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ASSURED CREW RETURN VEHICLE POST LANDING CONFIGURATION DESIGN AND TEST

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Abstract

The 1991-1992 senior Mechanical and Aerospace Engineering Design class continued work on the post landing configurations for the Assured Crew Return Vehicle (ACRV) and the Emergency Egress Couch (EEC). The ACRV will be permanently docked to Space Station *Freedom*, fulfilling NASA's commitment of Assured Crew Return Capability in the event of an accident or illness aboard Space Station *Freedom*. The EEC provides medical support and a transportation surface for an incapacitated crew member. The objective of the projects was to give the ACRV Project Office data to feed into their feasibility studies. Four design teams were given the task of developing models with dynamically and geometrically scaled characteristics. Groups one and two combined efforts to design a one-fifth scale model of the Apollo Command Module derivative, an on-board flotation system, and a lift attachment point system. This model was designed to test the feasibility of a rigid flotation and stabilization system and to determine the dynamics associated with lifting the vehicle during retrieval. However, due to priorities, it was not built. Group three designed a one-fifth scale model of the Johnson Space Center (JSC) benchmark configuration, the Station Crew Return Alternative Module (SCRAM) with a lift attachment point system. This model helped to determine the flotation and lifting characteristics of the SCRAM configuration. Group four designed a full scale EEC with changeable geometric and dynamic characteristics. This model provided data on the geometric characteristics of the EEC and on the placement of the CG and moment of inertia. It also gave the helicopter rescue personnel direct input to the feasibility study.

Introduction

For years, America's journey into space has demonstrated the benefits associated with working in the unique environment of microgravity. Continuing in this tradition, an ambitious and far-reaching program to further the advancement of space technology has been launched. With Space Station *Freedom* the United States enters an era marked by a permanent presence in space. The space station allows continuous rather than intermittent operations to be conducted in orbit. The space station opens doors to many new methods of research and experimentation. Included are better opportunities to observe the Earth and forecast future trends from a vantage point only partially exploited by previous shuttle missions.

Space Station *Freedom* is planned to initially have a crew of four, expandable to a permanent crew of eight. The crew will be rotated and resupplied by flights of the Orbiter on an interval currently planned for three months. Because of the isolation and potentially hazardous conditions involved in space operations, NASA is committed to the policy of Assured Crew Return Capability for Space Station crews in the event (1) a medical emergency occurs and an ill, injured, or deconditioned crewmember must be rapidly transported from the Space Station to a definitive health care facility on Earth; (2) a space station catastrophe forces a rapid evacuation of the crew from the station; and/or (3) the Space Shuttle Program (SSP) system becomes unavailable, and an orderly evacuation of the crew from the space station becomes necessary.

These events, or Design Reference Missions (DRMs), can be met by a concept known as the Assured Crew Return Vehicle (ACRV). Currently, NASA is considering three classes of ACRVs: water landers, runway landers, and open land or nonrunway landers.

The project objectives detailed in this report were developed in conjunction with the Kennedy Space Center ACRV Project Manager and are focused on requirements for a water landing ACRV and post landing operations. The craft configurations include an Apollo Command Module derivative (ACMD) and a Station Crew Return Alternative Module (SCRAM). The designs presented are: a one-fifth scale model of the ACMD with a lift attachment point system; a one-fifth scale model of an on-board Apollo Flotation and Stabilization system; a one-fifth scale model of the SCRAM with a lift attachment point system; and a full scale model of an Emergency Egress Couch.

Previous UCF ACRV Projects

The UCF senior-level Mechanical and Aerospace Engineering Design class has been working with the ACRV Project Office at KSC since 1989. During the 1989-1990 academic year four design considerations and solutions were investigated.

The first consideration was providing crew egress and rescue personnel support subsystems to ensure the safe and rapid removal of an ill or injured crewmember from the ACRV by recovery forces. An Emergency Egress Couch was designed to medically support a sick or injured crewmember during the ACRV mission. To move the couch from the floor to the hatch, a Four Link Injured Personnel Egress Mechanism (FLIPEM) was developed.

