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Paper Session II-B - NASA-ESA Technical Interchange: Capability of the Automated Transfer Vehicle to Resupply Space Station

Barbara S. Askins

Code DN NASA Headquarters Washington, DC United States

Francesco D. Mauro

Code STS/H-AT European Space Agency Toulouse Space Center France

NASA-ESA Technical Interchange: Capability of the Automated Transfer Vehicle to Resupply Space Station

Barbara S. Askins
Code DN
NASA Headquarters
Washington, DC
United States

Francesco Di Mauro
Code STS/H-AT
European Space Agency
Toulouse Space Center
France

The purpose of this paper is to describe the ATV configuration and focus on the NASA-ESA TI evaluation results associated with the use of ATV in the Station servicing scenario. In addition, the implications of using the ATV for resupply of the redesigned International Space Station are also briefly addressed.

Introduction

In January 1993 the National Aeronautics and Space Agency (NASA) and the European Space Agency (ESA) agreed to jointly assess the capability of ESA's proposed Automated Transfer Vehicle (ATV) to conduct unmanned resupply of Space Station Freedom (SSF). In July 1993 this Technical Interchange (TI) was extended to a Phase II to assess the impacts of the new Space Station. ESA also added potential ATV missions for the delivery of the Attached Pressurized Module (APM). In a separate effort, commencing in the spring of 1993, ESA and the Russian Space Agency (RSA) assessed the ATV capability to resupply Mir 2 in preparation for possible joint cooperation. The NASA-ESA TI Phase II activities were concluded in January 1994 with the issuance of a joint report entitled *Capability for ATV to Resupply Space Station.*

The ATV System

The Automated Transfer Vehicle (ATV) is a generic, versatile, expendable vehicle which is launched by Ariane 5 (Ar5) and is capable of delivering cargo to a space station in low Earth orbit (LEO). The vehicle is injected by the launcher into an elliptical orbit, then performs initial perigee raising maneuvers and orbital circularization to achieve a phasing orbit. After completion of phasing maneuvers the ATV performs the final approach to the Station which terminates either with its capture by the Station remote manipulator or with its direct docking to a Station port.

For the initial ESA-NASA TI assessment of the ATV design capability, the baseline SSF at 28.8° and 400 km was considered as target station. Subsequently the impact of delivery to 51.6 ° inclination was as-

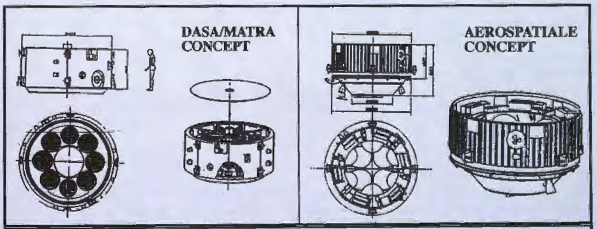

Figure 1: ATV Concepts of Two Contractors.

sessed. Analysis of ATV launch on a U.S. launch vehicle from Kennedy Space Center was included in the initial scope of the TI, but this was put on hold awaiting results of the NASA "Access to Space" study.

The ATV has a cargo delivery capability of approximately 14 tons to a 400 km circular, 51.6° inclination orbit. It will also have a trash disposal capability of 14 tons, but no return-to-Earth capability (although an ejectable recovery capsule concept has been introduced as an optional approach). The ATV is designed as a disposable vehicle that will perform its own destructive reentry together with its cargo carrier filled with Station trash.

The ATV System includes a Space Segment and a Ground Segment. The Space Segment is a composite of the ATV, the cargo, and all adapter devices required to integrate the ATV and cargo elements. The Ground Segment supports the Space Segment for mission preparation, execution, and post flight evaluation.

ATV Global Architecture

The ATV architecture was defined with the objective of not impacting the Ariane 5 launcher design (ATV + cargo is considered as a standard Ariane payload) or the design of the visited station. Therefore, the standard 3936 mm diameter interface of the Ar5 Vehicle Equipment Bay and the 4570 mm fairing envelope diameter were used for the sizing. In addition the Station interfaces and Station manned environments were considered in the definition of the vehicle characteristics, safety, and operations. Currently two concepts have been defined by the two major ATV contractors (Figure 1). The ATV architecture includes avionics, propulsion, thermal, structure, and mechanisms subsystems.

