Crew Tranfer Vehicle
Pégase

Pilot's Operating Handbook

Well & NoMatter

CONTENTS

1.1 How to use this handbook?

This handbook was carried out especially with the aim of being printed, You will find all the needed informations for an optimal flight with the CTV.

1.2 General description.

The CTV is a manned vessel operated by ESA, which offers to Europe manned flights. The spacecraft is derived from Atmospheric re-entry systems studies (Huygens shields, ARD) and space transport technology (Ariane launcher family, ATV, Hermes and Phoenix, demonstrator of Hopper).

Conceived within the framework of Aurora program, this vessel uses an architecture called in line. In other words, the vessel is a space capsule placed at the top of the launcher Ariane5. Diameter is approximately 4.5m. The CTV is designed to be reused 10 times and can carry from four to six astronauts.

Advantages of capsules are well-known: cost of flight is lower, served infrastructures are more accessible, safety of the crew...
The capsules are not purely ballistic missiles but have a certain lift, they can be launched in all circumstances, they are robust and easy to build.

The CTV is divided in 3 main parts:

- a service module (SSA):
  cylindrical structure used for propulsion feeding the module of order in electricity and other gases. This module is an improved version of the ATV's one.
- a command module (Pegase): conical section allowing transport of crew and freight. This capsule, able to transport up to 6 people, also offers a vast space adapted to the realization of experiments of microgravity and life sciences.
- heat shield: conceived by EADS space in collaboration with the CNES. The shield must handle atmospheric re-entries at 27.000 km/h from ISS and 40.000 km/h from Moon what is equivalent to a heat 5 times higher than when returning from low orbit.

EADS space acquired this technology within the framework of the X-38 development, a demonstrator which was to precede the CRV (Crew Return Vehicle), an ISS emergency vehicle (project given up in 2001 by NASA), the ESA was implied in the design of X-38's the nose.

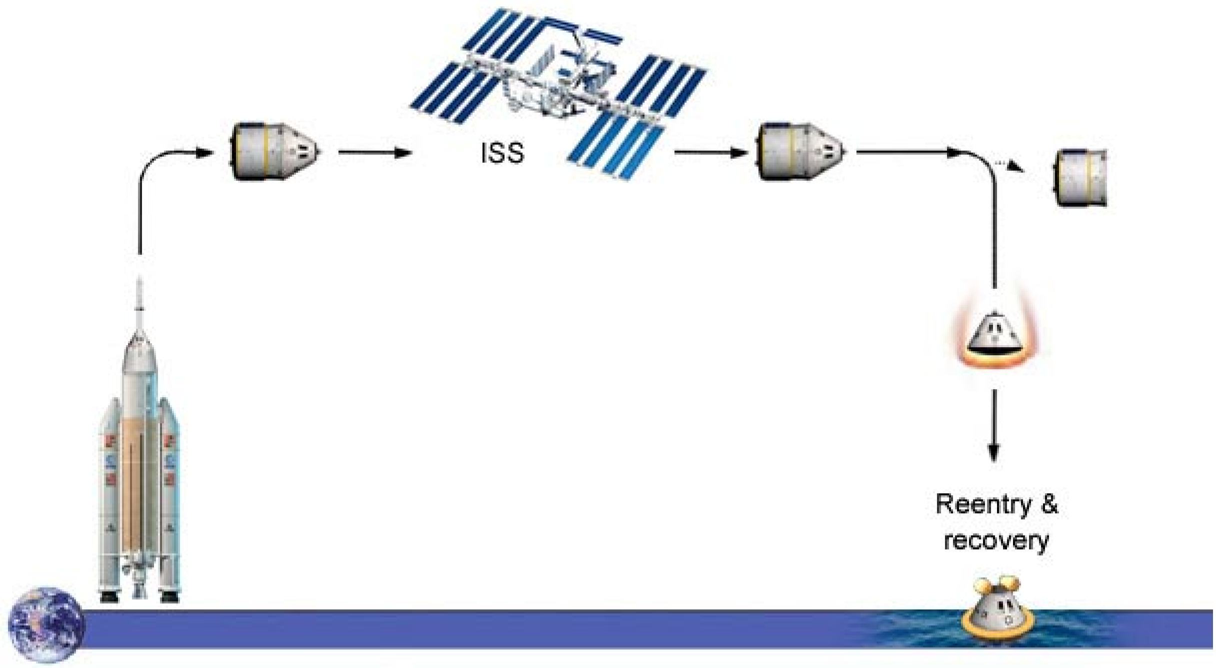
1.3 Design features

Implied Countries	Members of the ESA
Exploiting	ESA
Manufacturer	EADS Space Transportation - CNES
Dimensions	length 8.3 m, diameter 4.7 m, envergure 22.28 m
Power	4 solar panels (Dutch Space) provide 4.5 kw which supply 8 batteries with power.
Mass (launch)	15250 kg, capacity of carrying a payload (up to 4500kg) , 3.2t of dry loads (food, scientific eqipments), 100 kg of water, 840 kg of gas (air, N2, O2).
Orbit	120 km to 800 km, 51.6°
Launcher, Pad	ARIANE 5 ES, Kourou CSG ELA 3.
Mission	Transport of crew towards the ISS and all other infrastructures in orbit. Fuelling, experiments, food, air and water, raising of orbit of station, return of freight and experiments (4.5 T). Missions in low orbit, repair of satellites, experiments of microgravity or life science, Extension of the possibilities of missions and increase in material with the modules Viking. Missions in lunar Orbit with CTV-Lunar.
Crew	CTV-LEO4: 4, CTV-LEO6 :6, CTV-Lunar:4.
SSA service module	4 x R 4D-12 of Aerojet (4x12,5 kN), R-5L-10 (Aerojet) on CTV Lunar (4x20 kN) and 28 attitude thrusters (350 N) Snecma Moteurs, EADS Astrium avionics .
Propellant	7t
Pressurized space	length 3.3 m, diameter 4,5 m, livable volume 22 m ³ (including 10 m ³ for freight).
Splashdown Zone	134° W / 3.90° N.

1.4 Type of missions

The CTV can serve on Low earth orbit, especially towards the ISS as well as on lunar transfer and finally toward Mars .The CTV can carry out missions in high Earth Orbit to carry out repairs of satellites and complex scientific expeditions with the Viking module.

- Crew transport towards the ISS:



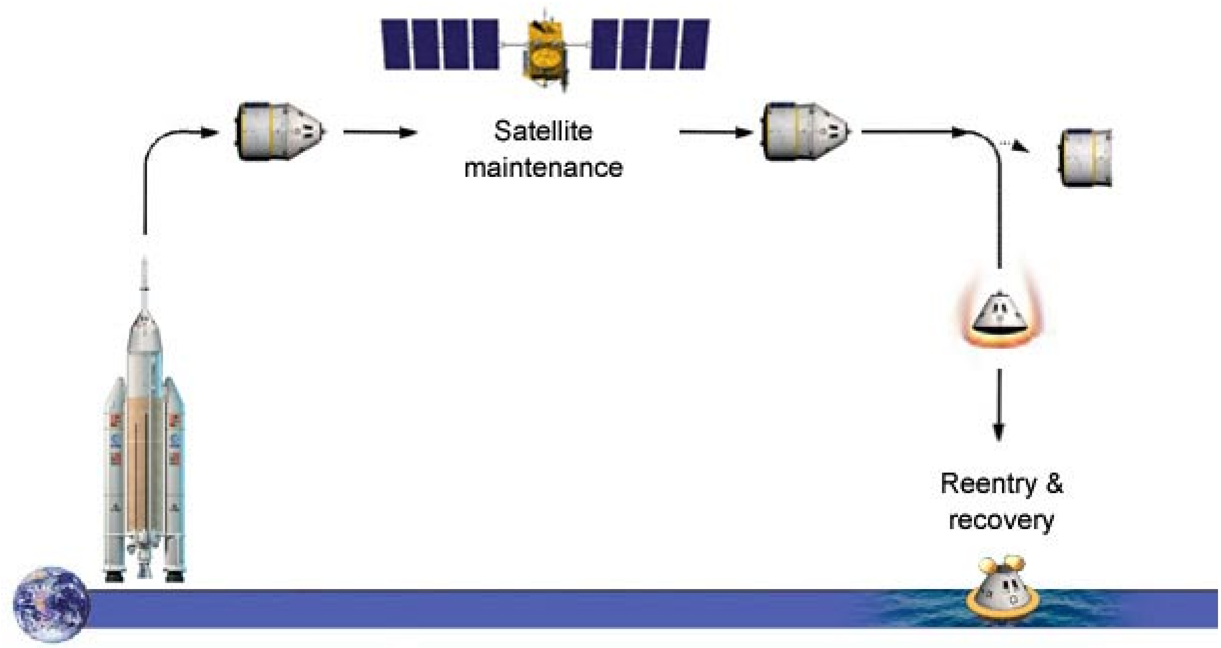
The Diagram above illustrates the mission.

The primary goal of this mission is to transport a crew of 4 to 6 astronauts towards the ISS. The CTV can be docked to the ISS for 6 months, with the possibility of returning to Earth at any time during the mission.

The required elements of architecture are: The CTV and its launcher ARIANE 5. The CTV, composed of a Crew Module (capsule) and a Service Module(SSA), is launched by ARIANE 5 to approx. 296 km with 51.6-deg of inclination.

Once docked to ISS, the CTV is configured in waking state and can serve as an emergency vehicle. Systems are periodically checked and tested. At the end of the mission, the crew can return freight to the Earth aboard the CTV.

- Repair of satellites and stations reboosts:



The Diagram above illustrates the mission.

The CTV is able to rendez-vous with a satellite for maintenance and can perform station reboosts.

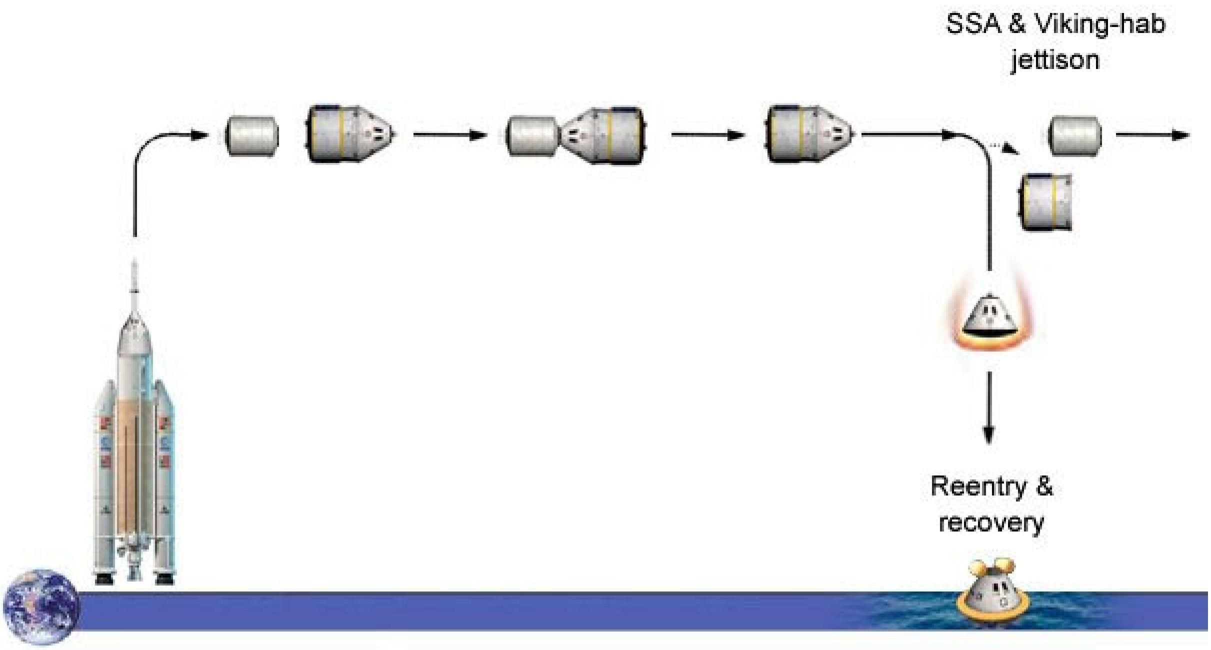
The elements of architecture required for the mission are: The CTV and its launcher. The CTV (SSA and capsule), is launched by an ARIANE 5 on an optimal orbit for capturing the target.

Crew: from 4 to 6 astronauts

Payloads: required tools and equipment to repair a satellite.

The CTV can remain 14 days in orbit, crew will do all the needed EVA to repair a satellite.

- Low earth orbit mission with Viking-hab module:



The Diagram above illustrates the mission.

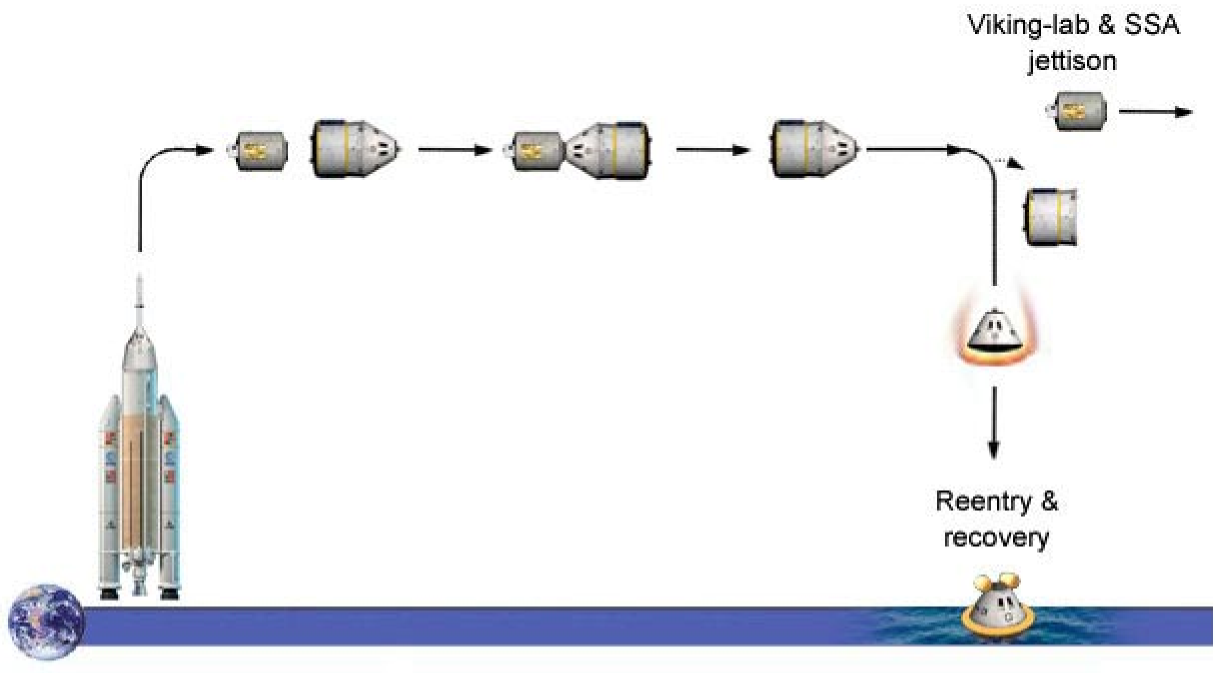
The CTV is also used for scientific expeditions. Viking-hab is designed to expand the workspace of the crew.

