Design of a Piloted Spacecraft to Bride the Gap between the Space Shuttle and Crew Exploration Vehicle

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With the space shuttle slated currently schedule for retirement in 2010 and the Crew Exploration Vehicle not expected to be crew rated before 2014, there will be the longest gap in US piloted orbital launch capability since the gap between the Apollo-Soyuz Test Project and the launch of the first space shuttle. After being reliant on the Russian Soyuz for crew transportation to and from the International Space Station for two years, it has become apparent that the operations, maintenance, and especially science have suffered as a result of the reduced crew size. A new spacecraft will be required to prevent a similar forced reduction in crew size after the retirement of the space shuttle. The five year timeframe to develop this vehicle will be the shortest in the history of human spaceflight, and in order to meet the 2010 deadline this new spacecraft's design will be such that it takes advantage of existing technologies and resources. This paper will cover the basic requirements and conceptual design of such a spacecraft. The project goals section will provide the rational of why such a vehicle is needed. The requirements section will include a discussion of the benefits and limitations of combined crew and cargo versus a crew only spacecraft. The same section will also provide an examination of the crew size, mission duration, rendezvous and docking systems, on-orbit cold storage capability, entry descent and landing, reusability, and possible stretch goals. Finally a conceptual design of vehicle meeting these requirements will be presented.

Nomenclature

ΔV = change in velocity
CEV = Crew Exploration Vehicle
CM = Crew Module
g = Force of gravity on Earth, $9.81 m/s^2$
ISS = International Space Station
LEO = Low Earth Orbit
OMS = Orbital Maneuvering System
PMA = Pressurize Mating Adapter
RCS = Reaction Control System
SM = Service Module

I. Introduction

On 14 January 2004, President George W. Bush unveiled the new Vision for Space Exploration. As part of NASA's new vision the space shuttle system will be used to complete construction of the International Space Station in 2010. Once assembly is completed the space shuttle will then be retired from service.

Based upon current development schedules for the next generation piloted spacecraft, the Crew Exploration Vehicle (CEV), the retirement of the shuttle in 2010 will mark the beginning of a four year hiatus in launches of piloted spacecraft from the United States. This will be the second longest hiatus in American piloted spaceflight since the nearly six year gap between the Apollo-Soyuz Test Project flight in July of 1975 and the launch of Columbia on STS-1 in April of 1981.[1]

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This four year hiatus will have major repercussions on the United States' human spaceflight program. Foremost, American astronauts will again become reliant on the Russian Soyuz or recently unveiled Klipper spacecraft for transportation of crews to and from the space station. Unlike the use of the Soyuz during the current stand down of the space shuttle fleet, the flights of American astronauts on the Soyuz starting in 2010 will not be free of charge. The Russians are only obligated to provide the Soyuz spacecraft as lifeboats for the ISS until the end of 2005 as it was originally intended to have an American spacecraft providing emergency return capability at this time. The Russians have agreed to continue providing Soyuz seats to American space station expedition members though the 2006 calendar year in exchange for the United States absolving the Russians of their commitment of providing 3,000 crew work hours on American research. These 3,000 crew hours were agreed to as compensation of NASA contributions towards completion of the Russian segment of the ISS in the early stages of the program.

The agreement forged with the Russians for crew transportation cannot be extended past 2006, nor can it be reinstated in 2010 during the planned hiatus in American piloted spaceflight capabilities. NASA is not legally permitted to exchange money for services or hardware from Russia per the Iran Nonproliferation Act of 1999. It is possible to obtain a waiver from the Congress to allow for the purchase of services from Russia to support the ISS, but the current political climate will likely prevent any such waiver from being approved. If no waiver is obtained the ISS may not see an American astronaut onboard during the hiatus.

A second repercussion to an extended hiatus in piloted spaceflight capabilities is the possibility of a second forced reduction of ISS expedition crew size to two. This may not be required as the European Space Agency's Automated Transfer Vehicles will have been operational for approximately four years when the space shuttle is retired and their payload will allow for the support of three astronauts onboard the ISS.

