EXCALIBUR ALMAZ

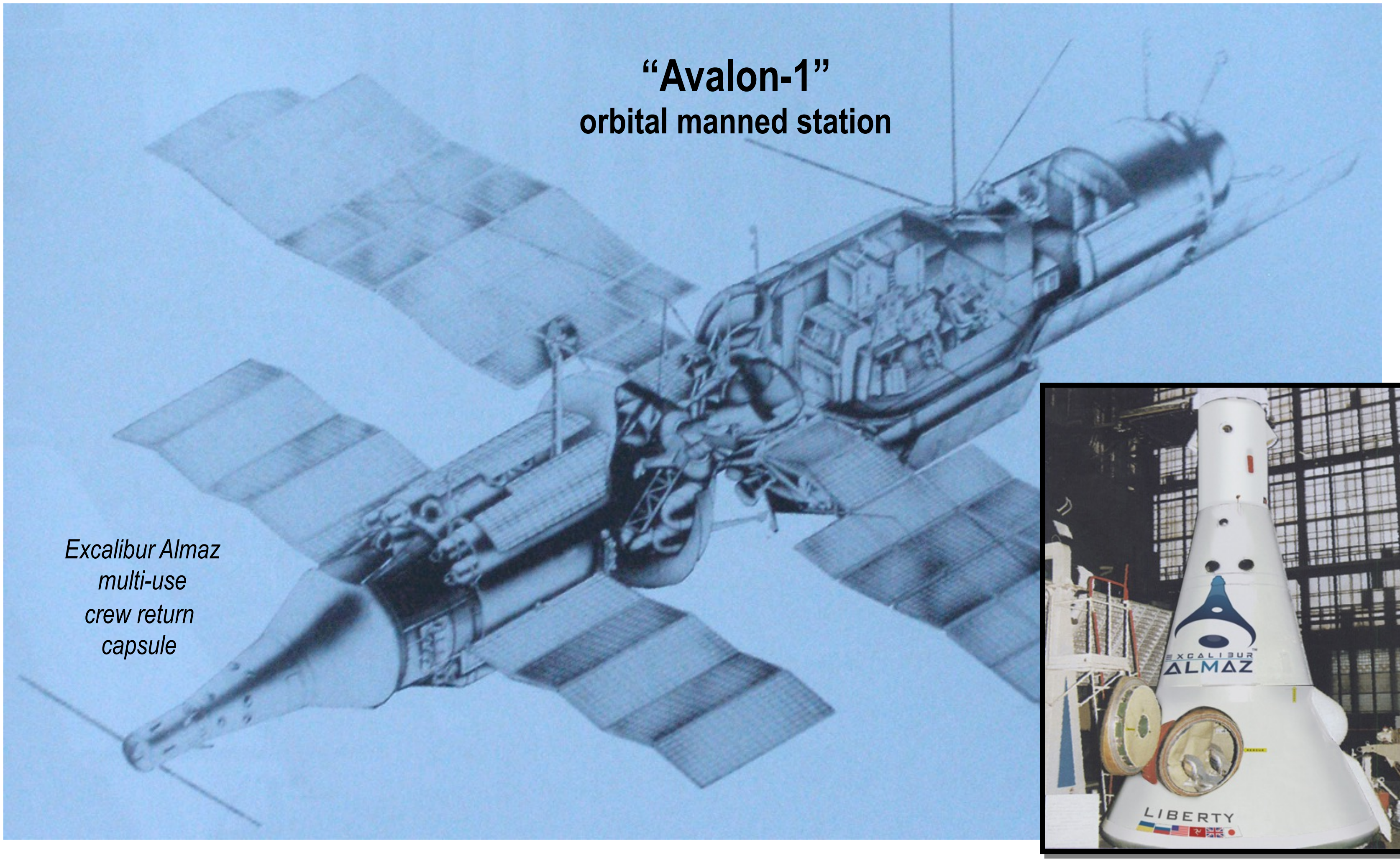
Almaz Technical Material

EA02P009

Background

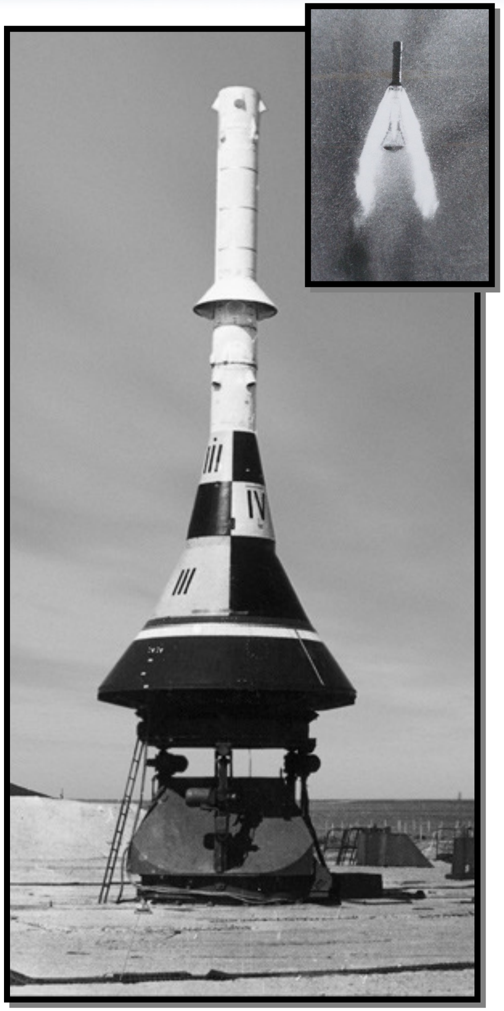
- The Russian hardware under review was developed in the 1970s and 1980s to support their Almaz Space Station
- Two Almaz capsules were located on the ALMAZ Station and were ultimately used for returning equipment and samples to the earth
- The capsules were "man rated" and were occupied on orbit to check out life support and habitability features but were never flown manned
- The Almaz Capsules were capable of carrying three crew members
- The general size of the capsules was comparable to the U.S. Gemini capsules. The total mass of the capsules is 4853 kg (10,700 lb)
- Delivery of the operational capsules to orbit is accomplished attached to the station
  - Four hard-points located in the heat shield provide the mechanical linkage with the station
  - A hatch, also in the heatshield, is connected via a flex section and tunnel to the station
  - Utility connections for power, cooling, atmosphere make-up, and data are provided

Avalon-1 Space Station

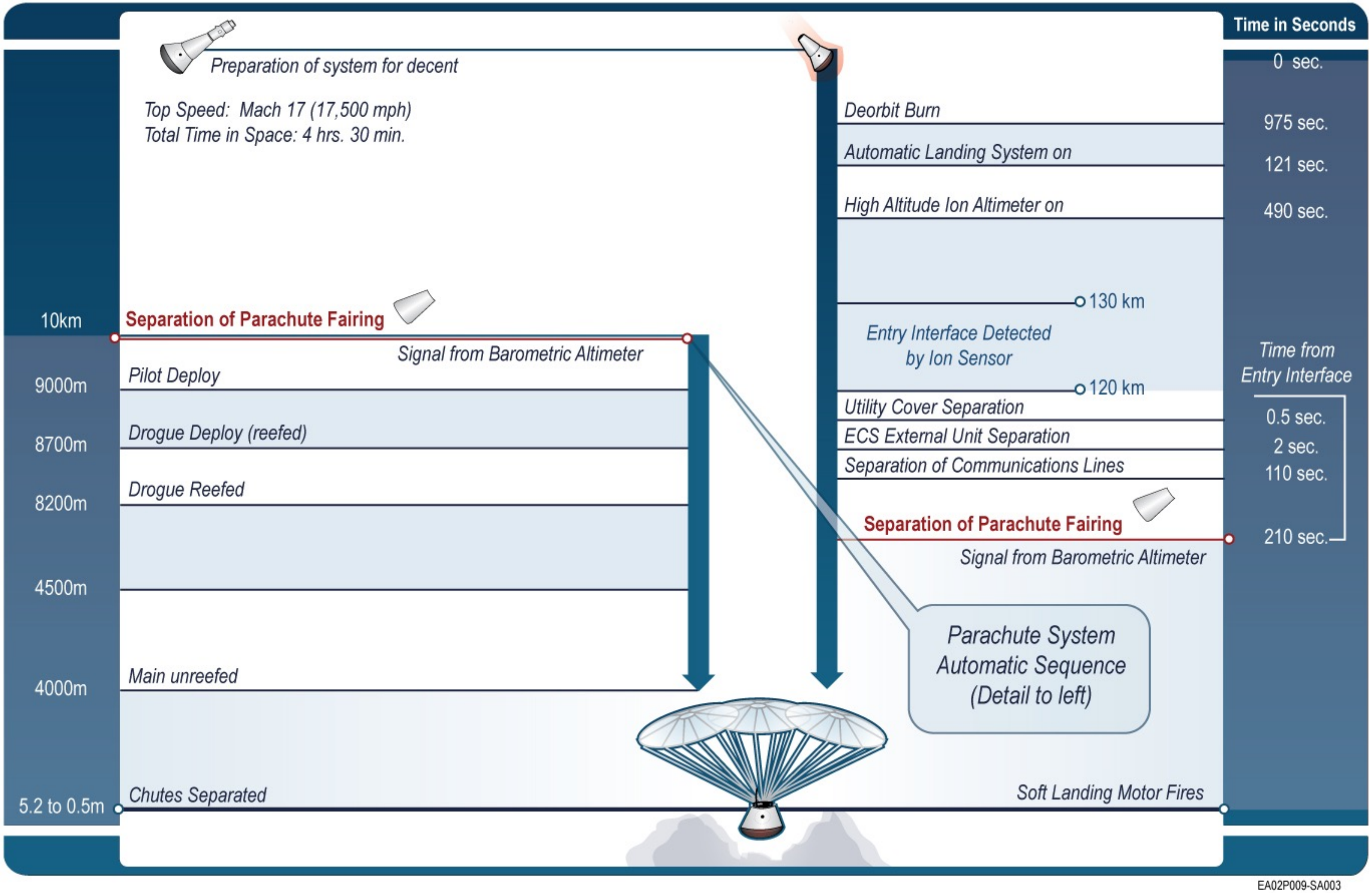


Flight Operations

- At separation, pyrotechnics separate the crew access tunnel, the utility lines and the hardpoints
- Alignment for re-entry can be performed manually or automatically
- The selection of landing sights can also be performed manually or automatically
- The solid propellant deorbit motor provides the delta v for entry
- Attitude control is via a UDMH/Nitric Acid bi-propellant system
- Pilot and drogue chutes are deployed followed by three main canopies
- At touchdown (generally on land) a breaking motor fires adaptively at from 1 to 5.2 meters above the ground depending on the decent velocity
  - Shock absorbers in the seats absorb additional shock from the landing
  - Water landings are also possible, have been tested, and the vehicle has only one stable position in the water



Flight Operations *(cont'd.)*



Flight Testing

- The vehicle has been extensively flight and ground tested
- Ten flight tests were conducted
- In three of these flights the capsules were flown two at a time
- Three failures occurred during the testing program
  – One failure was a result of a proton booster malfunction
  – On another, separation of the external Life Support unit caused a malfunction which prevented landing operations from occurring. The cause of the anomaly was discovered and modifications were implemented

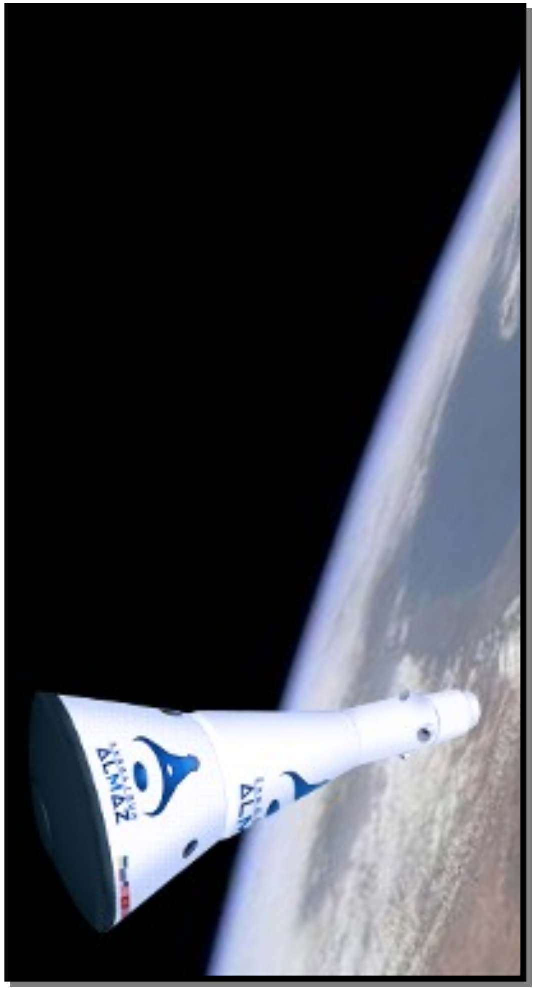
Flight Test Summary

Major Systems / Technical Parameters Under Test	Flight Object 1 (12/15/76) 009A Kosmos 881	Flight Object 1 (12/15/76) 009 Kosmos 882	Flight Object 2 (12/08/77) 009A/11	Flight Object 3 (03/30/78) 009A/112 Kosmos	Flight Object 3 (03/30/78) 009/112 Kosmos	Supply Spacecraft1 7/1/77 to 8/16/77 Kosmos 929	Flight Object 4 (05/23/79) 102/1 Kosmos 1100	Flight Object 4 (05/23/79) 102 Kosmos 1101	Supply Spacecraft 2 3/2/83 to 8/23/83 103/3 Kosmos 1267	Supply Spacecraft 3 4/25/81 to 5/24/81 103/4 Kosmos 1443	No. of Launches Accomplished and Partially Performed
Structure	●	●	●	●	●	●	●	●	●	●	*8 + 2*
Thermal Protection System	●	●	●	●	●	●	● *Emergency Landing*	● *Emergency Landing*	●	●	*7 + 2*
Including Restoration	→	→	●	●	●	←					*2*
Automatic Flight Control Systems	●	●	●	●	●	●	● *to 67 km*	● *to 80 km*	●	●	*8 + 2*
Control Systems	●	●	●	●	●	●	● *to 67 km*	● *to 80 km*	●	●	*7 + 2*
Landing System	●	●	●	●	●	●			●	●	*8*
Seats, Cosmonaut Control Panels, Suit Ventilation and Cooling System							●	●	●	●	*2 + 2*
Radio navigation											
Communications				*Includes Relaying* ●	*Includes Relaying* ●		*Includes Relaying* ●	*Includes Relaying* ●	*Includes Relaying* ●	●	*6*
Taking Bearings	●	●	●	●	●	●			●	●	*8*
Algorythms of Orientation, Decent Prior to Aviation of Chutes	●	●		●	●	●	● *to 67 km*	● *to 80 km*	●	●	
Flight Models											
Launch Vehicle Emergency			●								*1*
Not Stabilized							●				*1*
Restoring of Orientation							●				*1*
Ballistic Descent	●	●					● *to 67 km*				*2 + 1*
Controlled Descent				●	●	●		● *to 80 km*	●	●	*5 + 1*
Propulsion											
RCS System	●	●	●	●	●	●	● *to 67 km*	● *to 80 km*	●	●	*8 + 2*
Solid Motors	●	●	●	●	●	●	●	●	●	●	*10*
Flight Duration	*1 Orbit*	*1 Orbit*		*1 Orbit*	*1 Orbit*	*60 Days*	*2 Orbits*	*1 Orbit*	*50 Days*	*175 Days*	
Retro Rocket Fiting Altitude	*241*	*225*		*221*	*219*	*211*	*225*	*221*	*275*	*362*	
Maximum Acceleration (Gs)	*8.4*	*8.6*	*X= 10.5, Y=6, Z=4.3*	*4.5*	*5.3*				*5.0*	*5.0*	

