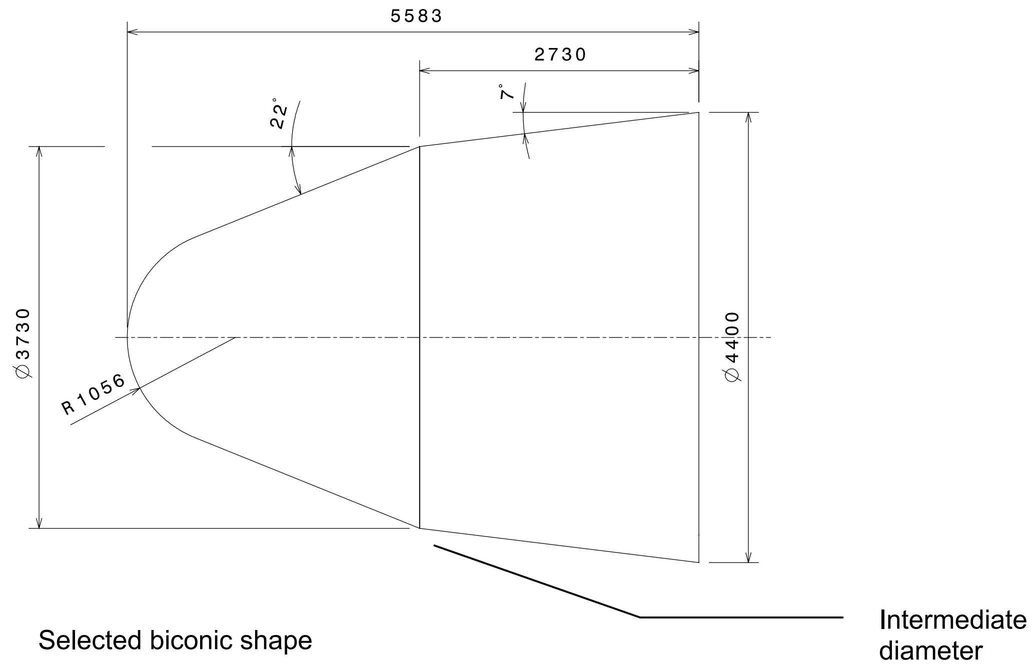


Figure 3.2-1: Selected biconic shape

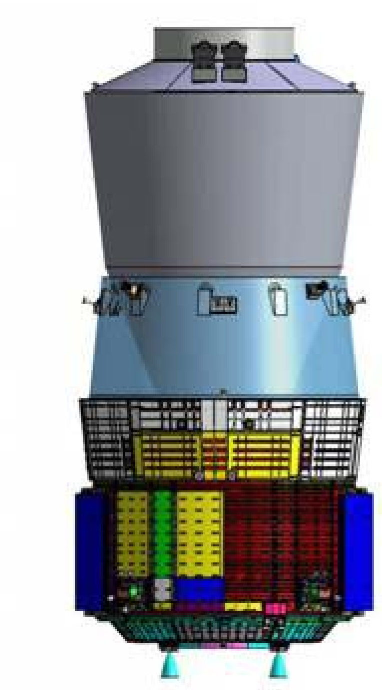
Maximum external diameter	4400 mm
Dry mass without Payload	7.00 tons
Consumables	0.20 tons
Payload maximum capacity	4.1 tons
X-CoG	55% from nose
Y, Z-CoG	~ 0 from X-axis

Table 3.2-1: Typical physical parameters of selected capsule shape

With a 15% system margin, the maximum capsule mass is 13.1 tons.

Global architecture choices
The new defined vehicle is composed of the following modules,

- A Front docking module
- A reentry capsule
- A capsule adapter module
- The current ATV Spacecraft



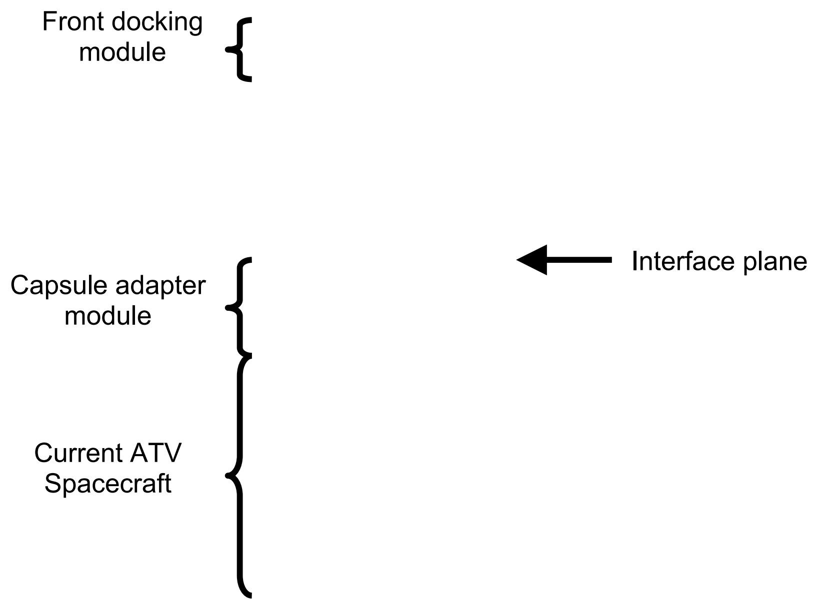


Figure 3.2-2: Global architecture of the selected concept

Capsule Adapter module
A conical capsule adapter module with an upper interface close to the capsule intermediate diameter has been chosen for the following points,

The center of gravity of the capsule is close to its intermediate diameter, thus low bending moments as a result of transverse loads would be generated at the capsule adapter to reentry capsule interface,

The center of gravity of the complete vehicle is below this interface plane, thus the Front Attitude Control System can be located on the adapter, reducing the piping and harness devices.

The connection would be on the 22° angle conical structure of the capsule, thus no significant problems are expected during the transitory separation phase.
This interface plane is located far from the nose of the reentry capsule, leading to low impact on the hottest thermal protection system of the reentry phase.

The capsule is made of stiffened aluminum alloy protected with some Meteorite and Debris Protection System as some harness, feeding lines and valves will be implemented in the capsule adapter to connect the Front Attitude Control System to the propulsion system. Moreover, it is also necessary to protect from meteorite and debris the internal wires and equipments of the Equipped Avionic Bay.

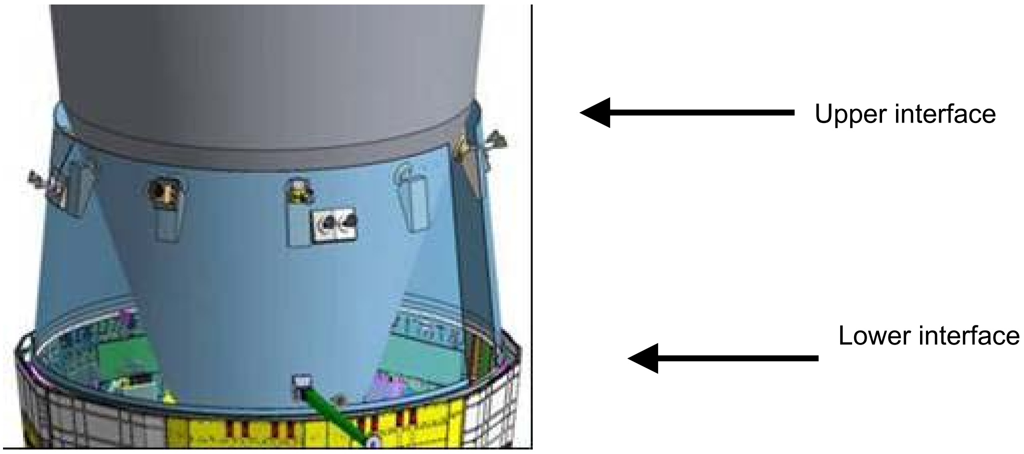


Figure 3.2-3: Capsule adapter module

The capsule adapter is connected,
To the current Equipped Avionic Bay upper interface at its lower interface,
To the reentry capsule through 10 punctual interfaces at its upper face. The estimated axial loads per punctual pyrotechnical bolts are +/-150 kN, based on the preliminary mass budget and quasi-static loads. The proposed diameter is 16mm. The number and diameter of that interface could be modified in the future without significant design modification. The pyrotechnical bolts could be similar to the one already proposed as part of old CTV/CRV studies (the shear behavior would need to be further investigated),

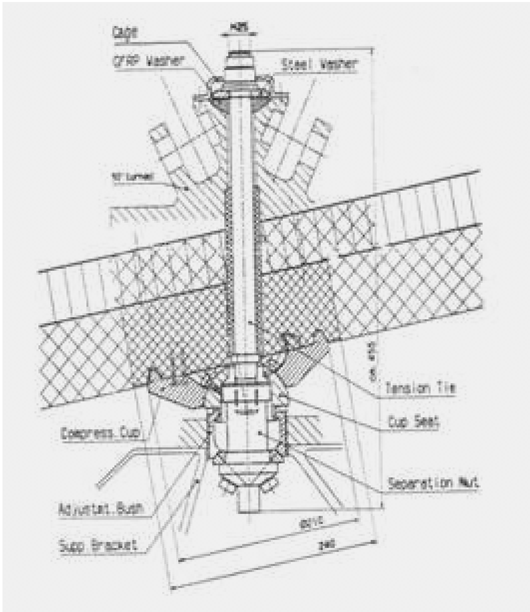


Figure 3.2-4: Typical fixation bolt arrangement

Front Docking Module
The Front Docking module design highly depends on,

- The ISS port, as during the docking phase interaction between the station and the vehicle should be avoided. This point has greatly impacted the current front design of the ATV (Slope of the conical structure).
- The rendez-vous equipment locations, as some equipment, depending on the accuracy and performances required, need a minimum distance with the ISS to communicate.

As the docking port is not yet frozen and as the ISS side is not yet defined with an IBDM, the Front Docking module design has been chosen as close as possible to the current ATV shape using a conical shape structure reinforced with internal triangular webs to provide sufficient stiffness for the equipment layout. This structure could however be easily modified in the future depending on the ISS requirements (Conical structure with a greater angle or even trays solution).

The Front Docking module includes,

- The conical structure reinforced by triangular webs
- The IBDM
- An extrusion of the tunnel capsule structure

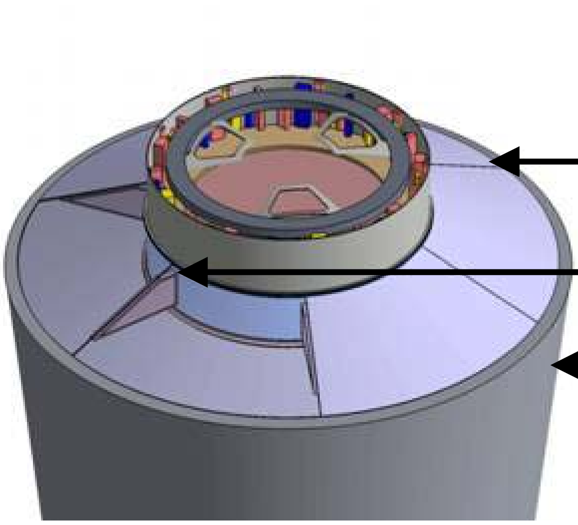


Figure 3.2-5: Front docking module

The Front Docking module is only connected to the reentry capsule through the tunnel structure; there is no connection on the maximum external diameter location to ease the separation phase, as the Front Docking module need to be released from the reentry capsule before re-entry phase for aerodynamic (stability) reasons

Meteorite and Debris Protection System (MDPS)
Compared to the current ATV mission, 2 opposite phenomenas are noticed from the PTV system requirements with respect to the need or not of MDPS,
The vehicle should docked on an US-port, thus, the ISS will not protect anymore the vehicle from meteorite and debris. Recent studies on Jules Verne flight configuration when the ISS is rotated 90° from its current position (and thus the ATV side face directly facing the meteorite without being protected by the ISS) have shown that the collision probability is multiplied by 2.
The vehicle docking phase is reduced to 1 month compared to 6 months for the current ATV.
As a result, it has been decided to keep the same MDPS as baseline for the proposed PTV and to implement some MDPS on the new defined structures, ie on the capsule adaptor module and on the front docking module. Moreover, some MDPS has also been added on the rear part of the vehicle on the thruster platform, since in the V-bar configuration this structure will directly face meteorite and debris. The thruster platform is currently made of metallic composite structure, which is not recommended with respect to meteorite aspects.

Front Attitude Control System (FACS)
The Front Attitude Control Systems are implemented on the upper part of the capsule adapter module since the center of gravity of the complete vehicle is located below, this enables to properly control the vehicle during the rendez-vous phase.

The FACS are composed of 4 thrusters pod equally space around the circumference. They have been located outside the adapter since there is not enough space inside (Interference of back-up lines and support with the reentry capsule).

The orientation of the thrusters would need to be adapted taking into account the interference with the Solar Generator panels and the surrounding equipments.