The avionics consists of guidance, navigation & control (GNC), data handling (DHS), communication, and power subsystems. The GNC/DHS includes computers, sensors, inertial reference units, buses and control units. The DHS executes mission timelines, manages and controls the other subsystems, monitors the health status of the ATV, and provides automated failure detection, isolation, and recovery capability. The ground and Station crew initiated wave-off will be handled by this subsystem to terminate ATV approach to Station in case of hazard.

GNC determines and controls the composite orbit attitude and maneuvers via Global Positioning System (GPS) rendezvous sensor, and attitude sensor data processing. GNC is two-fault tolerant for all functions performed in the Station Command and Control Zone (CCZ) — a 12 km in-plane radius and a 5 km out-of-plane dimension to either side of V-bar.

The communication subsystem provides the ATV links with Ground Segment using S-band, with Station using UHF-band, and receives GPS on L-band.

The power supply subsystem utilizes lithium batteries to generate 28 V power and 28 to 120 V interface converters units for connection to the cargo and Station. The ATV supplies a maximum of 500 W to the cargo. While it is attached to the Station the ATV receives approximately 300 W power.

The propulsion subsystem includes a main propulsion which provides thrust required for velocity changes (delta V) and attitude and orbit control as well as a cold gas system which provides thrust for final approach operations. The propulsion subsystem is two-fault tolerant in the Station CCZ and must be compatible with the Station requirements for rendezvous and docking.

Thermal control is accomplished through arrangement of ATV components and mainly by passive thermal means (thermal blanket, paint...). It includes also some heaters for batteries, fluids tanks & lines to protect the ATV components during cold cases.

Mechanical loads on the ATV are borne by the structural subsystem. The light alloy structure which has been selected is rather conventional and low cost to be adapted to a controlled destructive reentry. Preliminary dynamic analyses have been conducted and show that the design is compatible with current Ar5 specifications. The structural ATV interface for cargo is with the adapters used to mount the cargo for launch. A standard bolted interface with provisions for electrical power and data will be used to attach the cargo adapter to ATV.

Mating/demating mechanisms are used to remove the cargo from ATV and attach to a Station port as well as to mate another cargo to the ATV for reentry. A docking mechanism and grapple fixture are installed on the ATV to perform docking with the Station and to be captured and transferred by the Station manipulator arm. Attachment devices are used to park the ATV cargo carriers on the Station.

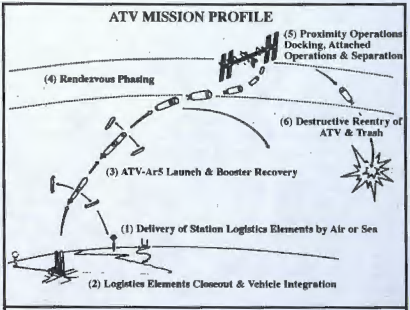

Figure 2: ATV Mission Scenario Overview

Mission Scenario

The ATV operational scenario (Figure 2) starts with the receipt of the ATV and cargo elements at the Cayenne port and/or Rochambeau airport located in French Guyana. The elements are then transported to the European Space Port by road, and unloaded in the Payload Processing Building for inspection and checkout. The hazardous processing is performed in a dedicated facility. The processed elements are then transferred to the Final Assembly Building (BAF) where ATV and cargo are integrated. The composite is checked, encapsulated into the Ar5 fairing, hoisted onto the platform and mated to the Ar5 launch vehicle. An end-to-end communications test and a launch rehearsal are held at the BAF. Not later than T-2 days the arming sequence is performed and the doors on the fairing are closed. The vehicle is transferred on the mobile launch table to the launch zone about 3 km away. The countdown begins at T-6 hours.

The Ariane 5 is a two-stage launch vehicle. The cryogenic main stage, EPC (Etage Principal Cryogenique) is powered by one vulcain engine. Two solid propellant boosters, EAP (Etage A Poudre), are strapped to the side of the EPC and jettisoned after burnout. The EPC is ignited at T-0, the EAPs are automatically ignited and lift-off occurs at T+3 seconds. After approximately 2 minutes burn time and at an altitude of 60 km, the EAPs are jettisoned. The fairing is separated between T+150 and T+200 seconds at an altitude of 110 km. The separation of the EPC from the composite follows at T+580 seconds.