The second consideration was the proper orientation, attitude control, and stabilization systems required for the ACRV in the marine environment. Post landing orientation of the ACRV is achieved through the use of three CO_2 charged balloons similar to those used during the Apollo program. Attitude control systems were designed that deploy three multichambered ring segments and an appurtenance to act as a platform for the rescue personnel. Multiple underwater parachute assemblies were designed to provide motion reduction.

The third consideration dealt with providing full medical support to an ill, injured, or deconditioned crewmember aboard the ACRV from the time of separation from the space station to rescue by recovery forces. Extensive research was performed to select suitable medical support equipment and monitors as required by NASA. Equipment was integrated into unified packages and power requirements were addressed.

The fourth consideration was to provide for the comfort and safety of the entire crew from splashdown to the time of rescue. Design solutions were presented for food, water, waste management, atmosphere, contaminant/odor control, and environmental control systems.[1]

The format for the senior-level design class changed in the 1990-1991 academic year. The design requirement was increased from one semester to two semesters. The students now design during the fall semester and build and test during the spring semester. The work continued on post landing operations for the water landing ACRV. The design objectives for this class were to determine the feasibility of the previously developed egress and stabilization systems for deployment on the ACRV. Four design teams were formed.

The first team designed, built, and tested a one-fifth scale model of the ACMD to be used as a test platform for the egress and stabilization systems. Test results indicated small deviations from the size and weight specifications provided by Rockwell International. Hardpoint accommodations and seal integrity were maintained throughout the water testing.

The second team worked during the fall semester investigating water test facility locations, as well as establishing designs for a permanent facility at the University of Central Florida. As a result of this investigation, stabilization testing with the ACRV model was performed at the O. H. Hinsdale Wave Research Laboratory (WRL) at Oregon State University in Corvallis, Oregon.

The third team designed, built, and tested a one-fifth scale working model of the Four Link Injured Personnel Egress Mechanism (FLIPEM) optimized in the previous academic year as well as a Two Slider Support Mechanism (TSSM) for egressing the couch out the hatch. Testing was conducted in the areas of lifting force with nominal and off-nominal loads, vertical and horizontal travel distances, redundancy characteristics of the FLIPEM and extension force, travel distance and redundancy characteristics of the TSSM. Test results indicate the design specifications for both systems were met or exceeded without interference to other systems.

The fourth team's objective was to determine, through modeling, the feasibility of reducing heave, surge, and pitch motions of the ACRV model on water using an underwater parachute system. Therefore, one-fifth scale models of the attitude ring and underwater parachute stabilization system, optimized during the previous year, were designed, built, and tested. Wave testing, in simulated sea states 2 to 4, at the O. H. Hinsdale WRL yielded results that indicate that the six-attitude sphere configuration produced minimal stabilizing effects on the ACRV model. The spheres, however, did have the effect of enhancing the flotation characteristics of the model. Numerous parachute arrangements, including single and multiple chutes per cable; an increase in the weight attached; the use of stiff and elastic cables; and devices to partially and totally open the chutes were tested. Results indicate that the parachutes did affect the motions induced on the model, but did not reduce or increase the frequencies out of the range that cause seasickness.[2]

A concept employing a Rocker Stoppers unit was built and tested at the water test facility to determine the effect a rigid system would have on reducing the oscillations. Two Rocker Stoppers were connected, nose-to-nose, at one end of a long threaded rod. The other end of the rod was connected to a metal plate attached to the model above the break line. Four of these arrangements were connected to the model. Since the Rocker Stoppers are made of rigid plastic, they perform the same work on the upstroke as on the downstroke. This configuration was tested in a simulated sea state 4 (1.2 ft wave height, 0.45 Hz) and the response compared with that from the clean model in the same sea state. The results indicate that a rigid system in this configuration reduces the heave amplitude the model experiences. [3]

1991-1992 ACRV Design Projects

The results of the testing from the 1990-1991 academic year revealed areas where further data was needed. The ACRV Project Office suggested that the senior-level design class develop designs applicable to the full scale ACRV for water landing and post landing operations. Four areas of interest were identified: craft retrieval or lifting characteristics, the geometric and dynamic characteristics of the EEC, the flotation characteristics of the SCRAM configuration, and the stabilization characteristics of a rigidly mounted flotation system for the ACMD. Four design teams were formed and tasked as follows:

Team #1-ACMD Configuration Model

The ACMD Configuration Model Team was to use geometric and dynamic constraints to design a one-fifth scale working model of the Apollo Command Module Derivative (ACMD) configuration with a Lift Attachment Point (LAP) system. This model was required to incorporate a rigidly mounted flotation system and the egress system designed the previous academic year. The LAP system was to be used to determine the dynamic effects of locating the lifting points at different locations. The team was then to build and test the model; however, due to higher priorities, this did not occur.