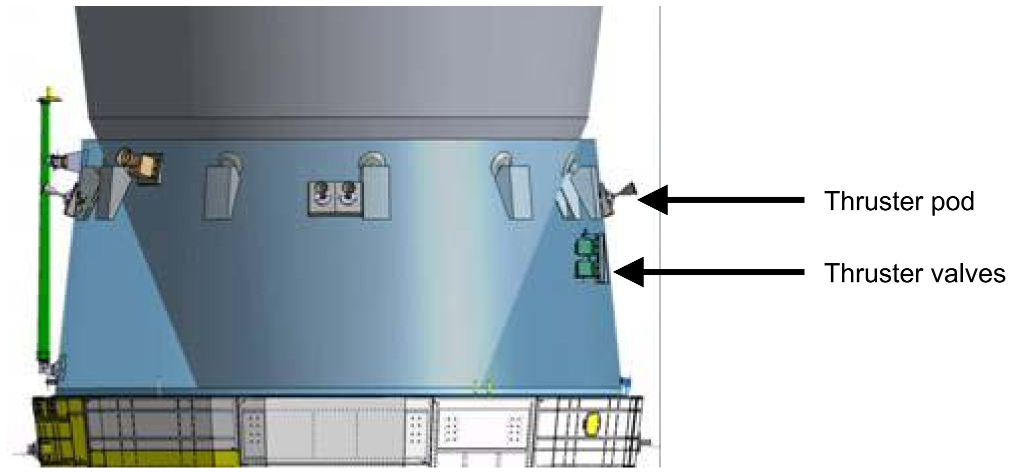


Figure 3.2-6: Front thrusters accommodation

3.3 Equipment layout

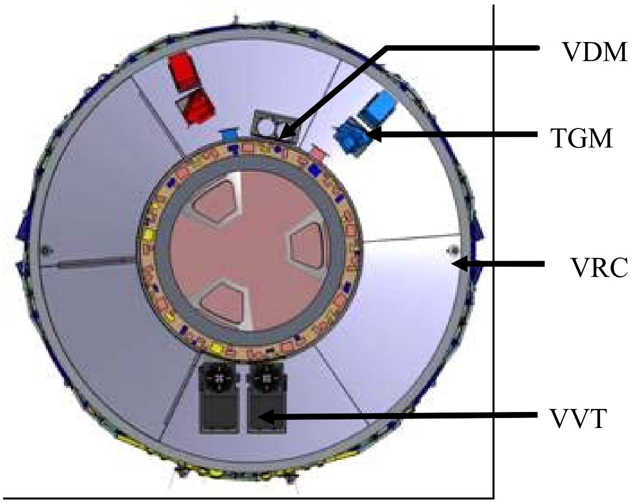
Rendez-vous equipments
As the IBDM equipments need is not yet completely frozen and as the ISS side equipments layout is not yet frozen either, most of current ATV equipments have been kept as baseline.

However, it has to be reminded that the type and location of the rendez-vous equipments on the vehicle highly depends on the rendez-vous scenario, the target (ISS) needs and layout.

The following equipments have been investigated,

Videometer - VDM	By default, same VDM/TGM have been kept with the same visual angles to ISS and a location as close as possible to the current ATV case
Telegiometer - TGM	VDM and TGM are composed of electrical box and optical head. The electrical boxes are kept outside of the structure for thermal exchanges and close to optical head to limit signal drop (wire <1.2 m)
Visual Video Target - VVT	By default, same VVT have been kept with the same visual angle to ISS and a location as close as possible to current ATV case
Visual Ranging Cues - VRC	By default, same front VRC have been kept with the same visual angle to ISS and a location as close as possible to current ATV case Lateral VRC are relocated on capsule adaptor
TDRS	Some additional TDRS for –R-bar scenario need to be implemented on front docking module
Star Tracker - STR	Relocated on capsule adaptor with same visual angle – The Visual view have been verified with respect to the Antenna deployable boom and the solar generators interference

Kurs antenna	Front and rear Kurs antenna suppressed
Antenna Deployable Boom - ADB	Kept and relocated on the conical adaptor



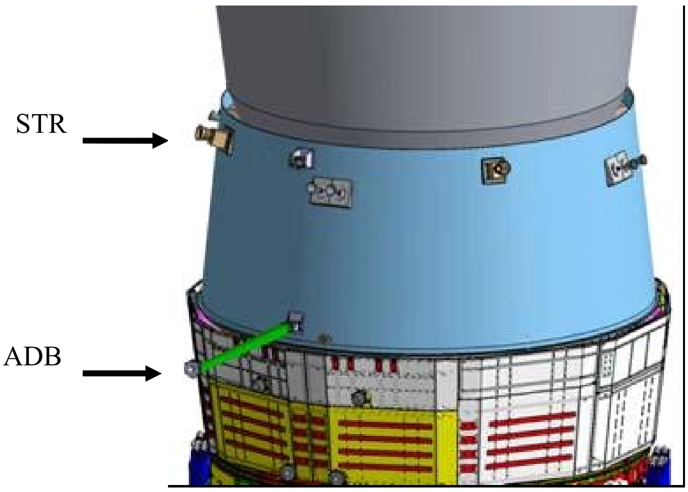


Figure 3.3-1: Accomodation of RvD equipment

As it is mandatory to dock on US-port, the rendez-vous scenario needs to be adapted and especially the PTV would need to fly under the ISS. This under station path might reduce the R-GPS/GPS data exchange because of shadowing effects of the station. The following options have been investigated,

- Use current DORIS system by vehicle to earth exchange. However, this solution is not optimized for the ISS altitude and is more dedicated to SPOT or POSEIDON satellite position (~800 Km orbits).
- Use full radar equipments on the vehicle. This will imply significant impact in terms of mass and layout on the PTV vehicle since antennas and new equipments would need to be integrated.
- Use of the current R-GPS/GPS data completed with distance and Doppler measurement from an omnidirectional antennas. The radar would be implemented in that case on the ISS, but the impact on the vehicle would be limited (implementation of an omnidirectional antennas on the PTV to respond to the ISS radar). In that case, the feasibility would need to be checked depending on the rendez-vous trajectory, on

the performance required during the under station path and on the ISS layout, especially the probability to have TBD satellites would need to be stated.

Avionic equipments

The following modifications need to be implemented on the vehicle,

- Addition of a Command and Monitoring Unit in the Equipped Avionic Bay
- Deletion of the RECS batteries and RSPCU from the Equipped Avionic Bay

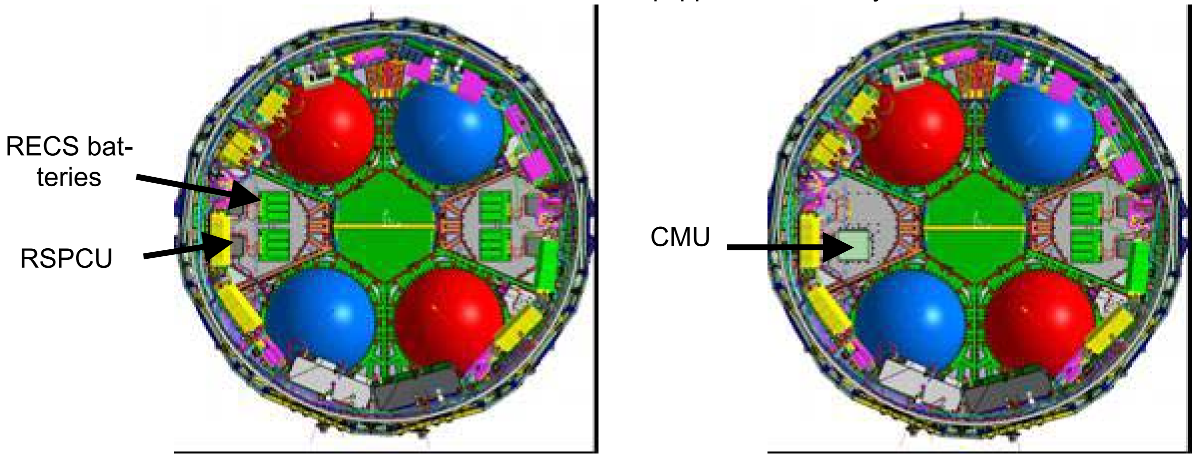


Figure 3.3-2: Avionics arangement

The electronic equipments necessary for the IBDM being not yet frozen, no additional equipments have been implemented. However, it has been verified that some more equipments could be mounted in the Equipped Avionic Bay in the future (if needed) since the External Module with its tanks have been removed. The addition of new equipments will however require extending the current equipment trays and the thermal control system (radiators and VCHP).

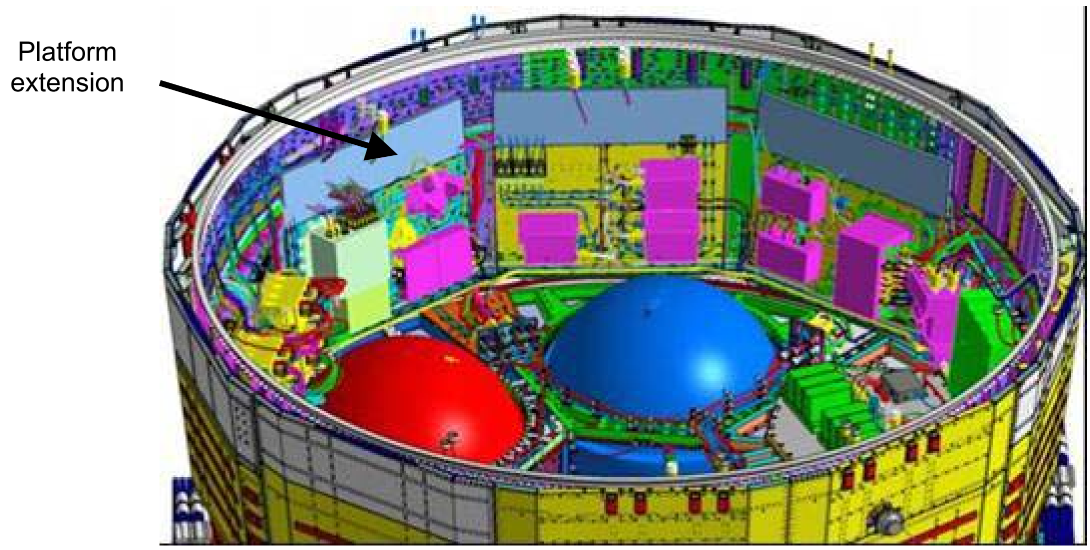


Figure 3.3-3: Platform extension

Harness
Some harness would need to be implemented in the future between the Spacecraft vehicle and the reentry capsule and between the spacecraft and the front docking module. The implementation of the harness could be made,

- Through the TPS of the reentry capsule.
- Using a retractable cable duct

The pros and the cons of each solution would need to be traded-off.

3.4 Payload Accomodation

The accessibility is limited to a portion of one ISPR (not the full ISPR but to its drawers portion in front of the ground hatch and close to the orbital hatch)
In the following figure this solution is presented :

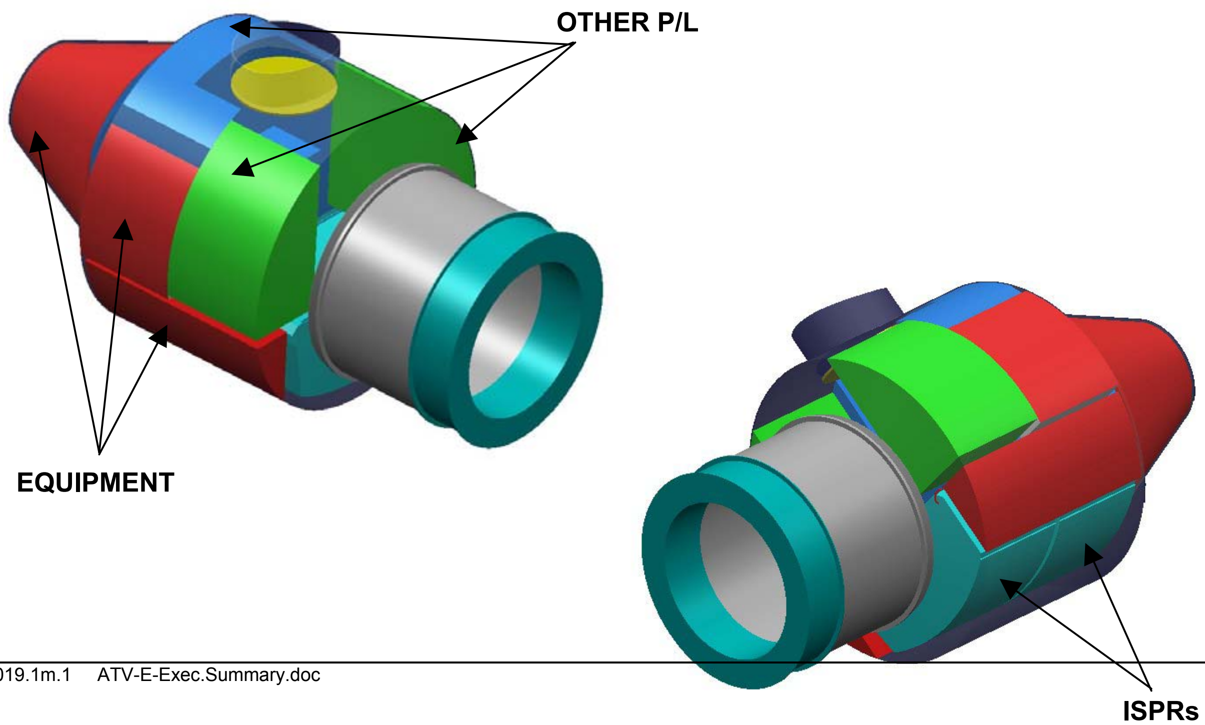


Figure 3.4-1: PTV Blunt Biconic Pressurized Compartment Layout (no full accessibility)

All the PTV equipment are located in the front cone and on the side of the fwd ISPR rack.
Assuming accessibility to only one rack from ground, around 6.7 m³ are available.
Considering the usual 20 % reduction factor, 5.3 m³ of payload can be located in the pressurized volume forward part (above forward ISPR rack) and on the side of the rear ISPR rack (but leaving clearance for drawers accessibility).
This can be translated in a potential for P/L (additional to ISPRs) in the order of 1.6 tons, leading to a total P/L mass of 3.2 tons.