After the ATV injection into an elliptical orbit the ATV performs perigee raising maneuvers, phasing and final approach to the Station. At the ATV entry into the Station CCZ the vehicle control is switched from the ATV to the Space Station Control Center.

ATV Candidate Missions

The major emphasis in the NASA-ESA TI was the assessment of potential use of ATV for Space Station logistics resupply missions. In TI Phase II the potential resupply mission list was adjusted to account for the changes from Station Freedom to the new Space Station.

Two major types of logistics elements remained as candidates for ATV-Ar5 delivery: the Unpressurized Logistics Carriers (ULCs) and the Mini-Pressurized Logistics Module (MPLM). (See Figure 3). The Design Reference Missions (DRMs) considered both the baseline design of these elements and modified designs (conceptual) that would closely match ATV-Ar5 capability. The DRMs included:

Unpressurized Cargo Delivery

- Two baseline ULCs
- One elongated, disposable ULC sized for ATV-Ar5 maximum capability

Pressurized Cargo Delivery

- One active (powered) MPLM
- One inactive MPLM
- One disposable, inactive MPLM (conceptual)

Mixed Cargo Delivery

- One ULC and one eight-rack, disposable MPLM (conceptual)

All the Space Station baseline logistics elements are designed to be reused. Because the ATV-Ar5 currently has no return capability, disposable logistics elements would have advantages. Disposable elements are lighter, allowing more cargo delivery, and they avoid the problem of finding a Shuttle flight to return the logistics element. However, no disposable logistics elements are in the current Station plans.

As an additional DRM, ESA assessed the potential to deliver an ESA Attached Pressurized Module (APM) five double racks in length. The preliminary results confirmed the feasibility of this mission and ESA proposed it as a part of the nominal Space Station assembly plan.

<u>Mission Analysis</u>

The study found that the use of ATV for resupply of Space Station would allow reduction in the Shuttle flight rate for Space Station support. This in turn would allow use of the Shuttle for other missions and an extension of the Shuttle fleet life, and would in general result in a more robust international space transportation infrastructure. Generally, one ATV flight can replace one Shuttle flight; however, the ATV provides only one-way transportation.

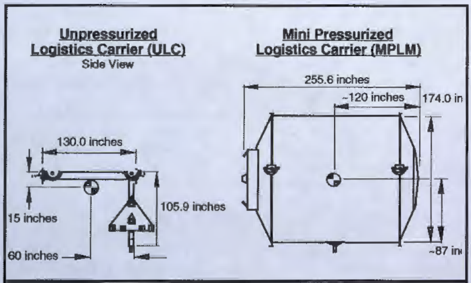

Figure 3: Station Logistics Elements

The extent to which ATV flights can replace Shuttle flights is largely driven by the need to return cargo. The Shuttle must provide all return transportation for both Shuttle-delivered and ATV-delivered cargo that is required to be recovered. The ATV can be used to deorbit trash, such as expended Orbital Replacement Units (ORUs), and other expendable cargo.

Prior to separation from the Space Station, the ATV can be loaded with trash and both the ATV and trash will be destroyed by controlled atmospheric destruction. In the mission analyses performed by ESA and NASA, trash disposal was considered an integral ATV mission function.

ATV Preferred Missions

More efficient use of the ATV is possible with the use of a special expendable ULC designed to optimize ATV capabilities. The ATV-Ar5 could also be used to supplement the Russian cargo vehicle (Progress) for delivery of dry cargo as well as water, propellant, and atmospheric gases for the Station. When the ATV is attached to the Station it could also be used for Station reboost.

With regard to pressurized cargo, e.g. the MPLM, a major issue is that the nominal ATV is not sized to provide the power (3 kW) and heat rejection required by the MPLM payload. Therefore, additional ATV batteries and MPLM body-mounted radiators would be required. This increases design complexity and reduces cargo-carrying capability. The most attractive element for ATV pressurized delivery would be an inactive MPLM designed to be disposable; however, currently all MPLMs are planned to be active as they can exploit the Shuttle energy resources and heat rejection capabilities. The final decision on the ATV missions will await updated analyses of the overall Station logistics and resupply requirements and integrated analysis of Shuttle, Russian, and European transport vehicles.

