Jules Verne
Automated Transfer Vehicle

Robert Lainé
ESA
ATV mission
ESA contribution to ISS operations

• Rendezvous, Re-supply and Re-boost the ISS
  – up to 5500 kg of equipment, food, 840 kg of water, 100 kg of combination of air / O2 / N2 for ISS crew,
  – up to 860 kg of refuelling for ISS,
  – up to 4700 kg of fuel to re-boost the ISS and steer it away from debris and meteorites.

• At the end of its mission ATV will be loaded with waste material, undocked and sent on a self-destructing return flight into the Earth’s atmosphere.

• The Control of ATV phasing, automatic approach and docking, attached phase operations and safe re-entry into earth atmosphere will be from the ATV-CC in CNES Toulouse using Artemis or TDRSS relay satellites.
ATV industrial team (1)
ATV (1)
ATV (2)
ATV at human scale
**ATV Comparison**

<table>
<thead>
<tr>
<th></th>
<th>ATV</th>
<th>Progress M1</th>
<th>Apollo CSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>10.3 m</td>
<td>7.4 m</td>
<td>11.03 m</td>
</tr>
<tr>
<td>Max Diam.</td>
<td>4.51 m</td>
<td>2.70 m</td>
<td>3.90 m</td>
</tr>
<tr>
<td>Launch Mass</td>
<td>20750 kg</td>
<td>7150 kg</td>
<td>30329 kg</td>
</tr>
<tr>
<td>Press. Volume</td>
<td>14 m³</td>
<td>6.6 m³</td>
<td>6.17 m³</td>
</tr>
<tr>
<td>Engine Thrust</td>
<td>1960 N</td>
<td>2942 N</td>
<td>97860 N</td>
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ATV Launch
Ariane 5 ES launcher for ATV

- **Injection** into a circular orbit at 260 km altitude, 51.6° inclination.

- **Fairing = standard**
  (long version; released at <1135 W/m² aerothermal flux)

- **Storable propellants upper stage EPS = adapted**
  2 re-ignitions)

- **Avionique bay VEB = adapted**
  structural reinforcement
  attitude control system with 6 N2H4 tanks

- **Cryotechnic main stage EPC = standard**
- **Solid propellant acceleration stages EAP = standard**
ATV LEOP

• Launch and Early in-Orbit Phase:
  – **Launch**: ATV on autonomous power ( ~1 hour)
  – **Early Orbit**: setting up of ATV for autonomous flight: ( ~ 1.5 hour)
    • ATC-CC communication via TDRSS/Artemis
    • propulsion priming
    • Guidance and Navigation initialization and position update by GPS
    • Attitude stabilization and update by star tracker
    • solar arrays deployment and locking
    • Proximity Link antenna deployment
ATV mission altitude profile
Demonstration Mission

**Philosophy**

- Demonstrate safety critical elements that cannot be fully tested on ground

- Demonstrate safety critical elements *before* they are relied upon during flight for safety
Rendezvous Constraints

• Russian Ground Station Visibility
• ISS attitude and array feathering limits
  – ATV/ISS: Communication
  – ATV/ISS: Common GPS satellites and visibility
  – ISS: Power
    – ISS configuration dependent
• Lighting for crew visual monitoring
• Lighting for ATV sensors
• ATV Power
## ATV Navigation

- **2x GPS receivers/antennas**
  - Absolute GPS
  - Relative GPS
- **3x 2-axis accelerometers**
- **4x 2-axis gyros**
- **KURS Range + range rate**

<table>
<thead>
<tr>
<th>DOCKING</th>
<th>PRIME</th>
<th>MONITORING</th>
<th>SENSORS</th>
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<tbody>
<tr>
<td>10 cm</td>
<td></td>
<td></td>
<td>Absolute GPS</td>
</tr>
<tr>
<td>1 m</td>
<td></td>
<td></td>
<td>Relative GPS</td>
</tr>
<tr>
<td>10 m</td>
<td></td>
<td></td>
<td>KURS (range)</td>
</tr>
<tr>
<td>100 m</td>
<td></td>
<td></td>
<td>TGM range + azimuth</td>
</tr>
<tr>
<td>1 km</td>
<td></td>
<td></td>
<td>VDM</td>
</tr>
<tr>
<td>10 km</td>
<td></td>
<td></td>
<td>VDM Relative Attitude</td>
</tr>
<tr>
<td>100 km</td>
<td></td>
<td></td>
<td>USOS Cameras</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SM Camera</td>
</tr>
</tbody>
</table>

- **2x Videometers**
  - Range (range rate) & LOS
  - Relative attitude
- **2x Telegoniometers**
  - Range (range rate) & LOS
ATV Rendezvous trajectory

Station keeping

CoM distances

- 3500 m
- 250 m

AE

KOS

30 km

Pre-homing Homing Closing FA

S_{-1/2} S_0 S_1 S_2 S_3
Rendezvous Monitoring

Crew monitoring during closing and final approach

– Independent safety level

– Dedicated video camera on aft end of Russian service module

– Dedicated hardware control panel to send discrete commands to ATV
Docking system

Same as Soyuz and Progress with new digital electronics.
Optical guidance on retro reflectors
ATV attached phase modes transition

Survival is triggered by ATV computers reset from:
- major system failures detection
- S/W exception detection
- ATV-CC command
ATV Cargo transfer