There are several solutions to prevent this hiatus from occurring. First, the space shuttle fleet's retirement could be delayed until the Crew Exploration Vehicle is ready. While a valid option it is possible that another orbiter could be lost over the course of the next ten years. A second option is drastically accelerate the development of the Crew Exploration Vehicle. This may be possible but will be victim of the faster, better, cheaper triangle. Either the accelerated development would be prohibitively expensive or the quality of the vehicle would result in it being unsafe to fly.

The third option is to develop a piloted spacecraft for the sole purpose of transporting crews to and from the ISS. With only five years remaining until the space shuttle is retired, this option would require that the vehicle be a simple as possible. It is possible to develop a piloted spacecraft in this amount of time as the Gemini spacecraft was developed and flown in just over 4 years.[2]

This paper will examine the third option of developing a new piloted spacecraft. The development of this vehicle would fall under NASA's Exploration Systems Directorate's Constellation Systems group. For the purposes of this paper the program vehicle being proposed will be referred to as the Argo Program. Argo was the ancient constellation of a ship.

II. Vehicle Requirements

In order to allow for the rapid development of the Argo spacecraft the number of firm requirements must be minimized to allow the design teams the flexibility needed to maximize the use of current technology in the vehicle design. The design areas that have firm requirements are: crew size, launch vehicle compatibility, launch abort, orbital maneuvering, rendezvous and docking, on-orbit lifetime, recovery, and reusability. Each of these areas has more detailed requirements and the rational behind each of the presented requirements will be discussed.

A. Crew Size

The first area that must be examined is number of crew members that need to be transported to and from the ISS. Two separate expedition crew size scenarios exist for operations of the ISS in 2010. The first is a full seven person crew, and the second is the current standard of a three person crew.

The seven person expedition scenario relies on both the Soyuz and Argo spacecraft for crew transportation. Assuming the standard Soyuz flight will carry one short term crew member and two long term expedition crew members, the Argo spacecraft will be required to transport five crew members to and from the ISS. Both the Soyuz and Argo spacecraft will be required to serve as lifeboats in the event of an emergency requiring evacuation of the ISS.

The three person expedition scenario relies primarily on the Argo spacecraft to transport the expedition crew members to and from the ISS. With the Russians no longer obligated to provide the Soyuz spacecraft as a lifeboat, thus the Argo will need to be used as the primary lifeboat. For this scenario the Argo spacecraft will be required to carry three crew members.

In order to support operations of the ISS once assembly is completed, the Argo spacecraft will be required to carry five crew members.

B. Launch Vehicle Compatibility

The Argo must be capable of launching on currently existing launch vehicles or launch vehicles that are in the final stages of development and have well defined performance characteristics.

C. Launch Abort

In the event of a launch vehicle failure the Argo must have the ability to separate from the vehicle, travel a distance sufficient to ensure the survival of the crew and minimize damage to the spacecraft, and to make an emergency landing. The ability safely abort while the launch vehicle is on the pad is also required. In the event emergency egress from the Argo spacecraft is required while on the launch pad, a hatch with explosive opening will be provided.

D. Orbital Maneuvering

In consideration of the orbital maneuvering requirements it is necessary to examine both the requirements for orbit changing as well as attitude changing systems. These systems will use the naming convention used for the space shuttle program. For changes to the orbit, such as altitude and limited orbital plane changes, the Orbital Maneuvering System (OMS) will be used. For changes in the attitude of the spacecraft the Reaction Control System (RCS) system will be used.

1. Orbital Maneuvering System

The OMS for the Argo spacecraft does not need to provide the same capability as the space shuttle OMS. For the purposes of the determining for the total required engine performance, measured in total change in velocity (delta V), it is assumed that the launch vehicle will be able to insert the spacecraft into a stable orbit without the using the Argo's OMS for circularization of the initial orbit.

Table 1. Similar Spacecraft Delta V

Spacecraft Model	**ΔV (m/s)**
Gemini	323
Soyuz TMA	200
Progress	390

Based upon historical data for similar spacecraft it is possible to determine the total delta V the Argo spacecraft must provide. Table 1 shows data for three similar spacecraft.[†]

2. Reaction Control System

The Argo RCS must be capable of providing translational and rotational movement. The thrusters used in translation of the Argo must be capable of providing a greater maximum translation rate in the forward and aft directions. In addition for space station approach the RCS must be able to provide indirect thruster firing in the same manner as the space shuttle's "high-z" indirect thruster firing configuration used when docking with the ISS.

