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ASSURED CREW RETURN VEHICLE
POST LANDING CONFIGURATION

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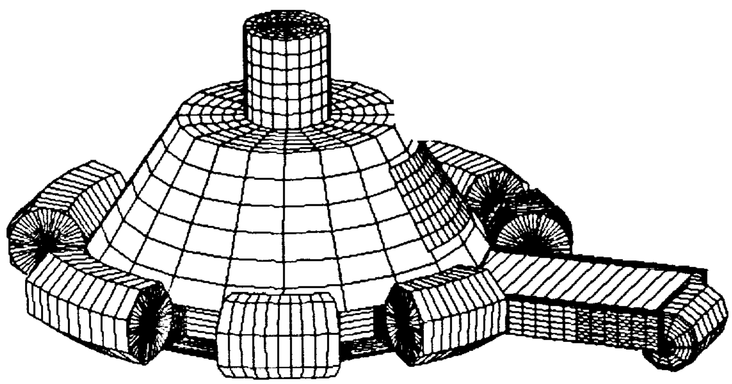

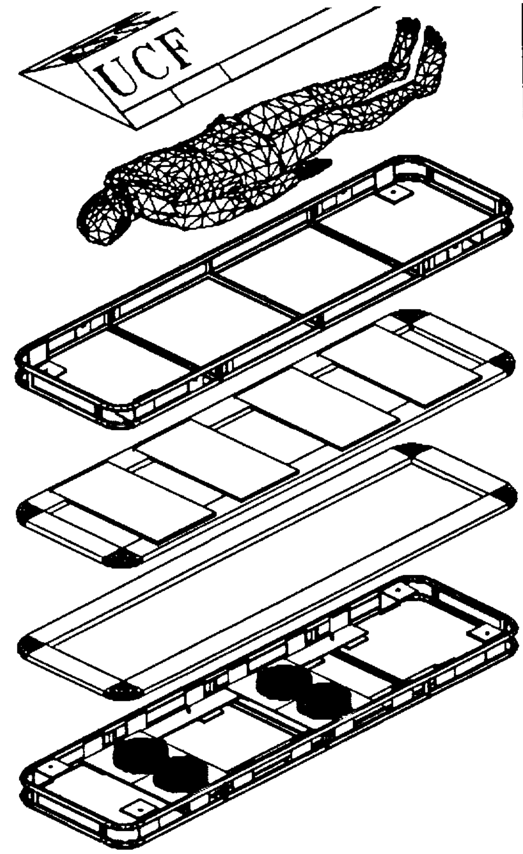

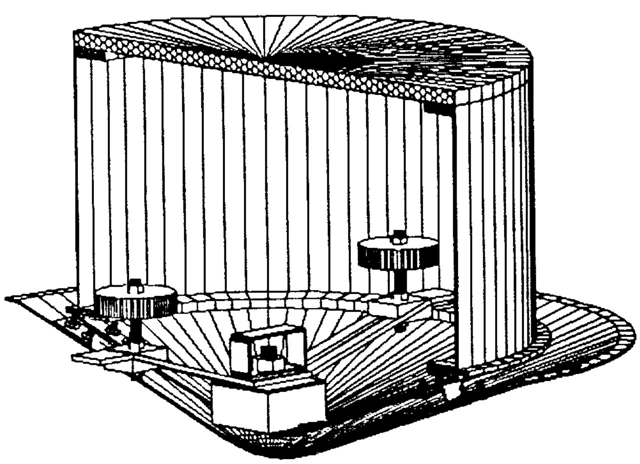

NASA/USRA FINAL REPORT 1992

UNIVERSITY OF CENTRAL FLORIDA

MECHANICAL AND AEROSPACE ENGINEERING

FOREWORD

During the 1991-1992 academic year Aerospace and Mechanical Engineering design students continued design and testing new models of the SPACE STATION ASSURED CREW RETURN VEHICLE (ACRV). Engineering Design 4501 and 4502 cater to a variety of design interests of senior aerospace and mechanical engineering students at the University of Central Florida (UCF). The output of the course sequence includes (a) oral design reviews, (b) a working model of the design and (c) a final report containing design information plus results of model construction and testing.

The goal of this year's work, conducted with the Space Station ACRV Project Office at Kennedy Space Center (KSC), was to design, build and test additional versions of the water landing ACRV. Emphasis was placed on the post landing tasks associated with the KSC mission. The fall semester was spent doing detailed designs of two one-fifth scale models of the ACRV for wave and lift testing, plus a full scale model of the Emergency Egress Couch (EEC) for helicopter lift testing. In the spring semester a scale model of the Station Crew Return Alternative Module (SCRAM) version of the ACRV was built at UCF, and tested at UCF and the Offshore Technology Research Center (OTRC) at Texas A&M University. Travel to the OTRC test site and cost associated with leasing the facility were sponsored by KSC. The EEC model was built at UCF. Preliminary testing was done at UCF, and lift testing with a search and rescue helicopter and crew was done at Patrick AFB, Florida. Wave tests of the SCRAM version of the ACRV showed increased damping with the shroud removed from the heat shield, and lift tests showed techniques that increased stability and ease of lifting. EEC helicopter lift tests showed weight limitations, and preferred moment of inertia and center of gravity locations for easy lifting of the couch.

