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THE OLYMPUS COMMERCIAL ORBITAL TRANSPORTATION SYSTEM

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ABSTRACT

Andrews Space, Inc. proposed the *Olympus* Commercial Orbital Transportation System under the NASA Crew / Cargo COTS procurement. *Olympus* Commercial Orbital Transportation includes the *Olympus* Space Utility Vehicle (SUV) and the *Olympus* Launch Vehicle. The *Olympus* SUV is a reusable spacecraft capable of transporting unpressurized cargo, pressurized cargo, and crew – all during the same mission - to and from the ISS and other orbital destinations. This paper outlines the proposed vehicle configuration and development approach to demonstrate critical technologies and compliance with ISS safety and NASA human rating requirements by 2009 with initial operating capability (IOC) by 2010.

FULL TEXT

Olympus SUV System Overview

In order to offer a full suite of products and services, the proposed Andrews Space business plan calls for developing the *Olympus* Space Utility Vehicle, a spacecraft capable of addressing NASA's Capabilities:

- Capability A: External cargo delivery and disposal
- Capability B: Internal cargo delivery and disposal
- Capability C: Internal cargo delivery and return
- Capability D: Crew transportation

as well as existing and emerging (future) commercial markets.

The *Olympus* SUV will be launch on the *Olympus* Launch Vehicle (*Olympus* LV), a simple, reliable two stage launch vehicle that uses existing human-rated motors, engines and components (Figure 1).

Our block development approach will reduce the risk for fielding the *Olympus* SUV commercial crew and cargo logistics system (Figure 2).

The Block 1 vehicle is a full-scale prototype system using operational subsystems that will demonstrate ISS operations, including: autonomous rendezvous and proximity operations (ARPO), berthing, as well as pressurized and unpressurized cargo operations; and vehicle recovery. Our Block 1 SUV, developed during Phase I of the COTS program, will fly in the first half of 2009 on the *Olympus* Launch Vehicle to demonstrate NASA's Capabilities A, B and C.

Block 2 SUV builds on the Block 1 vehicle contains all cargo accommodations and related subsystems to meet NASA's Capabilities A, B and C, including powered payloads. Our Block 2 SUV will enter service in 2010.

Block 3 builds on the Block 2 vehicle and includes the crew subsystems and Launch Abort System required to meet NASA's Capability D. We will provide piloted cargo and personnel transfer missions in 2012 following a NASA Capability D demonstration mission in 2011.