E. Rendezvous and Docking

The rendezvous and docking requirements for the Argo spacecraft are the most critical as the primary mission for an Argo spacecraft will be to transport crews to and from the ISS.

The rendezvous phase should not last more than two days. This requirement is put in place to reduce the amount of resources used during the rendezvous phase.

[†] The Gemini spacecraft delta V for on orbit operations is 222m/s, the remaining 101m/s capability was provided by the solid retrorockets.

Docking the Argo to the ISS will be accomplished through the use of the PMA-2 and -3 attached to the Unity Node. To dock with the PMAs the Argo will be required to have an androgynous docking adapter identical to that currently used on the space shuttle.

The Argo's final approach and docking will must be primarily controlled by the onboard computers. In the event of a failure in the automatic docking manual control of the docking must be possible. With the improvements in computer technology, the automated docking system can react to changes in spacecraft attitude faster and with a higher degree of accuracy than a human can.

F. On Orbit Lifetime

With the requirement of the Argo spacecraft serving as a lifeboat for the ISS it must have on orbit storage capability. The minimum storage life should be 100 days to support a three month expedition. It is preferable that the Argo be capable of 180 on orbit storage to support longer duration expeditions. On orbit storage can be either in powered up or powered down mode.

In order to support the crew during approach and departure to the ISS as well as during test flights the Argo will need to have the ability to support a full crew for five days or a two person crew for ten days.

G. Recovery

The recovery requirements cover reentry, descent, and landing.

1. Reentry

The Argo spacecraft shall have adequate thermal protection that ensures survival of the spacecraft and its crew. In addition to providing thermal protection the reentry must be controllable and provide a minimum cross range capability of 75km and down range capability of 500km. This requirement is in place to allow for precision approaches toward the landing point.

The acceleration experienced by the crew during a normal descent should not exceed five times the force of gravity (5g's).

2. Descent

Decent of the Argo spacecraft shall be controllable as to allow for precision landing at an airfield. Descent control should be possible under automatic and manual conditions.

3. Landing

The landing of the Argo spacecraft shall be nondestructive for the spacecraft and ensure the crew will not experience injuries from landing.

H. Reusability

The Argo spacecraft shall be designed have all components that are returned to earth either be reusable or replaceable for reduced vehicle servicing time. The majority of the replaceable components should be reusable after further post processing.

III. Conceptual Vehicle Design

While the vehicle requirements for the Argo spacecraft were presented in an order of mission events, the conceptual vehicle design cannot be presented in the same manner. The first issue that must be examined is the recovery requirements, specifically the differences between winged and capsule designs.

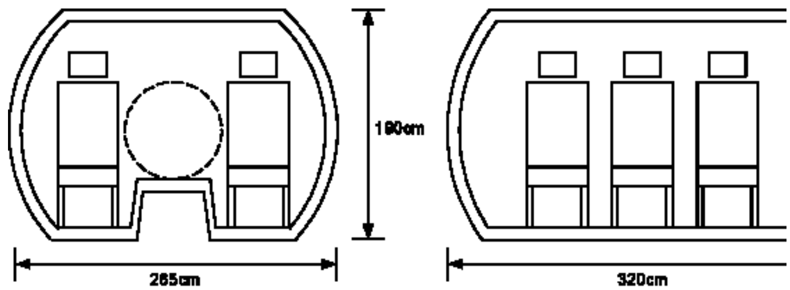
A winged vehicle will allow for greater maneuvering during reentry and descent. A by product of the increased maneuvering capability is increased heating during reentry, especially on the leading edges of the wings and on the spacecraft's nose. A winged vehicle also allows for landings in a similar manner to the space shuttle.

A capsule has a much lower temperature reentry as it is not capable of the complex maneuvering during reentry as a winged vehicle. This is not to say that the spacecraft cannot adjust its trajectory during reentry, by offsetting the center of mass from the roll axis it is possible to generate a small amount of lift around the capsule.

The lift vector can be changed by rolling the spacecraft. To allow for runway landings a capsule must be equipped with a parafoil to allow for descent maneuvering. This concept of using a parafoil for descent and equipping the capsule with skids is not new; McDonnell Douglas' original design for the Gemini spacecraft included a deployable wing similar to a hang glider wing and skids for landing and NASA explored this concept for the cancelled X-38.