At the end of fall semester a design review was conducted at KSC. At the end of spring semester results of wave and lift testing of the SCRAM model, and results of helicopter lift testing of the EEC model, were reviewed at KSC and Johnson Space Center (JSC). Comments received from NASA and contractor engineers during this review process have greatly influenced the content of this report and increased the engineering knowledge of the students.

The ACRV design team consisted of 21 engineering seniors. Pam Armitage served as Graduate Teaching Assistant during both fall and spring semesters. Pam's efforts coordinating and guiding the interfaces of the ACRV designs were invaluable. Eighteen seniors participated during the fall semester. Nine seniors from the fall semester group continued in the model building and testing during spring semester. They were joined by three additional seniors, for a total of twelve participating design students during spring semester. Pam Armitage had the major task of integrating the design and test reports into this final report. Jody Fuller of the SCRAM team, and Tamara Griffith of the EEC team, designed and created display models representing the work of their respective design teams.

John Brooks and David Van Sickle of last year's NASA/USRA design class continue graduate work as Rockwell Fellows. They are working on advanced ACRV designs at UCF.

We gratefully acknowledge support from NASA, USRA and Rockwell International in the NASA/USRA Advanced Space Design Program. Glenn Parker of the KSC Space Station (ACRV) Project Office has generously devoted his time guiding the design of successful ACRV models in UCF design classes over the past three years. His comprehensive knowledge made this work possible. Special recognition is due J.R. (Dick) Lyons, Space Station Project Manager at KSC, and Bill Martin, University Relations at KSC, for support of ACRV wave testing. At NASA Headquarters in Washington, D.C., special recognition is due Dr. Robert J. Hayduk, Program Manager of University Space Programs; and Sherry McGee, Higher Education. At USRA in Houston special recognition is due John Sevier, Director, Educational Programs, Vicki Johnson, Program Manager, ADP, and Barbara Rumbaugh, Senior Project Administrator, ADP for guidance and help. For guidance and advice in search and rescue operational matters, appreciation is given to Col. George D. (Dave) Phillips, Lt.Col. Ralph Abravaya, Lt.Col. Chris Malbon, Lt.Col. Scott Hogrefe, and Capt. Randy Heinbaugh from Patrick AFB. For technical support, a special thanks to Don Morris, Bob Mason and Dr. Ray Manion of Rockwell International in Downey, CA and Bob Miley of Lockheed Space Operations in Houston. For his advice on medical matters associated with the ACRV we thank Dr. Daniel Woodard of the Bionetics Corporation medical staff at KSC. We greatly appreciate the efforts of Jane Page, Dorothy Price, Donna Atkins, Ramon Budet, Cristal Woods, and Joann Ratliff for guidance and help searching out technical documentation at the KSC library. For support and advice on building the ACRV scale model we are grateful to Ed Guard and Tom Wilkes of Guard-Lee Inc. We are indebted to Greg Opresko, Jim Aliberti, Dennis Matthews, Jose Alonso, Cathy Parker, Bruce Larsen, and Dave Springer for their technical support and encouragement throughout the academic year. For their attendance and valuable comments at our design reviews, we thank our local industry representatives Joyanne Craft, Rockwell International; John Hammond, Lockheed Space Operations; and Keith Chandler, Boeing Aerospace.

Professor Loren A. Anderson August 1, 1992

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DESIGN PHASE

BUILDING PHASE

LIST OF ACRONYMS

41st ARS	41st Air Rescue Squadron
ACM	Apollo Command Module
ACMD	Apollo Command Module Derivative
ACRC	Assured Crew Return Capability
ACRV	Assured Crew Return Vehicle
AFB	Air Force Base
AS	Attitude System
CG	Center of Gravity
DDMS	Department of Defense Manager Space Transportation System Contingency Support Office
DRM	Design Reference Mission
DRM-1	Design Reference Mission 1
EEC	Emergency Egress Couch
EECM	Emergency Egress Couch Model
FD	Flotation Devices
FS	Flotation System
JSC	Johnson Space Center
KSC	Kennedy Space Center
LA	Lift Attachment
LAP	Lift Attachment Point
LD	Lift Device
LEO	Low Earth Orbit
MoI	Mass Moment of Inertia
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
OTRC	Offshore Technology Research Center
PAFB	Patrick Air Force Base
RCS	Reaction Control System
SAR	Search and Rescue
SCRAM	Station Crew Return Alternative Module
SSF	Space Station Freedom
TA	Test Article
TBD	To Be Determined
UCF	University of Central Florida
USRA	Universities Space Research Association
WATER	Wave Analysis and Test of Extraction Required

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ASSURED CREW RETURN VEHICLE POST LANDING CONFIGURATION DESIGN AND TEST

EXECUTIVE SUMMARY

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.