Team #2-ACMD Flotation Model

The ACMD Flotation Model team was to design, build, and test a one-fifth scale model of a flotation system. The flotation system had to move rigidly with the craft and provide a rigid work surface for the rescue personnel. The team was to address location, storage, deployment, and release or deflation. The model was not built and tested because of higher priorities.

Team #3-SCRAM Configuration Model

The objective of the SCRAM Configuration Model Team was to design, build, and test a one-fifth scale model of the Johnson Space Center benchmark configuration, Station Crew Return Alternative Module (SCRAM), with a LAP system. They were to address the water retention by the inverted cone shaped heat shield and consider that the area might need to be drained prior to vehicle retrieval.

Team #4-EEC Configuration Model

The EEC Configuration Model Team was to design, build, and test a full-scale representation of the Emergency Egress Couch, complete with simulated human weight and medical equipment weight. This model was to include a helicopter recovery system and have changeable geometric and dynamic characteristics.

A one-fifth scale was used both geometrically and dynamically for all ACMD and SCRAM models. To accomplish this a Buckingham Pi dimensional analysis was performed and the Froude scaling factors were determined. These factors allow the model to accurately simulate the characteristics of the full scale craft. While the geometric dimensions of the craft scaled directly by one-fifth, other parameters, including volume, weight, and mass moment of inertia scaled by powers of one-fifth.

1991-1992 ACRV Design, Building and Testing Results

ACMD Configuration Model

The ACMD Configuration Model team designed a one-fifth scale model based on the Apollo Command Module derivative (ACMD). Current data for the weight and geometric dimensions of the ACMD were supplied by Rockwell International. To better simulate the ACMD after a water landing, the nose cone section was removed and the deck area exposed. The areas researched during the design process were: construction, center of gravity and moment of inertia, and lift attachment points.

Fiberglass was the material chosen for model fabrication. To allow access to the interior of the finished model, the model construction was planned in three pieces: a lower section, an upper section, and a hatch. Planned fabrication of the model consisted of plug, mold, and shell construction. The upper and lower sections of the model attach using eight aluminum chest latches and a gasket seal. The hatch attaches to the model using a two-inch strap hinge, sealed with a gasket, and locked into place with 1 3/4-in turn buttons.

To incorporate the egress and flotation systems, the model was designed with the necessary space, hardpoints, and attachments. Hardpoints at the connection area of the flotation system distribute the load. These hardpoints consist of 1/8-in pieces of balsa core cut into 3-in squares. These pieces of wood are incorporated into the shell interior with layers of resin. Holes drilled into the floor serve as hardpoints for the egress mechanism.

The center of gravity (CG) and mass moment of inertia (MI) were modeled using a radial system. The radial system consists of two vertical 1/4-in threaded rods. One rod is placed in the top access hatch area and one in the bottom of the model, under the floor. Radial arms are made of hardwood dowels with a hole drilled through their centers. One or more of these arms are positioned along each vertical threaded rod by means of lock nuts. Weights consisting of groups of large metal washers are fastened along the radial arms and held in place with hose clamps on either side of the washer group. These weights are repositioned along the radial arms, as needed. The radial arm positions are varied along the vertical rods. By varying the weight amounts and positions and rotating the radial arms to any angle required, the center of gravity and moment of inertia are changed for accurate simulation (Figure 1). Pendulum tests performed on the empty shell determine the size and weight of the washers required.