EA02P009-SA004

Capsule Design Highlights

- The vehicle has been designed for simplicity of construction, operation and refurbishment
- The design is characteristic 1970's technology particularly in the avionics subsystems
- The high reliance on pyrotechnics characterizes the design in nearly all subsystems
- The heatshield is refurbishable (demonstrated)
  - A hatch penetrates the center of the heatshield
- A large part of the ECLS/TCS is mounted in on the heatshield exterior
  - Jettisoned prior to entry interface and not recovered
- The RCS assembly is jettisoned and not recovered
- Nearly all of the plumbing is of welded stainless steel construction and were performed with automated equipment
- The pressure shell is composed of waffle panels which are also welded automatically



Source: McDonnell Douglas 1997 Assessment

Capsule Design Challenges

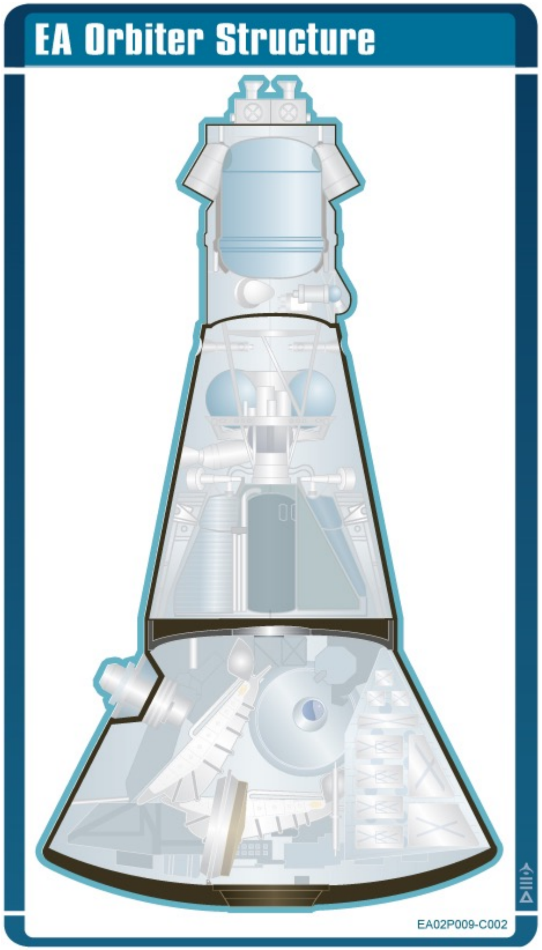
- The Nitric Acid propellant limits on-orbit life to less than 3 years. A change to Nitrogen Tetroxide in under consideration
- The Life Support system uses pressurization via suits as a back-up to cabin leakage. Reliance on suits should be reduced or eliminated
- ECS/TSC hardware and the RSC are lost during reentry. Reusable/recoverable designs are under consideration
- Most of the avionics and communications equipment should be upgraded to modern standards
- The seats do not accommodate the full anthropopetric range for Station crew. The redesigned Soyuz seats are a candidate for replacement
- An effort will be required to refurbish the solid motors and the parachute system to return them to flight status. Provisions on Russia can be made available on a non-recurring basis to accomplish the refurbishment
- The de-orbit motor needs additional thrust to return from the maximum Station altitude

Subsystem Overviews

- Structures/Mechanical
- Thermal Control
- Life Support
- Crew systems
- Avionics
- Propulsion Systems
- Parachute Systems
- Thermal Protection System
- Flight Dynamics
- Flight Support System Concepts

Structures and Mechanisms

- The Almaz capsule's basic structure is simple and efficient
  - The overall assembly is abeam-column with separable sections
  - Four "stringers" run the entire length of the assembly providing a backbone for load transfer
  - In the lower, manned portion of the capsule, an additional three stringers provide extra stiffness and locations for attachment of internal components
  - The four main stringers end at the four hardpoints used for support of the capsule on the ground or when connected to the station on-orbit
- The main structural materials in the capsule are aluminum alloys
  - The characteristics, uses (sheet, welded, extruded, etc.), and time frame of the design indicate that the manned portion is a 2000 series alloy and the other structures are a 6000 series alloy
  - Other materials, such as titanium and stainless steel are used in areas where high strength or low thermal conductance is needed



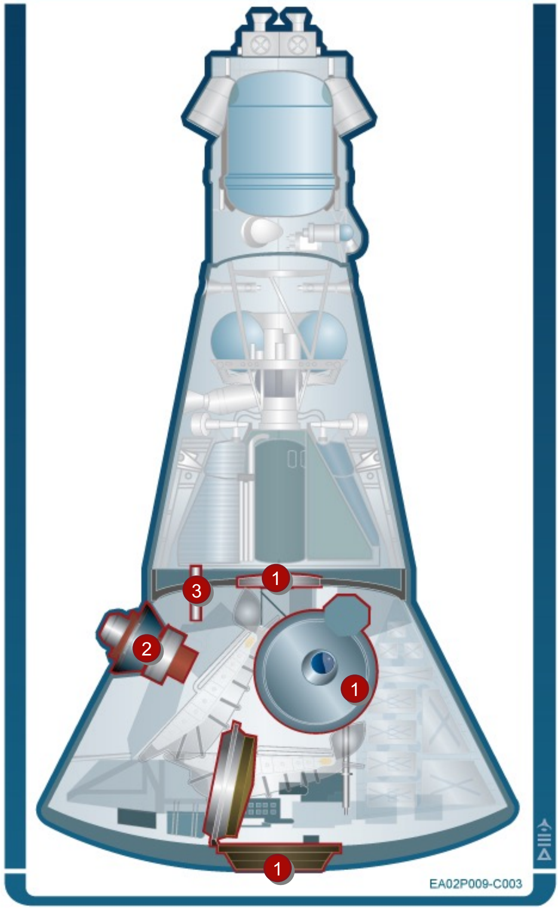
Structures and Mechanisms *(cont'd.)*

- The joining of components is done through fastening (rivets and bolts); welding; and lacing (parachute system)
  - Fasteners are Soviet military specification
  - Explosive bolts are used extensively in the separation systems
  - Lockwires are used as a positive locking device, but were only observed in areas not readily accessible to the crew (such as the reentry maneuvering engine)
- Space qualified welds are a specialty of the Russians
  - The air tight welds of the manned capsule were done using automated equipment with 100% X-ray inspection
  - Each part to be welded was oversized in order to cut away a sample of the welded joint
  - The sample was ultrasonically inspected, chemically and subjected to tension and bending tests
  - Any weld not passing these inspections was scrapped without attempting repair. New panels were fabricated and the process restarted
  - Welds not designed to hold pressure were done by hand, followed by a visual inspection and a proof test
  - All weld processes were perfected on prototypes before manned qualified capsules were built

Structures and Mechanisms (cont'd.)

- The pressure vessel portion of the Almaz capsule is penetrated at numerous points
  1. Three hatches (two with windows)
  2. Optical guidance system window
  3. Feed-through locations for cables and fluid lines
- Each penetration has redundant seals, with at least one of the seals held by the pressure inside the capsule
  - All seals are leak checked with helium at the local level and as part of the overall assembly
- The hatch and optical guidance windows are redundant against failure by including two quartz panes in each window
  - Each pane has three seals, any one of which can hold the total pressure
  - Leak checks are done to ensure that each seal is functioning properly
  - The space between the panes is filled with dry Nitrogen
  - A soft sealing material around the edge of each pane allows differential expansion between the pane and its frame without inducing stresses

EA Penetration Points



Structures and Mechanisms *(cont'd.)*

- The hardware was designed and verified by analysis and test. Safety factors used in the analyses are:
  - 2.0 for transportation and handling
  - 1.1 for on-orbit, decent, parachute deployment, landing, and splashdown
  - 1.3 for emergencies
  - 1.3 for active boost excluding areas in vicinity of maximum dynamic pressure
  - 1.5 for active boost in areas in vicinity of maximum dynamic pressure
- The only areas that do not meet current NASA requirements are
  - Non-critical structures during liftoff, where NASA requires a factor of 1.5 for proof test and 2.0 against ultimate strength. The Almaz orbiter proof tested at 1.5 times maximum design pressure
  - No analysis was done to determine fatigue of fracture life
    - A philosophy of extensive inspection after each flight was adopted. The high safety factor for ground handling and transportation was chosen to offset some of the uncertainty from these cyclic loading conditions.

Structures and Mechanisms *(cont'd.)*

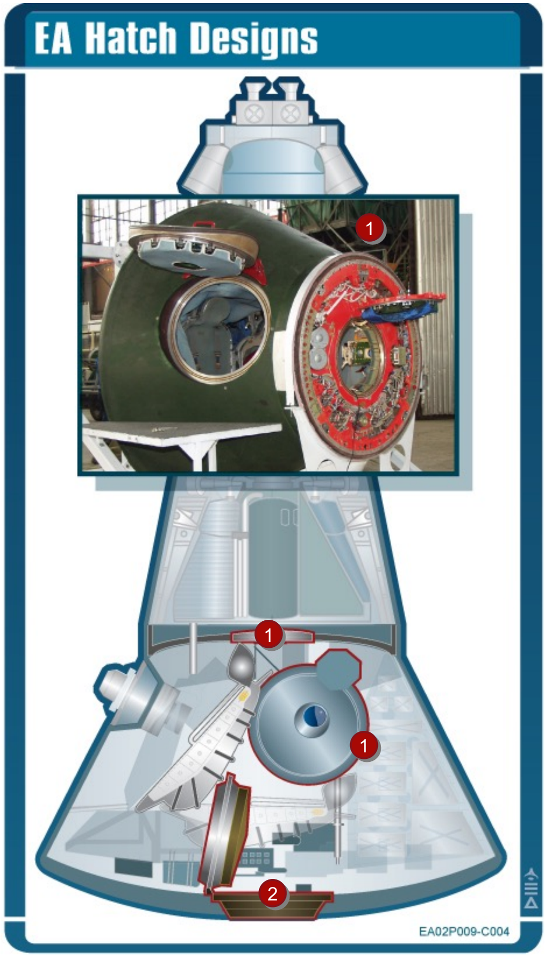
- Extensive test were conducted on qualification units
  - Loading conditions were checked through tests, including bending, tension, compression, buckling, and burst
  - The manned portion of the capsule was found to be able to withstand a negative pressure of 6.6 psi.
  - Dynamic tests were performed to characterize the structure and determine the environment to which internally mounted components will be subjected
  - These tests were extensive and to higher levels than those currently required by NASA for flight in the Space Shuttle
- The Almaz capsule uses five main types of mechanisms
  - Pyrotechnic devices (valves, cutters, explosive bolts, etc.)
  - Hatch opening and closing systems
  - Parachutes deployment system
  - Separation system (between sections of the spacecraft and for separating from the space station)
  - Seat shock absorption system
- The overall philosophy is to keep them light, simple, and redundant

Structures and Mechanisms *(cont'd.)*

- The Almaz capsule contains 39 pyrotechnic devices of 12 types
  - These devices are throughout the assembly, including inside the crew compartment
  - All use standard Russian explosive charges and design techniques
  - They are highly reliable, weigh very little, act almost instantaneously and allow redundancy to be built in relatively easily
- Safeguards are built in to prevent excess energy from breaking the device. Gas and fragments are not allowed to escape
- Explosive bolts operate in a manner similar to such devices around the head and nut
- The "High Current" design allows for continuity testing through the pyrotechnic device

Structures and Mechanisms *(cont'd.)*

- Two different designs are used for the hatch opening and closing mechanisms
  1. The first is contained in the side and top hatches
     - This design allows the seat to be broken and the hatch opened by moving a lever from a "closed" to an "open" position
     - The top hatch contains hinges and can be opened to several positions from just "cracked" to fully open
     - These two hatches can be opened from the outside through use of a special tool that fits onto a shaft that connects to the inner mechanism
     - These two hatches can make use of a single pull lever since their seal is checked on the ground before flight and they are not opened of closed again until after landing
  2. The bottom hatch mechanism requires the crew to set a toggle lever to "open" of "close" and then to pump a handle until the hatch seals
     - It is estimated that 20 pumps are required. Sealing is indicated by a light on the crew panel that is activated by two micro-switches on the hatch. The entire operation is estimated to take less than 30 seconds for an untrained crew member
     - This Hatch can be opened and closed while connected to the station, but is not opened after landing. Its mechanism is also designed to handle the loads that occur during impact
- Each mechanism makes use of such standard features as locking pins, travel-limiting stops, and over-center linkages to ensure safety and functionality