Section I describes in detail the design of a one-fifth scale model of the Apollo Command Module Derivative (ACMD) ACRV. The objective of 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 on the vehicle. The team was then to build and test the model, however, due to priorities, this did not occur. 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.

Section II describes in detail the design of a one-fifth scale flotation and attitude system for the Apollo Command Module Derivative (ACMD) ACRV. The objective of the ACMD Flotation and Attitude Model Team was to design, build and test a one-fifth scale model of a flotation and attitude system. The system must model the full scale flotation and attitude system. The flotation and attitude system must move rigidly with the craft and stay within storage space requirements. The flotation system maintains buoyancy and provides stability by increasing the surface area at the water line. It also allows for current structural limitations such as the Reaction Control System (RCS). The attitude system is needed to counter the moment caused by the extension of the Emergency Egress Couch (EEC) and maintain correct orientation of the craft. A description of the design options for each system follows. Then a more detailed description of the optimized system is presented along with observations and recommendations.

Section III describes in detail the design, construction, testing, and test results of a one-fifth scale Station Crew Return Alternative Module (SCRAM). 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 Lift Attachment Point (LAP) System. The LAP system aided in determining the lifting characteristics of the full scale SCRAM. Water retention by the inverted cone shaped heat shield and the need to drain the heat shield prior to vehicle retrieval was addressed. Current data for the geometric and dynamic constraints of the SCRAM was 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.

A three phase test plan was developed to evaluate the 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 water tightness of the model, as well as the durability of the LAP system. Test results show the static draft of the craft at 120 pounds without the heat shield shroud is seven inches, and with the heat shield shroud is 6 1/4 inches. The model did not take on water in either configuration. The LAP system and model showed no signs of failure after a 208 pound static hang test and a 120 pound 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 pound and a 120 pound weight configuration were evaluated. The CG locations that were evaluated were 1.2 inches above and 1.2 inches below the empty craft CG, and 1.2 inches 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 feet wave height and a 1.252 second period. The second was a scaled sea state 4 regular wave, with a 1.2 feet wave height and a 2.22 second period. The third wave state was a random wave with a .334 feet 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.

In the event a medical emergency occurs on Space Station Freedom, the Assured Crew Return Vehicle (ACRV) will be required to transport an injured crewmember safely to earth. The incapacitated crewmember may be in the supine position, hooked up to monitors, and intubated. Thus, a medical egress couch capable of supporting this crewmember is a necessity. The current rescue operation uses a helicopter pararescue team. The Emergency Egress Couch (EEC) is extended out of the hatch of the ACRV where Pararescue Jumpers (PJs) attach it to a helicopter hoist. The EEC is then hoisted, retrieved, and secured in the helicopter.

Section IV outlines in detail the design, construction, test procedures, results, and recommendations for the Emergency Egress Couch Model. The objective of this design team was to design, build, and test a full scale engineering test model of the EEC. This test model has variable geometric and dynamic characteristics to aid in determining the optimal constraints of the actual EEC. Definitive guidelines were given to the design group by NASA. The couch must have a length of seven feet and a width of two feet. The following requirements are placed on the design:

- Variable height (maximum 1 ft.)
- Variable CG (0 - 2 ft.) from center toward head
- Variable Flotation Characteristics
- Variable weight (300- 400 lbs.)
- Variable Moment of Inertia
- Lift Attachment System

The EECM consists of two litters constructed of chrome-moly steel tubing. The top litter contains the Human Weight System which consists of a dummy. The bottom litter houses a Medical Weight System to simulate placement of medical equipment. The Medical Weight System is made of weighted platforms fixed to support strips. Weight can be varied on the platforms which can be moved to alter the Center of Gravity (CG) and Moment of Inertia (MoI) during testing. Layers are attached between the two litters to vary the height of the EECM from 9 inches to 1 foot. The layers are made of wood frames with polystyrene foam in the interior for flotation. The EECM components are secured by four bolts passing through each layer and litter. Finally, a plywood cover is constructed and attached with straps. The EECM is attached to the helicopter hoist by a harness provided by the 41st Air Rescue Squadron (ARS) at Patrick Air Force Base (PAFB). The EECM is equipped with two sets of Lift Attachment Points (LAPs) to compensate for the changes in CG and MoI.

Testing was conducted at PAFB with the 41st ARS on six EECM configurations. Each configuration was attached to the helicopter cable and pulled in while the helicopter was on the ground, in low hover, in high hover, and in slow forward flight. The six configurations are as follows:

1. 296.5 lbs., 9 in. height, inside LAPs, CG at center, Medical Weight System at center, cover attached.

2. 296.5 lbs., 9 in. height, outside LAPs, CG at center, Medical Weight System at ends, cover attached.