The COG for the pressurized volume is not heavily affected by this solution being most of the new P/L on the front ISPR.

3.5 ISS Adapter Architecture

Based on a first assessment of the Interface and functional requirements, the ISS preliminary functional architecture has been identified.

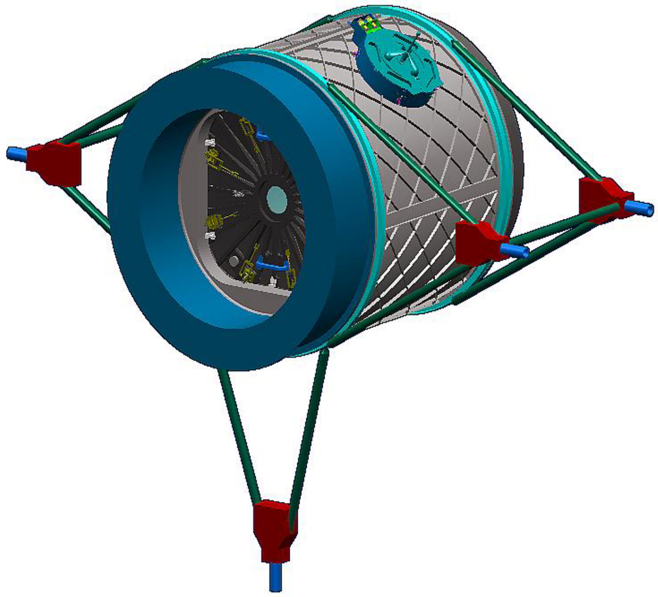
The ISS consists of a pressurized structure protected by MDPS and thermal blankets, equipped with environmental control system, power & data distribution system and one hatch (EV side).

It is equipped with a PCBM (Passive Common Berthing Mechanism) on one extremity side, while on the other side the Active IBDM (International Berthing Docking System) is mounted to connect the ISS to the Entry Vehicle. The IBDM provides a hatch located in the ISS inboard side, and designed to allow opening by the crew on both sides.

The external side allows to install two Power Data Grapple Fixture (PDGF), symmetrically to the X-axis.
The NSTS I/F or Airborne Support Equipment (ASE), if the NSTS is used for launch, is a truss structure integral to the ISS.

The ISS is launched not pressurized, but no functions and check-out are required during NSTS transportation, unless of heating of internals (TBC).

The module length is TBD according to volume needs because of storage of spare parts or others. A nominal length of 3.6 m allows an equipment / spares storage volume of about 4 m^3, much higher than what required for ISS equipment accommodation and ISPR size corridor.



3.6 Flight Segment development items for PTV

Development of a new scenario for ISS rendezvous and docking to Vbar
This development task is necessary for PTV due to the forgiving of the –Vbar docking port of the Russian Docking Module and its replacement by the +Vbar port.

Task 1: Design and qualification analysis of the new scenario. The engineering activity includes:

- Design and analyses of the nominal trajectories
- Design and analyses of the trajectories in contingencies (hold points and retreat strategies in case of delayed docking…)
- Design and analyses of the escape trajectories in case of rendezvous or docking abort
- Design and analyses of the Collision Avoidance Manoeuvre trajectories in case of critical failure or corridor violation
- Design and analysis of the flight corridors

This activity shall be made in close coherence with the architecture, design and specification of the relative navigation sensors and relative communication means, that might imply some constraints or raise some solutions

Task 2: Development and qualification of vehicle control procedures testing of the new scenario. The engineering activity includes:

- Development of the “on-board” and “on ground” procedures
- Testing of the scenarios and procedures on the Software Simulator Facility
- Testing of the scenarios and procedures on the Functional Simulator Facility

Development of a new nominal GNC
This development task is necessary for PTV, due to the new propulsion architecture and the new vehicle mass, centre of gravity and inertia.
Basically, the GNC architecture and algorithms of ATV should be convenient for the attitude control of the new vehicle. However, the IBDM specific docking conditions might require a significant accuracy improvement

Task 1: Design and qualification analysis of the new nominal GNC. The engineering activity includes:

- the preparation and operation of a algorithm validation simulator, to be derived from ATV's
- the preparation and operation of a SW validation simulator, to be derived from ATV's

A major development issue to be clarified quickly with VERHAERT in this field is the comparison of the acceptable kinematics docking conditions, compared to the ATV's. This might result into a significant improvement of the GNC and Propulsion performances.

Development of a new Monitoring and Safety GNC
This development task is necessary for PTV due to the new propulsion architecture and the new vehicle mass, centre of gravity and inertia. It is also required by the change of docking port, and the new relative trajectories of ATV with respect to the ISS.
Basically, the Monitoring and Safety architecture and algorithms of ATV should be convenient for the Collision Avoidance Manoeuvre of the new vehicle.

Task 1: Design and qualification analysis of the new nominal GNC. The engineering activity includes:

- the design and validation of the Collision Avoidance Manoeuvre, over a wide range of relative ATV/ISS positions (ATV behind, below, in front of ISS)
- the preparation and operation of a algorithm validation simulator, to be derived from ATV's
- the preparation and operation of a SW validation simulator, to be derived from ATV's

Adaptation of the architecture of relative navigation
GPS will be kept for the purpose of far Rendezvous and ISS acquisition.

Task 1 : analyse and qualify impact of the masking effects on GPS when flying below the ISS. From ATV designer's standpoint, this perturbation is considered in principle quite low and should not prevent a quasi continuous navigation.

VDM and TGM will be kept for the purpose of final approach navigation (closed loop + monitoring).

Task 2 : design and specify the targets to be implemented ISS

Task 3 : Qualify the VDM and TGM performances in the environment of the new docking port (ISS surfaces properties, modified exposure to solar fluxes, Albedo fluxes…

An additional navigation mean might be required to ensure the navigation continuity. Several candidates can be envisaged:
re-use of KURS navigation system
Implementation of a radar system?
This would of course make an impact on the avionics architecture and on the vehicle layout

Tank Configuration
The baseline ATV uses MMH and MON as propellants for the performance of all propulsive operations, inclusive the reboost of the ISS. While 2880 kg are budgeted for the mission itself (including contingencies and at

least three docking retries), 4080 kg are reserved for ISS reboosting. Thus a total of 6960 kg of propellants are carried.

The propellant demand of a PTV mission, with no reboost foreseen, is less than 2800 kg. Therefore it is possible to adapt the tank configuration to this mission by removal of 4 Tanks in order to reduce the S/C dry mass. Each tank weights 75 kg, but acts as load carrying structure. If a tank is removed, a stiffening structure has to be installed, weighting at least 20-25 kg (estimate).

Two options have been evaluated

a) Removal of the 4 tanks mounted in the Upper Tank Platform: Total PRSS mass saving about 300 kg. Due to design, these tanks act as Bubble Traps for the lower tanks in tandem. If removed, the lower tanks need additional sieves, which can be mounted below the tanks. New development and re-qualification of S/S required. Max. propellant mass that could be carried about 3000 kg.

b) Removal of 2 tank tandems: technically feasible, with a total PRSS mass saving of about 320 kg, incl. equipments and piping. But one level of redundancy is completely lost.

A trading of both options resulted in selection of a) for a dedicated PTV-PRSS.

Front Thrusters Configuration and Relocation

While in the baseline ATV the Front ACS thrusters are accommodated on the Front Cone of the Integrated Cargo Carrier (ICC), in case of the PTV mission have to be relocated to the S/C-Capsule interface adapter. These modifications are feasible without major problems to be expected. It will imply:

- Redesign of the clusters, also to implement a third, dedicated braking thrusters within each cluster. Thrust vectors of these thrusters have to be defined by GNC demands. These additional engines are operated separately from the other FACS thrusters, as are the present braking engines in the ACS thrusters.
- Redesign of the Isolation Valves Assembly (IVP), also to implement a third set of Latch Valves, dedicated to the new braking thrusters
- New layout of the connecting piping network inside the adapter

ACS Cluster Modifications
One thruster per ACS cluster is added in order to improve the overall manouverability of the S/C. Like for the new FACS thrusters, the thrust vectors have to be defined by GNC demands. Unlike in FACS, these additional thrusters are integrated in the normal AOCS supply system and do not need their own Latch Valves.

PTV-PRSS Flow Schematic
The above modifications have been integrated in the dedicated PTV-PRSS Flow Schematic, that is shown in Figure 3.6-1.

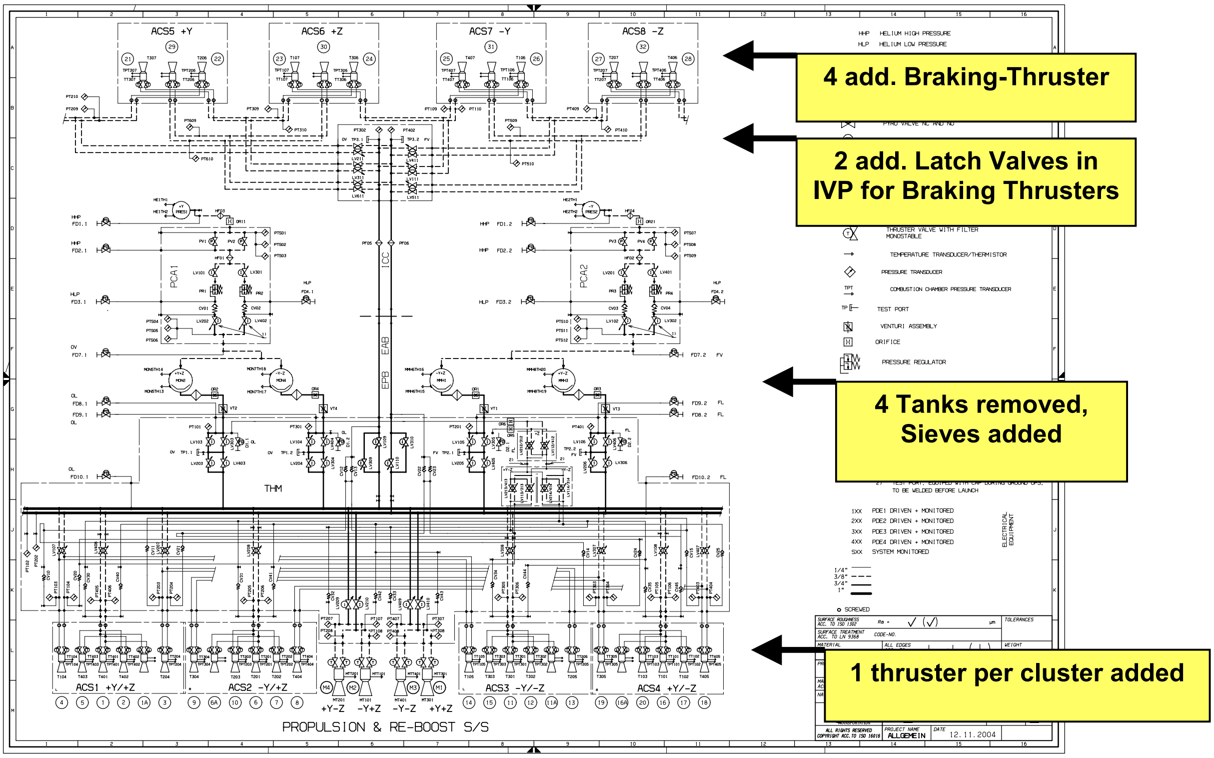


Figure 3.6-1: PTV-PRSS Flow Schematic

Verification Results of the structure subsystem:

- Strength

Certainly a complete screening and MoS calculation could not be done in the available time. In order to nevertheless be able to make a statement of the loads carrying capability of the PTV S/C, the engineering fluxes at chosen interfaces are listed. These are the peak fluxes occurring at any location of the I/F for any of the load cases. The results are compared to the ones obtained for the ATV.

The results for the axial flux (fx, N/mm) are summarised in the next tables:

	AR5 / SDM INTERFACE			
	Min.	**LC**	**Max.**	**LC**
PTV	-301.1	12105	223.2	11103
ATV	-233.8	12105	150.1	11103

	SDM / PRM INTERFACE			
	Min.	**LC**	**Max.**	**LC**
PTV	-245.0	13105	166.4	11103
ATV	-299.4	23107	110.0	23103

	PRM / AVM INTERFACE			
	Min.	**LC**	**Max.**	**LC**
PTV	-166.8	13105	113.0	11103
ATV	-174.8	23107	65.3	11103

Table 3.6-1: Comparison between PTV and ATV

LC 11103 = QS only, Lift-off, Max. Cargo, Max. tension at 45°

LC 12105 = QS only, Max. Aerodyn., Max. Cargo, Max. compression at 270°

LC 13105 = QS only, EAP Burnout, Max. Cargo, Max. compression at 270°

LC 23103 = Combined dyn. Loads, EAP Burnout, Max. Cargo, Max. tension at 45°

As can be seen from the tables above, except for the I/F to the Launcher, the axial compressive fluxes (left column) for PTV are equal to or lower than the ones for ATV. This comes from the fact that although the CoG of PTV is higher, this is compensated by dropping the ICC overfluxes which have a considerable resultant. The maximum tensioning fluxes (right column) increase but still remain smaller than the compressive ones. It is considered that if any low margins should be identified, these would only be local problems which can be solved relatively easily. It is recalled that the ATV main structure is not sized by the load transfer capability but by the stiffness requirement.

The load carrying capability of the CA can only be roughly assessed with the given FEM. Since the section properties are the same as for the Tankage Cylinder which is further down, it can be stated that it is globally capable of carrying the loads. Certainly the discrete load introduction points will have to be looked at separately since extreme load peeks have to be expected there. An optimisation of the design would certainly take more time than what is available for this study.