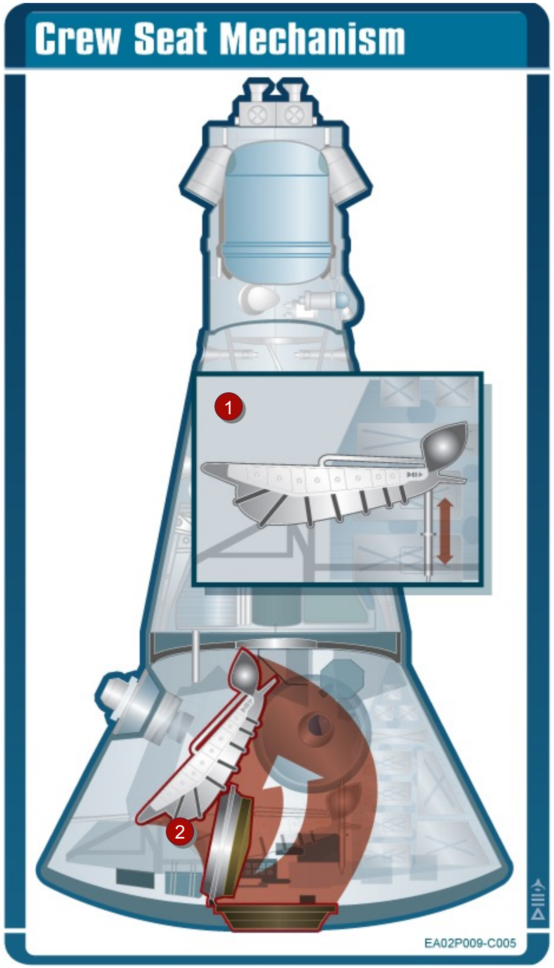


Structures and Mechanisms *(cont'd.)*

- Separation systems are very simple, pyrotechnically initiated assemblies
- Cables are separated using a cutter that has booth redundant charges and blades
- The crew entry"tunnel" is held together by a band clamp that fits into groves on either side of the interface
  - To separate, explosive bolts are fired that then release the tension on the band , allowing separation of occur
  - The assembly is set up to allow the failure of one of the bolts to shear without compromising function
- The separation mechanisms between the various sections of the overall orbiter assembly are fail-safe
  - Each joint contains a triangular link held to the the section above by an explosive bolt and to the section below by two explosive bolts
  - This creates a stable joint that can handle failure of one of the bolts to shear

Structures and Mechanisms *(cont'd.)*

- (1) Each crew seat is a mechanism that deploys upward to prepare for landing
  - This is accomplished through a hinge at the foot of each seat and a shock absorption system at the head
  - The shock absorber is essentially a piston in a cylinder. A charge fills the chamber with gas, moving the piston (and the seat) about 10 inches
  - During landing, the piston moves back along the cylinder, resisted only by friction
  - Test have shown that this system keeps the acceleration on the the crew to 3 g or less
- (2) The center seat moves away from the hatch below it to allow crew ingress to the orbiter
- This is the same seat used in the Soyuz vehicle, and NASA and Energia and currently redesigning it to allow larger crew members to use it



Structures and Mechanisms Summary

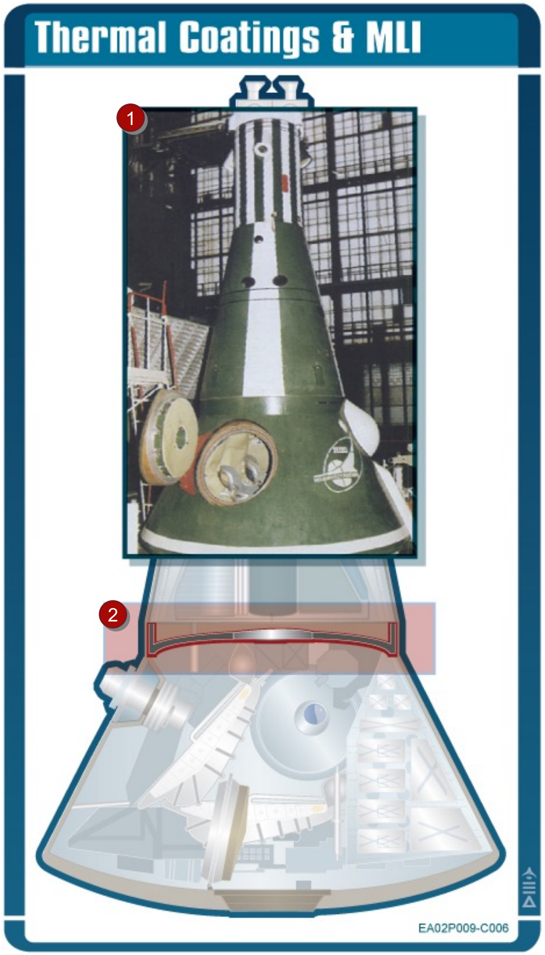
- All structural hardware will require a detailed inspection and cleaning. Any areas not passing inspection (such as due to corrosion) will require an assessment
  - It is anticipated that most problems will be resolved by minor repair or designated "use as is"
  - Mechanisms will require complete refurbishment to ensure proper operation
- All areas accessed by the crew during normal or contingency operations will require an inspection for sharp edges
  - All areas not meeting the Space Station requirements will need to be reworked
  - Based on the visual inspection of the hardware, most of the hardware will need some rework
- Structural hardware that will be replaced:
  - Seats and seat attachment hardware (including shock absorber)
  - Hatch and shell penetration seals
- In addition, any brackets or secondary support structure hardware that supports systems that are being redesigned or replaced (such as avionics or ECLSS) will likely require modification or replacement

Thermal Control

- Passive thermal control on the Almaz orbiter is used primarily to maintain the thermal control of the subsystem equipment which is exposed to space vacuum
- Two principal passive thermal control techniques used are multilayer insulation and thermal coatings with selected optical properties
- The primary equipment that is thermally protected using passive mechanisms include the
  - RCS system where the UDMH and Nitric Acid must be protected from freezing
  - External Life Support equipment assembly
- For the original mission there were no attitude constraints for the capsule
- Thermal control was predicted analytically and the results compared with thermal vacuum chamber data and actual flight data using an instrumented capsule
- The flight data was generally more benign than the analytical predictions

Thermal Control *(cont'd.)*

- (1) The Thermal Coatings for the vehicle have been selected to provide the best thermal balance for the vehicle considering the influence of direct solar radiation, albedo, and earth infrared sources
  - A dark green coating covers the capsule body and parts of the RCS/parachute shroud and the Deorbit motor shroud
  - White stripes are used on the RCS/Parachute enclosure to lower the average surface temperature and are used to a greater extent on the Deorbit motor shroud
- (2) The Multi-layer Insulation (MLI) design is similar to the U.S. designs for the Shuttle, Spacelab and SPACEHAB
  - Almaz uses a 17 reflector layer separated by a fine mesh
  - The outer layer used a fiberglass cloth to provide abrasion resistance
  - The MLI is applied on the inside surface of the RCS/parachute shroud as well as inside the deorbit motor shroud



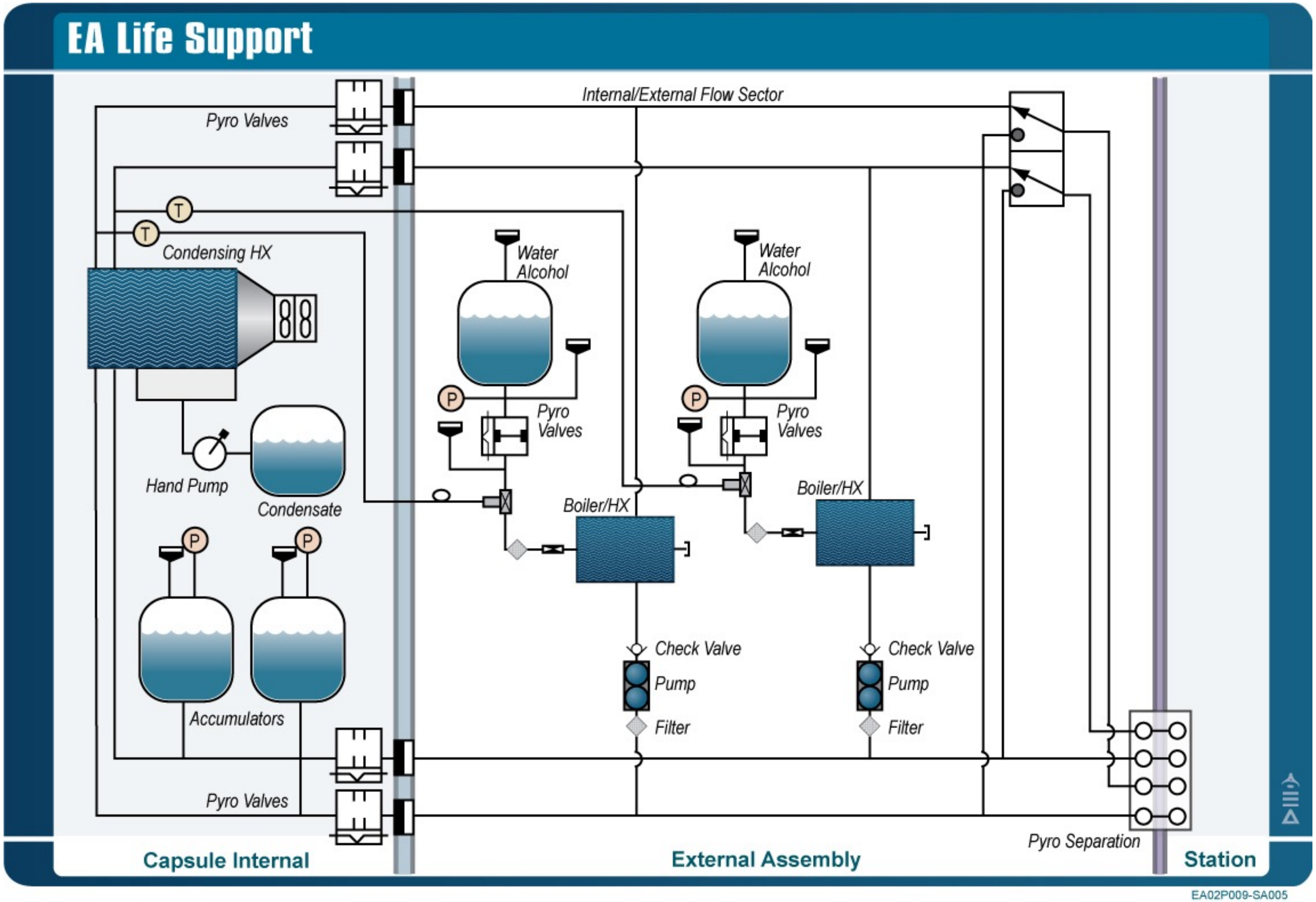
Thermal Control Summary

- No modifications are considered necessary for the vehicle thermal coatings to the support the ACRV mission
- Some analytical examination of the vehicle thermal response to the Space Station environment will be necessary to certify the design and this will be supported by optical property measurement on the received capsules
- One of the critical life issues for the Almaz capsule is the storage life of the Nitric Acid component of the bi-propellant RCS
  - It has been proposed that the Nitric Acid be changed to Nitrogen Tetroxide which has essentially an indefinite storage life. This change, however, raises the minimum temperature limit for the RCS from -40° C to -2° C
  - To provide better thermal control of the RCS assembly the MLI can be moved from the inside to the outside surface. This moves additional "thermal mass" inside the blankets and allows for a cleaner MLI design with fewer penetrations
  - This change is possible because an Almaz orbiter ACRV would probably be launched on the shuttle which will not expose the surface to aerodynamic loads

Life Support

- The Almaz orbiter Environmental Control and Life support System performs the following functions:
  - Temperature and Humidity Control
  - Atmosphere Composition Control
  - Atmosphere Pressure Control
- On-orbit, the air temperature is maintained from 15 to 25 ° C
  - During reentry, the cabin air temperature is maintained from 30 to 35 ° C
  - No structural condensation has been observed during periods when the capsule was manned on-orbit
- Oxygen partial pressures, humidity levels and CO_2 concentrations are maintained well within allowable limits for the nominal mission profile
- Due to the short duration of the mission, no trace contamination control provisions exist in the capsule
  - The control of trace contaminates is accomplished by the air exchange with the station which is maintained during capsule storage on-orbit

Life Support (cont'd.)



Life Support *(cont'd.)*

- The Temperature and Humidity Control system is a dual system which circulates a water glycol mixture (40% glycol) to control the temperature and humidity in the orbiter
  - While attached to the Almaz Station, the mode selector was configured to direct the flow to the station where the fluid pumping functions and the heat rejection were provided by the station
  - For the Space Station crew return mission, the capsule will not need to support crew operations while attached to the station, therefore, the fluid interface with the station is not required
- The orbiter will exchange air with the Space Station during quiescent periods which is sufficient to maintain temperature, humidity and composition control within the uninhabited orbiter volume
- When the Temperature and Humidity control system is activated to support return operations, the primary heat sink is provided by water alcohol (20% alcohol) boilers which transfer the latent heat of vaporization to the fluid loop
- Both fluid loops are active in normal operation and each of the pumps provide a 130 kg/hr pumping rate
- The plumbing system is stainless steel and all joints except for LRU interfaces are welded

Life Support *(cont'd.)*

- The condensing heat exchanger is of plate-fin construction and includes a wicking material to direct the condensate to a holding manifold. The condensate is transferred to a holding tank by the use of a manual pump which is used by a crew member every 2 hours
- The cabin fan provides flow for the condensing heat exchanger and ventilation for the cabin. The fans are arranged in series. The air flow rate is 220 kg/hr
- A large part of the Temperature and Humidity control assembly is located on the External Unit which is mounted outside of the module on the heatshield
  - This unit is separated from the orbiter pyrotechnically prior to entry interface (120 km). The fluid system is isolated at the separation plane by pyro valves

Life Support *(cont'd.)*

- Atmosphere Composition control is accomplished using an O_2/N_2 gas supply and a CO_2 regeneration unit.
  - The atmosphere make-up is provided from a storage tank which is mounted both internally and on the external assembly and contains a mixture of Oxygen and Nitrogen.
  - The current system is designed to support suit operation and provides a 40% Oxygen / 60% Nitrogen mixture which is compatible with the 400 mm Hg suit operating pressure.
- The CO_2 scrubber used potassium Peroxide to remove Carbon Dioxide from the air. The reaction is as follows:
  - $4\,KO_2 + 2\,CO_2 \rightarrow 2\,K_2CO_3 + 3\,O_2$
  - The regeneration unit is a cylindrical assembly mounted in the capsule. Approximately 20 kg of KO_2 is contained within the 32 Kg assembly.
  - The unit has it's own fan for exchange of atmosphere with cabin.
- A gas analyzer monitors the O_2, CO_2 and Humidity. The monitor provides a caution and warning function but does not participate as an active element in the control loop.