3. 296. lbs., 9 in. height, inside LAPs, CG toward the head, Medical Weight System shifted toward the head, cover attached.

4. 362 lbs., 10 in. height, inside LAPs, CG toward the head, Medial Weight System shifted toward the head, cover attached.

5. 362 lbs., 10 in. height, inside LAPs, CG at center, Medical Weight System at ends, cover attached.

6. 362 lbs., 10 in. height, inside LAPs, CG toward the head, Medical Weight System shifted toward the head no cover.

The optimum weight distribution was found to be with the CG toward the head. Use of the outside LAPs was discarded because the lift cables bent at 90 degrees and were subject to an unsafe amount of stress in this configuration. One flight engineer is responsible for pulling in the EEC. Therefore, keeping the weight to a minimum is recommended. The EECM rectangular shape is bulky and difficult to work with. Contouring the couch to the human form and shortening its length to 6.5 feet would further enhance the handling qualities of the EEC.

The H-3 helicopter, used in testing, is being phased out and replaced by the H-60. The h-60 has a much smaller cabin and lower ceiling than the H-3. The flight engineer will be on his knees when attempting to retrieve the EEC. Special consideration must be given to make retrieval as easy as possible. The forward CG, shape modifications mentioned above, and minimum weight of 300 pounds is recommended.

Flotation tests were conducted at the University of Central Florida (UCF) pool. The EECM floats when all layers containing flotation elements are attached. Solid side floats that deploy only when necessary are recommended for additional buoyancy and stability.

INTRODUCTION

* Space Station: A New Beginning
* Assured Crew Return Vehicle Concept
* UCF ACRV Projects (1989-1991)
* 1991-1992 UCF ACRV Design Projects

INTRODUCTION

Space Station: A New Beginning

"The congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind..."[1]

With these words congress enacted the National Aeronautics and Space Act which created NASA in 1958 and continues to guide its policies today. following in the same enthusiasm and determination, President Ronald Reagan, in his State of the Union Message on January 5, 1984, directed NASA to "...develop a permanently manned Space Station and to do it within a decade. "

This commitment to the future, ripe with intellectual and technical challenge, holds vast opportunities for commercial profit and the preservation of the nation's economic vitality. The Space Station symbolizes America's significant advancements in space and a determination to remain undeterred by the loss of Challenger and her crew.

The practical benefits of the Space Station will be many, serving a diverse range of functions. A few of these functions are anticipated to be:

* A laboratory in space, for the development of new technologies and the conduct of science,
* A permanent observation post used for the study of Earth sciences, as well as to peer out to the edge of the universe,
* A facility where payloads and spacecraft can be maintained and repaired,
* A location where vehicles can be deployed to their destinations,
* A staging base for future space endeavors.

Progress has already been made in the development of this program.. The road ahead will be rigorous and demanding. A unique partnership has been established with Canada, Europe, and Japan to provide elements, that together, will make the Space Station a fully functional reality.

The Space Station project symbolizes leadership in space for the United States as a necessary component of civil space policy. Opportunities for private business profits will also improve the national economy. However, the advantages are not just limited to the United States. Because the operation of the Space Station is to be an international effort, it will benefit everyone by allowing mankind to move beyond the confines of Earth as never before possible.

Assured Crew Return Vehicle Concept

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.[2] 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.

UCF ACRV Projects (1989-1991)

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.[3]

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, increasing the weight attached, using 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 causes seasickness.[4]

A concept employing Rocker Stoppers 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.[5]

1991-1992 UCF 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 priorities, this did not occur. The ACMD Configuration Model design is presented in Section I of this report.

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. Section II of this report presents the ACMD Flotation Model design effort.

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. The design, building and testing of the SCRAM Configuration Model is presented in Section III.

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. The design, building and testing of the EEC Configuration Model is presented in Section IV.

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.

SECTION I

ACMD CONFIGURATION MODEL

DESIGN PHASE

* SCALING
* MATERIALS
* SUBSYSTEM INCORPORATION
* SECTIONING
* SEALS
* CENTER OF GRAVITY AND MASS MOMENT OF INERTIA
* LIFT ATTACHMENT POINTS
* OPTIMAL SOLUTION
* OBSERVATIONS AND RECOMMENDATIONS

SECTION I. ACMD CONFIGURATION MODEL

INTRODUCTION

The ACMD Configuration Model team used 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 incorporates a rigidly mounted flotation system and the egress system designed the previous academic year. The model is to determine the stabilization characteristics of the flotation system, and the retrieval or lifting characteristics of the ACMD configuration. Current data for the weight, geometric, and dynamic 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. Specifications were written to aid in the design. (Appendix E). The design efforts of the ACMD Configuration Model team are presented in this section. The model was not built or tested due to higher priorities. The areas researched during the design process were: Construction, Center of Gravity and Mass Moment of Inertia, and Lift Attachment Points.