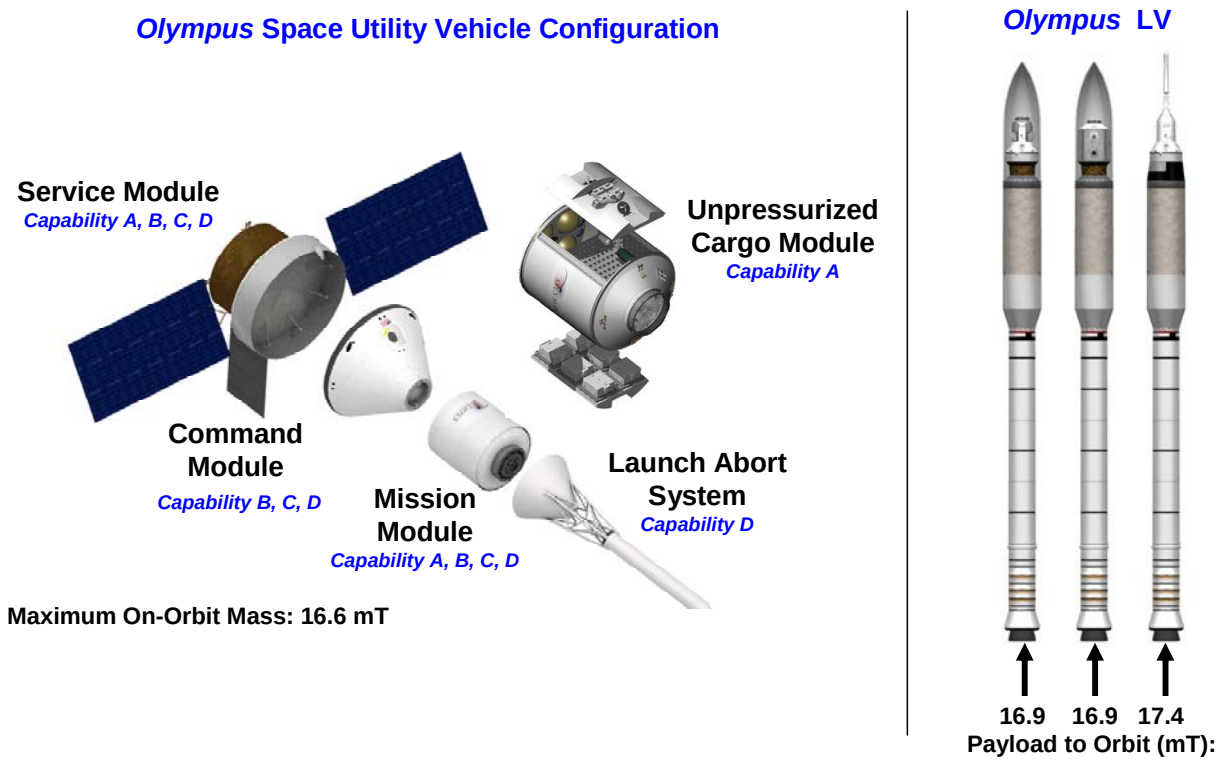


Figure 1. During NASA's Concept Exploration & Refinement effort Andrews developed a crew and cargo logistics system around a scaled Apollo capsule and a Shuttle derived launch vehicle.

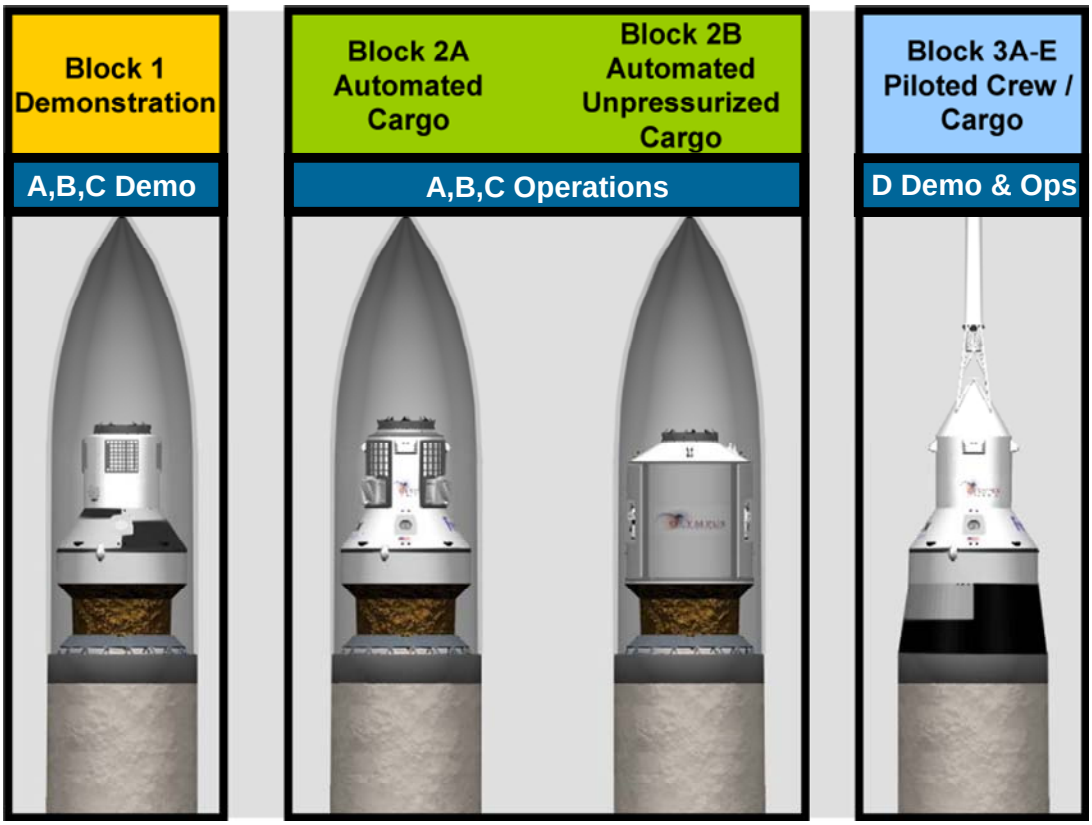
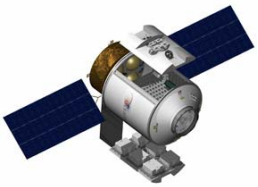
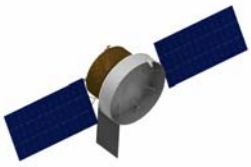


Figure 2. The 4.6 meter Olympus SUV fits within a standard five meter fairing for automated cargo operations.