Life Support *(cont'd.)*

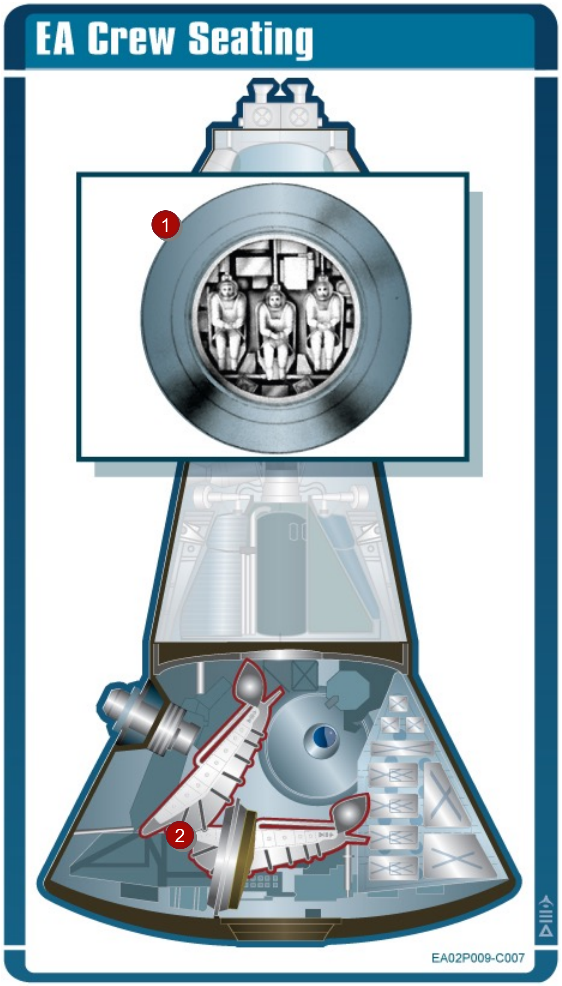
- Module pressure control is a contingency function only due to, the short duration of the reference mission
  - The pressure control is designed to maintain the cabin pressure at 760+200/-120mm Hg
  - In the event of an over pressure condition pyro valves fire to enable the system for operation
  - Electrically operated valves will open to vent cabin atmosphere overboard. A manual valve is provided to override the venting function
  - In a low pressure condition pyro valves operate to enable the space suits. The suits operate at 400 mm Hg
- At 3.8 km altitude, ventilation valves operate to open the cabin to external air
  - Fans are activated to provide 80 m3/hr of air exchange
  - These valves are electrically operated and have manual override
  - The operation of these valves also prevents negative pressure loads on the capsule, however the capsule can structurally withstand 0.4 atm (6.6 psi) without collapse

Life Support Summary

- The basic design of the Life Support System is considered adequate to support the Space Station ACRV mission
- The TCS coolant may need to be changed from water/glycol to another fluid if toxicity is deemed unacceptable
- The system design also will need to be modified to eliminate the reliance on suits for contingency crew support in low pressure conditions
  - This modification may require additional gas supply inside the cabin for leakage make-up

Crew Systems

- The seating arrangement for the crew is three abreast
  - (1) The right-hand (starboard) crew person enters the capsule, followed by the left-hand (port) crew (the co-pilot position, unless a sick crew is being transferred), followed by the capsule commander in the center seat
  - (2) The commander seat/couch is in a raised position, allowing access for the lower transfer hatch to be closed and verified
  - (2) The center seat is then lowered and secured, and the commander and the remaining crew can secure their seat harness restraints.
  - (1) The current seats/couches are similar to those of the Soyuz vehicle. The crew is required to sit in a tight "fetal" position
  - (2) The Almaz seats can accommodate a crew height of 182 cm (95 cm in seated position) and a weight up to 80 kg
- The capsule crew compartment is covered with a blue colored closeout fabric material
  - The closeouts are used on the hatches and the slide wall surfaces
  - They present the crew with a "clean" appearance by covering up the myriad of mechanical boxes, cables/connectors and fluid lines/fittings; as well as heir supporting structure



Crew Systems *(cont'd.)*

- The commander occupies the center seat.
  - There is a display of the earth surface (projected from an image coming through a window in the lower/earth side on the capsule) on the center line in the commander' s primary field-of-view. (The observation window is 200 mm in diameter, with two panes of optical glass.)
  - There are two major control panels, one on each side of the capsule, within the commander' s reach and field-of view.
- The majority of the crew operated controls are large hand knobs (shape coded), handles and switches (toggles, push buttons, and selector switches)
  - Inadvertent actuation of switches is prevented by pull-to-operate toggles, flip-up switch covers (for push buttons) and prerequisite witch operations to make matrixed push-button switches active.
  - The major control panels are a light gray color, much like the U.S. capsules
    - The push button/lights are also color-coded to signify their functional criticality (red-warning/most critical; yellow/amber-caution, less critical, etc.).
    - Push button switches are back-lighted when pushed
    - The controls, especially the push buttons, are configured for operation by a suited crew member, so they are well spaced and large

Crew Systems *(cont'd.)*

- The primary operational crew roles resides with the commander. The commander' s role includes:
  - The closing, latching and verification of the lower/transfer hatch 9in heat shield).
  - Separation of capsule from station.
  - Selection of a landing site.
  - Selection of re-entry mode (automated/manual) (orbital maneuvering/orientation, de-orbiting, etc., if manual).
  - Monitor automatic sequences (ready to override, if required).
  - Monitor other subsystems, with assistance of other crew members.
- The co-commander is responsible for pumping out the condensate tank.
  - This is accomplished by moving a short handle back and forth.
  - This control is located on the port side of the capsule. The operation must be repeated every two hours (it takes about 15 seconds to complete).

Crew Systems Summary

- The crew system design is robust and was very capable of meeting the then current Almaz mission requirement to safely return a crew of three from orbit
- The following items are recommended system refurbishment and technology updates
  - The medical and rescue related kits should be refurbished or replaced with standard, planned NASA and/or Russian Space Agency provided items (GFE).
  - The seats and their associated sock attenuation system should be replaced. The new seat system should be able to accommodate a person ranging from 5 percentile Oriental female to 95 percentile American male (projected to the ISS timeframe).
  - Crew aids, such as hand holds, should be provided for mobility tasks.
  - The communication system should be capable of providing voice connectivity between the capsule, the ISS, and both the control centers (NASA and RSA).
  - The ECLSS should be upgraded to assure and environment for nominal non-suited crew.
  - If it is deemed cost effective to replace much of the components behind the control and display panels (relays, computers, etc.) then consideration should be given to update these panels with state-of-the-art computerized keyboards/displays.

Avionics

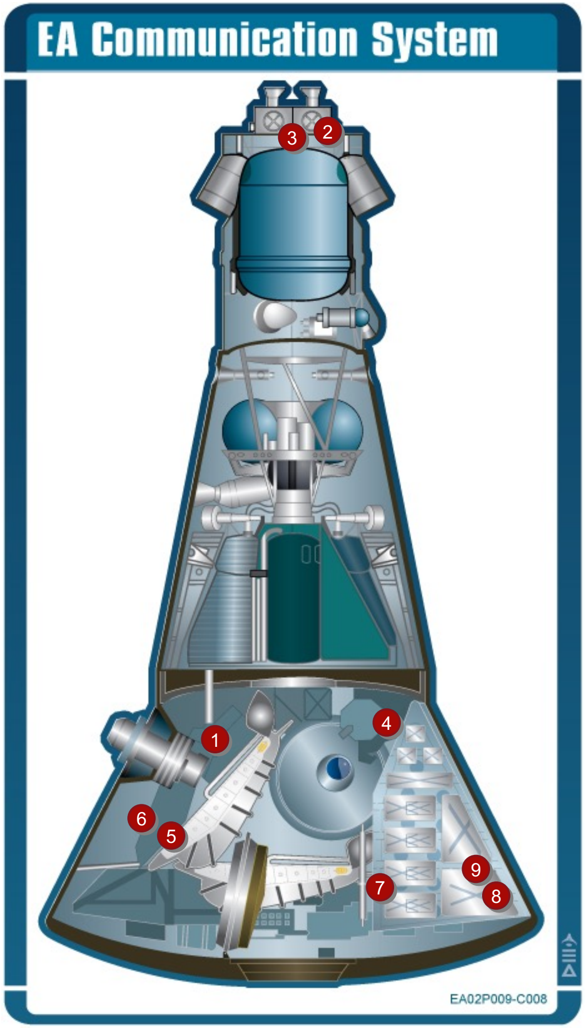
- The Electrical Power Distribution System consists of the following components
  - Two (primary and backup) silver zinc batteries (75amp Hr capacity)
  - 50 fuses and Cabling
  - 40 Vac 1000hrz converters
  - (0-6) Vdc regulators
- The ACRV electrical system is a 27 Vdc (+5/-2V) system comprised of two batteries.
  - Once the voltage level of the main battery falls below 25 Vdc, the vehicle will operated off both batteries, or the system can be reconfigured to operated off of the second battery only.
  - The batteries themselves are composed of silver zinc and are charged for 110 amp-hr. (75 amp-hr./battery requirement) operation.
  - The batteries have a shelf life of one year and have been shown to operate effectively after 186 days on orbit.
  - Activation/switching of batteries can be achieved automatically via computer command or manually via crew command.
- Power system hardware are selected in lots and are tested at the piece part level. Once assembled the undergo wide regimen of tests including thermal, vibration, and EMI/EMC.

Avionics *(cont'd.)*

- This system contains discrete converters and regulators to provide secondary voltages of 0 to 6 Vdc for telemetric measurements/sensors and 100Hz 40 Vac for stabilization gyros
- The cabling for the system is composed of Teflon insulated, silver plated copper which is sized to allow a maximum of one volt drop to any subsystem
  - Connections are made via chrome plated, circular screw type connectors, with silver plated contacts
  - Connectors are keyed so that cross connection is prevented and all external connections use hermetically sealed connectors of the same configuration
  - Circuit protection is provided by 50 crew replaceable fuses. These fuses are sized to allow 10 to 15 A operation on conductors rated for 20 amps and 4 to 5A operation on conductors rated for 10 amps
  - Corona hazards are controlled by hermetically sealing all power switching devices
  - All equipment is bonded directly to the vehicle structure and maintains a maximum of .1 ohm resistance (Class R is .2 ohm)
  - All returns are isolated from structure and a single point ground scheme is not utilized

Avionics *(cont'd.)*

- The communications system consists of the following components
  1. Removable communications unit
  2. 13 antennas of different types
  3. Short Wave (SW) and Ultra Short Wave (USF) RF transmitters/receivers
  4. Radar beacon
  5. Detachable beacon
  6. TV camera
  7. Voice recorder box
  8. Light beacon
  9. USW beacon
- The communication hardware is comprised of discrete components using single and multilayer board technology. These components are selected in lots and tested at the piece part level. Once assembled they undergo a wide regimen of tests including thermal, vibration, and EMI/EMC



Avionics *(cont'd.)*

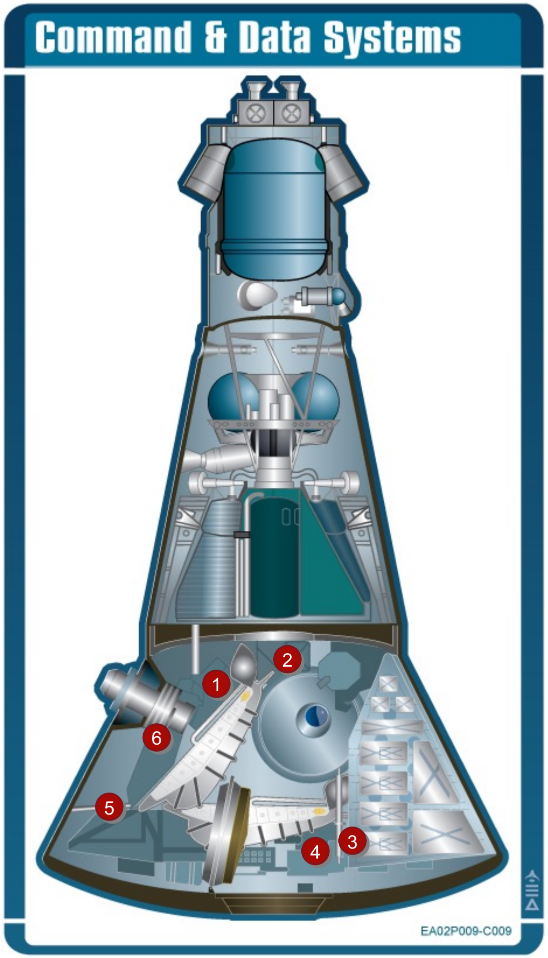
- ACRV communications system provides for crew/ground communications, vehicle tracking, and video down link
- Communication between crew and ground stations is supported through all phases of flight via two frequency bands
  - These frequencies are USW which is 121 MHz to 143 MHz and SW which is 8.3 MHz to 20 MHZ
  - USW communication utilizes three antennas which are mounted to the vehicle hull
  - SW transmission utilizes different antennas depending on the particular flight phase that the vehicle is in
    - During on orbit operations, the SW communication is supported via three antennas located on top of the crew section of this vehicle
    - Prior to decent, SW communication is terminated as these antennas are jettisoned from the vehicle so that the vehicle's reentry aerodynamics are maintained
    - SW communication is then restored post reentry via 6 antennas located in the parachute lines. These antennas are 9 meters long and the vehicle is equipped with two per parachute cupola
  - The vehicle is also equipped with crew select capability between frequencies so that two crew members can communicate with ground stations simultaneously on different frequencies