The elements of architecture necessary to the mission are: The CTV and its launcher ARIANE 5 with Systa stage and Viking-hab. The CTV and Viking-hab are launched by an ARIANE 5 on an optimal orbit for the mission and a crew from 4 to 6 astronauts.

In orbit, after EPC jettison, the CTV performs a 180° turn to dock with Viking-hab. After system controls, the hatch is opened and the crew starts the mission.

The CTV can remain 14 days in orbit, the crew will carry out the scientific experiments. At the end of the mission, Viking modules can remain in orbit.

- Low earth orbit mission with Viking-lab module:



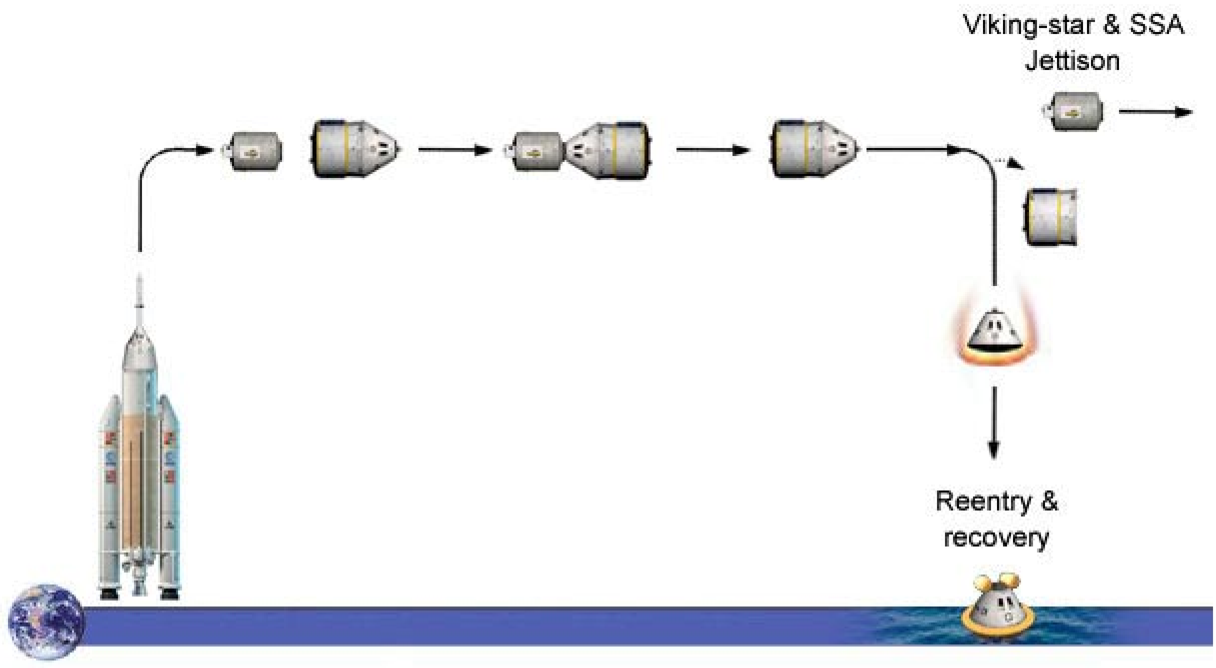
Viking-lab increases the workspace and contains several scientific instruments to do research about science life, microgravity, botany, biology and chemistry.

The elements of architecture necessary to the mission are: The CTV and its launcher ARIANE 5 with Systa stage and Viking-lab. The CTV and Viking-lab are launched by an ARIANE 5 on an optimal orbit for the mission and a crew from 4 to 6 astronauts.

In orbit, after separation of the launcher, the CTV performs a 180° turn to dock with Viking-lab. After system controls, the hatch is opened and the crew starts the mission.

The CTV can remain 14 days in orbit, the crew will carry out the scientific experiments. At the end of the mission, Viking modules can remain in orbit.

- Low earth orbit mission with Viking-star module:



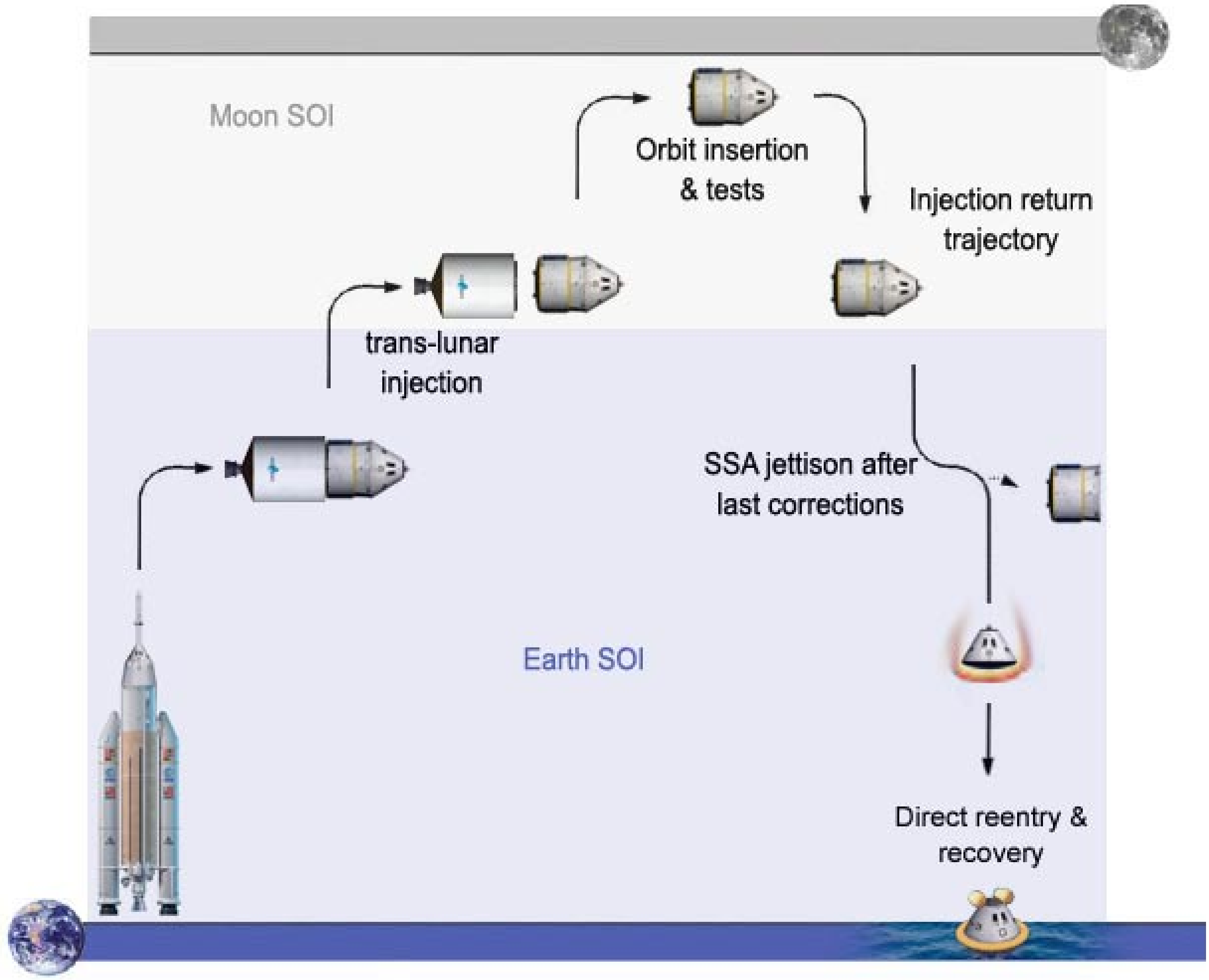
Viking-star increases the workspace and contains scientific instruments to perform astronomy and astrphysics research.