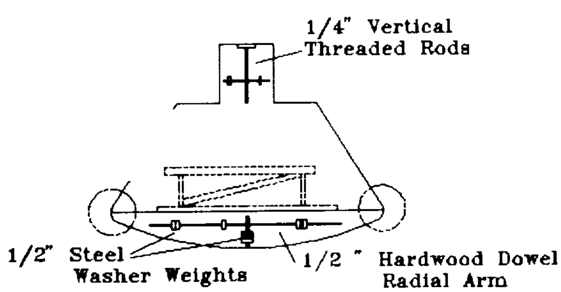

Fig. 1 Radial system, egress system, and flotation system

The Lift Attachment Point (LAP) system used to model retrieval of the craft was a dual attachment system with an angled lift. The dual attachment points offer redundancy. There are two attachment points each with its own sling; however, both are attached to a single lifting cable. The sling angle that offers the least force on the attachment points and the least tension on the cables is 60 degrees. The LAPs are placed on the upper deck area. This location takes advantage of the parachute reinforcement area and a high location relative to the CG (Figure 2).

ACMD Flotation Model

The ACMD Flotation Model team designed a one-fifth scale flotation and attitude system for the ACMD. The system forms a rigid body with the ACMD after deployment. Four areas incorporated into the design of this model were: (1) flotation, (2) attitude, (3) materials, and (4) inflation.

The flotation system was designed with a segmented ring constructed out of woven nylon fabric coated with butyl rubber. This ring is composed of three or more sections, each extending around a portion of the ACMD along the water line. Each segment is stored in compartments along the water line. The storage space required is approximately 1/50 of the inflated volume. The segmented ring allows for the placement of the Reaction Control System jets. A rigid system is obtained by attaching the segmented ring to the ACMD inside the storage compartment and pressurizing the segments to rigidity. The volume of air needed to keep the ACMD model afloat provided it does not float was calculated from Archimedes' principle as 2.05 ft^3. To achieve this volume, each segment has a radius of 4.6 inches, and the combined length of all segments is 46.3 inches.

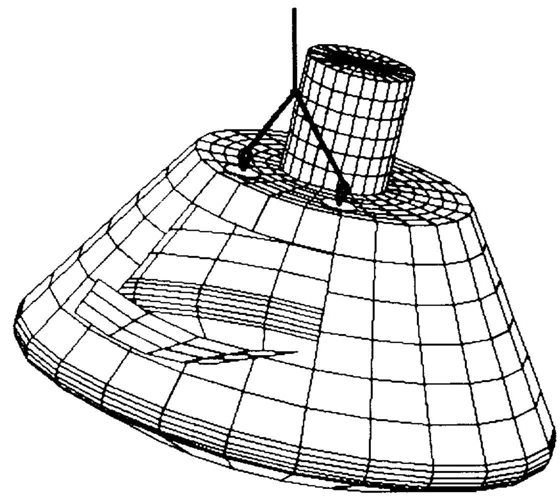

Fig. 2 Deck-mounted dual attachment with angled lift

The attitude system provides support to the Emergency Egress Couch (EEC) and counters the moment the EEC places on the craft. A telescoping beam configuration provides the necessary support and attitude control for the EEC. This system consists of aluminum box beams that rotate ninety degrees from their storage position inside the ACMD, then telescope out to a specified length. A rigid surface is rolled out on top of the beams and an inflatable cylinder is attached at the end of the beams to provide the attitude control. The inflatable cylinder is constructed of woven nylon covered with butyl rubber (Figure 3).

The inflation method for the model is a threaded valve similar to that used for automobile tires. These valves are attached to the segmented ring sections and to the inflatable cylinder at the end of the attitude system. The segments are then inflated using a hand or foot pump. Inflation for the full scale ACMD needs further investigation.

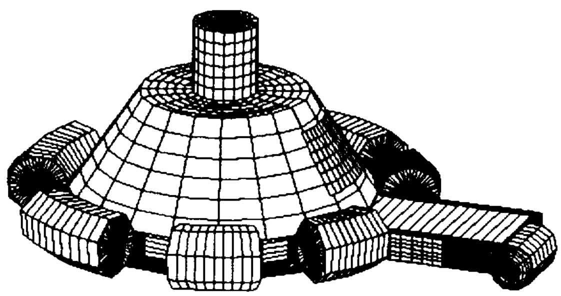

Fig. 3 Complete flotation and attitude systems

SCRAM Configuration Model

The SCRAM Configuration Model team designed, built, and tested a one-fifth scale model of the Johnson Space Center benchmark configuration, the Station Crew Return Alternative Module (SCRAM). Current data for the geometric and dynamic constraints of the SCRAM were supplied by the ACRV Project Office at Johnson Space Center. Four areas were researched during the design process. These areas were: (1) construction, (2) center of gravity and mass moment systems, (3) heat shield shroud, and (4) lift attachment points.