Avionics *(cont'd.)*

- In the event of loss of voice communication capability, a telegraph system is utilized to communicate with ground stations
- The orbiter is also equipped with a black box which records all audio conversations for up to eighty minutes, and an onboard camera which transmits crew compartment video to the ground while in flight
- Prior to the firing of the soft landing system, a detachable USW beacon operating at 114 MHz is deployed to aid in vehicle location and recovery
- The vehicle is equipped with several devices to aid in location and recovery operations. These devices include:
  - A USW beacon transmitting at 121.5MHz
  - A radar beacon with 150 KM range
  - A light beacon is raised and SW communication is restored via the deployment of a coiled antenna
- Included in the communication system is a removable communications unit
  - This unit is used after landing and can be taken with the crew upon egress for continued voice communications in SW and USW frequencies

Avionics *(cont'd.)*

- The Command and Data System consists of the following components:
  1. On board computer
  2. Quartz oscillator
  3. A/D converters
  4. Flight recorder box
  5. 64 Analog input sensors
  6. Two Telemetric units
- ACRV Command and Data handling is performed by an on board computer with a custom built processor and ferrite core memory
  - The computer has approximately 8K of permanent memory and 256 bytes of RAM
  - The computer can be programmed with state vector and attitude data while docked with an orbiting platform. This procedure takes 15 minutes and is used for vehicle reentry
  - Once programmed, the computer initiates reentry timelines utilizing a high precision quartz oscillator with a total of ±1ms. This timing device count down from t=1 (separation from orbiting platform) and at programmed intervals provides control of the vehicle's decent and landing phases
  - Bus communication protocol for this system is NPO Machinostroenia proprietary



Avionics *(cont'd.)*

- There are a total of two hundred discrete output commands and 64 analog inputs
- The discrete out commands are at 20V levels and 38 of them are critical to vehicle contingency/emergency functions
  - The critical commands have arm and fire capability and can be used in place of the computer generated commands to effect manual decent and landing of the vehicle
  - These commands are entirely redundant to the computer generated commands and are routed in separate cable bundles
  - These commands include, but are not limited to, firing of separation bolts, firing of braking motor and thrusters, and soft landiNg motor activation
  - Some of the non critical commands include activation of lights and fans

Avionics *(cont'd.)*

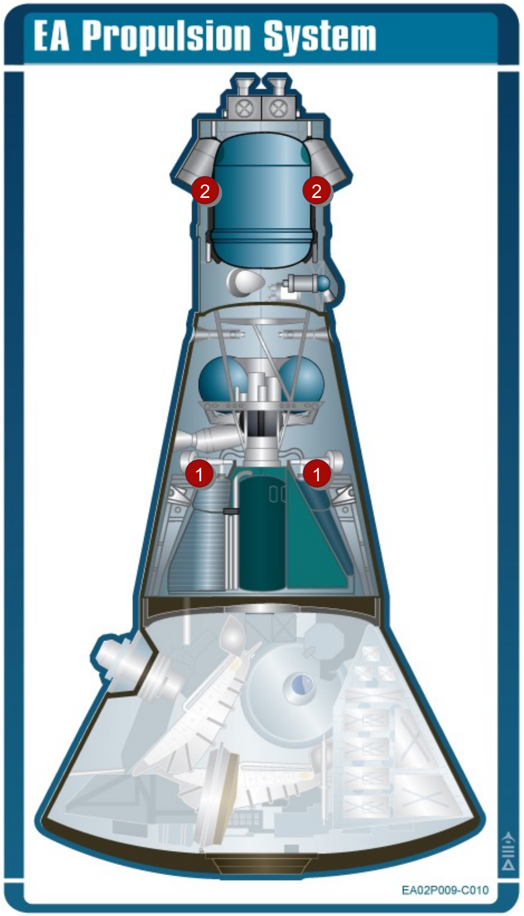
- The analog inputs are sampled by two independent telemetric units at 50hz.
  - The analogs are at 0 to 6 Vdc $\pm$ 50 mV and contain health and status measurements for the vehicle and crew
  - Once sampled the telemetric unit multiplexes the data and converts it into 9 bit words (8bits + parity) using A/D converters
  - This data is down linked to the ground at two different frequencies (160Mhz, 190Mhz) at a rate of 3.2K samples per second and is displayed at 1.5hz rate
  - This data is recorded on board by a flight recorder (black box) at the same rate
  - Some of the telemetric measurements include atmospheric density to determine altitude, capsule pressure, gas composition, humidity, temperature, and crew suit parameters
- The cabling for the command and data system is identical to the rest of the electrical system with the exception that all signal connections use gold plated contacts

Avionics Summary

- The Almaz orbiter has a simple and efficient electronic design
- When considering the intended future use of the vehicle, candidate areas for upgrade have been identified
  - The batteries do not meet the shelf life requirements. The batteries have a shelf life of 1 year and the intent is to have batteries with a 3 year life
  - Most of the computer, communications, and telemetric devices were custom built by Machinostroenia and subcontractors. This makes it impossible to build or acquire replacement components and there are no existing spares at this time
  - The associated Electrical Ground Support Equipment (EGSE) is no longer available. This makes it impossible to test and maintain the vehicle's current avionics system throughout its intended ten year life
  - Umbilical cable connections would also have to be modified in order to meet compatibility requirements with ISS
- The avionics system should be replaced before the vehicle can be utilized and maintained for its intended use

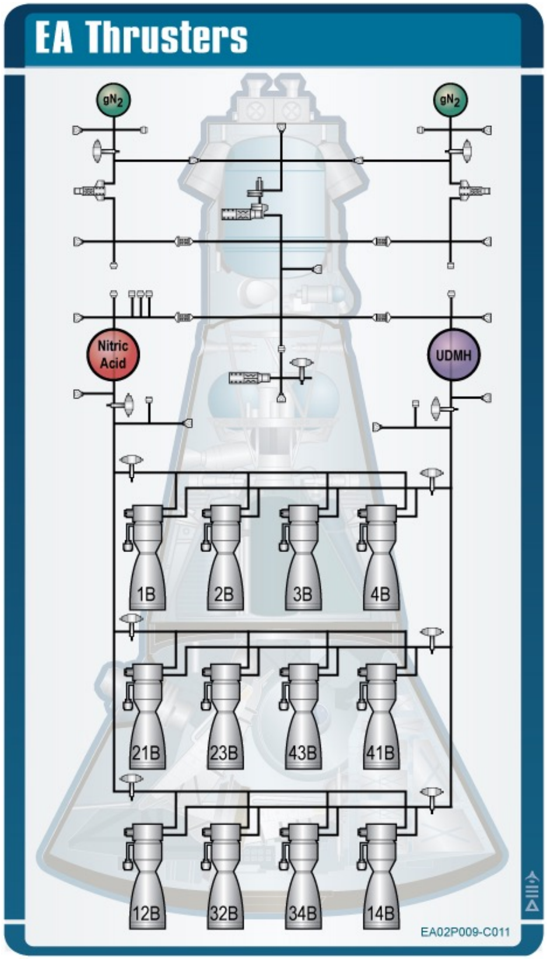
Propulsion

- The propulsion system on the Almaz capsule is composed of
  1. Liquid propellant reaction control system
  2. Solid propellant braking and diverter motors and a launch pad abort motor
- The reaction control system for the ALMAZ orbiter performs three functions
  - On-orbit attitude orientation
  - Yaw and pitch damping during atmospheric entry
  - The reaction control system is a bi-propellant system of twelve thrusters (~50# each) utilizing nitric acid as the oxidizer and unsymmetrical dimethydrazine (UDMH) as the fuel
  - The propellants are stored in aluminum spherical tanks of equal volume (~2ft Diameter) with aluminum foil bladders
    - The pressurization is provided by two spheres of gaseous nitrogen (GN2)
    - The total usable propellant load is 61kg (134.5 lb). The two bottles are stored at different pressures to provide a bi-level pressurization capability
  - This bi-level pressurization enables the RCS to provide the required attitude torque for operations for the two primary mass and center of gravity states during RCS operation
    - With braking motor and external environmental control unit (ECU) attached
    - With these systems jettisoned



Propulsion *(cont'd.)*

- The twelve thrusters are arranged in three groups of four thrusters manifolds
  - A pyrotechnic valve is located ahead of the thrusters in each manifold. This valve serves to isolate a manifold in the event of a thruster failure
  - The geometric layout of the thrusters facilitates a single "manifold out" scenario. Therefore, the system is single thruster fault tolerant
  - Pressure sensors in each thruster provide the feedback to verify proper operation
- As terminal velocity conditions are approached, the propellants in the RCS units are expended to the extent possible through successive balanced firings of the thrusters
  - At an altitude of 10 km the RCS unit is ejected from the capsule
  - The propellant purge operation is intended to minimize the possibility of explosion and/or fire when the RCS unit impacts the ground

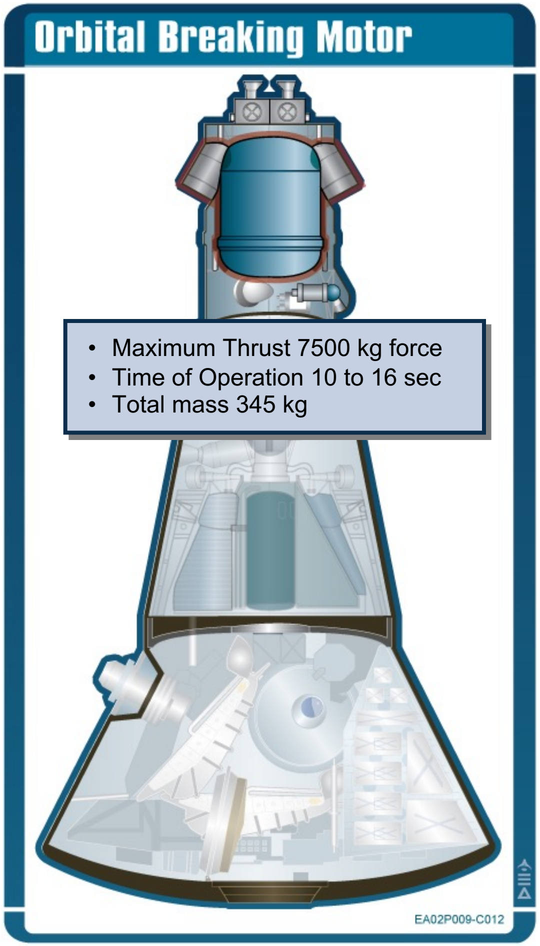


Propulsion *(cont'd.)*

- The reaction control motors are made of stainless steel with a brass jacket around the external throat section
  - The UDMH provides film cooling of the reaction control jets allowing unlimited operation time
  - The brass jacket is painted with a high emmissivity coating on the external surface to provide a high radiosity for heat rejection to space
- The orbital braking maneuver, soft landing, and fairing separation are accomplished using solid propellant motors
  - All motors use a double-base propellant form formulated with 57% Nitrocellulose (binder), 28% Nitrogen (plasticizer) and 15% additives
  - This is a propellant combination that NPO Mashinostroenia feels is very stable and has a ling (20 years) shelf life
  - All of the motors are of single impulse, fixed thrust vector design. Steel is used as the motorcase structural material

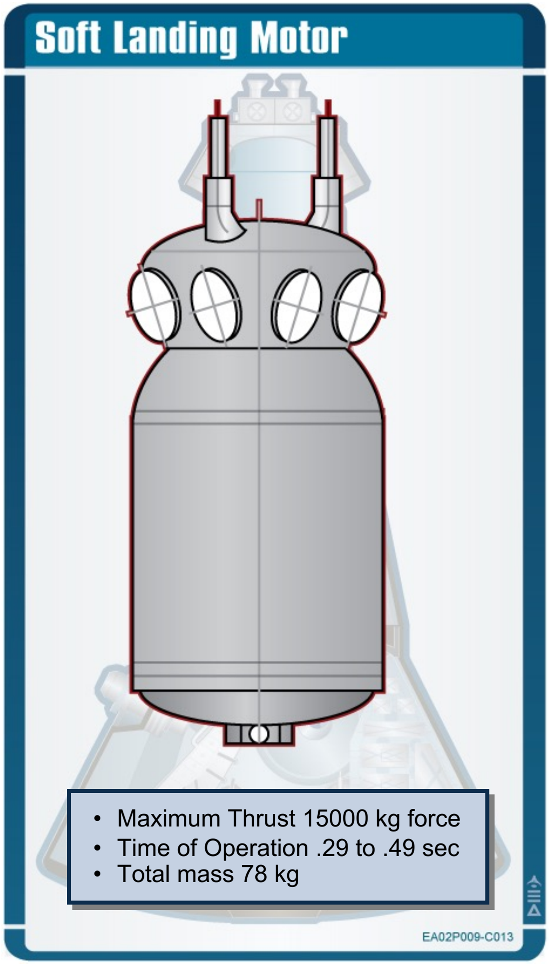
Propulsion *(cont'd.)*

- The orbital braking motor serves the purpose of creating the required deceleration (~90m/sec) for entering the required reentry corridor
- The spent motor along with the environmental control unit
- The motor has four nozzles separated by 90 degree angles from the centerline
  - The nozzles are canted at a 45° angle from the vehicle centerline. This provides a balance between useable impulse and thrust impingement of the capsule
  - The orientation of the nozzles in this manner creates a situation in which nozzles on opposite sides create opposing force components, thus diminishing the overall maximum impulse that could be attained if the nozzles were aligned with the center of gravity and flight path