The model construction plan was divided into the following areas: Scaling, Materials, Subsystem Incorporation, Sectioning, and Seals. A Buckingham Pi dimensional analysis was performed and the Froude scaling factors were determined. The materials considered were wood, plastic, fiberglass, and aluminum. The space needed for the incorporation of an egress and system and a rigidly mounted flotation and attitude system were determined. The model is sectioned to allow access to the egress couch and other test equipment located inside the model. The sectioning methods investigated include upper deck, low horizontal, and back door. To seal the model from water intrusion during water testing the following seals were considered; weatherstripping, appliance seals, and o-rings.

The center of gravity and mass moment of inertia of the model simulate those of the ACRV. A subsystem was designed to model the weight, CG and mass moment of inertia. The designs investigated were; radial mass system, flat plate system, peripheral weight system, and a combined system.

To determine the lifting characteristics of the ACMD, lift attachment points were investigated. These points were to simulate the type of lift and the location of the lifting points on the full scale ACMD. The methods considered were; single pickup, multiple pickup and net pickup.

Decision matrices, aided in determining the optimal solution for each area. These results are presented followed by observations and recommendations.

DESIGN PHASE

Several design alternatives were considered. Integration meetings and briefings were held with NASA/KSC, Rockwell/SSD, and the Department of Defense Manager Space Transportation System Contingency Support Office (DDMS) throughout the academic year to ensure the fidelity and acceptance of the ACRV ACMD configuration model.

Chapter 1.0 SCALING

The parameters for the model specify a one-fifth scale of the ACRV be used both geometrically and dynamically. To accomplish this, a Buckingham Pi dimensional analysis (Appendix A, Figure A-1) was performed and the Froude scaling factors were determined. These factors allow the model to accurately simulate the characteristics of the ACRV. 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 (Figure 1.0.1)[6]. Completed model dimensions are as shown in Figure 1.0.2.

FROUDE SCALING LAWS

Scale Factor	$\lambda = 1/5$
Length	$\lambda = 1/5$
Area	$\lambda^2 = 1/25$
Volume	$\lambda^3 = 1/125$
Mass	$\lambda^3 = 1/125$
Moment of Inertia	$\lambda^5 = 1/3125$

Figure 1.0.1 Froude Scaling Laws

Chapter 2.0 MATERIALS

There are several material alternatives for the construction of the model. Each material considered affects the model's construction. The types of materials reviewed are:

1. Wood
2. Plastic
3. Fiberglass
4. Aluminum

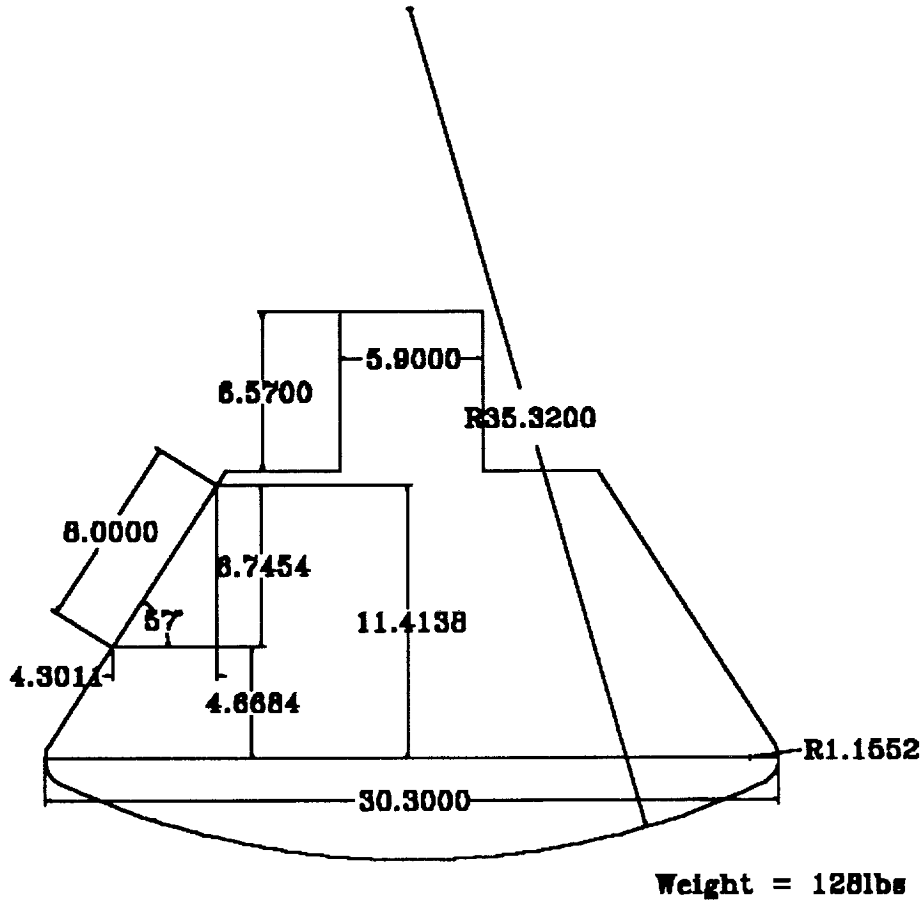
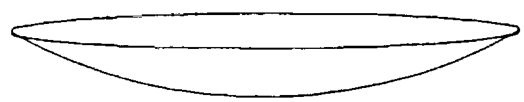