The elements of architecture necessary to the mission are: The CTV and its launcher ARIANE 5 with Systa stage and Viking-star. The CTV and Viking-star are launched by an ARIANE 5 on an optimal orbit for the mission and a crew from 4 to 6 astronauts.

In orbit, after separation of the launcher, the CTV performs a 180° turn to dock with Viking-star. After system controls, the hatch is opened and the crew starts the mission.

The CTV can remain 14 days in orbit, the crew will carry out the scientific experiments. At the end of the mission, Viking modules remain in orbit.

- Circumlunar validation:



The Diagram above illustrates the mission.

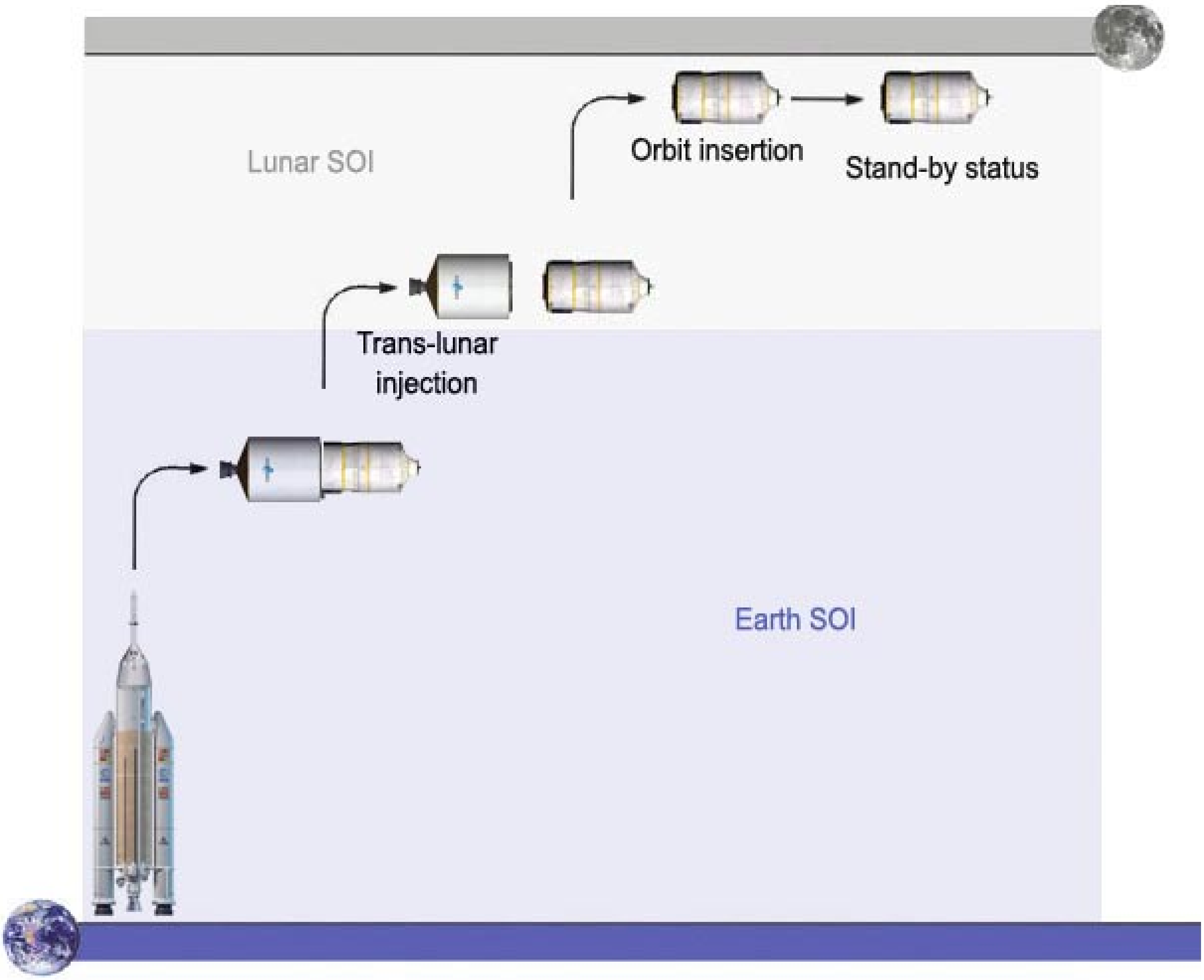
The elements of architecture necessary to the mission are: The CTV and its launcher ARIANE 5 with TLI stage. The CTV is launched by an ARIANE 5. The crew is composed of 4 members.

This mission was conceived to guarantee the viability of the CTV for phases such as the trans-lunar injection (TLI stage operation), communication with the Earth and to validate computer guidance. The mission will not exceed 12 days, travel included.

- Lunar orbit mission:

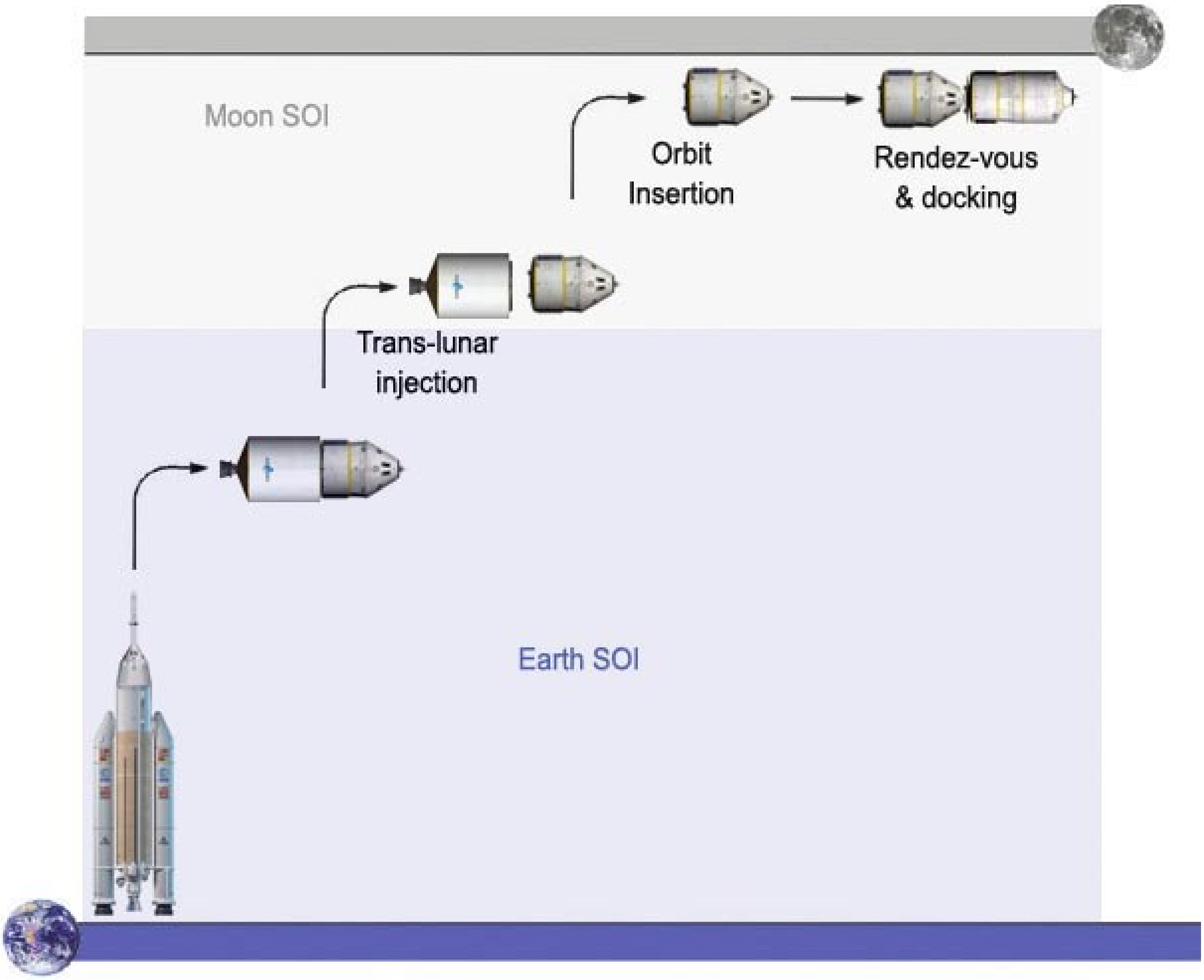
This mission requires an ATV2 in lunar orbit and thus occurs in 3 phases:

1 - Launching ATV2 in lunar orbit:



The ATV2 is launched unmanned and unpressurized. Pressurization and requested parameters for hosting CTV can be initiated from the CTV or at CSG. ATV2 carries reserves of additional food and oxygen as well as a vaster space for a long mission in lunar orbit. The role of such a vessel in lunar orbit can be multiple. First of all it will be used as a place where the CTV will find its alunissor when this one will be built ;). In the optics of a Lunar colonization it can also be used as relay with the lunar ground and the Earth according to the orbital situation.

2 - Launching CTV in lunar orbit and perform docking with ATV2:

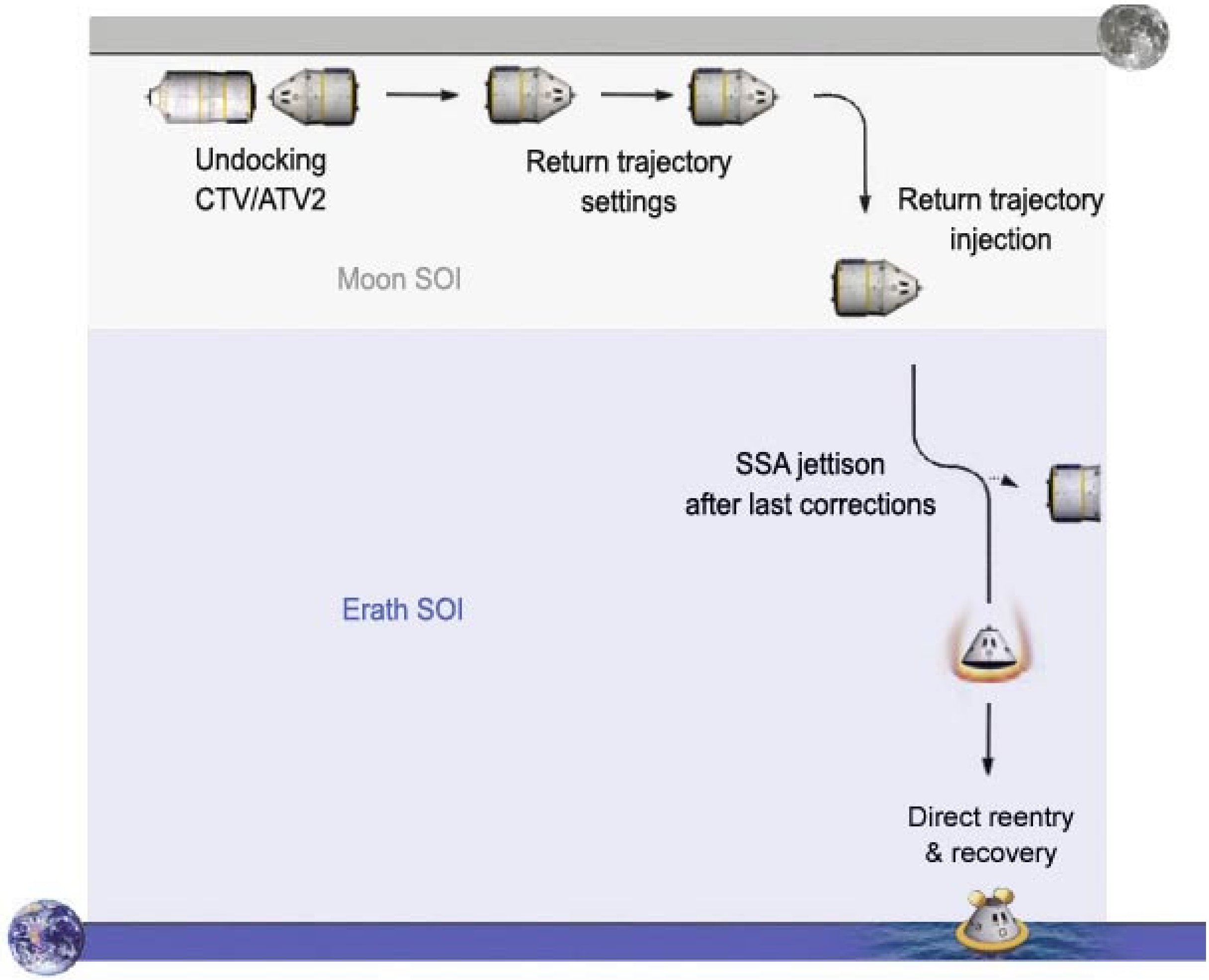


The Diagram above illustrates the mission.

The elements of architecture necessary to the mission are: The CTV and ARIANE 5 with TLI stage. The crew is composed of 4 members. Once in orbit, the crew set TLI stage for trans-lunar injection. Insertion in lunar orbit occurs at an altitude lowered from 30km but according to same orbital parameters as the ATV2 in order to rendez-vous and dock. The mission can last up to 2 weeks in lunar orbit. Up to 24 days in space.