- Stiffness

Following first frequencies are required in structural specifications

First global lateral mode: f_1> 6 Hz

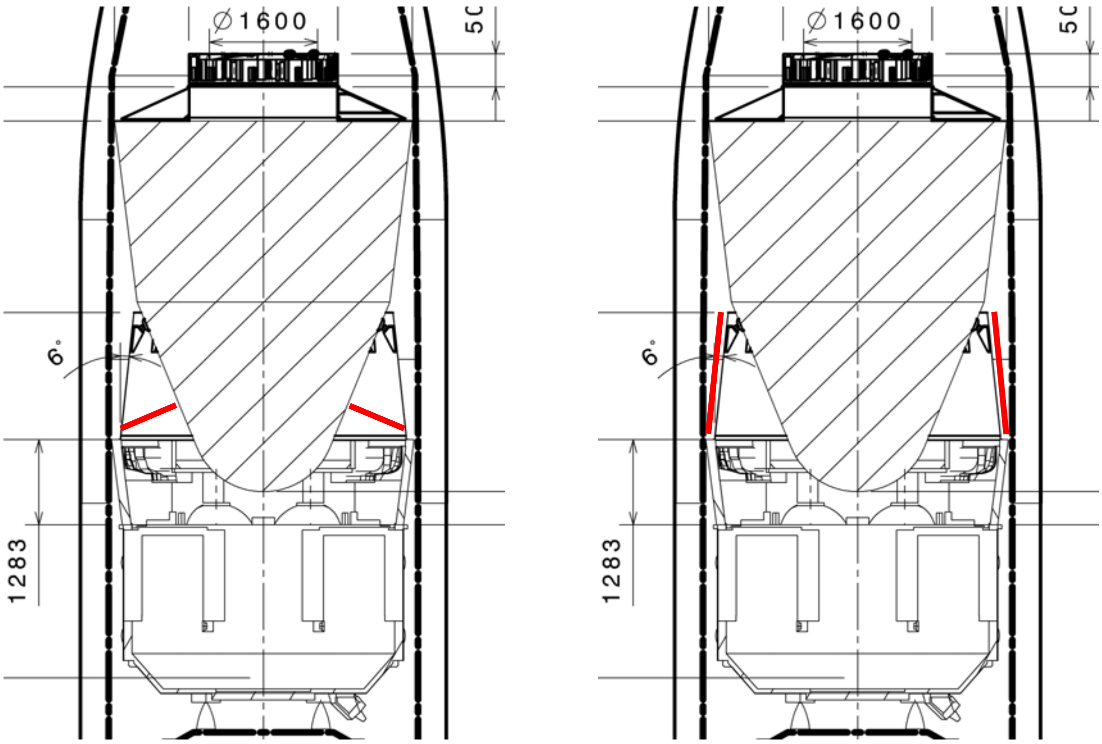
- First global axial mode: f_1> 25 Hz

As can be seen from the table above both the axial and lateral frequency requirement are slightly violated.

MDPS Performance

On top of the existing MDPS items following modification might be necessary:

1. In order to prevent particles from penetrating into the EAB through the CA, a shield closing the EAB compartment might be needed. The design of this structure is open but it seem that the sizing will be driven by stiffness rather than MDPS function. A very preliminary assessment gives a mass of this structure in the area of 50-80 kg (assuming an aluminum sandwich platform).
2. Alternatively a dedicated MDPS on the external side of the CA could be foreseen. Based on the experience made with the MDPS and AVR, this structure would weigh roughly 100-110 kg. Although heavier, this solution provides a far better protection performance for the front side of the Capsule or any equipment mounted on the inner side of the CA. It will depend on the MDPS requirements for the Capsule and CA is this additional capability is needed at all.



Option 1. Option 2.

Figure 3.6-2: MDPS alternatives

3. Reinforcement of the THM MDPS. This might be necessary to optimise the today's MDPS since the rear part of the PTV (THM) will point for long periods to the direction where most of the debris are coming from. It is considered that taking advantage of existing parts, a realistic mass impact would be in the order of 50-60 kg which is in line with the assessment of EADS-ST Les Mureaux. This mass figure results from an increase by 0.5 mm of the outer skin and 1.0 mm of the inner skin of the THM cone and platform as well as a doubling of the distance between the 2 skins.

In the impact assessment below no extra MDPS on the THM is considered. The below assessment assumes that impacts on the PTV S/C only.

To assess the MDPS performance following approach was chosen:

1. Same requirement for PF (< 0.00190) / PNF (> 0.99810) as for ATV.
2. The results from ATV are extrapolated to the PTV mission durations.
3. The contribution from the **free-flying** phase of PTV is considered as for the **free-flying** phase of ATV.
4. The contribution from the **docked** phase of PTV is considered as for the **free-flying** phase of ATV (same probability of failure per unit of time). This assumption comes close to reality since while docked the PTV sees a far worse MOD environment than ATV. Being docked at the US of the ISS is considered similarly severe to free-flying.

PTV mission: Free-Flight phase: 144 hours (6 days)

Docked phase: 1 month (~30 days)

Corresponds to an ATV mission of 6 + 30 = 36 days of free-flight.

Results for PTV S/C Structure:

PTV mission: PF = 0.00146 (PNF = 0.99854)

(requirement PF < 0.00190) 0% of failures during docked phase (by definition)

100% of failures during free-flying phase

For comparison:

ATV Reference mission: PF = 0.00154 (PNF = 0.99846)

78% of failures during docked phase

22% of failures during free-flying phase

As can be seen, with the given assumptions, the today's ATV S/C is capable of performing the PTV mission from the MDPS point of view.

3.7 Mass budget

The following mass budget has been issued considering the above mentionned modifications. The mass data are extracted from the current ATV mass budget ATV-AS-TN-1007-01.

Suppressed mass

The mass suppressed compared to current ATV hardware is,

Integrated Cargo Carrier	- 5447.4 Kg
RECS batteries	- 37.7 Kg
RSPCU	- 6.0 Kg
Kurs antenna	- 6.8 Kg

Added mass

The mass added compared to current ATV hardware is,

Conical adaptor (including MDPS)	~+600 Kg (1)
IBDM	+ 600 Kg
Front docking module (including MDPS)	+ 176 Kg (2)
MDPS on rear side	+ 60 Kg

Rendez vous equipments (VDM, TGM, VVT, VRC, STR, ADB)	+92.1 Kg
CMU	+16.0 Kg
FACS	+78 Kg
Propulsion	-180 Kg

(1) Preliminary estimated mass using a 6Kg/m^2 for the MDPS and a 19 Kg/m^2 for the aluminum alloy material.

(2) Preliminary estimated mass extrapolated from current ATV mass budget and using a 6Kg/m^2 for the MDPS.

System mass budget

The final system mass budget is the following one,

Spacecraft	5166 Kg
Consumables	2348 Kg
Front docking module	853 Kg
Capsule adaptor module	693 Kg
Reentry capsule without system margin	7200 Kg
Total without system margin without Payload	16260 Kg

Spacecraft – 5% system margin	452 Kg
Reentry capsule – 15 % system margin	1080 Kg
Total with system margin without Payload	17792 Kg
Up Payload capacity	2708 Kg

For a 10 % margin for the reentry capsule the payload up capability improves by 360 kg to 3068 kg.

The up payload mass capacity is calculated using the 20.5 tons Ariane5 maximum capacity.

Note:

1. The above budget mass is set up with 8 tanks configuration considering that the communality of the ATV is predominant compared to the mass budget.

2. At this step of the projet, it is recommended to use a 5% system margin on the spacecraft, consumables, capsule adapter and frond docking module for growth allowance.

4. CTV - Architectural and System Design

The same biconic shape re-entry capsule as for the PTV studies has been selected for the CTV system architecture for communality reasons.

System requirements

The same system requirements of the PTV configuration except for the following point, the CTV will be launched with an Ariane5 ESC-B launcher with a maximum capacity of 23.0 tons and the consequences for the safeguard tools during the launch mission phases.

4.1 Vehicle concept design

Global architecture choices

The new defined vehicle is composed of the following modules,

- A Front docking module
- An Emergency Escape module
- A re-entry capsule
- A capsule adapter module
- The current ATV Spacecraft

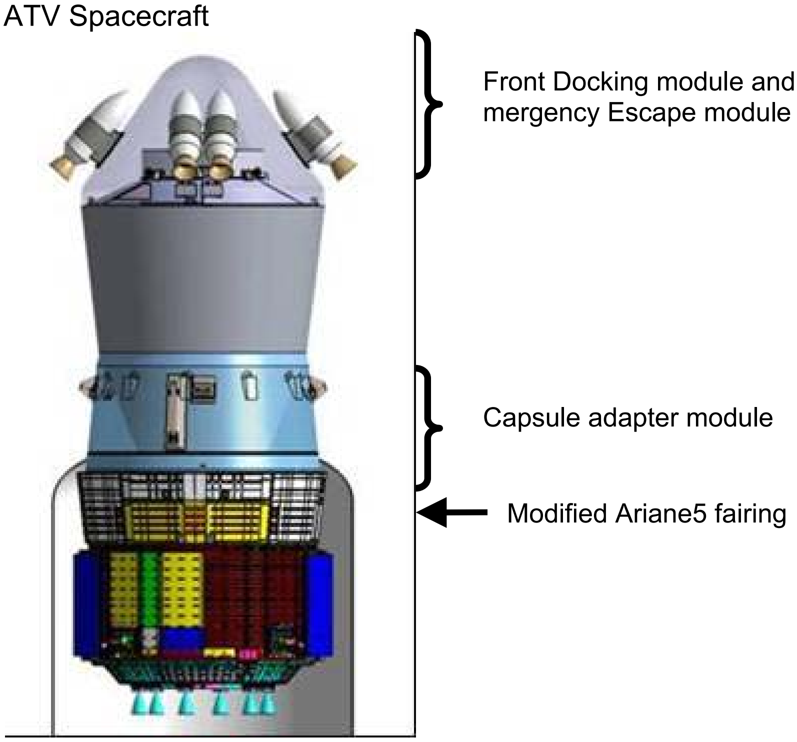


Figure 4.1-1: CTV vehicle configuration

Capsule Adapter module

The capsule Adapter is similar to the PTV one with the following differences:

- The capsule adapter includes in its lower part a pyro jetcord separation system to separate the capsule adapter + the reentry capsule from Ariane5 launcher in case of emergency escape. The separation plane is located above the connection of the modified ariane5 fairing to the capsule adapter.

- An elastomeric joint would need to be mounted at the top of the adapter to fill the gap between the adapter and the reentry capsule. This joint is especially necessary for the atmospheric phase since this part is not protected anymore by Ariane5 fairing compared to PTV configuration.

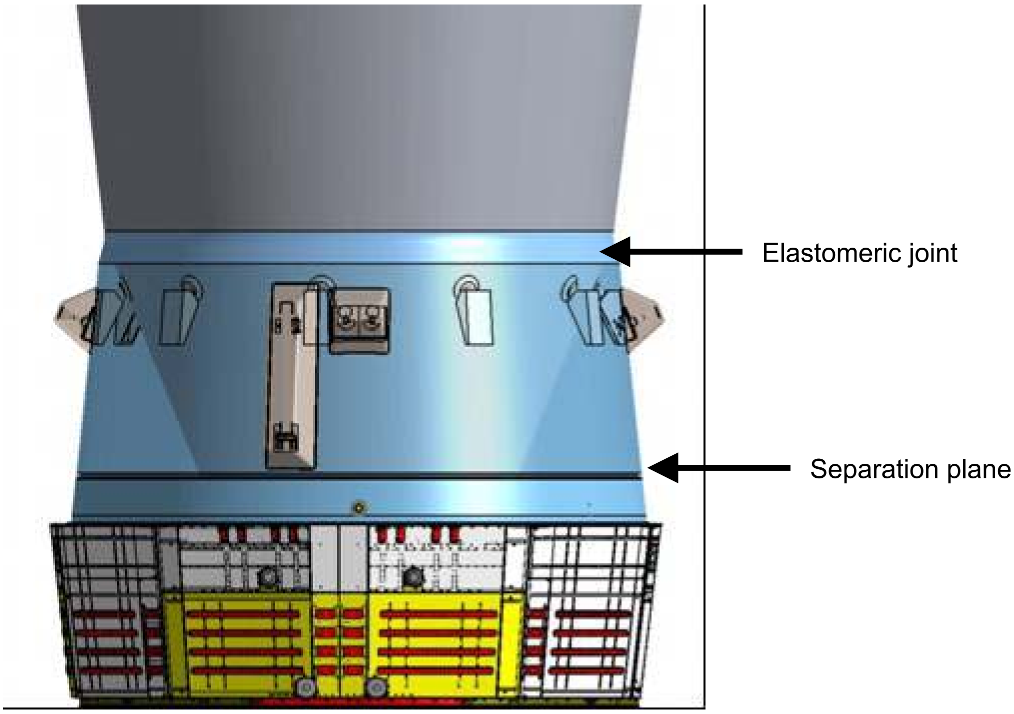


Figure 4.1-2: CTV Separation planes

Front Docking Module

The front docking module is similar to the PTV one.

Emergency Escape module

In case of Ariane5 problem during the atmospheric flight, it is mandatory to have an emergency escape system for safety reasons. The proposed emergency escape systems are extracted from old CTV/CRV studies.