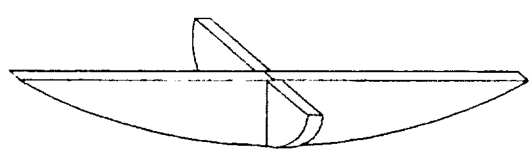
Figure 1.0.2 Model Dimensions (in inches)

2.1 WOOD

A possible construction material for the shell of the model is 1/4 inch to 1/8 inch thick plywood. There are three major sections that must be fabricated separately. The first section is the bottom hemispherical shape (Figure 2.1.1a). This section is the most difficult to fabricate due to its curvature. One method of incorporating this shape is to make a mold of wood beams cut with the same curvature as the bottom hemisphere (Figure 2.1.1b). These beams, mounted together, are used as a support for bending the plywood skin. After fabrication of the bottom section, the side sections are formed. The outer layer of plywood is cut into V-sections (Figure 2.1.2a) and wrapped around the frame structure (Figure 2.1.2b) to form the conical shape. The top structure is the easiest to fabricate due to its simple tube shape. However, the radius of this small tube shape requires several beam supports and plywood skin sections to prevent the wood skin from splitting.

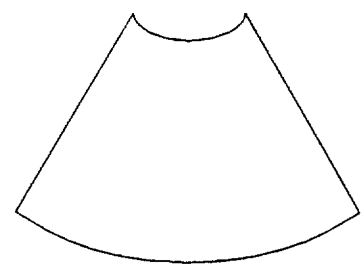


(a.)

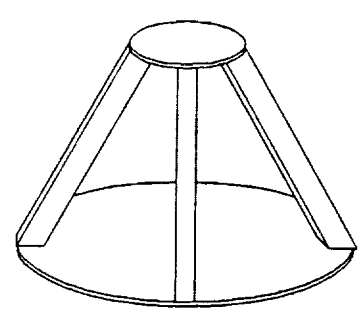


(b.)

Figure 2.1.1 Wood Bottom



(a.)



(b.)

Figure 2.1.2 Wood Frame

Plywood is easy to obtain and is formed around a frame into the desired shape. It is an inexpensive alternative for the shell construction, but must be extensively caulked and waterproofed to prevent warping and water weight gain. Sharp radii cannot be fabricated because the plywood splinters and breaks.

2.2 PLASTIC

Plastics include acrylic, butyrate, and foamed varieties. They are used predominantly in the model industry because they are easy to work with and can be fabricated into complex, rigid shapes.[7] Plastics are light-weight, inexpensive materials, which are naturally waterproof.

Fabricating plastic objects requires the construction of a solid mold approximately 1/8 inch smaller in dimension than the model. The smaller mold compensates for the material thickness of the outer skin. After the mold is built, the plastic is pulled over the top in sheets and formed in a process known as vacuum molding. This process may cause a non-homogeneous thickness of the material. The shell tends to be thicker at the top where the sheets are applied, and thinner at the bottom, creating weak areas in the model. Unless applied in thick layers, plastic may not be able to support the required weight or withstand test conditions. Vacuum molding makes it difficult to form any inner flanges that are required to join sections of the model together. The molding process is expensive because a specialized technique is required to form the mold. Plastic is also difficult to repair. Any damage to the model requires epoxy application for repair.

2.3 FIBERGLASS

Fiberglass is another material considered for the construction of the model. Fabrication of the shell of the model requires the construction of both plugs and molds. Plugs are made in several ways and are constructed from wood, or wire mesh and plaster formed around a frame and sanded to a smooth finish.[8] Once plugs are completed, molds are formed from the fiberglass. Fiberglass is supplied in thin sheets of cloth and is wrapped around each plug as resin is applied. After drying, the fiberglass mold is removed from the plug and is treated and sealed. The model shell is formed by layering fiberglass and resin in the prepared mold.[9]

Molding fiberglass is an easy process and does not require any special epoxies or materials. Fiberglass is strong and is waterproof. It handles impacts and supports weight better than plastic, and does not need an inner frame structure for extra support. It is also possible to incorporate any required radii of curvature into the fiberglass structure. Several companies in Orlando, Florida, are capable of doing this type of work.

Fiberglass is not strong in shear, therefore, any attachment points for bolts or fasteners must be reinforced. A disadvantage of using fiberglass is the plug and mold construction. To obtain the desired shape the plugs must be very accurate. Plug construction is time consuming and must be done with care and skill. Using plaster makes the plug construction easier. It also permits future dimension changes to be made. A wood plug is more difficult to make and cannot be modified as easily to accommodate any model changes.