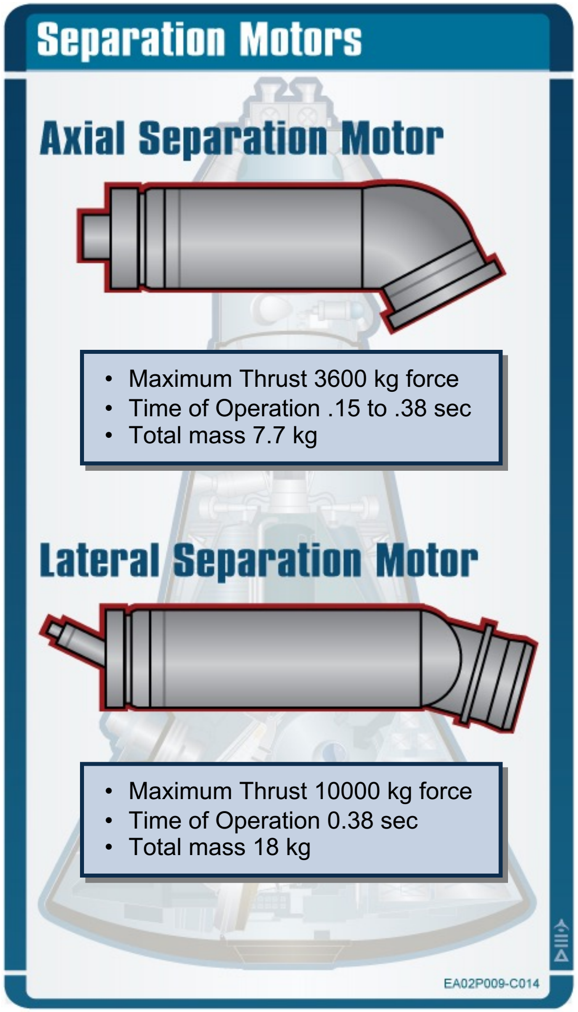
Propulsion *(cont'd.)*

- The soft landing motor is used to provide an impulse just before touchdown to reduce the terminal velocity of the orbiter/parachute system prior to contact with the landing surface
  - The motor is initiated by a signal from a gamma ray altimeter located within the capsule near the base
  - The motor assembly is located within the packed parachute assembly
  - The motor consists of nine nozzles with three each centered in each of the three sectors of the parachute pack shear panel structure assembly
  - Each nozzle is canted approximately 45° from vertical. Some plume impingement does occur on the structural panels of the parachute pack structure



Propulsion *(cont'd.)*

- The fairing separation motors are used to impart a lateral impulse on the ejected propulsion unit to prevent the unit from re-contacting the orbiter or parachutes after ejection
  - These solid motors accomplish axial and lateral separation of the fairing structure to expose the parachute and landing motor assembly



Propulsion Summary

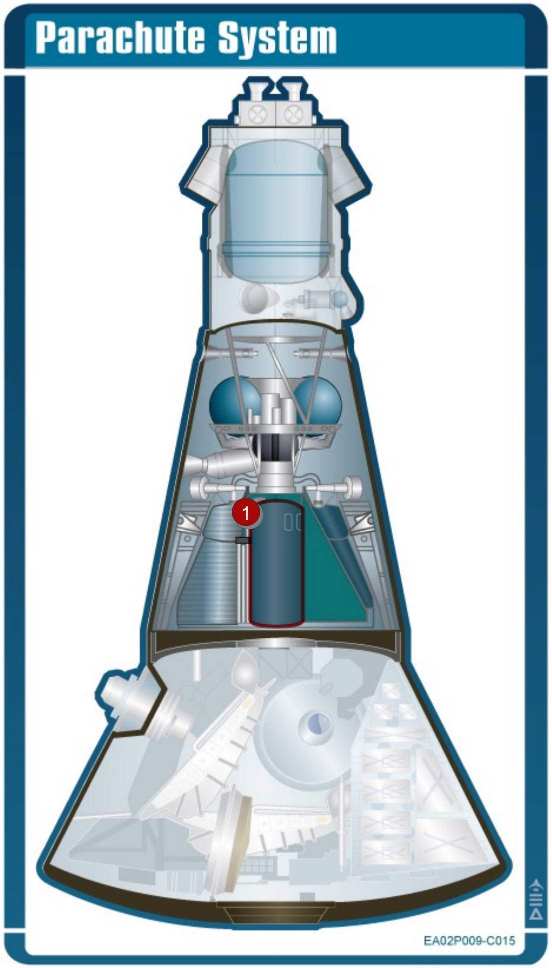
- Nitric Acid as a propellant oxidizer is an inhibitor to a three year on-orbit storage life. The RCS unit should be investigated for the possibility of changing the propellants to monomethylhydrazine (MMH) and nitrogen tetroxide (N_2O_4)
  - N_2O_4 has a higher freezing point than nitric acid introducing the possibility of the oxidizer freezing during long duration cold soak. N_2O_4 has a freezing point of 11.3° F while nitric acid has a freezing point of -52.6° F. Special insulation or heaters may be required to facilitate this change
  - MMH adnN_2O_4 have lower viscosities than UDMH and nitric acid introducing issues relative to the pressure balance of the system. A through analysis and ground test demonstration program is required to verify and validate a substitution of RCS propellants
- Almaz solid motors do not currently exist and their designs are only qualified for 1 year on-orbit storage life
  - All leftover solid motors have been destroyed since they have all exceeded their shelf life
  - NPO Mashinostroenia solid motor production program needs to be reinstated to support motors required for the ACRV
  - All future solid motors produced for the Almaz in support of the ACRV need to be re-qualified for three year on-orbit storage

Propulsion Summary *(cont'd.)*

- The braking motor for the Almaz orbiter does not meet ACRV requirements for transfer to the proper entry ellipse orbit
  - The de-orbit motor or "braking motor" needs modification to meet ACRV requirements
  - The velocity change increase required for an ACRV is estimated to be 113m/sec (369ft/sec) compared to the original Almaz design capability of 90m/sec (295ft/sec)
  - This increase in impulse will require modification of the motor
- The RCS propellant load may not be adequate to provide the necessary attitude stabilization for operation from ISSA orbit
  - RCS propellant is used on the Almaz orbiter to provide vehicle rotation and damping inall axis during orbital coast and atmospheric entry
  - Operation from the higher orbit of the ISSA with its slightly longer orbital period and transfer ellipse time is considered marginal by NPO Mashinostroenia
  - Increases in propellant consumption for limit cycling may require an increase in the RCS propellant load
  - A thorough vehicle rotation and limit cycling analysis should be done to provide a direct estimate of the propellants required and the margin that exists for using the Almaz capsule as an ISSA ACRV

Parachute System

- The parachute system for the Almaz capsule is a conventional series of closed canopy parachutes initially deployed by a mortar
  - The series of parachutes are packed in sectors around the axis of the subassembly
  - The deployment mortar, pilot and drogue parachutes are packed on the upper portion of the subassembly while the main parachutes are packed in 120 degree sectors on the lower section
  - The parachute system consists of a primary and reserve pilot chute, primary and reserve drogue chutes and three main canopies mounted on the top of the capsule
- The structural loads are reached into the capsule main structure by three primary load-bearing ribs
- The parachute material is a material similar to domestic nylon which give the system a maximum load limit of 16 metric tons



Parachute System *(cont'd.)*

- The pilot chute (1m2 and 17m shroud length) is deployed using a pyrotechnic mortar at a nominal altitude of 9000 meters in response to a signal from a barometric altimeter
- The drogue (18m2 and 11m shroud length) is deployed in a reefed condition at an altitude of 8700 meters
  - At 8200 meters (after approximately 7 seconds) pyrotechnic cutters cut the reefing belt to allow the drogue to open completely
- The three main chutes (590m2 each) are deployed reefed at an altitude of 4500 meters
  - Seven seconds later pyrotechnic cutters cut the reefing belts to allow the mains to open completely at 4000 meters
- Normal descent on the three main chutes is 5.9 meters/sec
- The solid landing motor reduces the decent rate to 0 to 3 meters/sec at touchdown
- Upon landing the parachutes along wiith the parachutes structural subsystem is jettisoned using pyrotechnics
  - This eliminates the potential for wind gusts on the main parachutes to tip the orbiter
  - Removal of the parachute structural sub assembly allows the cosmonauts to open the top hatch and egress

Parachute System *(cont'd.)*

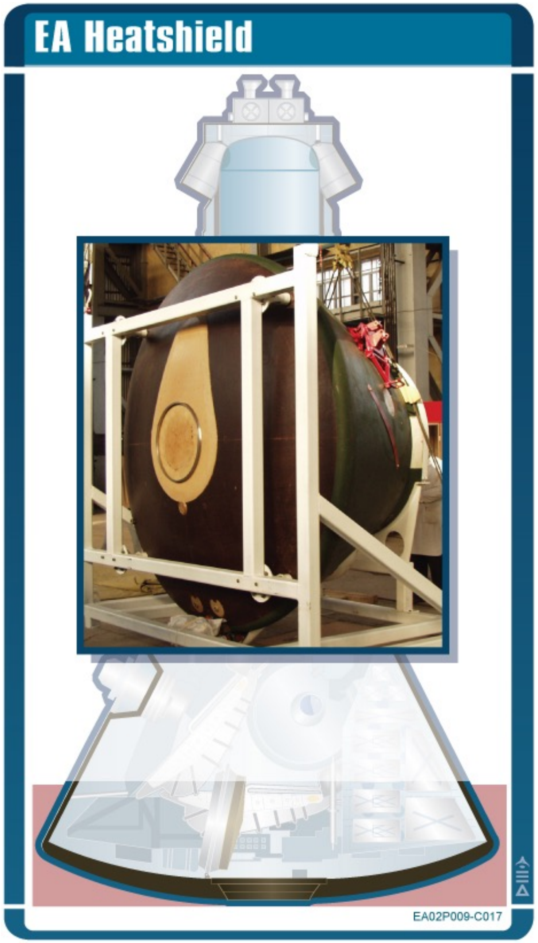
- The parachute system was qualified during full scale deployment tests in a wind tunnel and through numerous drop tests from an aircraft
- During aircraft drop tests the orbiter parachute system has been demonstrated to land without tipover in winds of up to 17m/sec (55.8ft/sec)
  - Further analysis performed by NPO Mashinostroenia suggests he landing winds up to 20 m/sec (65.6ft/sec) are possible without tipover
- The parachute system is designed to accommodate a number of contingency situations
  - A safe landing can be made if only two of the three main chutes deploy. Under this condition the increased rate of decent is sensed by the decent control avionics and the soft landing motor is fired early (an increase in height above the ground from 0.5 meters up to 5.2 meters)
  - A rotating attach structure allows the chutes to rotate relative to the orbiter without twisting the shroud lines
- The main parachutes contain 6 antennas imbedded in the risers to provide a signal for indication to the flight control system that successful parachute deployment occurred

Parachute System Summary

- The parachute system does not meet 3 year storage life requirements. The parachute systems is not qualified for reuse except for orbiter aircraft drop tests and currently no Almaz parachute systems are available for operational use
  - It is recommended that the parachute production capability be reestablished by NPO Mashinostroenia subcontractor
  - It is also, recommended that a life extension program for the parachute pack deployment and swivel operation be conducted to validate 3 year on-orbit life
- The pilot chute deployment motor is composed of a similar propellant system as the other solid motors on the Almaz capsule
  - The mortar should be included in the same propellant redefinition and life extension program as the other required solid motor systems

Thermal Protection System

- The orbiter primary heatshield is fabricated from three primary elements with varying thicknesses and installed on the orbiter structure with a combination of gap fillers and mechanical fasteners
  - The primary elements are a bottom spherical segment heatshield, the conical truncated cone segment and the propulsion section segment
  - A teardrop shaped layer of Teflon is bondedaround the center section of the lower surface of the heatshield to provide protection during the peak heating
- The transfer tunnel ring and Teflon heatshield are burned away from the lower surface of the refurbished heatshield
- The structural attach fittings are also burned off with local erosion of the heatshield in these highly augmented heated areas
- A unique approach was chosen that would allow reuse of most of the orbiter and heatshield system
  - A process to was developed revitalize the ablative heatshield for reuse of up to approximately ten times
  - The process that is used by NPO Mashinostroenia to recondition these heatshield is proprietary and would not be disclosed
  - The refurbishment process results in the replacement of the material thickness eroded from the fiberglass matrix and results ins small density increase in the outer layer of the heatshield



Thermal Protection System (cont'd.)

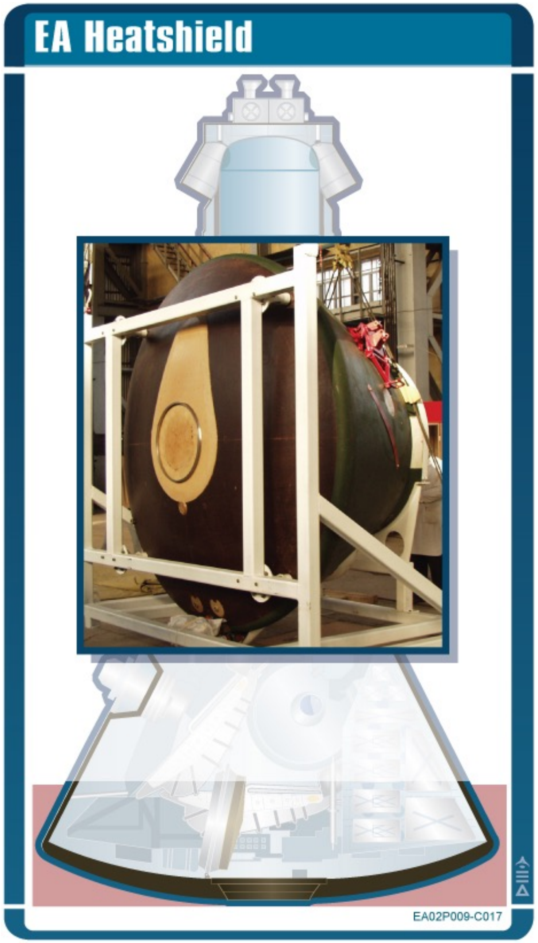
- The heatshield system is composed of a flat lay-up 2-dimentional glass fabric/phenolic resin matrix system
  - This material system is tailored overall density range to optimize its performance depending on its application on the vehicle. The material density ranges from approximately 1000 to 1600 kg/m3 (62.4 TO 100.LB/FT3)
  - The in-depth stackup of the heatshield is composed of two distinct layers
    - The outer layer contains the densified glass/phenolic layer that is optimized to provide structural rigidity against the point loading of the landing impact and good ablative performance against reentry heating
    - The second layer in-depth is composed of an organic foam that has a lower density but an overall equivalent thermal diffusion coefficient. This layer also has local sections of fully dense glass/phenolic in local areas to provide load transfer to the structural shell and local stiffness around penetrations
- The heatshield element fabrication process involves a dry fabric lay-up with an impregnation process similar to a resin transfer molding process