***** The CTV-MFD is not designed for this kind of mission Do not use the MFD for missions exceeding 14 Days. *****

3 - Return to the Earth:



After undocking, the return happens in the same way for each lunar mission:

- Calculation of the trajectory in agreement with the CSG.

- Return trajectory injection.

- Re-entry angle checking and correction if necessary.

- Direct re-entry after SSA jettison

- Splashdow & security checklist execution.

Further operations accomplished by recovery team .

2. Procedures of flight

2.1 Controls and activation.

After EPC jettison, use CTRL+F7 to display engine status (otherwise you won’t have any fuel and engine will not be able to work).
Check that you are on a circular Orbit. If needed, do a correction.

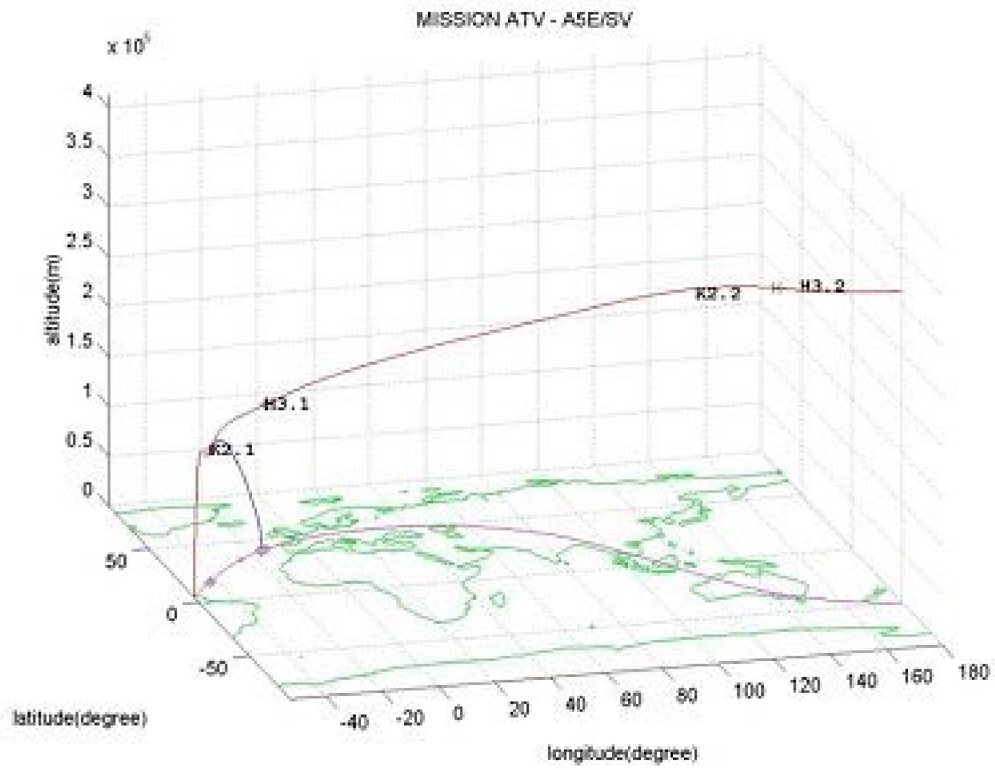
Once in suitable Orbit, check the basic controls of the vessel. When done deploy the solar panels with the key K. To adjust the orientation of the panels hit key G for a maximum exposure to the solar rays.

Use key 0 (not numpad) to unstow all the antennas and key 9 to activate beacon, nav and strobe lights.

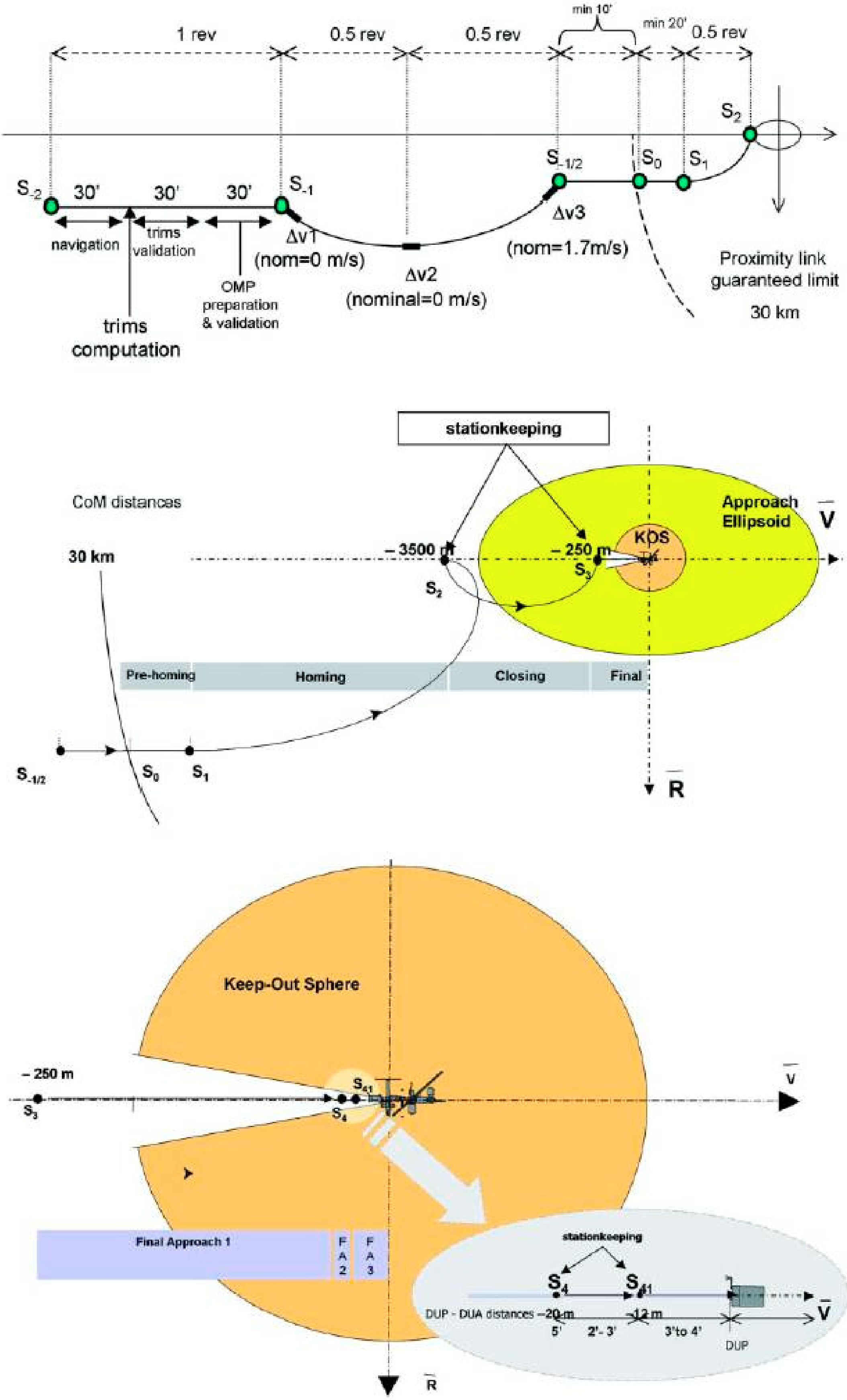
Check the HUD in generic cockpit, to verify the parameters of your vessel.