2 options are foreseen,

- Tower escape system including boosters
- Scattered boosters mounted on a fairing

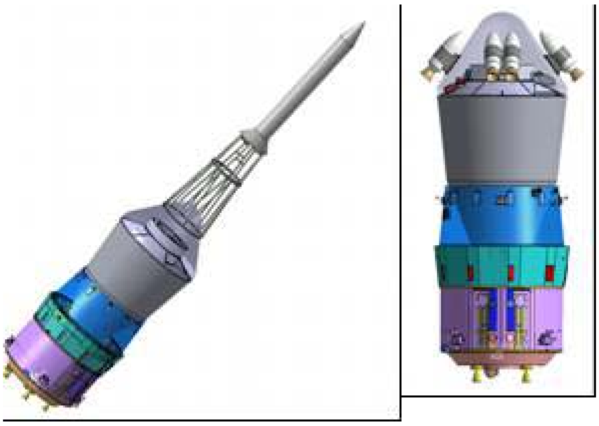


Figure 4.1-3: CTV Launch safeguard alternatives

	Tower escape	Scattered boosters
PROS	No synchronization problems Already used	Lower center of gravity location Lower loads Versatile options
CONS	Very high tower to avoid to damage the reentry capsule → Kourou facilities problem High center of gravity → increase of loads	Synchronization of all boosters and same level of thrusts for all boosters

Table 4.1-1: Discussion of safeguard tools

The scattered boosters option has been chosen for the CTV analysis to limit the impact on the spacecraft structure.

The scattered boosters configuration module will include in its lower part a pyro tight separation system to separate the Emergency Escape module from the vehicle in case of safe Ariane5 flight. This separation will be done TBD seconds after lift-off depending on RAMS and safety analysis.

Indeed, as a pyro jetcord separation system would generate some debris in the vicinity, a pyro tight separation system is foreseen to avoid damaging the rendez-vous equipments located on the front docking module. However, it would be necessary to verify if the generated pyrotechnical environment is compatible with the rendez-vous equipments (very sensitive equipments).

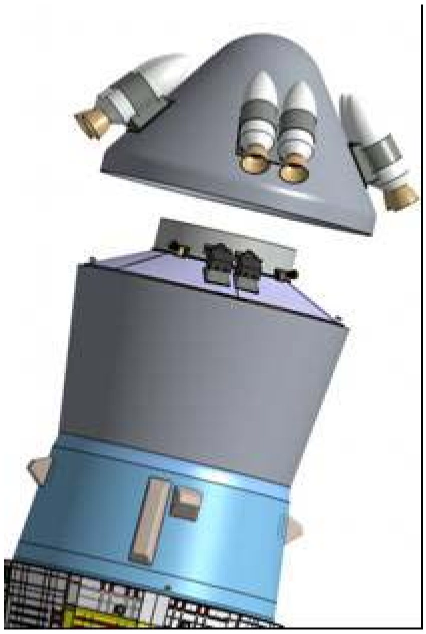


Figure 4.1-4: Separation of safeguard booster set

Meteorite and Debris Protection System (MDPS)

Same as PTV configuration.

Propulsion aspects

Propellants need

Same as PTV configuration

Front Attitude Control System (FACS)

The same localization of the FACS is foreseen for the CTV configuration. However, they would need to be protected during the atmospheric flight period of Ariane5.

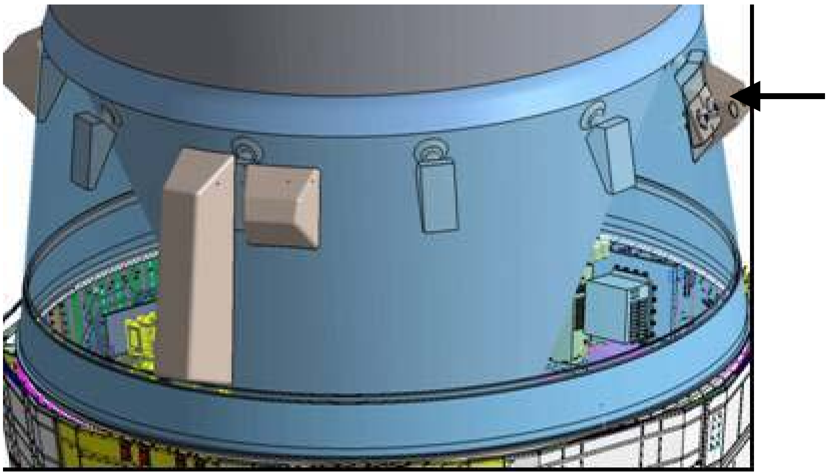


Figure 4.1-5: ATV fairing for front thrusters

Note: If the FACS could be slightly relocated in a lower position on the capsule adapter, it could be possible to implement them in the capsule adapter to avoid fairings. However, today, it is not possible because of interferences with the reentry capsule.

Main propulsion and rear attitude control system

For the CTV mission, according to subsystems analysis (See paragraph 5.4 for details) it is foreseen,

- To add 2 main thrusters assembly
- To add braking thrusters for the CAM phases.

The two main thrusters assembly can be implemented on the thruster platform, this will however impact the design of this platform. In addition, it might also be necessary to add PDE's and PCA to monitor those additional thrusters. This would require the modification of the struts assembly and could impact the dynamic sizing of the spacecraft.

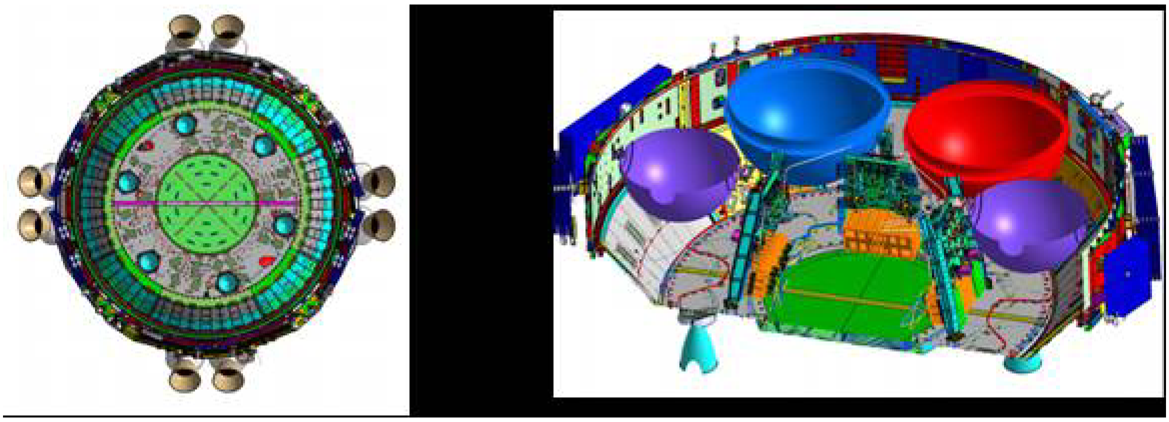


Figure 4.1-6: Main Thrusters and PDE accommodations

As concerns to the implementation of additional braking thrusters, a trade-off would need to be carried out to compare 2 options,

- Addition of pods
- Addition of thrusters on the current pods.

Thermal aspects / Power generation

The solar generators will need to be improved to generate more power. As the panels sizes are currently at their limits with respect to length and width dimensions, it would be necessary to improve the cells capacity.

4.2 CTV Internal Vehicle Layout

Potential of crew seat accommodation

The accommodation assessment consideration have been done for the Blunt Biconic shape in the nose-down launch configuration.

For the Blunt Biconic concept launched "nose-up", the same consideration on the volumes in the pressurized compartment are applicable (the major difference is due to the seat positions with respect to the launch direction).

The following figure reports the accommodation of the four crew members in the pressurized compartment in launch configuration.

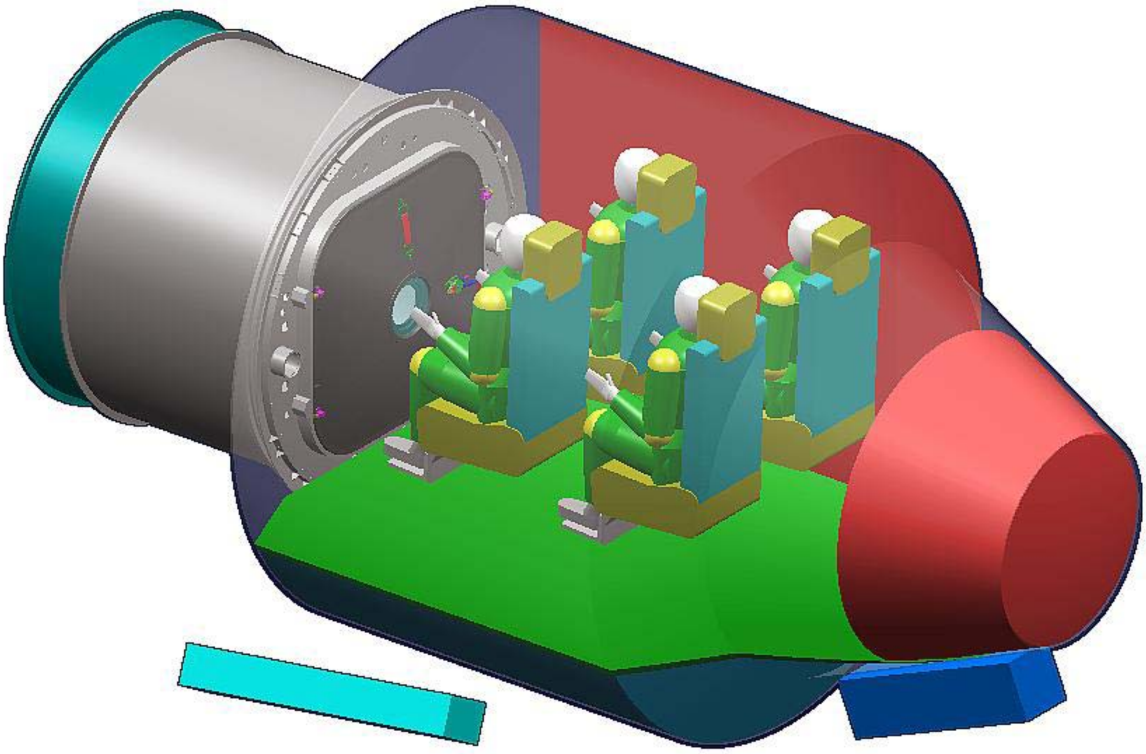


Figure 4.2-1: Blunt Biconic CTV – Launch configuration nose-down

The following figure reports the accommodation of the four crew members in the pressurized compartment in landing configuration. To achieve a better acceleration field during re-entry and landing, a tilting of the seats in the order of 30 deg has been implemented.

Considering that the internal total volume for the Blunt Biconic concept is equal to 25.8 m³ and that, from a rough estimation, the volume occupied by the crew equipment plus the internal components is equivalent to 7.8 m³ we can derive that the crew (composed by 4 people) has 18 m³ of free volume.
Leaving for any crew member a free volume of 2 m³ we can assess that a transportable payload of 10 m³ can be accommodated inside the pressurized compartment.

Considering:
- a 20% volume margin to account for secondary structures and packaging factors and
- a payload density of about 300 Kg per cubic meter,

the theoretical P/L occupying all the residual volume of about 10 m³ is about 2400 kg of transportable payload.

Verification on the re-entry mass has been conducted analyzing the mass estimation of the re-entry vehicle compared with the limit mass considered equal to 13.1 tons.
The Blunt Biconic re-entry mass has been evaluated equal to 9930 Kg that means a payload mass of 3170 Kg.

As a conclusion, the Blunt Biconic option can easily accommodate the 4 crew members required.
A preliminary investigation on a 5 crew member has been conducted as reported in the following figures.

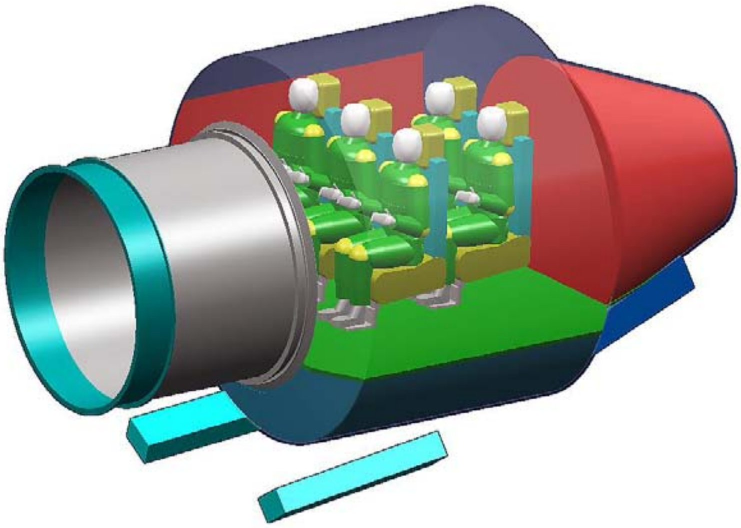


Figure 4.2-2: Blunt Biconic CTV – Launch configuration nose-down - 5 crew members

4.3 ATV modifications analysis

This chapter describes the modifications to be implemented to derive a CTV from the PTV, as understood with the ATV designer background. This chapter references to the ATV modification already necessary for the PTV. All these modifications are considered already acquired in the next chapters.
The modification analysis and description is presented in a top down approach featuring :

- First, the modification to be analysed, designed and implemented at Flight Segment level
- second, the modification to be analysed, designed and implemented at subassembly level

The projection of these modifications on the ATV subsystem level has not been assessed in detail for CTV due to the very deep redesign effort deemed necessary.

The next chapter present a more precise analysis of the critical modification areas of ATV subsystems.