In order to allow the Argo spacecraft to be developed prior to the retirement of the space shuttle it is necessary to have as simple a system as possible, thus the capsule design has been selected.

To allow for cold storage while in orbit the Argo will need to have several redundant systems. As it is not necessary to reuse some systems, a service module can be used to house those systems that will only be used for ascent and possibly through ISS departure. The Argo design will utilize a separate Crew Module (CM) and Service Module (SM)



The first requirement addressed is the configuration of the crew compartment as this will directly affect the size of the Argo spacecraft. Figure 1 shows the configuration used for the Argo spacecraft. The spacing of the crew member seats is similar to the pitch and width used in the coach section of a commercial airliner. A distance of 10cm around the crew compartment pressure vessel has been provided to allow for structural supports.

For automated rendezvous and docking the Argo will be equipped with a deployable radar system. For ascent and descent the radar mast will be stowed in an external compartment located on the starboard side of the spacecraft's nose. Once in orbit and within range of the ISS the radar mast will be deployed and activated.

To allow the Argo to dock with the American segment of the ISS the spacecraft will need to be equipped with a variant of the APAS-89 docking adapter. The APAS-89 docking adapter, while originally developed by the Soviets to support the Buran and Mir 2 programs, has since been modified for use on the space shuttle, ISS, and the Chinese Shenzhou spacecraft. While the APAS-89 can be placed at any location on the spacecraft, it will be placed on the front of the Argo to simplify the design by reducing the thermal protection needed. An adequate amount of area will surround the docking mechanism as to allow for the attachment of the tow rocket launch abort system.

The location of the Argo's stowed parafoil is another component that will affect the external shape of the spacecraft. Two options exist for the parachute compartment, the first being in the nose and the second being on the top side of the spacecraft. Stowage in the nose provides the simplest means of deployment. Stowage on the top side of the spacecraft allows for the best configuration for landing of the spacecraft. With the majority of the nose of the Argo being taken up by the forward maneuvering thrusters, it is necessary to locate the parafoil compartment on the top side of the spacecraft. In order to provide a large enough compartment, the majority of the compartment will be located to the rear of the crew cabin.

A drogue parachute will be required to stabilize the Argo prior to parafoil deployment. The drogue chute will be stowed in a separate compartment forward of the parafoil compartment. After deployment of the drogue and reorientation of the spacecraft from tail (heat shield) first to belly first orientation the parafoil compartment will be opened. The aerodynamic forces on the drogue will be used to pull the parafoil out of its compartment. The parafoil will be automatically detached from the spacecraft after touchdown of all landing gear wheels.

While the parafoil will only provide one to two miles of flight after deployment that is sufficient when used with modern guidance systems which allow for landings within several hundred meters of the target.

The RCS system is a system that can be separated into CM and SM segments. For ascent and departure from the ISS the nose control jets on the CM and the SM control jets. For reentry, and as a in the event of a failure of the SM RCS all CM jets will be used. The CM will have eight pairs of opposing roll/translation thrusters mounted in the nose, four pairs of coarse thrusters and four pairs of fine control thrusters as well as eight identical pairs mounted just forward of the heat shield. The CM RCS configuration is shown in Figure 2.

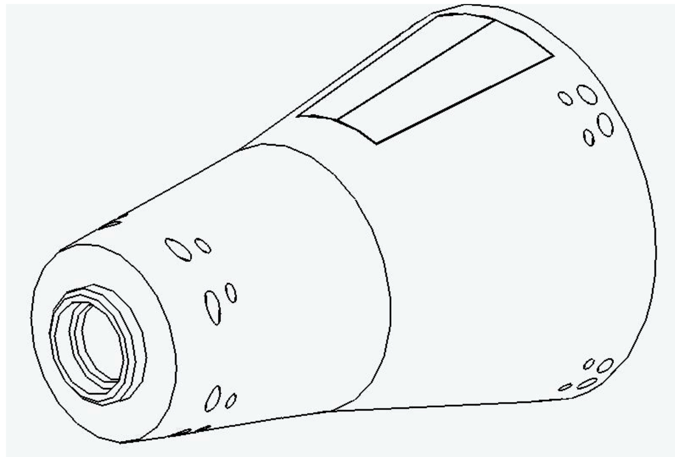


Figure 2. Forward Isometric View of the CM External Design with RCS Jets and Parafoil Compartment Doors Visible