2.2 Approach & docking

Three and a half minutes after takeoff, emergency tower and CTV's fairing are jettisonned. 5 min 30 S after takeoff, the main stage (EPC) stops and jettisons the CTV and second stage (EPS). This stage puts the CTV on a circular orbit, 260 km alt, using the re-ignitable Aestus engine. 4 minutes later, the CTV leaves the EPS behind. EPS with VEB complete a full orbit before being re-ignited to burn in the atmosphere over inhabited zones.



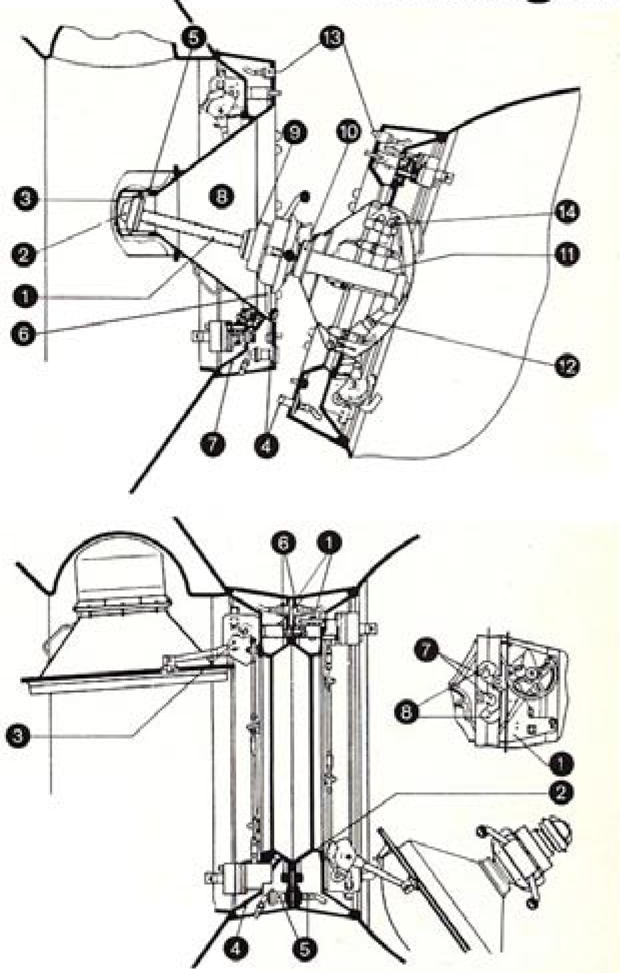
At S1 point, 20 km behind the station, the CTV begins its operation of «homing», two burns to put itself on a transfer trajectory rendez-vous with ISS within 45 minutes. At S2 point, 3500 m behind the station, the CTV is on an approach path centered on the station (4000 X 2000 m) under the control of the centers of Houston, Moscow and Toulouse. The CTV remains there during 90 minutes for the final approach. When clearance from Houston is annouced, the CTV follows the path to 250 m of the station (closing) at the S3 point. The CTV should not enter the zone of safety, a sphere around ISS 200 m in diameter. If braking cannot be done at the S3 point, the CTV turns over to the S2 point. Between the S3 point and docking, the CTV aligns by translation to the back of the Zvezda module with its frontface.



Approach path

The docking mechnism and its sensors establish a direct contact with the ISS. In addition to already established radio connection, the astronauts on board ISS can watch the docking by video. The laser measurement unit of the CTV checks the datas transmitted by the GPS. After having obtained the clearance from ISS and stations on the ground, the CTV continues its approach up to 12 m and covers the last meters to the docking at a speed of a few cm.s-1. The 15 cm diameter probe must be captured by the port of the Russian module Zevzda, 90 cm in diameter.

Docking mechanism - Viking/CTV



The docking system is a declination of the soyuz one. Several types and reincarnations of this docking hardware were tested between 1967 and 1975, before a long-lived design of the «drog-andcone system» has emerged.

Such mechanism involves a rod the spacecraft, which serves as an active spacecraft during the rendezvous, and a receptive cone, installed onboard the space station.

During nominal docking, a radio-control system or a pilot bring two spacecraft close enough for the rod to touch receptive cone of the station. As the Soyuz continues moving toward the station, the rod slides toward the center of the cone, where it is finally reaches a latch in the center of the cone.

Electrical motors then retract the rod, pulling two spacecraft together and creating an air-tight transfer tunnel between two spacecraft.

In addition, peripheral rings surrounding the tunnel carry interfaces, which enable the transfer of electrical power, control and signaling commands and atmosphere exchange between the two spacecraft if wanted.

The docking hardware also includes Interface Leak Check System which monitors interface pressure integrity and equalizes the pressure between two spacecraft, provides a leak check of the transfer hatches, and releases pressure from the docking assembly for undocking. It is considered a subsystem of both the Life Support System and the Docking and Internal Transfer System.

As soon as the contact is made, the CTV provides a weak final push to ensure the capture of the European space vehicle by the port. The CTV is aligned with the longitudinal axis of the ISS. All electric, mechanical connections and fluids between the ISS and the spacecraft are automatically established. After shutting down all the systems and putting the CTV in «stand-by» mode, the astronauts swivel the system and open the hatch.

2.3 Un-docking

Use CTRL+D to undock.

2.4 De-orbit and re-entry

We use **BaseSyncMFD** to determine ignition time according to the desired splashdown point.

BaseSyncMFD 2.1: http://koti.mbnet.fi/jarmonik/Orbiter.html
AeroBrakeMFD: http://www.orbithangar.com/searchid.php?ID=2139

A- Désorbitation

1 - Earth orbit

Orient retrograde. Use Basesync MFD to determine time to burn (cf.reentry)

2 - Moon return

Correct your trajectory with IMFD or any other tool for navigation in order to obtain a satisfying re-entry angle.

B - Re-entry

Jettison SSA between 200km and 150 km of altitude. Check that the docking probe is stowed before any separation!

Enter in Basesync, ReA = 2, Ant = 16,5 for Alt of 80. Then, activate level before the entry in the atmosphere, then deactivate. To prevent risks of too many «g» while reentering the atmosphere, activate lift (trim).

AeroBrake does not take account of the trim in its calculation. 9,2 G approximately are announced but in practice, the lift will soften the re-entry. Gradually, G max decreases, until being around 7 or 7,3 g.

Eject reentry section fairing when reentry flammes end. The drogue chute brake has no real actiondon't pay too much attention to it, just release when you think it's OK. Only the main parachute really brakes, open it at reasonable speed, attitude ranging between 70 and 90°, altitude between 20 and 10km.

Some clue: Set the point of impact further from approximately 4,5km to the target. In general, you will obtain a landing in a ray of 1km around the target, and even better (less than 30 meters succeeded by Pagir…).

2.5 EVA

Specifications of the spacesuit:

Nominal duration of autonomous mode: 7 h

CO_2 cartridge operating time : 9 hours

Suit positive pressure: *Nominal mode: 392 hPa
*Emergency mode: 270 hPa

Available O_2 (main and back-up): 1 kg each

Available cooling water: 3.6 kg

Assured heat removal: Average: 350 W

Maximum: 600 W max

Power consumed : up to 54 W

Number of measured telemetry parameters: 29

Weight of suit: ~120 kg with (70kg astronaut)

Service life: 20 EVA/5 years (no return to the Earth)

3.1 Main and Attitude engines.

The CTV has 4 main engines and 28 attitude thrusters, the CTV can initiate maneuver such as avoidance and reboosts of station.
Flight control is carried out by software, installed on a fault-tolerant computer.