The construction of the model was contracted to Guard-Lee, Inc. and completed in four sections. The crew compartment, lid, and heat shield were constructed of fiberglass, and the heat shield shroud of sheet aluminum. The lid was attached to the crew compartment by eight bolts and sealed with a weather stripping material. The heat shield was fastened to the crew compartment bottom with four symmetrically placed joints. The heat shield shroud attached to the lip of the heat shield and the lip at the bottom of the crew compartment cylindrical section with bolts. This assembly was sealed with a silicone-based seal. Locking washers were used on all bolt assemblies to avoid crack propagation from the bolt holes.

The weight, mass moment of inertia, and CG were adjusted with the Adjustable Rotating Weight System (ARWS). The ARWS consists of a length of aluminum flat stock (arm) that is bent on each side 2 in from the center to 18.43 degrees upward and 10.7 in from the center 18.43 degrees downward. Slots are machined in the arm and a hole drilled through the center of the arm. Four wedge-shaped compression blocks mount on risers (threaded rod) that are placed in the arm slots. The compression blocks hold the risers in place. Weights are placed on the risers at the necessary locations and held in place by washers and bolts. A threaded spindle is mounted to a spindle retention plate that is affixed to a wood block fiberglassed to the bottom of the crew compartment. The whole system is placed over the spindle and bolted to the bottom of the crew compartment (Figure 4). This system was machined by F & E Machine, Orlando, Florida.

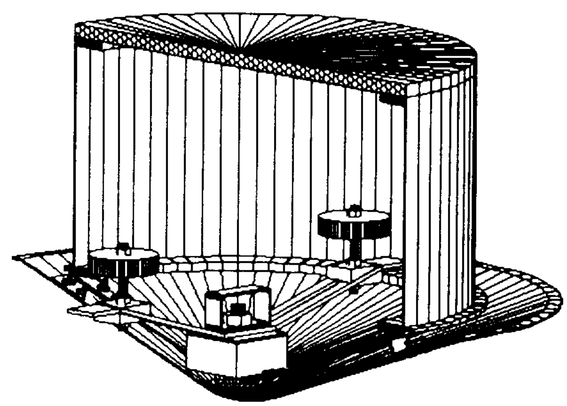

Fig. 4 Adjustable rotating weight system

Attached to the crew compartment lid is the Lift Attachment Point (LAP) system. The system is constructed of 3 pieces of angle iron bolted 90 degrees apart radiating from the center. Multiple holes drilled in the upper portion of the angle iron allow for different angles in the lifting lines. The attachment is accomplished with three D-rings attached to the holes in the angle iron. Three cables are connected to the D-rings and are clamped together at one central cable. The central cable is then attached to the lifting apparatus (Figure 5).

A three-phase test plan was developed to evaluate the

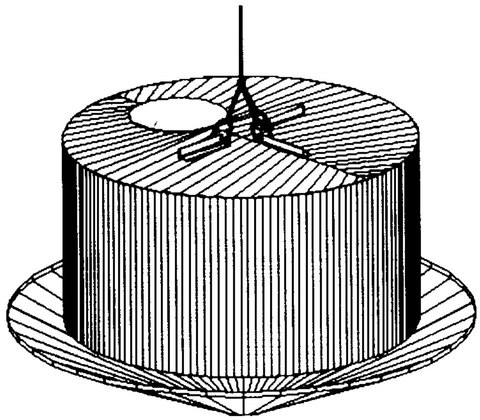

Fig. 5 Lift attachment point system

model. Phase I took place at UCF in the Senior Design Lab and consisted of a series of pre-tests to confirm the SCRAM model met its specifications. The tests included geometric similitude, ease of transportation, CG and mass moment of inertia adjustability, and the rapid and accurate positioning of the ARWS. Test results indicate that the model meets its geometric constraints. Model assembly and disassembly times were 12 and 15 minutes respectively. The required CG offsets are accomplished by accurate placement of the ARWS. Mass moment of inertia data was not specified; therefore, it was not configured to a specific value.