2.4 ALUMINUM

Thin aluminum sheets of 1/16 inch to 1/8 inch thickness can be used to fabricate the outer skin of the model. These sheets are cut to form the conical shape of the vehicle and welded to seal out water. Aluminum corrodes if left unprotected, especially in a water environment, however, this model is protected by paint which slows down the corrosion process. The top tunnel section is fabricated from a single sheet of aluminum bent in a cylindrical shape and welded. The bottom hemisphere is the most difficult section to fabricate. It requires special tooling and the construction of a mold. The sheet metal for this section needs to be pressed onto the mold using a hydraulic press to obtain the required radius of curvature. Aluminum is the strongest of any of the materials discussed and forms the most sturdy model. Aluminum is easy to obtain, durable, and waterproof, and no inner support is required. Due to the nature of aluminum it can only be bent to 1.5 times its thickness. Incorporating equipment into an aluminum model would be difficult. Drilling and possible threading is required since wood screws cannot be used. No local companies are capable of performing the more complicated procedures required to form the bottom section.[10]

Chapter 3.0 SUBSYSTEM INCORPORATION

During model construction all subsystems designed for the model must be incorporated. Two major systems to be included are the egress mechanism and the flotation devices.

3.1 EGRESS COUCH

The egress couch (Figure 3.1.1) will be placed in the center of the model floor for testing, and sufficient interior space must be left for its operation. Its measured base dimensions are approximately 22 inches by 13 inches. Before the couch is deployed its height is approximately 5 inches. Since its total height is about 10 inches after deployment, the bulk of the interior space of the model must be kept clear. A functional hatch must be provided to allow the couch mechanism to egress. The hatch, which scales to 8 inches by 8 inches, must be located no more than 6.4 inches above the floor level to provide the necessary clearance.[11]

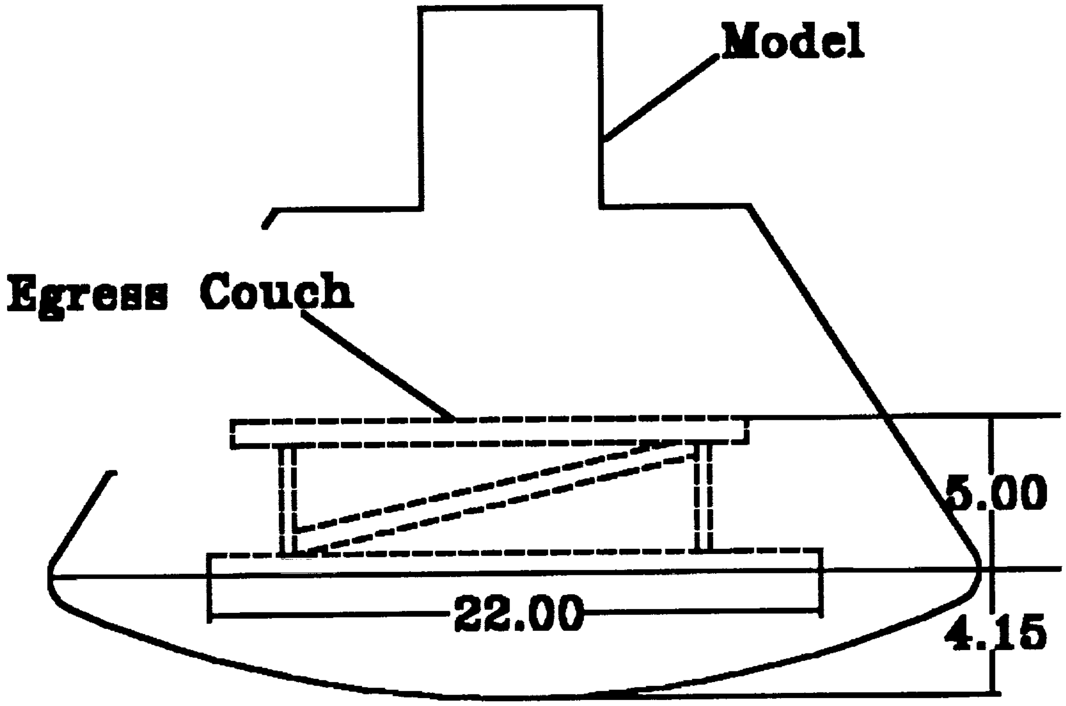


Figure 3.1.1 Egress Mechanism (in inches)

3.2 FLOTATION DEVICES

The flotation devices are located on the lower portion of the craft at the water line. The exact position and spatial requirements as specified by the flotation design team are given in Figure 3.2.1. The model is designed such that all the space required in this vicinity is available.