As a critical step in this process, Andrews and ATK will form a new entity, *Olympus Spacelines*, which will be the crew and cargo logistics services provider. *Olympus Spacelines* will secure financing to develop the *Olympus* LV, field the operational fleet, and build the supporting infrastructure to enter commercial service for automated cargo logistics (Capabilities A, B, and C) in 2010.

The *Olympus* SUV is capable of transporting unpressurized cargo, pressurized cargo, and crew. The SUV comprises a 4.6-meter-diameter scaled Apollo capsule termed the Command Module (CM), a Services Module (SM), and a Mission Module (MM). The *Olympus* architecture also includes an Unpressurized Cargo Module (UCM) for large unpressurized cargo missions. These elements are outlined in Table 1.

Table 1. The Olympus SUV is comprised of five elements to address all of NASA's requirements.

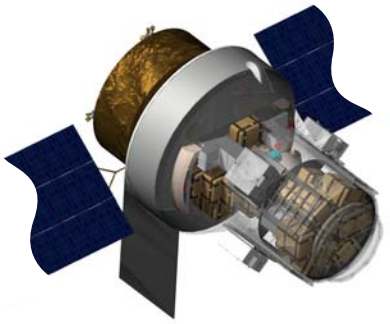
Olympus SUV Element	Description
	Command Module (CM) – A scaled Apollo capsule 4.6 meters in diameter. The internal volume has a flat back wall for mounting powered and unpowered Mid-Deck Lockers as well as Cargo Transfer Bags. Cargo Transfer Bag payloads while water and gas bottles, fill the remaining cargo volume. The Command Module incorporates structural provisions for seats to rapidly convert the capsule for crew transfer missions. This packaging arrangement provides flexibility for meeting a broad range of commercial customer requirements.
	Mission Module (MM) - A pressurized module mounted in front of the Command Module. The Mission Module provides additional pressurized volume for transporting cargo as well as crew operations. In addition, FRAM's can be externally mounted for additional cargo transfer capability. The Mission Module supports the ISS interface (CBM for autonomous cargo, APAS for piloted missions) and is expended prior to re-entry.
 Shown with Service Module	Unpressurized Cargo Module (UCM) – A 4.6-meter-diameter cylindrical structure that houses one or two removable drawers to transport FRAM-based and out-sized payloads. The UCM is capable of transporting all NASA ORU's with the exception of the radiator and solar array assemblies.
	Service Module (SM) – The SUV spacecraft bus contains propellant, thrusters, and solar arrays. The Service Module can be equipped with additional propellant tanks to provide up to 2,000 kg of reboost propellant for the ISS.
	Launch Abort System (LAS) - The Launch Abort System will be derived from development work being conducted by ATK and Aerojet under IRAD, as well as NASA funded Crew Exploration Vehicle Launch Abort System development. The Olympus LAS will be flown with all crewed (Block 3) missions and capable of pulling the Command Module clear of the launch vehicle in the event of an on-the-pad or in-flight abort.

The Olympus SUV system will be certified to approach and interfaces with the International Space Station, as well as to fly NASA astronauts. Our Human Rating Process is detailed in our original proposal submittal.

The primary SUV configuration is comprised of a Service Module, a Command Module, and a Mission Module. This configuration is capable of transporting unpressurized cargo, pressurized cargo, and crew within the same mission. Autonomous cargo missions are flown inside a fairing to support externally mounted FRAM based payloads. Crewed missions are flown without a fairing and include a Launch Abort System (LAS). The Mission Module accommodates the ISS interface, and can be configured to meet unique mission requirements. As an example, autonomous missions are berthed to ISS, while crewed mission dock using the APAS mechanism. These different docking mechanisms are integrated into their respective mission modules.

The *Olympus* SUV is designed to fly inside a standard five meter fairing for all automated cargo (Capability A, B and C) missions, which provides significant launch flexibility. Capability D missions, the *Olympus* SUV will fly on the *Olympus* LV or, as an option for NASA crew transfer missions, the Ares-1. For all crewed missions the *Olympus* SUV will fly with a Launch Abort System.

The *Olympus* architecture elements are combined to create vehicle configurations that meet the Business Plan and NASA requirements. The *Olympus* SUV family of vehicles is pictured in Figure 3 through Figure 6.