Phase II took place at UCF in the Fluids Lab and consisted of tests to determine the static draft and watertightness of the model, as well as the durability of the LAP system. Test results show the static draft of the craft at 120 lbs without the heat shield shroud is seven in, and with the heat shield shroud is 6 1/4 in. The model did not take on water in either configuration. The LAP system and model showed no signs of failure after a 208-lb static hang test and a 120-lb jerk test.

Phase III took place at Offshore Technology Research Center at Texas A & M University in College Station, Texas. Tests were completed to determine the SCRAM's flotation characteristics as well as various methods of vehicle recovery. This testing involved a number of changes to the model configuration and to the wave environment. Configuration parameters were established and sea state conditions set during the development of the model. All possible combinations of critical parameters could not be evaluated; therefore, a bracketed method of evaluation was employed. The parameters evaluated were: weight, CG, open/closed heat shield, and sea state. A 76-lb and a 120-lb weight configuration were evaluated. The CG locations that were evaluated were 1.2 in above and 1.2 in below the empty craft CG, and 1.2 in from the vertical axis toward the hatch and away from the hatch. Three wave states were evaluated. The first was an intermediate regular wave state with a .52-ft wave height and a 1.252-second period. The second was a scaled sea state 4 regular wave, with a 1.2-ft wave height and a 2.22-second period. The third wave state was a random wave with a .334-ft average wave height and a 1.118-second average significant period. The test results provide the flotation and lifting characteristics of the SCRAM configuration. Additional design/operational suggestions, which were derived from the test results, were also provided to the ACRV Program. These suggestions were: (1) crew member extraction should not be attempted from a top hatch because of the pitch and heave motions of the craft; (2) the side hatch should be relocated to a higher vertical position to prevent vehicle flooding during crew extraction; (3) attenuators and stabilization loops should be integrated into the lifting crane cables, and the crane lifting capacity should have a safety factor of 5.0; and (4) in the open heat shield configuration, the lift attachment points should allow for lifting the vehicle at an angle to allow for water drainage and a smoother lift in rough seas.

EEC Configuration Model

The EEC Configuration Model team designed, built, and tested a full scale model of the Emergency Egress Couch (EEC). The dynamic and geometric characteristics of the EEC that best suit the ACRV mission are currently to be determined. The maximum weight and geometric data is known. The EEC can weigh no more than 400 lbs and must not exceed the geometric constraints of 7 × 2 × 1 ft. The EEC consists of two basic litters, one human weight system, one medical weight system, three layers with flotation, two sets of lift attachment points (LAP), and a cover.

The basic litter was constructed in the UCF Engineering R & D Shop. The material chosen for the basic litter was Chrome-Moly steel tubing with a 1-in outer diameter and a 0.095-in wall thickness.

The basic litter consists of two frames 7 × 2 ft that are joined together by ten 2-in spacers welded between the two frames. The bottom of each frame has three 2-ft runs spaced 1 ft 9 in apart for support. To avoid having any sharp objects on the EEC the corners have a 4-in radius.

The human weight system was a weighted dummy with the same dynamic and geometric characteristics as a human. The dummy weighed 102 lbs with the CG corresponding to the CG of a crewmember. The dummy was secured by strapping it to the upper litter.

The medical weight system is housed in the bottom litter and consists of two movable weight platforms mounted on two support strips along either side of the bottom litter. Weights can be added to vary the total weight of the EEC. The CG and mass moment of inertia can be varied by moving the weight platforms to the desired location.

Layers are used to change the height of the EEC and add flotation. There are three layers, one with a 2-in height and two with a 1-in height. The frames of the layers are 7 × 2 ft and are constructed from pressure-treated wood that has been planed to the proper height. The corners have a 4-in radius for proper interface with the other EEC components. Two attachment holes are located in each 7-ft side of the layer frame. A polystyrene sheet fills the center of each frame for flotation.