General assumptions
All what regards the crew accommodation is considered as part of capsule design and analysis and is not considered hereby. The CTV safety requirements are equivalent to the ATV safety requirement, in so far no double failure shall induce a catastrophic event. From the CTV S/C standpoint, that implies that no double failure shall prevent crew de-orbitation towards a safe re-entry trajectory.
The principles developed hereby consist of presenting how the qualified ATV architecture could be developed and reused in the perspective of a CTV. However, the development effort for a CTV is so large that a strong analysis of phase B level shall be made to trade several options, in the context of the neighborhood of “manned capsule” with its own resources (data processing, crew capacities…). These might demonstrate that the development and qualification is reduced by forgiving some of the ATV principles.

4.4 Flight Segment development items for a CTV

Man rated architecture for the orbital transfer and de-orbitation functions
This development task is necessary for CTV due to the absolute necessity to de-orbit the manned capsule in case of contingency.
The present analysis assumes that the general requirement applicable for that development is that the crew capsule shall be de-orbited safely.
The ATV heritage and its foreseeable modifications is the following:

- the data processing architecture is based on :
  - the Data Management System (DMS) composed with three Fault Tolerant Computer (FTC) and running the Flight Applicative Software (FAS)
  - the Monitoring and Safety Unit (MSU) composed with two parallel data processing units running the MSU software.

The DMS/FAS ensures the nominal vehicle function with tolerance to any single failure throughout the vehicle. It still works an operation after a double FTC failure. The MSA chain ensure the monitoring of RV and the realization of a 0FT manoeuvre.
This architecture is judged convenient to a man rated the CTV, especially is we consider that the capsule brings a third computer on board. However, this specific point should be subject to an extensive set of early analysis and trade-off at a "phase B level". An improvement of fiability is credibly required in any case.
The MSU functions have to be extended so as to cover not only the Collision Avoidance Manoeuver and a stabilized attitude control as presently on ATV, but also the de-orbitation boost. This should a certain extension of data processing and of memory capacities of the MSU. The need for a similar extension is also credible for DMS.

The power supply architecture is based on 4 segregated chains, with segregated power users (except for few items like the CMU or PDE, that accommodates two redundant chains supplied differently). The ATV power capacities are capable to sustain a nominal mission with any first failure. Some additional primary batteries are affected to the MSU to complement the main power distribution in case of second failure.
This architecture is judged convenient to a man rated CTV. However, this specific point should be subject to an extensive set of early analysis and trade-off at a "phase B level".

A severe extension of the power resources is in principle needed:

- extension of the MSU "primary batteries": so as to ensure a mission of typically 1,5 days on the MSU chain,
- extension of the SGS performances (TBC) : this point is deemed required by the supply during the free flight periods of a capsule power budget significantly higher than the ATV ICC budget. This point is critical in so far the present wingspan is at the limit of GNC tolerance (a longer wingspan would reduce the frequency flexible mode and conflict with the GNC)
- extension of the battery capacities : this is deemed required by the supply during the free flight periods of a capsule power budget significantly higher than the ATV ICC budget and also needed as an improvement of the operational flexibility on the vehicle.

Note the extension of batteries (especially rechargeable batteries) implies a general resizing of the EAB dimensions.

- the propulsion architecture is based on 4 segregated chains. The ATV propulsion capacities are capable to sustain a nominal mission with any first failure (e.g. complete loss of one chain).

This architecture is judged convenient to a man rated CTV. However, this specific point should be subject to an extensive set of early analysis and trade-off at a "phase B level".

An extension of the CAM thrusters is in principle needed. Additional ACS thrusters shall be installed so as to be able ensure the de-orbitation force and ensure the associated attitude control.
An important “phase B” trade-off shall be made at vehicle level, on the “man-rated” de-orbitation. The introduction of a third couple of Main Thrusters is another option.
Also, the requirements on the propulsion safety and reliability should be significantly stronger than on ATV. This should imply some verification and possibly some modification and development efforts on the thrusters.

- the communications architecture is based on 2 segregated chains. The ATV communication capacities are capable to sustain a nominal mission with any first failure (e.g. complete loss of one chain).

This architecture is judged convenient to a man rated CTV, since the capsule it self should provide with an additional communication link.

- The thermal control architecture is based on 4 segregated chains, associated each to one power chain. The ATV thermal control capacities are capable to sustain a nominal mission with any first failure (e.g. complete loss of one chain). In the case of a second failure, the ATV thermal control is not able to guarantee the mission completion.

This architecture is judged not convenient and shall be modified. A third redundancy shall be provided. Several options can be traded for that purpose:

- Extension of the TCU capacity and triplication of all the heater lines and thermistor lines (they are presently only duplicated on the ATV) (Note: this also implies an increase of the power supply capacity on each chain)

- Introduction of a “third level” with reduced performances based on a robust thermal regulation (e.g. thermostats). This has to be analyzed in an avionics analysis all together with the power supply.

The semi-active architecture with VCHP is judged convenient but shall be extended so as to accommodate a wider number of avionics boxes and reject a larger thermal power. This should basically require some additional VCHPs. It shall be noted that the heater system implemented to regulate the ATV VCHPs is already redundant (twice) and is then ready to support a 2 FT requirement. Beside, a re-optimization of the general heater line breakdown is to be envisaged: the control of VCHP could be made with a smaller number of regulation lines and the liberated lines could be reused to minimize the TCU growth required by general improvement of the failure tolerance.

- the navigation architecture shall be revisited since the ATV MSU chain only refers to a small amount of captor (Accelerometers, Gyros, STR). The necessity to improve these means for the purpose of a de-orbitation has to be analyzed.

- the Separation and Distancing shall be modified (a double redundancy might be required, TBC) so to ensure the failure tolerance requirement associated to a manned mission

- the docking architecture shall be revisited (TBC) so to ensure the failure tolerance requirement associated to a manned mission.

4.5 Mass budget

The following mass budget has been issued considering the above mentionned modifications. The mass data are extracted from the current ATV mass budget ATV-AS-TN-1007-01.

Suppressed mass

The mass suppressed compared to current ATV hardware is,

Integrated Cargo Carrier	- 5447.4 Kg
RECS batteries	- 37.7 Kg
RSPCU	- 6.0 Kg
Kurs antenna	- 6.8 Kg

Added mass

The mass added compared to current ATV hardware is,

Spacecraft mass increase	~+900 Kg (*)
Conical adaptor (including MDPS)	~+600 Kg (**)
IBDM	+ 600 Kg
Front docking module (including MDPS)	+ 176 Kg (**)
MDPS on rear side	+ 60 Kg
Emergency Escape module	+ 7800 Kg (***)

(*) Estimated mass – See paragraph 5.4 for details
(**) Preliminary estimated mass – Same as PTV
(***) Preliminary mass – extracted from old CTV/CRV studies based on tower escape configuration – Effective mass for Ariane5 budget mass 2.2 tons

Rendez vous equipments (VDM, TGM, VVT, VRC, STR, ADB + ADB fairing(*))	+102.1 Kg
Avionic equipments	+640.0 Kg (**)
FACS (including fairings(*))	+118 Kg
Main propulsion	+98 Kg(**)
Propulsion	-180 Kg

(**) preliminary estimated mass extrapolated from current ATV budget mass.

System mass budget

The final system mass budget is the following one,

Spacecraft	6790 Kg
Consumables	2348 Kg
Front docking module (including Emergency Escape module)	3060 Kg
Capsule adaptor module	683 Kg
Reentry capsule without system margin	7200 Kg
Total w/o system margin without payload	20 081 Kg
Spacecraft – 5% system margin	544 Kg
Reentry capsule – 15 % system margin	1080 Kg
Total with system margin without payload	21 705 Kg
Up payload (crew) capacity	1295 Kg

For a 10 % system margin for the re-entry capsule the up payload (crew) capacity improves to 1655 kg.

The up payload mass capacity is calculated using the 23.0 tons Ariane5 ESC-B maximum capacity.

Note:

1. The above budget mass is set up with 8 tanks configuration considering that the communality of the ATV is predominant compared to the mass budget.

2. At this step of the projet, it is recommended to use a 5% system margin on the spacecraft, consumables, capsule adapter and frond docking module for growth allowance.

3. the maximum lift-off mass of the launcher should be verified with respect to 28.6 tons.

5. ULC - Architectural and System Design

5.1 ATV ULC Layout and Configuration

Two alternate payload accommodation layouts will be considered in parallel during this project phase. The layout version 1 is based on the nominal planned external payload platform for ISS the Express Pallet (see 0). The layout version 2 is based on the existing and proofed logistics carrier for external cargos transported in the cargo bay of the US Space Shuttles, the ICC (see **Error! Reference source not found.**) A brief characterization of both alternate concepts is summarized in the following table:

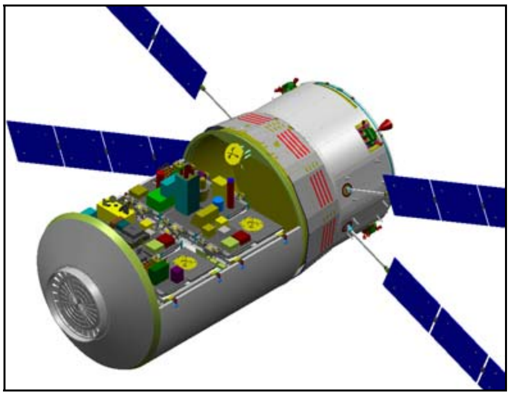
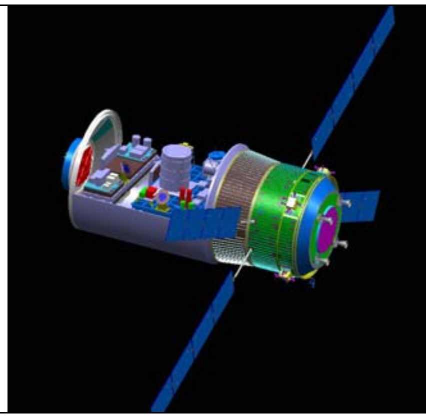
Layout Version	***1***	***2***
Figure		
Cargo Carrier Concept	Express Pallet	Integrated Cargo Carrier (ICC)
Max. Cargo Mass	2267 kg (2 Express Pallets)	4542 kg (ICC-G + ICC-L)
Sub-Assembly Concept	ExPA (10) Top loading	ExPA, … (9 - 20) Loading of both sides
Handling	EVR, EVA	EVR, EVA
Status	Development Phase	In Operation

Table 5.1-1: Overview of alternative ATV ULC Cargo Carrier Concepts

ATV ULC Cargo Compartment Bay (CCB) Layout Version 1

5.2 Standard P/L Accommodation Assessment

The ULC concept is based on the ATV ICC concept with a cylindrical cargo compartment (smaller with respect to the US STS cargo bay in order to be contained in the Ariane 5 Long Fairing) and a door that can be jettisoned or opened (as Shuttle Cargo bay) after separation from the launcher.

Every payload provides interfaces to the ISS robotic arm for the movement to the ISS final location.

Based on these considerations, an accommodation exercise has been performed on two Express Pallets, as envisaged by NASA for the NSTS cargo bay (modifying the trunnions mounting brackets). The accommodation is shown in Figure 5.2-1 .

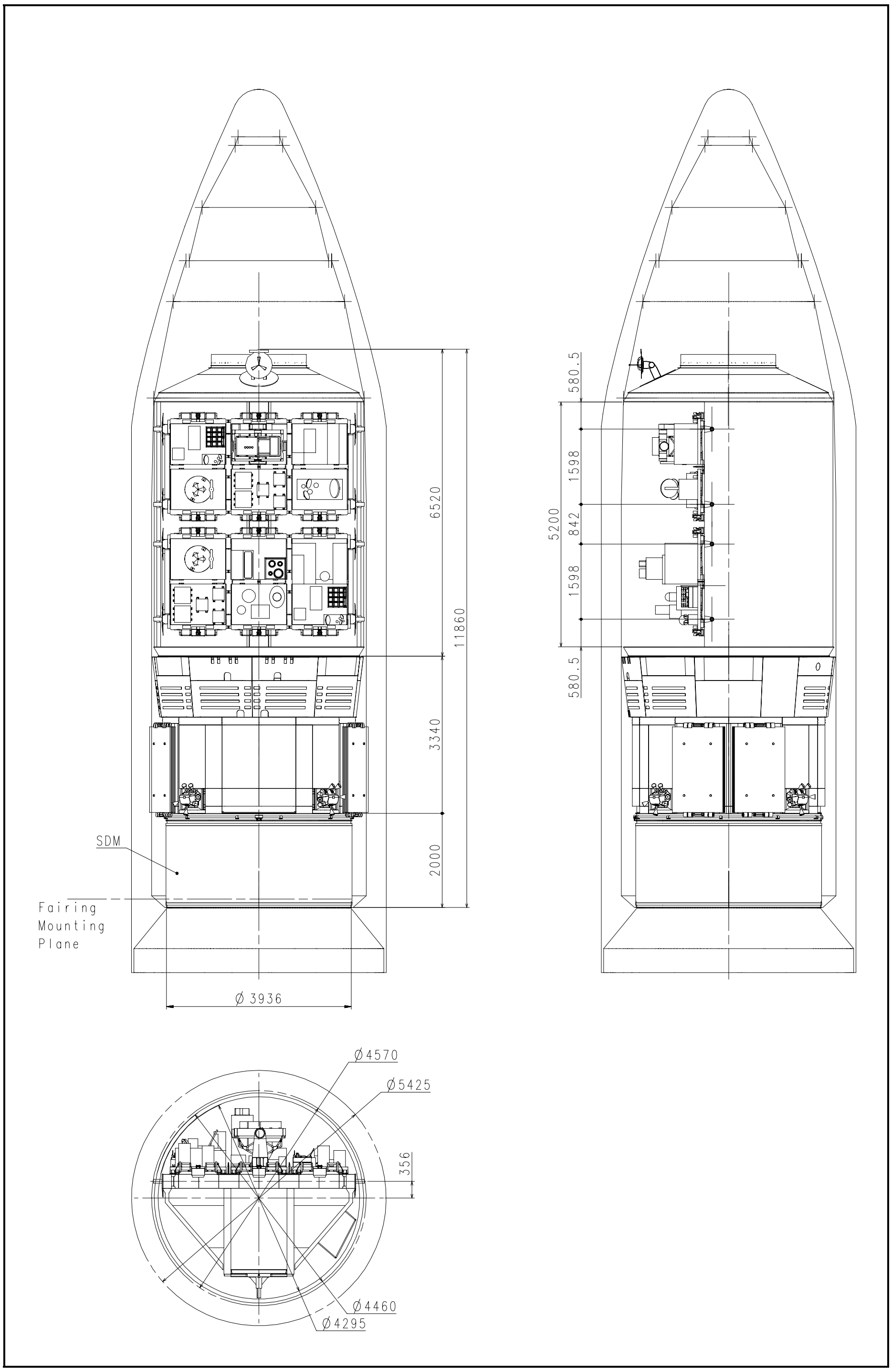


Figure 5.2-1: ATV ULC cargo compartment design (Layout Version 1)

The MCAS mechanism has been installed close to the keel in the lower part of the Express Pallet.
Every Express Pallet considered in this study is able to accommodate six FRAM, but one of the envisaged locations is blocked by the installation of the Grapple Fixture, that cannot be located on the side because of SSRMS accessibility.