SUV-2A Capabilities
(NASA Capability A,B,C)

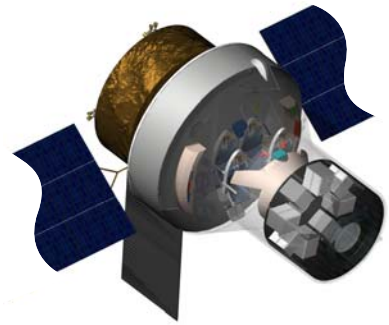
- 23 Mid-deck Locker Equivalents (8 Powered)
- 150 CTBEs
- 4 FRAM-based unpressurized payload sites
- 2 kW Payload Power (avg.)
- Captures 65% External ORU Manifest

Figure 3. Configuration SUV-2A.

SUV-2B Capabilities
(NASA Capability A)

- Up to 16 FRAM-based Unpressurized Payload Sites
- 1.5 kW Payload Power (avg.)
- 220 kg Water
- 60 kg Gases
- Captures 95% External ORU Manifest

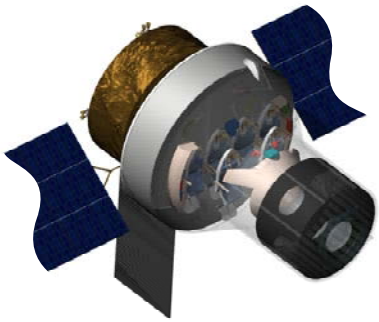
Figure 4. Configuration SUV-2B.



Block 3C SUV Capabilities
(NASA Capability D)

- 4 Crew / Passengers
(meets Std-3000 volume / crew)
- 23 Mid-deck Lockers Equivalents
(8 Powered)
- 1 kW Payload Power (avg.)

Figure 5. Configuration SUV-3C.



Block 3E SUV Capabilities
(NASA Capability D)

- 6 Crew / Passengers in high-density transit or lifeboat missions

Figure 6. Configuration SUV-3E.

Olympus SUV Launch Vehicle

The *Olympus* SUV will fly on the *Olympus* Launch Vehicle (*Olympus* LV). The *Olympus* LV is designed as a simple, reliable two stage launch vehicle. The first stage uses an existing four segment RSRM with a new interstage, nearly identical to the interstage being developed by NASA for the Crew Launch Vehicle. The *Olympus* LV uses a new LOX / RP upper stage powered by an existing human rated NK-43 rocket engine. The *Olympus* LV can accommodate an industry standard 5.0 or 5.4 meter diameter payload fairing. The *Olympus* LV system reliability is comparable to the Ares-1 (NASA Crew Launch Vehicle) and will be certified to fly NASA astronauts.

As programmatic risk reduction options, Andrews has received quotes from Boeing Launch Services, International Launch Services, and SeaLaunch for demonstration and operational launch costs on the Delta IV family, Atlas V family and SeaLaunch family of launch vehicles (respectively). In addition, as there are a number of emerging launch service providers, including SpaceX and the Falcon 9 family of vehicles. These development stage vehicles have quoted launch prices below the existing launch service providers. If these vehicles are developed, and provide an attractive value proposition (trade of cost, reliability and performance), then they will be considered as viable candidates. The Falcon 9 family is a five meter fairing that is compatible with our 4.6 meter *Olympus* SUV.

The *Olympus* SUV launch options are summarized in Figure 7.

Baseline	Backup Options			
Olympus LV	Atlas V	Delta IV	SeaLaunch	Falcon 9
Block 1, 2 and 3	Block 1 and 2	Block 1 and 2	Block 1 and 2	Block 1 and 2
				

Figure 7. The Olympus SUV can fly on a wide range of launch vehicles, but will use Shuttle derived systems because of lower cost and higher safety

Olympus SUV System Performance Summary and NASA Capability Compliance

For each mission a Service Module is combined with either a Command Module and Mission Module or an Unpressurized Cargo Module to provide a mix of pressurized and unpressurized cargo and / or crew logistics. To track the type of mission, Andrews developed a naming convention: autonomous operational missions begin with "2" and piloted missions begin with "3". Furthermore, given the flexibility provided by the different configurations, a second character ("A" through "E") denotes a specific crew and cargo capability. These configurations and capabilities are summarized in Table **2**.

Table 2. The Olympus SUV is flexible enough to meet a wide range of commercial requirements.