Bolts are used to attach all the EEC components together. Both basic litters have two L-brackets welded on each 7-ft side of the litter. The L-brackets have holes drilled in the center. These holes line up with the holes in the layers. To attach the components of the EEC, the bolt passes through the angle iron from the bottom litter, through the layers to the top litter, and is secured by nuts and washers.

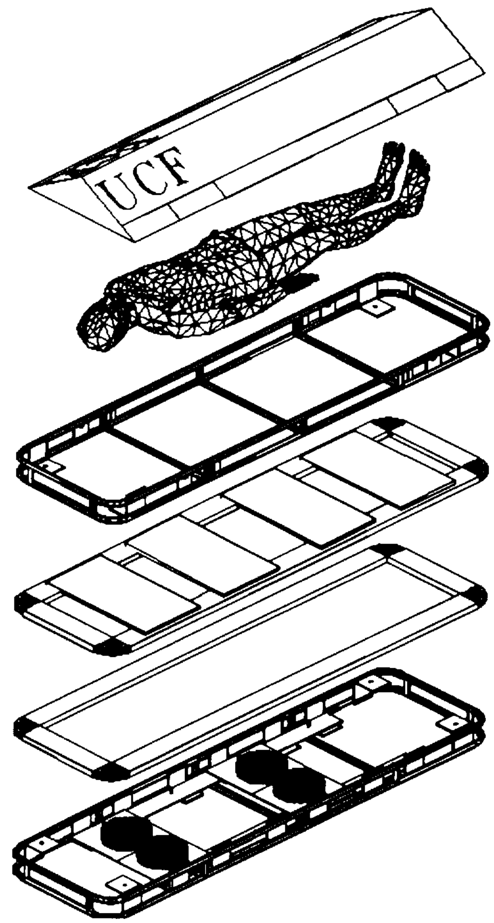

Fig. 6 EEC model

The EEC is equipped with two sets of LAPs and allows the harness to be attached in different configurations. The first set of LAPs emulates the LAPs on the Stokes litter. The second set of LAPs is for stability tests. The first set of LAPs are small metal plates that are welded close to the spacers on the top litter. The lift harness carabinier fits securely between the spacer and the metal plate. The second set of LAPs is designated by iron plates welded between the upper and lower tubular frames on the top litter. The lift harness carabinier is put through a semicircular opening cut in the iron plates and secured around the tubular frame (Figure 6).

A three-phase test plan was developed to evaluate the model. Phase I was performed in the UCF Senior Design Lab and consisted of a series of pre-tests to confirm that the EEC model met its specifications. The tests included verifying geometric constraints, weight, CG and mass moment of inertia variability, and safety. Test results indicate that the model meets its geometric constraints. There are no sharp edges and all components fasten securely. The weight, CG and mass moment of inertia are adjustable.

Phase II testing was performed at Patrick Air Force Base (PAFB) with the Department of Defense Manager Space Transportation System Contingency Support Office (DDMS), and the 41st Air Rescue Squadron (ARS). This testing phase consisted of compatibility tests, a spin test, a low hover test, a high hover test, and a slow forward flight test. These tests were performed for six configurations of the EEC. Test results and input from the 41st Air Rescue Squadron indicate that the EEC should be no longer than 6 feet 5 inches and have a tapered width. To use volume efficiently the medical equipment should be placed around the body in the top litter. The CG should be forward (toward the head), and weight should be kept to a minimum (Figure 7).

Phase III testing was performed at the UCF pool. This

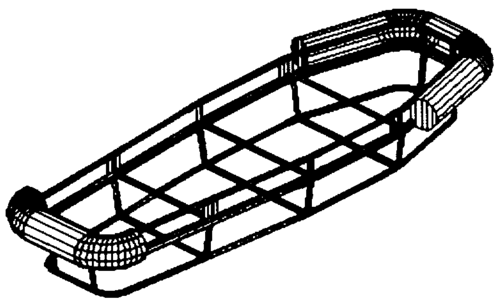

Fig. 7 Recommended configuration

testing phase consisted of flotation tests. These tests revealed that the EEC is buoyant when all layers containing polystyrene are attached. For additional buoyancy and stability, solid side floats that deploy only when necessary and flotation elements placed around the body in the top litter could be used.