The SM RCS will have 14 jets arranged in two three jet and two four jet configurations. The three jet configuration will consist of two opposing roll/translation thrusters and a 30 degree outward canted reverse translation thrusters. The four jet configuration will have the same three jets as well as a single forward translation thruster. The reason for the outward facing reverse translation thruster is to prevent damage to the ISS during breaking maneuvers on final approach to the Pressurized Mating Adapter. The SM will also contain the Argo's OMS. A single fixed engine will be fitted on the roll axis. The OMS engine will provide thrust for major orbit maneuvers as well as the deorbit burn. The configuration of the SM RCS jets and OMS engine is shown in Figure 3.

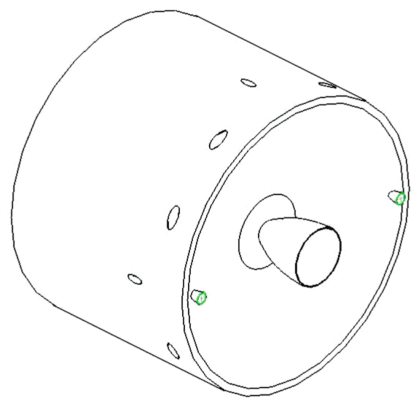


Figure 3. Aft Isometric View of the SM RCS and OMS Configuration

To ensure that the Argo will have an on orbit lifetime of 100 days, it will utilize separate systems for ascent and descent. There will be a single set of hydrogen and oxygen tanks feeding two independent fuel cells. One fuel cell will be activated before launch and shutdown after docking has been completed. The second fuel cell will be activated prior to undocking and will be shutdown prior to SM jettison. For power during reentry and landing batteries will be used. Power for battery charging while docked will be provided by a power umbilical from the ISS. The water supply for the crew will be provided by the fuel cells.

The life support system will also be separated into ascent and descent systems. The breathable air supply will be stored in two separate tanks. The ascent tank is located in the SM, while the descent tank is located in the CM. The breathable air that is required will only be needed to account for losses due to leaks and controlled depressurizations, air filtration will be handled by lithium hydroxide canisters located in the crew cabin.

Spacecraft cooling will be accomplished through the use of heat exchangers to pass heat from the crew cabin to the ammonia based radiators on the exterior of the SM.

The landing gear configuration used on the Argo is a tricycle configuration. The forward landing gear will be stowed in a compartment that extends from between the two forward crew seats and forward below the docking tunnel. The aft landing gear will be stowed below and two the rear of the crew cabin. The landing gear systems will gravity deployed with the assistance of a deployment spring. Automatically locking clamps will secure the landing gear in the deployed position. The aft landing gear will be equipped with brakes to control the roll out of the spacecraft after touchdown. The forward wheel will be able to rotate freely to allow for movement when differential braking is used for control during roll out and while the spacecraft is being towed off the landing strip.

In the event of an emergency landing at sea air bags in the landing gear bays will inflate to stabilize the spacecraft.

With the primary systems accounted for, it is now possible to determine the location of the crew entry/egress hatch. To ease egress the hatch will be located on the port side of the spacecraft at the same position as the rear seats. The hatch will be fitted with a 30cm diameter window; an identical window will be fitted on the opposite side of the spacecraft. Windows to be used by the pilot and commander during landing are located on the forward section of the CM. These windows will not provide forward viewing as the forward view will be provided by video feed from a camera located below the docking collar.

Figure 4 shows the configuration of the conceptual design for the Argo spacecraft. It should be noted that not all features discussed above are shown.