Thermal Protection System *(cont'd.)*

- The material characterization tests included density, dimensional stability, thermal diffusion and strength over a wide temperature range
  - Coupon and component level tests were performed under a variety of simulated thermal conditions which met or exceeded the flight heating rates or heating load levels
  - Ground testing included the use of a 4200° C arc jet for simulation of the aerothermodynamic environment
- During design entry trajectories surface temperatures are predicted to exceed 1800° C (greater than 3000° F) while maintaining the structural backface to no more than 100° C (212° F)
- The heatshield /structural shell system under load, however, has been qualified to an interface temperature of 200° C (392° F)
- Pyrolysis of the resin in the outer layer occurs during each reentry and degrades the resins down to a depth of approximately 20mm (.8in)

Thermal Protection System *(cont'd.)*

- The heatshield system has a hatch that penetrates the bottom heatshield
  - A seal system provides a way of opening and closing the hatch on-orbit, verifying seal integrity after orbiter ingress that survives the pressure and heating environment of reentry
  - The seal system is composed of the residual material from the titanium tunnel fixed to the capsule structure, a steel ring imbedded in the heatshield portion of the hatch and two elastometric O-rings on the hatch near the interior lip
  - The O-rings provide the primary seal against vacuum in space. This vacuum seal is protected from reentry by a another seal composed of a steel ring which expands against the titanium sleeve due to to the initial heat penetration through the heatshield material
  - As the seal is exposed to additional heat he thermal expansion differential causes the ring to press harder and harder against the titanium sleeve thus creating a tighter seal
- This design feature has been verified through numerous full scale ground tests as well as five flight tests



Thermal Protection System Summary

- ACRV entry trajectories will begin at slightly higher energies than the Almaz design conditions
  - The heatshield design for the Almaz orbiter appears to have fully met its design objectives
  - Erosion data and post flight structural integrity attest to the performance of the heatshield for its intended use
  - Detailed entry simulation and performance should be done to verify that the intended re-entry conditions are consistent with the heatshield qualification
  - Details regarding heatshield outgassing will require review in light of ISSA contamination issues
- The on-orbit ingress-egress hatch is through the aft primary heatshield and represents a Critical 1 failure mode
  - The design, materials, fabrication, quality control, analyses and ground/flight test data available should undergo a rigorous review for ACRV application

Flight Dynamics

- The flight dynamics and control of the entry orbiter can be described as being composed of three primary phases
  - Vacuum ballistic flight
  - Atmospheric entry
  - Parachute descent
- The vacuum ballistic flight is characterized by central force motion and the impulse of the orbital braking motor
- The atmospheric entry is dominated by central force motion and the lift and drag forces generated by the aerodynamic characteristics of the orbiter
- The final phase of flight is characterized by motion due to near terminal flight mechanics, capsule aerodynamics and parachute deployment dynamics and aerodynamics

Flight Dynamics *(cont'd.)*

- The vacuum ballistic flight begins with detachment from the station. Initialization of spacecraft position and attitude is normally handed over to the Almaz orbiter from the space station navigation system
- Attitude and position are provided by onboard set of three gyroscopes and accelerometers
- Vehicle positioning via the reaction control system is performed automatically
- The vehicle coasts in a circular orbit at an altitude of 225km at an orbital inclination of 51.6°
- After separation from the station the vehicle has the opportunity to make two orbits to select its landing point
  - Once the landing point is defined the braking motor impulse point is automatically determined
  - The braking motor is fired to provide a transfer ellipse that intersects with the upper atmosphere at the correct flight path angle the impulse provided can vary as much as 5m/sec
- The tolerance on the transfer ellipse flight path angle at entry interface is -.9° to -1.7°
- Vacuum ballistic flight ends when a sense deceleration of .03gs occurs

Flight Dynamics *(cont'd.)*

- The nominal relative entry velocity for the orbiter is 7.57 (24,800ft/sec) at a flight path angle of 1.38°
- Depending on the time it takes from braking motor impulse and registering .03gs the capsule roll vector is initialed either lift up or lift down
- The vehicle is trimmed at a fixed angle of attack by means of an off center axis shift of the center of gravity. This shift produces a nominal angle of attack of 18° which produces a hypersonic lift to drag ratio of about .25
- Flight path shift is produced by rolling the vehicle using the RCS about the trimmed angle of attack. The ballistic coefficient varies from 471.9kg/m2 to 646.5kg/m2 (98psf - 128psf) over the flight path. This compares to around 379kg/m2)78psf) for the Apollo capsule
- This combination of entry condition, ballistic coefficient and L/D can produce a nominal theoretical entry peak acceleration as low as 3gs total
  - Since the control system must accommodate off nominal conditions and the roll position is unlikely to provide continuous "maximum lift up" in the entry plane, a peak level of 4gs total is typical
- The aerodynamic characteristic of the vehicle were developed through a ground test program that included continuous wind tunnel, shock tunnel and ballistic range testing
- Over 100 models were tested over the full Mach number range up to Mach 30. The control and aerodynamic qualities were validated through 5 flight tests

Flight Dynamics *(cont'd.)*

- The final phase of flight begins with parachute deployment
- Nominally at an altitude of 10km (32,810ft) and 900kg/m2 (185 psf) dynamic pressure the parachute deployment sequence is initiated
- Three main parachutes are deployed providing a terminal decent rate of 6.5m/sec (21.3ft/sec)
- Prior to touchdown a gamma ray altimeter is used to determine the proper timing for firing the soft landing motors
  - This nominally occurs at 1 meter above surface level
  - This motor provides an impulse of 2500 kg-sec (5511 lb-sec) to decelerate the vehicle to under 3m/sec (9.8ft/sec)
- The landings point error is a culmination of several sources occurring from the time of the braking motor maneuver
  - These include braking motor impulse magnitude, atmospheric dispersions, and capsule aerodynamic characteristics
  - The 3-sigma landing error ellipse has a major radius of 27km and a minor radius of 13km

Flight Dynamics *(cont'd.)*

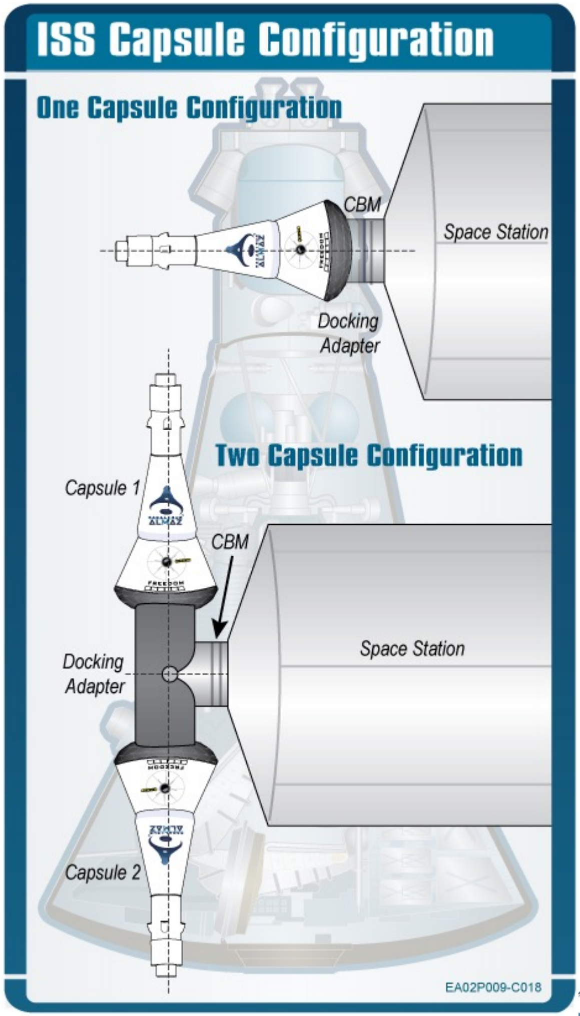
- In the event the vehicle attitude is not successfully initialized from the Almaz station, a manual backup system exists
  - The manual system is composed of an infered horizon sensor and an ion sensor. The crew can manually position the vehicle by viewing the horizon through six optical inputs
- In the event that the vehicle cannot be properly oriented and stabilized in pitch and yaw after a successful braking event and prior to atmospheric entry the scarfed nose that results from jettisoned a portion of the braking motor shroud produces a configuration that has a single aerodynamic trim condition
  - Through this feature and natural aerodynamic damping , the vehicle is correctly oriented in the upper atmosphere prior to maximum heating and maximum dynamic pressure conditions
  - In the event roll attitude cannot be properly initialized, a constant roll rate is imparted to the vehicle to provide a near ballistic entry
  - The peak deceleration for thios condition is 8gs total

Flight Dynamics Summary

- The Almaz orbiter appears to meet all minimum GN&C and flight dynamic ACRV requirements
  - The current system of position and attitude determination should be investigated for upgrade. Existing integrated GPS/INS systems could significantly increase the accuracy and reliability of position initialization and propagation. Attitude initialization systems are currently being tested to investigate the potential of using GPS for attitude determination using locally spaced antennas (~1m) on a space craft
- A lower parachute deployment altitude along with ground updates of landing zone wind conditions should be investigated to decrease the size of the landing zone ellipse
  - This is feasible based on technology advances in communications, on-board data processing and GPS navigation as compared to 1970
- The RCS propellant load may not be adequate to provide the necessary attitude stabilization for operation from ISSA orbit
  - The propellant budget required to perform post ISSA separation RCS functions should be thoroughly investigated

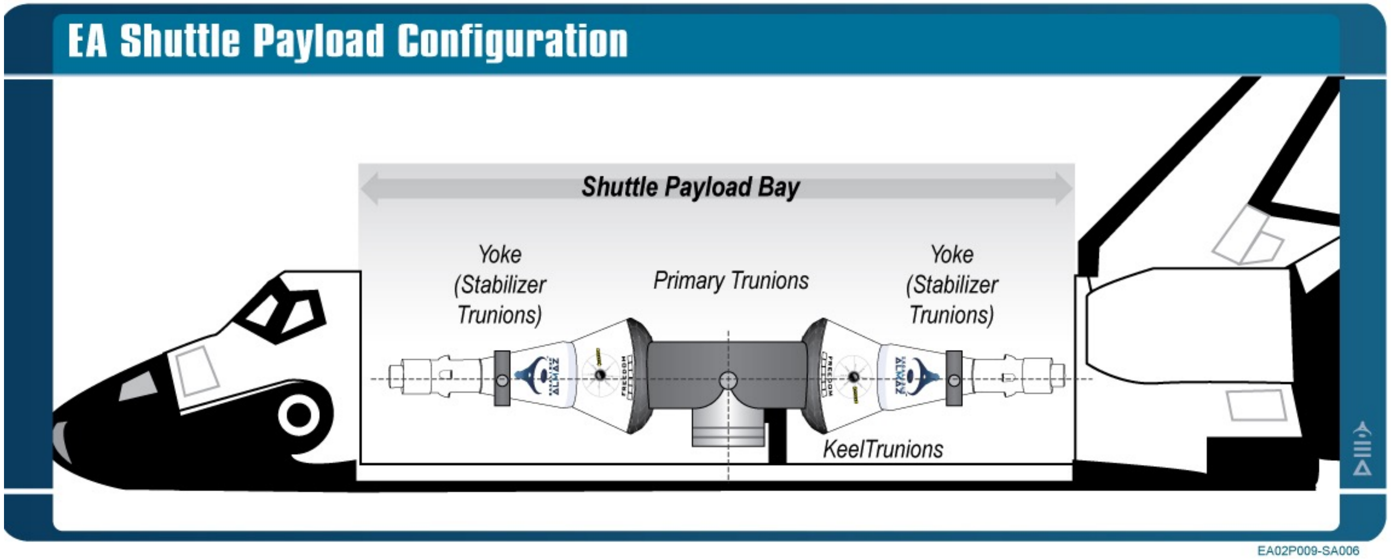
Flight Support Equipment

- The need to deliver the Almaz orbiter on the shuttle and then to attach it to the space station requires the development of several pieces of flight support equipment
- Deliveries of other hardware or the return of a orbiter without requiring refurbishment must see the shuttle
- Attachment of a orbiter or docking mechanism to the station without astronaut EVA will require the shuttle's remote arm
- To provide the capability for 6 crew members to return to Earth, at least two orbiters are required
- Any scheme for attaching an Almaz orbiter to the space station must use the station's common berthing mechanism
- To attach the Almaz orbiter to the CBM an adapter or docking assembly is necessary
  - A two capsule system was used as the baseline for purposes of cost estimation
  - The use of an adapter also provides a mounting location for other capsule -to -station adapting hardware (command and data system, power system, etc.)
  - Mechanisms for sealing the station when a orbiter is not docked or has left the station will also be contained within the adapter