Olympus SUV Configuration Summary	Demo	Autonomous Cargo		Piloted Crew and Cargo				
	SUV-1	SUV-2A	SUV-2B	SUV-3A	SUV-3B	SUV-3C	SUV-3D	SUV-3E
Initial Operating Capability	2009	2010	2010	2012	2012	2013	2012	2013
Docking / Berthing	Berthing	Berthing	Berthing	Docking	Docking	Docking	Docking	Docking
Addresses NASA Capability	A,B,C	A,B,C	A	B,C	B,C	B, D	B, D	D
Powered MDKs	Simulated (8)	8	-	8	8	8	8	-
Unpowered MDKs	Simulated (15)	15	-	15	3	15	15	-
Cargo Transfer Bags	Simulated (150)	150	-	90	108	-	48	-
Cargo Water (220 kg)	-	Yes[3]	Yes	-	-	-	-	-
Cargo Gases (60 kg)	-	-	Yes	-	-	-	-	-
Crew (including pilot)	-	-	-	1	1	4	6	6
UCM (FRAM sites)	Simulated (4)	4	12 to 16	-	-	-	-	-
Reboost Module (2 MT propellant)	-	-	-	Yes	-	Yes	-	-
Total P/L Power (kW)		2 kW	1.5 kW	1 kW	1 kW	1 kW	1 kW	1 kW
Launch Mass (kg)	16,757	17,301	15,640	22,061[1]	22,115[1]	23,127[1]	21,909[1]	20,766[1]
On-orbit Mass (kg)[2]	16,047	16,591	14,930	15,351	15,406	16,417	15,200	14,056
Launch Vehicle Compatibility	*Olympus* LV, Atlas 551, Delta 4H	*Olympus* LV, Atlas 551, Delta 4H	*Olympus* LV, Atlas 551, Delta 4H	*Olympus* LV, CLV	*Olympus* LV, CLV	*Olympus* LV, CLV	*Olympus* LV, CLV	*Olympus* LV, CLV

[1] Includes 6000kg Launch Abort System (LAS) Allocation for Manned Configurations
[2] SUV Weight Only (Excludes Launch Vehicle / SUV Adapter Weight)
[3] Assumes use of water transfer bags

All of NASA's Capability A, B and C requirements can be accomplished with four SUV-2A and two SUV 2B missions. All of NASA's Capability D requirements can be accomplished with two SUV-3 missions. Table 3 summarizes how we meet NASA's requirements.

Table 3. NASA's Capability A,B and C can be satisfied with four SUV-2A and two SUV-2B missions while Capability D can be satisfied with two SUV-3 missions.

COTS SRMs	*Olympus* Capability	SRM-A	SRM-B	SRM-C	SRM-D
Useful Cargo Mass (kg)	Four SUV-2A plus two SUV-2B plus two SUV-3C annual capability: 5,000 external 6,820 internal up 3,450 internal down 230 kg per crew	Up to 5,000	Up to 7,000	Up to 7,000/3,000	Max. 3 crew – 700 kg Min. 2 crew – 450 kg ISS Cargo – 250kg
Water (kg) without container	1,100 in 1 SUV-2B flight	1,100	1,100	0	N/A
Gas (kg) without container	300 in 1 SUV-2B flight	300	300	0	N/A
Accommodation Mass (kg)	Four SUV-2A plus two SUV-2B plus two SUV-3C annual capability: 6,000 external * 2,050 internal up * 1,040 internal down *	Up to 6,600	Up to 2,700	Up to 2,700/1,000	Internal – 100
Total Mass (kg)	Four SUV-2A plus two SUV-2B plus two SUV-3C annual capability: 11,000 external * 8,870 internal up * 4,490 internal down *	Up to 13,000	Up to 11,000	Up to 9,700/4,000	Up to 1,050
Total Volume, m^3	Four SUV-2A plus two SUV-2B plus two SUV-3C annual capability: 90.6 external 40.8 internal up 20.7 internal down 2.6 ISS cargo w/3 crew	Up to 42	Up to 28	Up to 28/23	3 crew + gear + 1 m^3 ISS cargo

Summary

While Andrews Space was not selected for a funded Space Act Agreement at this time, we stand by the *Olympus* COTS Design. The Andrews mission statement is to be "a catalyst in the commercialization and development of space." We fully embrace the COTS objectives to:

- implement U.S. Space Exploration policy with an investment to stimulate commercial enterprises in space,
- facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with the goal of achieving reliable, cost effective access to low-earth-orbit,
- create a market environment in which commercial space transportation services are available to Government and private sector customers.

Our *Olympus* SUV and *Olympus* LV meet these objectives and provide a robust, human rated space transportation system capable of satisfying NASA's space logistics requirements.