CTV main engines :

LEO4 - LEO6	:	12.5 kN
Lunar	:	25 kN

Attitude thrusters: 400N

The engines are built by EADS Astrium Space and implemented by the DASA (German space agency).

3.2 Fuel & tanks

In addition to the engines and system of control, the avionics and propulsion module contains 8 titanium tanks able to support up to 8 tons of propellants, MMH and dioxide nitrogen.
For low orbits, the CTV embarks 4 tons of fuel. For lunar missions, the whole capacity is filled.

3.3 Life Support

The environment system of Pegase has the role to maintain the conditions favorable to life with comfort. It includes a storage system of supplies , nitrogen & oxygen, a temperature control system, a water treatment and feeding system.

The system of storage of nitrogen, oxygen and supplies maintains the pressure at 101,36 kilo pascals (14,7 psi). The system allows a crew from 4 to 6 members for 14 days.

The temperature control system comprises air, water and freon circuitry. SSA radiators controls heat by thermal exchange. Radiators are exposed to the vacuum, heat is evacuated by one water evaporator and one ammoniac evaporator. CO_2 level is lowered by a lithium hydroxide cartridge.

Water vapour level is also controlled. Extra water is condensed by the same system that maintain a comfortable temperature by transferring heat in the water circuitry.

It is used for the cooling of the electronics components too.

Supplies and water treatment system comprises tanks of storage which receives the water produced at a rate of 25 kilograms per day. This water is used for drinking and to feed the toilet circuit which is also fed by the condensation of water in excess in the capsule.

3.4 Electric systems

The power is supplied is by four extendable solar panels (6,7 m x 1,1 m each) which are orientable around their axis in order to follow the sun. The CTV is autonomous when docked to ISS, thus minimizing the recourse to the station power.

3.5 Scientific payloads

Fluid Science Laboratory

Fluid physics research facility

The Fluid Science Laboratory is a multi user facility to study the dynamics of fluids in the absence of gravitational forces. This allows investigation on fluid dynamic effects, phenomena that are normally masked by gravity driven convection, sedimentation, stratification and fluid static pressure. These effects include e.g.diffusion-controlled heat and mass transfer in crystallization processes, interfacial mass exchange, simulation of geophysical fluid flows, emulsion stability and many more.

Operational concept

An individually-developed Experiment Container will be used for each experiment or experiment Category, and will be removed from on-board storage and inserted into the Central Experiment Modules drawer by a crew-member. The Experiment Container will then be cycled through an experiment and diagnostics calibration processing prior to initiation of the actual experiment itself.

Each Experiment Container has a typical mass of ~25 kg, with a maximum allowable mass of 40 kg, and standard dimensions of 400 x 270 x 280 mm. The fluid cell assembly (including the process stimuli and control electronics) are accommodated within this volume. An Experiment Container may also be equipped with dedicated experiment diagnostics to complement the standard diagnostics provided by the Fluid Science Laboratory itself.

The control concept allows alternative modes of operation consisting of fully automatic, semi-automatic and fully interactive experiment processing (step-by-step command keying by a member of the crew). All these modes may be initiated either by the flight crew or from the ground (quasi-real-time telescience).

European Physiology Modules (EPM)

Research facility for human physiology experiments

An International Standard Payload Rack, equipped with Science Modules to investigate the effects of long-duration spaceflight on the human body. The experiment results will also contribute to an increased understanding of terrestrial problems such as the ageing process, osteoporosis, balance disorders, and muscle wastage.

Operational Concept

To correctly evaluate the on-board data, it is essential that reference (or base-line) data are collected prior to flight and following the return of the crew (the experiment subjects) to Earth. For this reason, the EPM facility will provide Baseline Data Collection Models that are functional copies of the on-board instruments.

The Baseline Data Collection Models will be readily transportable to ensure availability of the equipment for the crew pre-launch and post-flight activities.

BIOLAB: Biological Experiment laboratory

Operations and utilisation

The Biolab facility is the laboratory designed to support biological experiments on micro-organisms, cells, tissue cultures, small plants and small invertebrates. The major objective of performing Life Sciences experiments in space is to identify the role that microgravity plays at all levels of an organism, from the effects on a single cell up to a complex organism including humans.

Operationnal concept

The biological samples, together with their ancillary items are transported from the ground to Biolab either within the Experiment Containers or in small vials. The latter case will apply if the samples require storage prior to use, in the Minus Eighty Laboratory Freezer for ISS (MELFI). On-orbit, the Experiment Containers are manually inserted into Biolab for processing, whereas the frozen sample will first be thawed-out in the Experiment Preparation Unit (EPU) installed inside the BioGlovebox. Once this manual loading is accomplished, the automatic processing of the experiment can be initiated by the crew member. The experiments are undertaken in parallel on a 0g and a 1g centrifuge respectively, the latter providing the flight reference experiment, whilst the ground reference experiment is performed at the Facility Responsible Centre (FRC). During processing of the experiment, the facility handling mechanism will transport the samples to the facility's diagnostic instrumentation, where, through teleoperations, the scientist on the ground can actively participate in the preliminary in-situ analyses. Typical experiment durations range from 1 day to 3 months.

European Drawer Rack (EDR)

Multi-discipline flexible experiment carrier

The European Drawer Rack provides a modular capability for sub-rack payloads in International Sub-rack Interface Standard (ISIS) drawers and ISS Lockers accommodated in an International Standard Payload Rack (ISPR).

Facility description

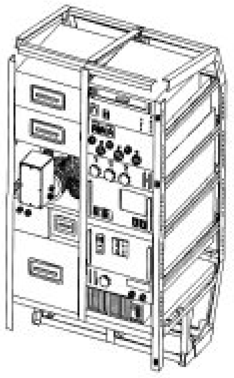
The European Drawer Rack provides a flexible experiment carrier for a large variety of scientific disciplines, and provides the accommodation and resources to experiment modules housed within standardised drawers and lockers called International Subrack Interface Standard (ISIS) drawers and ISS Lockers. This approach allows a quick turn-around capability, and provides increased flight opportunities for the user community wishing to fly payloads that do not require a complete rack. Currently, the European Drawer Rack facility can accommodate up to 3 drawers, and up to 4 lockers. The overall design of the facility is optimised for the parallel accommodation of three to four payloads, i.e. an average payload size of 2 drawers/lockers, but both larger and smaller payloads may be accommodated.

The resource management covers the monitoring of resource allocations to individual payloads, but is not intended to perform dynamic resource management and/or process control for individual experiments. It is assumed that the payloads will have their own intelligence and processing capability. Only in exceptional circumstances may a limited process control capability be provided to payloads.

ISIS Drawer

ISS locker

Material Science Laboratory Electromagnetic Levitator (MSL-EML)



The MSL-EML is the result of cooperation between ESA and DLR. MSL-EML is a multi-user facility for the melting and solidification of conductive metals, alloys, or semiconductors, in ultra-high vacuum, or in high-purity gaseous atmospheres. This is especially important for reactive materials, whose properties can be very sensitive to contamination. The heating and positioning of the sample are accomplished using electromagnetic fields generated by a coil system. Melting and solidification can both take place without containers, thanks to the 0 g environment.

The facility will contain an Experiment Unit (EU) that can accept different Experiment Inserts (EI). The Experiment Carrier will provide all necessary services to the EU.