Flight Support Equipment *(cont'd.)*

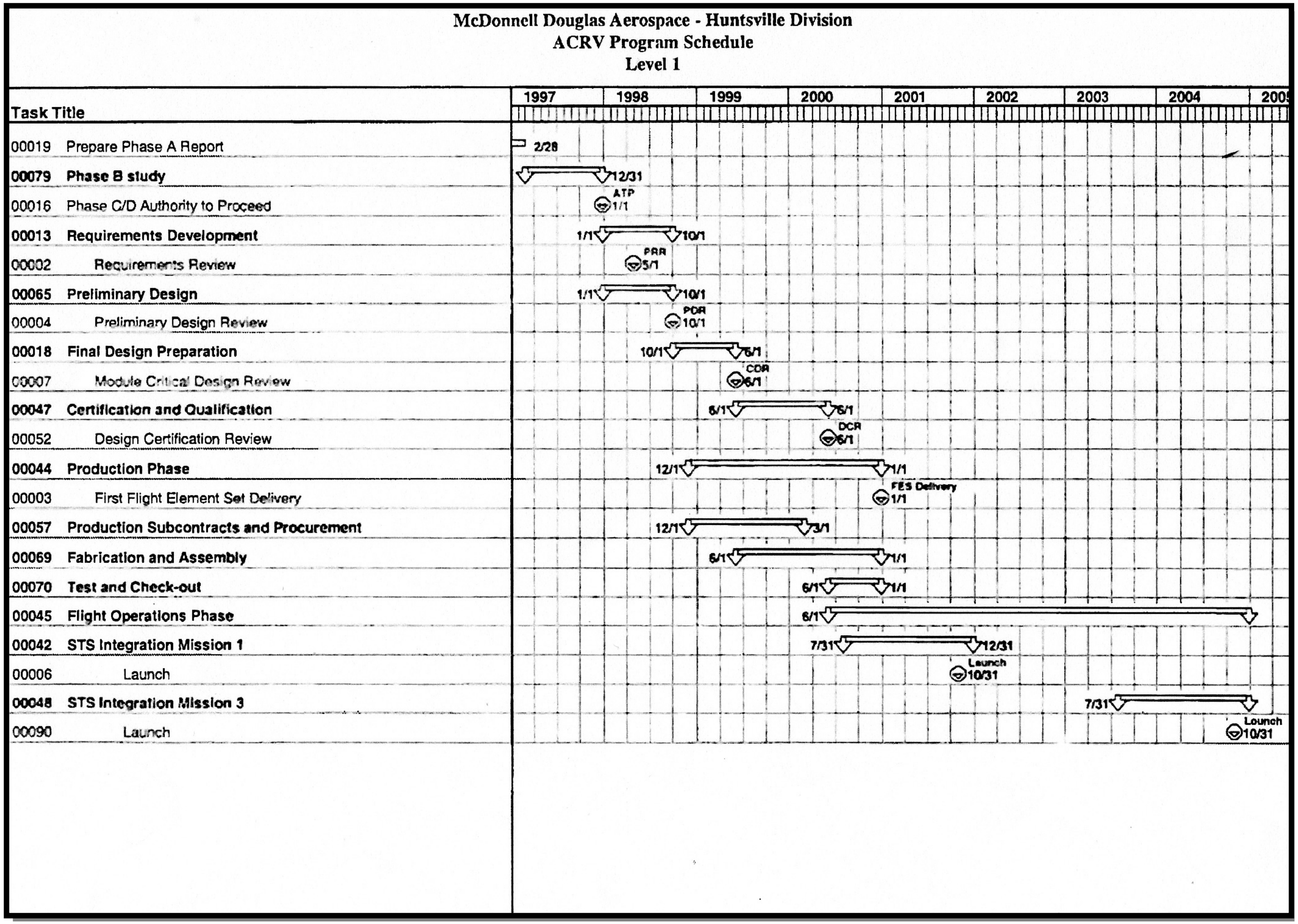
- Launch carriers are required for initial (two capsules and docking mechanisms) deployment and capsule re-supply
- For the "T" configurations, initial deployment may look like the Figure below with the docking adapter used as a carrier
- This configuration also has the advantage that the entire assembly (capsules and docking hardware) can be moved from the shuttle to the station



Cost and Schedule

- The level 1 Program Schedule begins with a 9 month Phase B effort which is completed at the end of CY 97
- The phase C/D program is a three year program from ATP through Hardware delivery to the KSC Integration site
- The program includes the standard DDT&E milestones including Requirements Review, Preliminary Design Review, Critical Design Review and Design Certification Review
- The STS Integration and Operations activities follows the standard SPACEHAB 15 moth template which includes the Phased Safety Reviews, Flight Operations Reviews and Flight Readiness Reviews
- All STS data products such as the PIP and PIP Annex are included in the template

Cost and Schedule *(cont'd.)*



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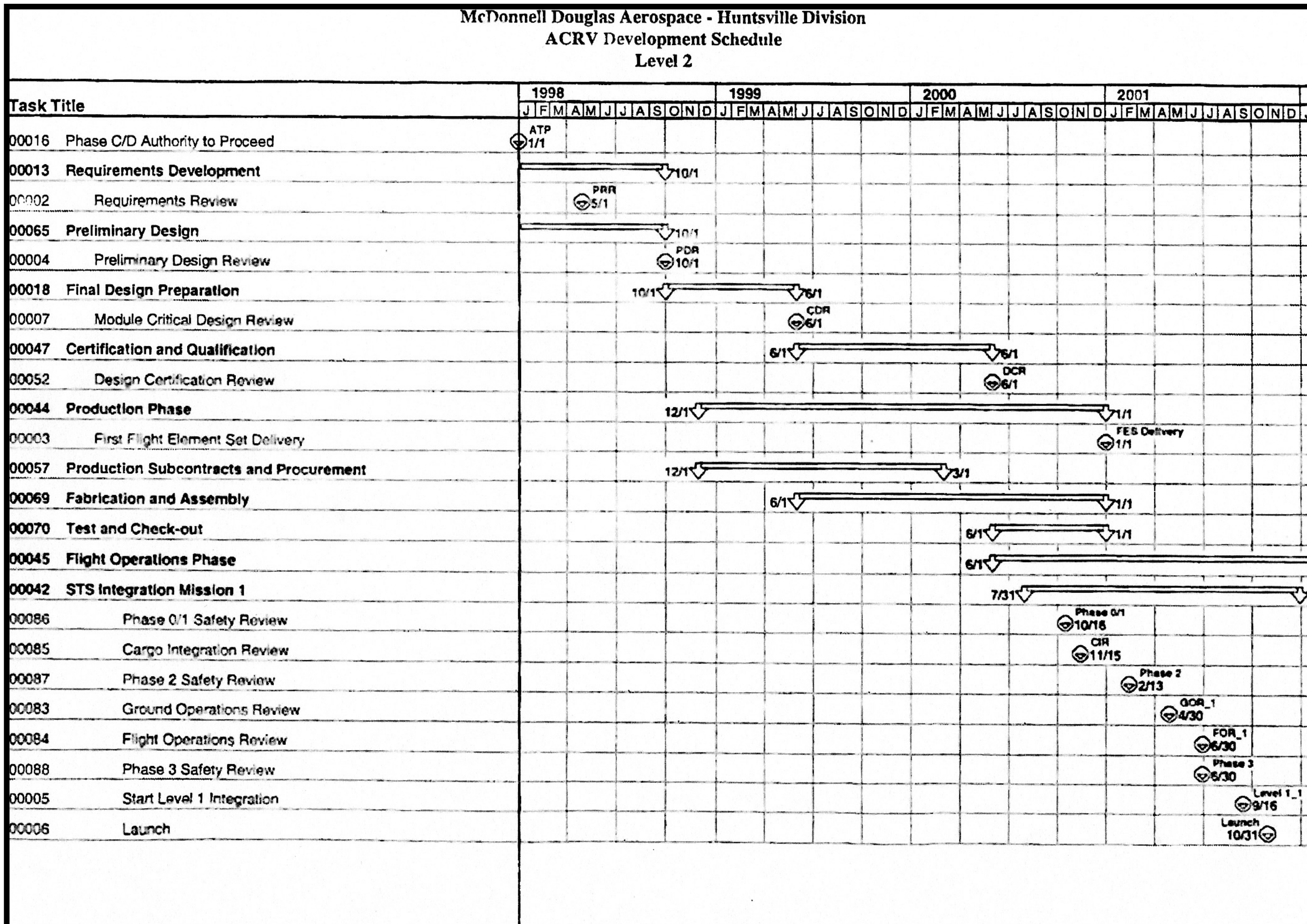
Cost and Schedule *(cont'd.)*



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Cost and Schedule *(cont'd.)*

- Time phased cost is derived from resource loaded labor and non-labor elements of cost which are tied directly to the networked events, milestones and activities
- The Labor cost is derived from the time phased manpower levels
- The dramatic reduction in sustaining level followed by the activity to replace the on-orbit capsules after the 3 year life has expired
- The program cost is presented as a cumulative curve ($K)
- These estimates include all haqses from Phase B through the operational Phases and includes a 20% management reserve during the Phase C/D Phase
- The high slope of the cumulative curve in mid program represents the acquisition of materials and components as well as subcontracts for fabrication of major structural elements such as the structural flight support equipment

Cost and Schedule *(cont'd.)*

McDonnell Douglas Aerospace - Huntsville Division
Task Planning System
Current Month Labor Headcount Report

JAN 5, 1997
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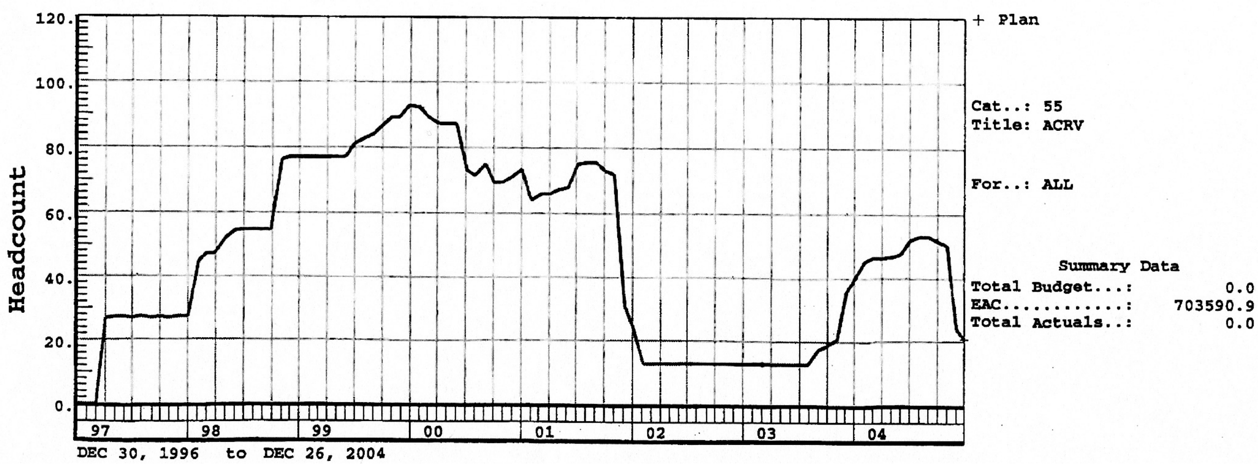
Year		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1997	Budget												
	Plan			27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
	Actuals												
1998	Budget												
	Plan	44.96	47.09	47.34	51.84	54.59	54.64	54.64	54.64	54.64	76.47	77.20	77.20
	Actuals												
1999	Budget												
	Plan	77.20	77.20	77.20	77.20	77.20	80.70	82.61	84.19	86.29	89.20	89.20	92.78
	Actuals												
2000	Budget												
	Plan	91.90	89.24	87.40	87.20	87.20	73.13	71.69	75.09	69.48	69.49	71.67	73.47
	Actuals												
2001	Budget												
	Plan	64.11	66.09	66.09	67.01	68.02	75.18	75.72	75.72	73.33	71.87	30.69	24.30
	Actuals												
2002	Budget												
	Plan	12.75	12.75	12.75	12.75	12.75	12.75	12.75	12.75	12.75	12.75	12.75	12.75
	Actuals												
2003	Budget												
	Plan	12.75	12.75	12.75	12.75	12.75	12.75	12.75	17.48	18.98	20.81	35.45	39.63
	Actuals												
2004	Budget												
	Plan	45.01	46.35	46.35	46.94	47.70	51.94	53.07	53.07	51.94	50.38	24.10	20.81
	Actuals												



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Cost and Schedule *(cont'd.)*

McDonnell Douglas Aerospace - Huntsville Division
Task Planning System
Cumulative Burdened Dollars Report

JAN 5, 1997
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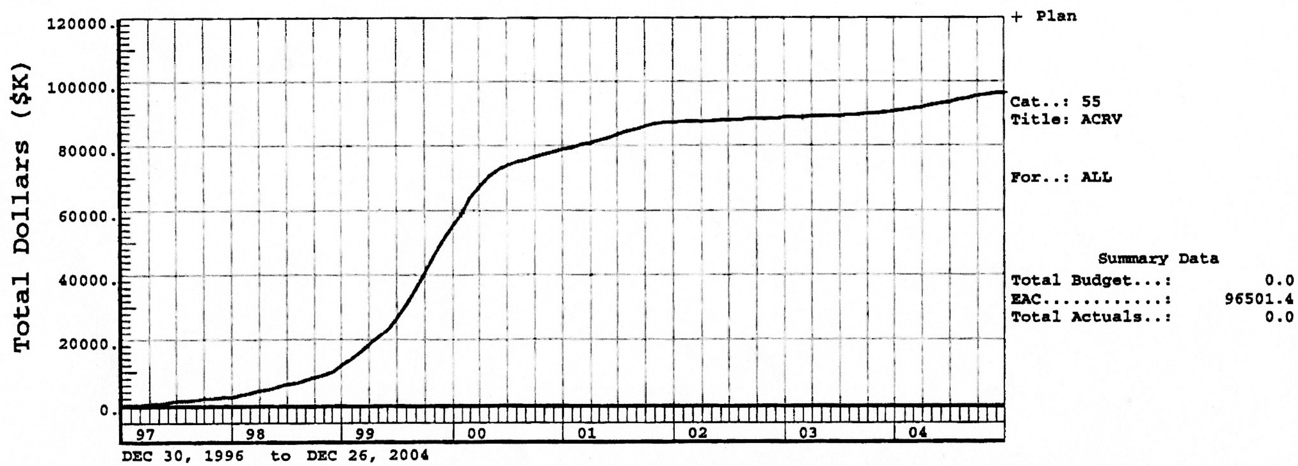
Year		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1997	Budget												
	Plan			245.	311.	236.	249.	236.	311.	236.	250.	287.	212.
	Actuals												
1998	Budget												
	Plan	537.	557.	560.	759.	602.	634.	762.	635.	603.	1060.	770.	1824.
	Actuals												
1999	Budget												
	Plan	1990.	2095.	2095.	2628.	2102.	3124.	5075.	4572.	4506.	5976.	4303.	4576.
	Actuals												
2000	Budget												
	Plan	4327.	4783.	3655.	2541.	2366.	1415.	701.	1019.	723.	763.	899.	559.
	Actuals												
2001	Budget												
	Plan	639.	911.	729.	743.	904.	823.	787.	1036.	765.	793.	343.	166.
	Actuals												
2002	Budget												
	Plan	120.	109.	109.	110.	132.	110.	105.	138.	105.	111.	127.	89.
	Actuals												
2003	Budget												
	Plan	117.	111.	111.	112.	135.	112.	107.	204.	170.	249.	321.	342.
	Actuals												
2004	Budget												
	Plan	455.	469.	469.	599.	487.	506.	654.	545.	506.	647.	209.	187.
	Actuals												



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