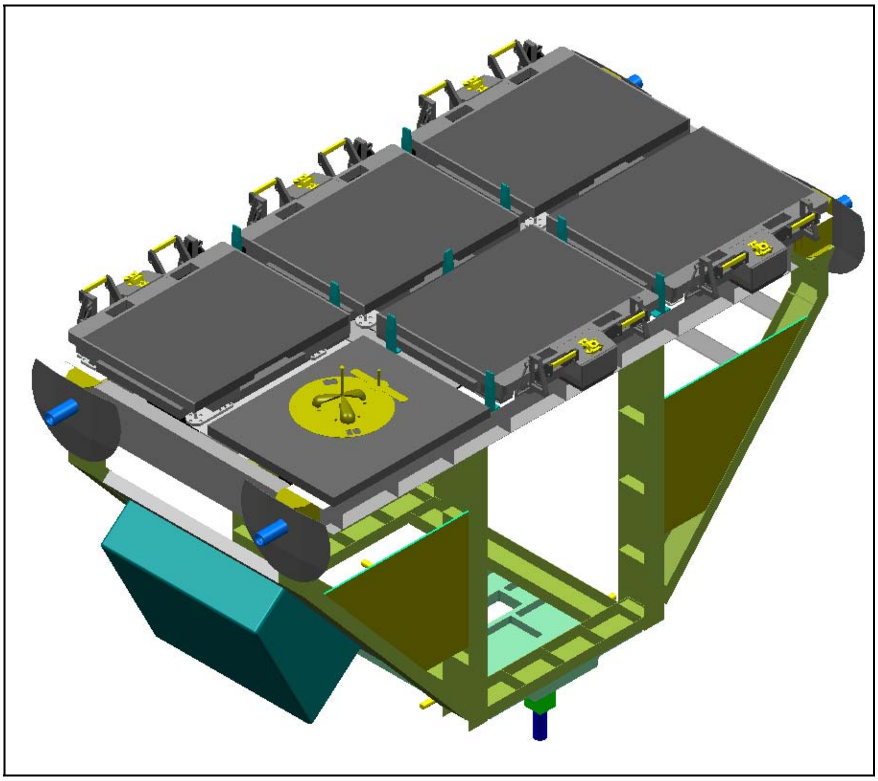


Figure 5.2-2: Express pallet with FRAM adapters (ExPA)

Non Standard P/L Accommodation Assessment
Beside the above mentioned standard payloads, which are limited in mass and volume, also non-standard payloads of higher mass and volume have to be transported to the ISS within the CCB. AMS, complete ExPS systems and EUSO are typical examples of a non-standard P/L. EUSO as large telescope for example can be accommodated by the present configuration as shown in the following figure. The EUSO instrument can be integrated in a frame work which is compatible with the dimensions of the fixation points (trunnions) of the cargo carriers (Express / ICC) mated within the CCB.

Accommodation of non standard P/Ls of this size is feasible provided that acceptable clearances are ensured for P/L extraction. The attachment with the ISS can be realized via standard ISS interfaces like the existing trunnions, FRAM or MCAS.

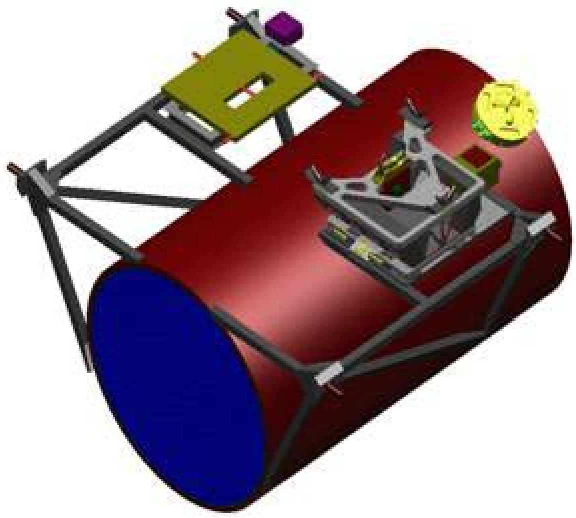


Figure 5.2-3: Non-Standard Payload (EUSO) including trunnions to be fitted in CCB

ULC P/L Accommodation Requirements

Volume: The volume should be sufficient to carry or 1 Non-standard P/L EUSO like or 2 standard P/L carriers as Express Pallet or ICC

Mass: Theoretical mass of the two carriers + P/L in the order of 5.3 tons (up to 8 tons can be accommodated)
EUSO mass is well below the above figures and is not deemed design driving

Thermal Control: Passive thermal control only. No need for active thermal control detected because of active P/L (P/L is activated only after installation on the ISS)

Data: No data link is deemed necessary with the ULC (check-up can be performed via PDGF)

Power: P/L can receive Power from the ULC (a dedicated connector with pyro cutters is sufficient) and from the ISS grapple fixture before to be installed on the ISS truss structure or the Columbus EPF

ULC P/L Bay Assessment Conclusions

The identified ULC solution can accommodate the required P/L amount, providing all foreseen resources to ensure P/L survival during transfer to the ISS.

The ULC P/L bay concept investigated can accommodate up to 8 tons of P/L and cargo inside of the structure, with a net bay mass in the order of 2.5 tons. This means the overall P/L bay mass (including P/L) is in the order of 10.5 tons.

The doors opening solution proposed by EADS ST ensures the required stack stiffness during launch and, once doors are pyro separated and ejected during ascent, ensures the required clearances for P/L operation. Alternative solutions including doors opening mechanisms can be justified if doors closing is required during the mission (not required today based on P/L operational requirements). Doors opening mechanisms can be implemented only at the price of higher development and recurring costs, reduced stiffness on the launch pad (higher P/L bay mass required to compensate loss of structure performance), higher system complexity and reduced system reliability. Doors separation is required before begin ULC insertion towards ISS after separation from the burnt-out of Ariane 5 upper stage in an orbital height of 200 km ***x*** 300 km. Whether a 1-door concept or a 2-doors concept, this is not important during this stage of project phase. Both solutions fulfil the requirements. The following figure shows a 2-doors solution.

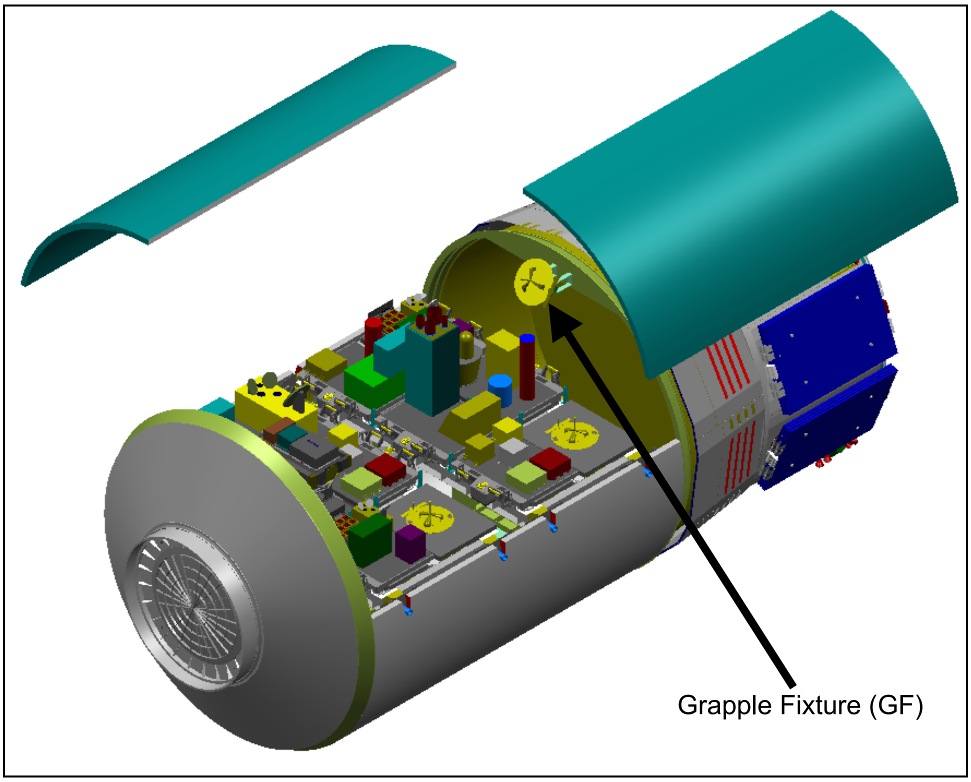


Figure 5.2-4: ATV-E ULC 2-doors principle design (Layout Version 1)

A grapple fixture is also to be installed on the ULC to allow the use of the ISS robotic arm for the berthing to the Station and for relocation of the ULC to another docking port.

Figure 5.2-5 represents an isometric view of the ULC with two Express Pallets installed in it.

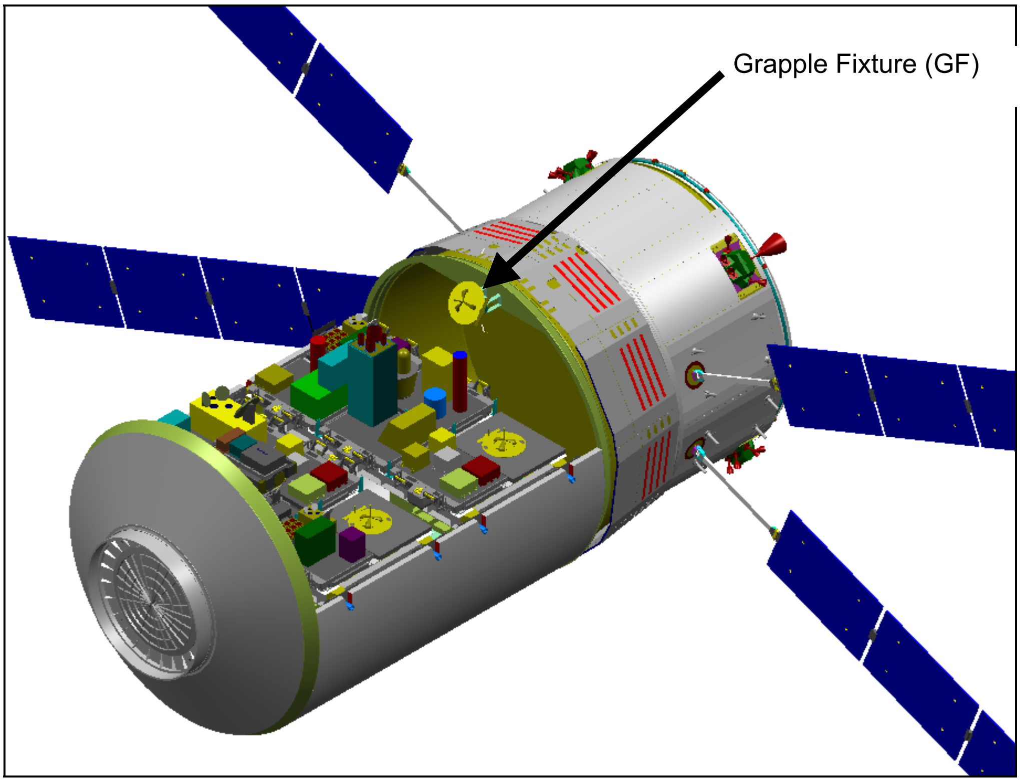


Figure 5.2-5: ULC flight configuration, doors jettisoned (Layout Version 1)

Assessment of Flight Sensors on Cargo Compartment Bay
This development consists of:

TASK 1: Designing the general architecture and layout of the Un-pressurized Cargo Compartment Bay sensors and accommodation of the following ATV equipment within the un-pressurized Cargo Compartment Bay:

- 2 Star Tracker units, (as per ATV design)
- 4 Front Attitude Control Thrusters
- 1 CMU (CMU2, formerly accommodated in the ATV cargo Carrier ICC)
- 2 Videometer units, 2 telegoniometer unit (as per ATV design) necessary to relative navigation at docking
- 2 Visual Video Target units (developed for ATV and used by the crew for ATV alignment verification in the final rendezvous) can also be implemented if a Video Camera is implemented to monitor it.
- The electronics boxes for drive of the IBDM / CBM (to be assessed)
- The interfaces on one side with the Equipped Avionics Bay. The EAB interface should be as per ATV design, with some modified avionics interfaces.
- On the other side, the unpressurised Cargo Compartment Bay interfaces with the ISS via IBDM / CBM.