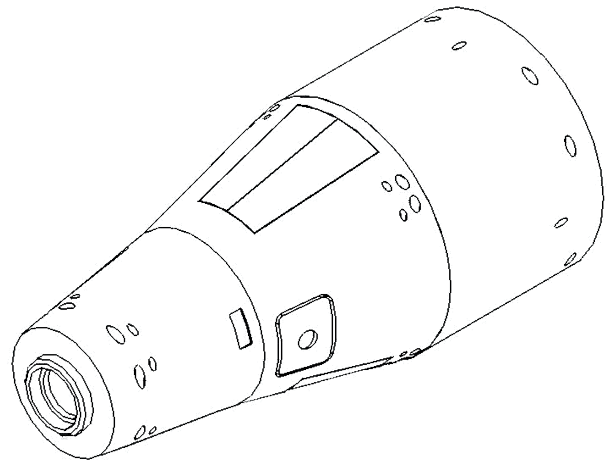


Figure 4. Argo Conceptual Configuration

IV. Compatible Launch Vehicles

This conceptual design has a total spacecraft volume of 68.92 cubic meters. As this is only a conceptual design the mass of the vehicle can only be estimated. Table 2 shows the densities for the Apollo (both command and service modules) and the Gemini spacecraft. With the advancements in materials, as well as in computers, fuel cells, and batteries; it is possible to assume that the Argo will have a mass density closer to that of the Gemini spacecraft. For the purposes of this discussion it will be assumed that the overall density of the Argo is 160kg/m^3. This will result in a spacecraft mass of approximately 11000kg.

Table 2. Historical Spacecraft Densities

Spacecraft	Density (kg/m^3)
Apollo	407
Gemini	123.3

With an estimated maximum mass it is possible to determine which launch vehicles are will be capable of launching an Argo spacecraft. Two variants of Boeing's Delta IV family will be capable of launching the Argo. These are the Medium+(4,2) and the Medium+(5,4) which are capable of placing 11,455kg and 12,894kg in to ISS orbit respectively. The Lockheed Martin Atlas V 401, the smallest of the Atlas V family, is also capable of placing the Argo in ISS orbit as it has a low earth orbit (LEO) payload capability of 12500kg. Table 3 shows the per unit cost of these three launch vehicles.

Table 3. Launch Vehicle Cost

Launch Vehicle	Per Unit Cost ($\$10^6$)
Delta IV Medium+ (4,2)	138
Delta IV Medium+ (5,4)	160
Atlas V 402	138

Both the Atlas V and Delta IV launch vehicles are part of the EELV program which will give the Argo unprecedented launch flexibility. If it is deemed necessary and Argo could be mated the next available booster and launched to the ISS on short notice. This will also allow for Argo flights to continue uninterrupted in the event either booster family experiences a catastrophic failure and is temporarily grounded.

V. Mission Profile

This section will outline the major events for a typical Argo mission to the ISS. The launch vehicle for this mission profile is the Atlas V. The launch section is the only section that will detail flight events with specific event times.

A. Launch

All times are shown in days, hours, minutes, and seconds as appropriate.

T- 0:09:00	Launch vehicle rollout begins
T- 0:08:30	Launch vehicle arrives at the pad at Launch Complex 41
T- 0:06:30	Atlas and Centaur power up and checkout
T- 0:06:00	Argo spacecraft power up and checkout
T- 0:05:30	RP-1 propellant loading begins
T- 0:04:20	RP-1 propellant loading completed
T- 0:03:00	Crew enters the spacecraft
T- 0:02:15	Spacecraft hatch is sealed
T- 0:02:00	Centaur LOX loading begins
T- 0:01:35	Atlas LOX loading begins
T- 0:01:20	Centaur LOX loading completed
T- 0:01:15	Centaur LH_2 loading begins
T- 0:00:35	Centaur LH_2 loading completed
T- 0:00:20	Crew access arm retracted
	Launch abort system armed
T- 0:00:03	Atlas LOX loading/replenishment complete
T- 0:00:00	Liftoff
T+ 0:00:04:41	Atlas shutdown
T+ 0:00:04:55	Centaur ignition
T+ 0:00:06:00	Launch abort system jettison
T+ 0:00:12:18	Centaur shutdown
T+ 0:00:13:30	Argo spacecraft separation from Centaur

In the event of a scrubbed launch the crew will be required to remain in the spacecraft until the LOX and LH_2 are off loaded from the launch vehicle.

B. Rendezvous and Docking

The Argo spacecraft will approach the ISS from the positive in-track side of the complex. Once the Argo has closed to within five kilometers of the ISS it will be determined which docking port will be used. The two available option are PMA-2 and PMA-3. If it is decided to dock at PMA-2 the docking approach will continue. If it is decided to use PMA-3, the Argo will need to maneuver to below the ISS to begin the approach to PMA-3. At a range of 200m the Argo will slow to a relative speed of 0.5m/s for docking. At any time during the automated approach a crew member can take over and manually dock the Argo to the ISS using docking alignment target in the PMA as seen through a video feed from a camera in the center of the APAS-89 docking mechanism.