- Up to 8 racks for:
  - inert payloads
  - standard bags
  - waste cargo return

- Water transfer

- Air/O2 transfer

**Jules Verne** dry cargo:
6 racks carrying mainly crew items (food, clothes, hygiene)
Inside the integrated cargo carrier
ATV to ISS Refueling

- 2 refueling kits identical to those of PROGRESS vehicles.
  UDMH and NTO pressurized by Helium

- Russian propellant segregated from ATV propellant, transferred to Russian Segment (RS) tanks through docking ring built-in pipes
ATV to ISS propulsive support

4 x 490 N
Thrusters used for orbit control of the ISS
ATV undocking phase

• Cargo (waste) loading,

• **Pressurized module preparation**
  – ATV hatch closure
  – Removal of 16 clamps
  – ISS hatch closure, inter hatch volume depressurization + leak check
  – ATV avionics wake-up (Gyros, TDRS, GNC, MSU initialized)
  – ISS hooks opening (with ground coverage, 1 orbit before separation)
  – ATV moves ISS in LVLH (0,0,0) attitude

• **Electrical undocking**
  – ATV switch to Proximity Link and autonomous power

• **Mechanical undocking**
  – ISS put in free drift
  – ATV hooks opening → passive separation by spring pushers
  – Electrical, fluid lines disconnections
ATV de-orbit

- ATV phasing with the predefined authorized re-entry zone in the south Pacific ocean
- Navigation by GPS and ground tracking (like initial phasing)
- Attitude by Star Tracker and Gyros (like phasing)
- 15 hours after departure, 2 de-orbit boosts (90 to 150 m/s total)
- Tumbling to improve destruction in the atmosphere
ATV Control Centre

Hosted by CNES–Toulouse Space Centre
ATV Operations partners

Entities participating in ATV operations

- CNES Toulouse ATV-CC
- DLR (Germany) ATV-communications hub
- Moscow Control Centre (MCC-M)
- NASA Houston Control Centre (MCC-H)
- White Sand Ground Stations (for TDRS) in US
- Redu Ground Station (for Artemis) in Belgium
- Kourou Launch Base (French Guyana)
ATV Ground Communication Network

Ku-Band
Fwd 3Mbps (OCA)
Rtn 50Mbps

S-Band

ATV Prox Link

ESA IGS cloud

IGS Central Node and Network Services
Data, Voice & Video Services

IGS Node
Columbus ATV ESCs

IGS Node
USOCs

ESA MSM Communications Infrastructure

European Astronaut Centre

TsUP
MCC-M

Russian GS

European
Astroaut
Centre

ESA G/W

ESAs

ARTEMIS

REDU EET

ESA G/W

TDRSS

WSGT

N/W
Mgt &
Control
NISN

POIC &
PDSS

HOSC

SSCC

MCC-H

A5 GSC
Kourou

ATV-CC

Columbus-CC
ATV Design Requirements

• ATV is designed to man rated requirements
• Failure Tolerance and Design for Minimum Risk applied
  – 2-failure tolerant for safety
  – 1-failure tolerant for mission success
  – Structures/mechanisms designed to be fail-safe or safe-life (factor of 4)
  – Flight Software independent validation
• CSG rules are applicable for ascent and descent
  – the probability of a catastrophic event for the ground population not to exceed $10^{-7}$
• Mission reliability requirements
  – Overall mission success from separation to re-entry: 0.95
  – Successful docking to ISS: 0.99
Jules Verne milestones
Final integration and environment tests started in ESTEC in July 04

- Acoustic noise test - March 05
- Thermal vacuum test - May 05
- Qualification Board - end 05
- Shipment to KRU – early 2006

Safety first:
No technical risk policy
Jules Verne is real
Jules Verne fully assembled
Main assets of ATV

• **Versatility and autonomy**
  – Payload elements can vary on each flight depending upon ISS needs
  – De-docking and re-docking capability
  – Autonomous manoeuvring up to docking

• **Precise navigation and guidance**
  – Stellar and GPS navigation, optical systems for finding and homing to docking port
    → High docking accuracy: +/-1cm = 50%, 10 cm = 100% (when ISS in thruster attitude control mode)

• **Safety**
  – Fully redundant architecture
  – Independent safety monitoring
  – Autonomous anti collision system (intelligent airbag equivalent)
**Jules Verne paves the way towards more “extraordinary voyages”**

Transportation of crew between space stations/modules

Man tended free flyer laboratory

Orbital safe haven

Automatic in orbit assembly of large space vessels
  - Earth application satellites
  - Very large space telescopes
  - Missions toward other planets

Evolutions of ATV in preliminary studies
  - Cargo return, crew transport, un-pressurized logistics carrier
  - CARV phase-B study
ATV prospective evolutions (1)

small payload return
ATV prospective evolutions (2)

large payload return
ATV prospective evolutions (3) – dual docking
Synthesis

ATV *Jules Verne* is a fantastic vehicle

Very large cargo ship

Very powerful tug

Combination of manned-unmanned technologies

New experience for Europe

Space rendezvous

In orbit refuelling

Optical guidance
For kids (young and older)

The Paper Model of the Automated Transfer Vehicle

BUILD YOUR OWN!

- http://esamultimedia.esa.int/docs/atv_model/ATV_2002.htm