Also the following effects should be analyzed:

Plume effects: the effects of the relocated FACS on the critical surfaces of the vehicle shall be assessed (e.g. the ATV experience indicates that this analysis should indicate a constraint on the Front ACS orientation, so as to not violate the heat flux tolerated by the ATV solar generator)

EMC/ESD environment: Optical environment: verification of the new STR and VDM/TGM environment, taking into consideration the solar generator wings, the antenna deployable boom

5.3 Mass Budget

The following mass budget has been issued considering the above mentioned modifications. The mass data are extracted from the current ATV mass budget ATV-AS-TN-1007-01.

Suppressed Mass
The mass suppressed compared to current ATV hardware is:

Integrated Cargo Carrier	- 5447.4 Kg
RECS batteries	- 37.7 Kg
RSPCU	- 6.0 Kg
Propellant Tanks (4)	-302,4 Kg

Table 5.3-1: ATV ULC Suppressed Mass

Added Mass
The mass added compared to current ATV hardware is:

CCB: Cylindrical Structure & Doors	+1749 Kg
IBDM	+600 Kg
Grapple Fixture (3)	+39 Kg
Latches (2 sets)	+ 520 Kg
ICC (G+L)	+1600 Kg
TVS (heaters, MLI)	+200 Kg
MDPS on rear side	+ 60 Kg

Table 5.3-2: ATV ULC Added Mass

System Mass Budget
The final system mass budget is the following one:

ATV Spacecraft for ULC	5 118 Kg
CCB	4 708 Kg
Propellants	2 981 Kg
Total w/o system margin without payload	12 807 Kg
Spacecraft – 5% system margin	491 Kg
Total with system margin without payload	13 298 Kg
ATV-ULC Launch Mass	20 500 Kg
Up load cargo Mass (max.) (payload)	**7 202 Kg**

The up payload mass capacity is calculated using the 20.5 tons Ariane 5ES maximum launch capacity.

Table 5.3-3: ATV ULC System Mass Budget

Note:

4. At this step of the project, it is recommended to use a 5% system margin on the spacecraft, w/o propellants, which include separately margins

5. The maximum lift-off mass of the launcher is assumed by 20.5 tons

6. Mission and Operations

The mission phases for all 3 vehicles are nearly the same with the exception that the ULC will not land on earth but will burn-off in the atmosphere. In the following is presented therefore only the PTV.

The main PTV mission phases are defined as follows:

Phase	Start	End
Pre-launch	When the PTV is totally integrated (RPM, CRM, late cargo), on the launch pad, being activated by EGSE.	PTV switch to internal power provision
Launch and Early Orbit Phase (LEOP)	PTV switch to internal power provision	When the full on-orbit PTV setting has been completed, SGS stiffening done and PTV is ready to execute transfer maneuver to reach the phasing orbit (adequate OMP is loaded)
Phasing with ISS	End of LEOP	When the last trim maneuver ends and the PTV drift towards S0 way point
Rendez-vous with ISS	When the PTV has arrived is at S-1/2 (cfr ATV rendez-vous phase definition)	In case of docking: with the first physical contact of PTV IBDM forward ring. In case of berthing: when the PTV has arrived in the 'berthing box' and ready to be grappled by the

		ISS Robotic Arm
Docking	End of Rendez-vous	when the crew reports “end of PTV docking operations” after having opened the hatches and installed the safety devices and when PTV-CC declares PTV is in a stable configuration
Berthing	*End of Rendez-vous*	*when the crew reports “end of PTV berthing operations” after having disposed the SSRMS opened the hatches and installed the safety devices and when PTV-CC declares PTV is in a stable configuration*
Attached Payload/Cargo Operations	End of Docking/*Berthing*	when all download cargo has been entered into the CRM, and the PTV is ready, and the crew is ready to close the hatch.
Undocking	End of Attached Payload/Cargo Operations	when PTV is no more in physical contact with ISS
Departure	End of undocking	when the PTV leaves the Approach Ellipsoid of the ISS, and PTV-CC has verified that the proximity link is switched off, the functional monitoring disabled, the CAM disarmed and the MSU switched off
De-orbitation	End of departure – includes ‘loitering’	After the second of 2 retro-burns, upon RPM-CRM separation
RPM – CRM Separation	End of de-orbitation	Short duration operation, few seconds.
Atmospheric Re-entry RPM	TBD time after RPM – CRM Separation, at 120 km altitude	Destruction of the RPM
Atmospheric Re-entry CRM	TBD Time after RPM – CRM Separation – at 120 km altitude	Includes: IBDM ejection; Drogue chute opening and ends when main chute is extracted
Descent & Landing	Main chute deployed	At touch-down
On-Ground Recovery	At Touch-down	After transport to intermediate storage location. Express P/L delivery to final destination.

Table 6-1: Main PTV Mission Phase Definitions

7. Programmatics

7.1 System Planning

The following aspects have to be considered for the programmatical planning:

- Model philosophy and qualification is primarily based on protoflight approach on equipment, subsystem and system level supported by test models (STM, ETM) and simulators (SITE, FES, FSF)
- Apply to the extent possible commonality with standard ATV system core components and functional units
- safety critical functions shall be verified by test and demonstration
- Flight Configuration level tests shall qualify system functional performance, compatibility of the subsystems, and functional /dimensional interfaces

- deliverable operational software and operational procedures shall be subjected to formal validation/qualification

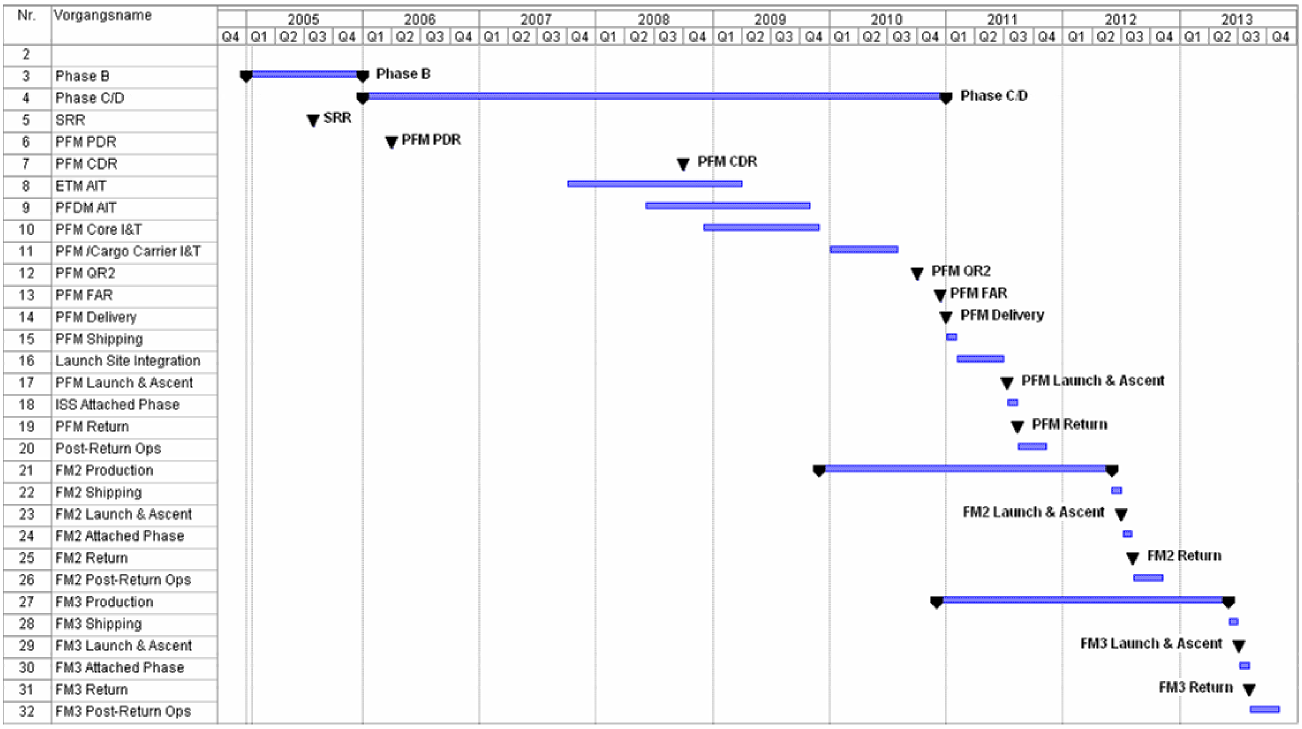


Table 7.1-1: Programme Schedule for PTV and ULC

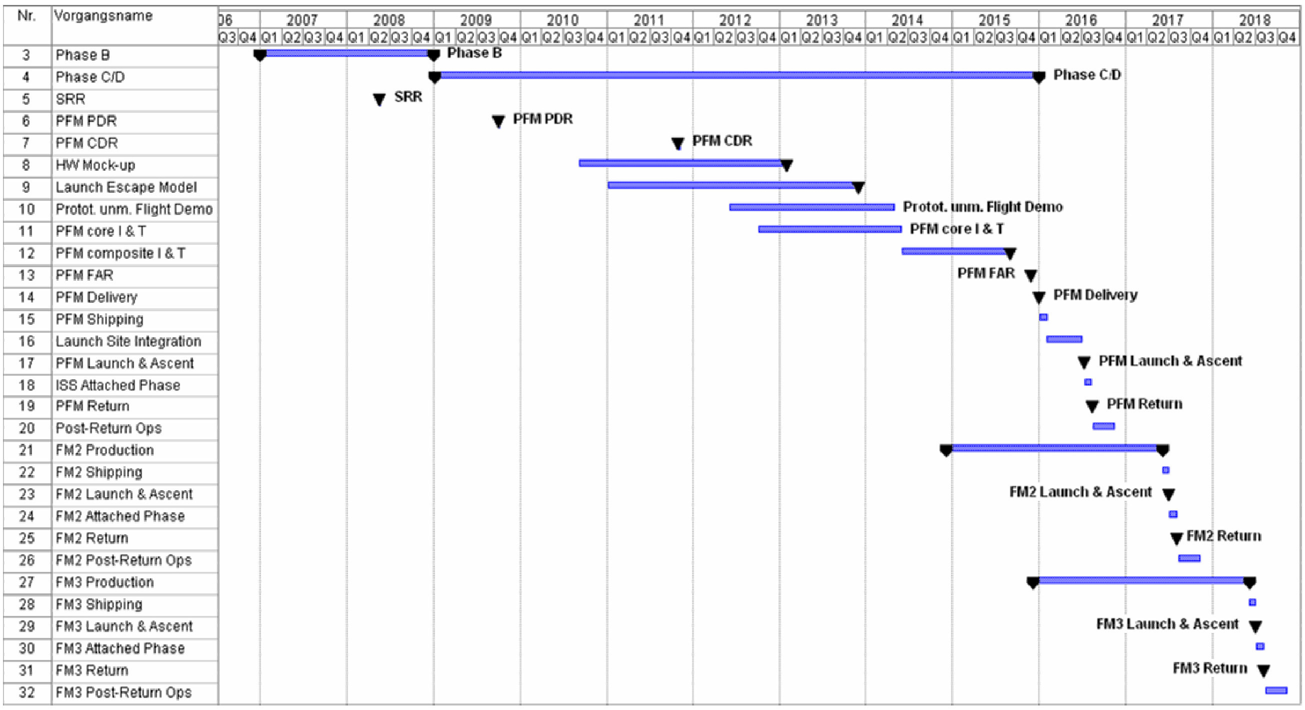


Table 7.1-2: Programme Schedule for CTV

7.2 Cost Estimation

The approach for the cost estimation is the following:

- Build-up of Parametric Models for ATV, PTV and CTV
  - Stable **recurring** costs derived from existing ATV data
  - LCCM algorithms and key-values used to estimate **non-recurring** costs (on basis of the recurring costs)
  - LCCM algorithms used to convert Program Requirements and Industrial Culture from **unmanned** to **man-tended** and **manned spacecrafts**
- Technical baseline of the concepts as documented in **ATV-E-ENG-21/22**, Issue 0 dated 10.01.05
- Further configuration details from ATV Mass Properties, PTA Issue, Doc. **ATV-AS-TN-1007-01**, Issue 12A dated 07.02.03
- Also the ATV-E Obsolescence and Production Capability Report is recognized, Doc. **ATV-E-RIBRE-RP-0010**
- Subcontractors and Engineering Teams provided independent cost estimates and support:
  - Contraves — Structures
  - Alenia — Thermal Subsystems
  - SAS — Operations Activities and Cost
    (a very good cost assessment: ATVE-SA-WP5000-TN-001, Issue1 dated 08.12.2004)
  - Verhaert — IBDM
  - EADS ST — Propulsion
  - EADS ST — Avionics

Vehicle	Necessary Modifications	Schedule for FRR	Cost for ATV S/C Modificat.
PTV	**Modified GNC; IBDM ACS thruster relocation; Conical adapter & sep. mech.**	**2010**	**191 M€**
CTV	**Modified GNC; IBDM ACS & braking thruster relocation ;8kN thruster safeguard means Conical adapter & sep. mech New structure/therm/ avion.**	**2015**	**413 M€**
ULC	**Modified GNC; IBDM**	**2010**	**182 M€**

Table 7.2-1: Modification and Cost Overview