After the Argo has docked with the ISS, the docking tunnel must be pressurized to the internal pressure of the ISS. The Argo spacecraft will then be pressurized/depressurized as need to match ISS atmospheric pressure. After all pressures have been equalized, the forward hatch will be opened and the hatch to the ISS will be opened.

The Argo will be powered down by the commander and pilot once the three passenger crew members have entered the ISS.

C. Departure and Deorbit

Several hours before departure from the ISS the commander and pilot will enter the Argo and begin the startup sequence. The power umbilical from the ISS will be used to start up the descent fuel cell. Once the descent fuel cell is fully operation the electrical umbilical to the ISS will be shutoff.

One hour before departure all crew members will be onboard and the hatches between the Argo and ISS will be closed. After depressurizing the docking tunnel the Argo will be checked for leaks. If all leak checks are passed the Argo will undock by firing the outward angled translation thrusters on the service module. Once sufficiently clear of the ISS the Argo will fire its OMS engine to lower its orbit taking the spacecraft away from the ISS. A second firing of the OMS engine will be required to recircularize the orbit at the lower altitude. Between these two OMS firings the radar mast will be retracted into is stowage compartment.

Once all final checks have been completed the crew will strap in to their seats as the final preparation for reentry. The Argo will be oriented with the OMS engine leading in preparation for the deorbit burn. At the appropriate point in the orbit the commander will transfer the CM to battery power and start the automatic firing sequence. Once the deorbit burn in completed the SM will be separated. To prevent a collision between the CM and SM during reentry, the CM will translate to the left after separation, once the CM has moved approximately 10m away from the SM, the SM will automatically fire its forward translation thrusters moving it away from the CM.

During a nominal reentry the CM will be put into a 20deg/s roll to cancel out the effects of the Argo’s lift vector which is created by an offset center mass. If descent rate or cross track maneuvering is required, the roll can be stopped and the lift vector aim appropriately. Angle of attack control will be provided by the RCS thruster on the nose of the CM.

D. Landing

After slowing the Argo will continue on a semi-ballistic trajectory. At 45,000ft the drogue chute will deploy to slow, reorient, and stabilize the spacecraft in preparation for parafoil deployment. At 20,000ft the parafoil will be deployed. Once fully deployed, the parafoil will allow the Argo to maneuver to a landing at a runway within one and a half miles of the parafoil deployment point.

The landing gear will deploy 1000 feet above ground level and lock into place. Landing will occur by first weighting the aft landing gear wheels and then having the nose wheel lower under the restraint of the parafoil. Once all three landing gear struts register continuous loading the parafoil will be cut free. At this point the commander will use differential breaking to keep the Argo on the runway.

Once the RCS system has been secured, the egress hatch will be opened from the inside and the crew will exit the spacecraft.

E. Launch Abort

In the event of an abort in the final 20 minutes of the countdown or during the first six minutes of flight, the launch abort system will be activated. When activated a solid motor tow rocket mounted in front of the CM will fire simultaneous with the release of the CM from the SM. After motor shutdown the launch abort system separation motor will fire separating the system from the CM. The CM will then make an emergency water landing.

VI. Conclusion

It is possible to develop the Argo spacecraft such that it operational prior to the retirement of the space shuttle fleet. To achieve this firm spacecraft requirements have been minimized. As a result the design of the Argo resulted in a two section spacecraft with the Crew Module capable of making controlled landing at a conventional runway under a parafoil. Based upon weight estimates it will be possible to have the Argo launch atop either a Delta IV Medium+ or an Atlas V 400 series booster. This gives the Argo a flexibility no piloted spacecraft has ever had. By providing a launch abort system the Argo will be the first American spacecraft in 30 years to provide a means for crew survival in the event of a launch vehicle failure.

While not an inexpensive option for crew transportation during between the space shuttle and CEV programs, the Argo spacecraft will ensure a continued American presence and space and will serve a complementary vehicle to the CEV once the exploration beyond low earth orbit resumes.

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