Summary

The 1991-1992 senior Mechanical and Aerospace Engineering Design class completed the design, building, and testing of the Assured Crew Return Vehicle Post Landing Configuration. The objective was to develop designs applicable to the full scale ACRV for water landing and post landing operation and provide data to NASA for feasibility studies. Work was conducted in the following areas: Craft retrieval or lifting characteristics, the geometric and dynamic characteristics of the EEC, the flotation characteristics of the SCRAM configuration, and the stabilization characteristics of a rigidly mounted flotation system for the ACMD.

A one-fifth scale model of the Apollo Command Module Derivative (ACMD) with a Lift Attachment Point (LAP) system was designed by the ACMD Configuration Team. This model incorporates a rigidly mounted flotation and stabilization system and the egress system designed the previous academic year. The LAP system was designed to determine the dynamic effects of locating the lifting points at different locations. This model was not built and tested, because of higher priorities.

The ACMD Flotation Model team designed a one-fifth scale model of a flotation and stabilization system. The two systems were designed to move rigidly with the craft and provide a rigid work surface for the rescue personnel. This model was to be built and incorporated into the ACMD Configuration Model for testing. However, due to higher priorities this did not occur.

A one-fifth scale model of the Johnson Space Center benchmark configuration, the Station Crew Return Alternative Module (SCRAM) with a LAP system was designed, built and tested by the SCRAM Configuration Model Team. Testing took place in three phases. The fidelity of the model was established from geometric and dynamic characteristic tests performed on the model in Phase I and II. Results indicate that the model meets its geometric constraints, and CG offsets are accomplished by accurate placement of the ARWS. The model did not leak, and the model and LAP system withstood a 120 pound jerk test. Phase III testing took place at Offshore Technology Research Center at Texas A & M University. The facility accommodated all testing configurations and the staff provided excellent support. Tests were completed to determine the SCRAM's flotation characteristics as well as various methods of vehicle recovery. The parameters evaluated were: weight, CG, open/closed heat shield, and sea state. Two weight configurations, four CG locations and three wave states were evaluated. Test results provide the flotation and lifting characteristics of the SCRAM configuration. Additional design/operational suggestions were also provided to the ACRV Program, which were derived from the test results. These suggestions were: (1) Crew Member extraction should not be attempted from a top hatch, (2) The side hatch should be relocated to a higher vertical position, (3) Attenuators and stabilization loops should be integrated into the lifting crane cables, and the crane lifting capacity should have a safety factor of 5.0, (4) In the open heat shield configuration, the lift attachment points should allow for lifting the vehicle at an angle.

The EEC Configuration Model Team completed the design, building and testing of a full scale representation of the Emergency Egress Couch, complete with simulated human weight and medical equipment weight. This model includes a helicopter recovery system and has changeable geometric and dynamic characteristics. Testing occurred in three phases. Phase I results confirm the model meets its geometric constraints, the weight, CG and mass moment of inertia are adjustable, and the model components fasten securely and have no sharp edges. Phase II testing was performed at Patrick Air Force Base (PAFB) with the Department of Defense Manager Space Transportation System Contingency Support Office (DDMS) and the 41st Air Rescue Squadron (ARS). The 41st ARS provided excellent support and accommodated all testing configurations. Tests were completed on six configurations to determine geometric and dynamic constraints for the EEC. Test results and input from the 41st ARS indicate that the EEC should be no longer than 6 ft 5 in and have a tapered width. To use volume efficiently the medical equipment should be forward and weight should be kept to a minimum. Phase III testing consisted of flotation tests. The tests revealed that the EEC is buoyant when all layers containing polystyrene are attached.

Several recommendations are suggested for future design projects in the area of post landing operations associated with the ACRV. The flotation and wave motion characteristics of the ACRV HL-20 configuration could be examined. The EEC could be redisigned to the recommended configuration and tested for compatibility with the ACRV and the SAR forces. The possibility exists that the Soyuz will be used as the ACRV. Therefore, a need exists to design and test the Soyuz configuration in post landing operations.

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