ATV Project Status

During July through October 1993 ESA conducted a pre-Phase B Configuration Review which NASA supported. The recommendations of the Configuration Review Board for preferred ATV concept and subsystem definitions have been passed on to the ATV contractors (Aerospatiale-Fiat Spazio and Deutsche Aerospace Ag-Matra Marconi Space) as part of the consolidation phase studies that are currently in progress. A delta Configuration Review is scheduled for mid-1994.

The ESA ATV contribution to the Space Station operation and utilization scenario was evaluated at the beginning of 1994 — start of the NASA-ESA TI Phase III. The evaluation was performed by the JSC Space Station Office and supported by ESA and NASA TI representatives. The Station office reviewed several possible ATV

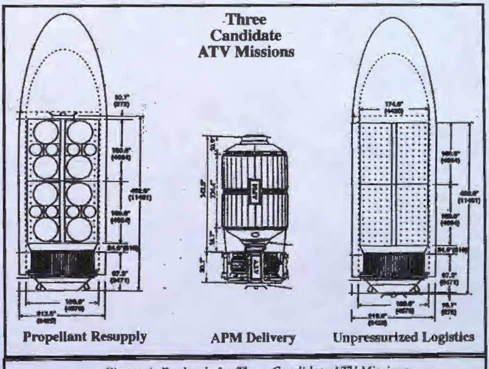

Figure 4: Payloads for Three Candidate ATV Missions

missions that appeared useful and complementary to those of the Shuttle Orbiter and Russian Progress vehicles. The primary reference missions were delivery of the APM, resupply of propellant, and delivery of unpressurized logistics.

With regard to the transport of Russian propellant and cargoes, the European Space Agency had initiated studies with Russian industry, upon agreement with the Russian Space Agency, to verify (first study) the ATV capability to perform missions to Mir 2 and (second study) missions to the Russian segment of the International Space Station. The objective of the second study was the Station's propellant resupply and boosting. The ATV to Mir 2 study, completed in January 1994, confirmed that the ATV was capable of replacing the mission of two Russian Progress vehicles launched by the Soyuz launcher. The second study is ongoing. Results will be used to confirm the ATV capabilities to replace the mission of two Progress vehicles launched by the Zenit launcher.

Summary

The European program for the development of an Automated Transfer Vehicle that started in 1986 has been evaluated by a NASA-ESA interchange group in 1993 and proposed in 1994 to the Space Station Program Office. The TI analysis provided reference missions and initial technical analyses to support the Program Office evaluation.

In ESA's view, the ATV, together with the ESA APM, is a cornerstone of the European participation in the development and operations of the Space Station. The ATV capabilities are complementary to those of the U.S. Shuttle and Russian Progress for cargo transportation.

The Space Station Program's technical evaluation will be consolidated by the ESA industrial Phase B activities that will start in July 1994. In addition, formal agreements will have to be established between the International Space Station partners to determine the exact ATV role and missions in the Station operations and utilization scenario. Also, the benefits and impacts of ATV missions will continue to be reviewed to assure minimum impacts on Station development and operations costs.

The ATV first mission is planned for 2000 and will be followed by the APM launch mission in 2001.

Acronyms

ACS	Attitude Control System
Ar5	Ariane 5
APM	Attached Pressurized Module
ATV	Automated Transfer Vehicle
CCZ	Command Control Zone
CSG	Guyana Space Center
DHS	Data Handling System
DRM	Design Reference Missions
EAP	Etage A Poudre
ESA	European Space Agency
EPC	Etage Principal Cryogenique
GNC	Guidance Navigation & Control
GPS	Global Positioning System
kW	Kilowatts
LEO	Low Earth Orbit
MPLM	Mini-Pressurized Logistics Module
NASA	National Aeronautics and Space Agency
ORU	Orbital Replacement Unit
RSA	Russian Space Agency
SSF	Space Station Freedom
TI	Technical Interchange
V	Volt
W	Watts

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