Chapter 4.0 SECTIONING

To allow access to the egress couch and other test equipment located inside the model, the model must be sectioned. The site chosen for the sectioning must not interfere with the flotation devices and must create an opening sufficient to accommodate the egress couch. Despite these restrictions, there are several ways to section the model. The sectioning methods investigated include:

1. Upper deck
2. Low Horizontal
3. Back door

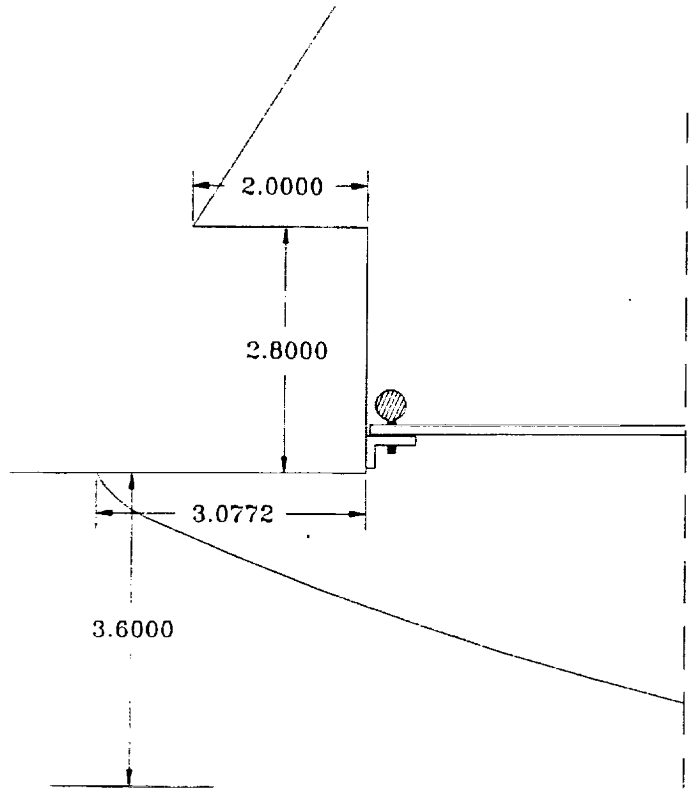


Figure 3.2.1 Flotation (in inches)

4.1 UPPER DECK SECTIONING

In this method the upper deck and access tunnel form a single lift-away unit (Figure 4.1.1), is the simplest method of sectioning the model. Each section requires an inner flange around its perimeter to permit assembly of the shell. This location is far enough from the water line that the seal between the sections is not as critical as it is for lower sectioning locations. Upper deck sectioning has the disadvantage of providing the smallest access opening. It requires that the egress couch be lowered into the model vertically and tilted down into position. Visibility is also limited in the interior space due to the size of the opening and the depth of the lower section.

4.2 LOW HORIZONTAL SECTIONING

Low horizontal sectioning, cuts the model horizontally at the base of the hatch which is above the flotation equipment (Figure 4.2.1). This provides the largest opening of the three alternatives, making the positioning of the egress couch and test equipment simpler and allowing a full visual range during adjustments. However, because this location sections the model so near the water line, an adequate seal between the sections must be provided to prevent leakage.

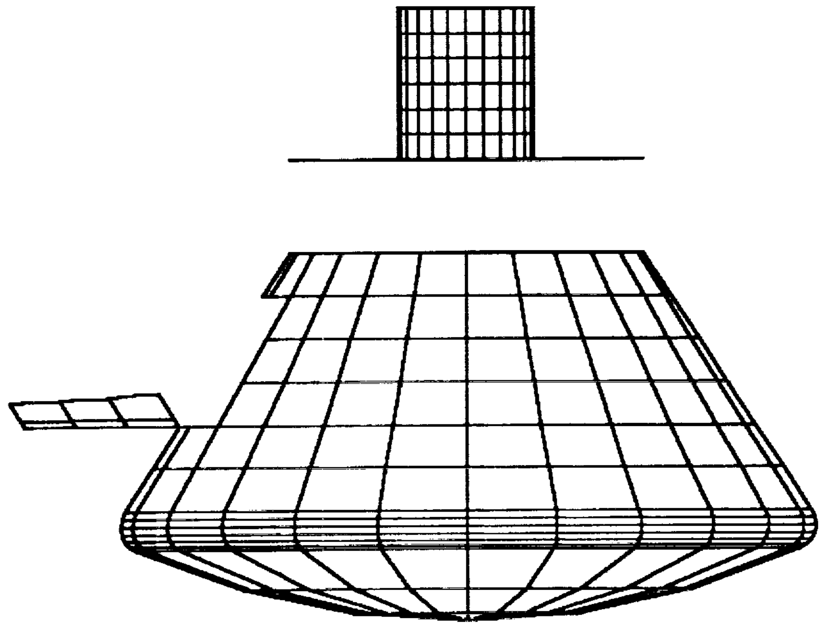


Figure 4.1.1 Upper Deck Sectioning

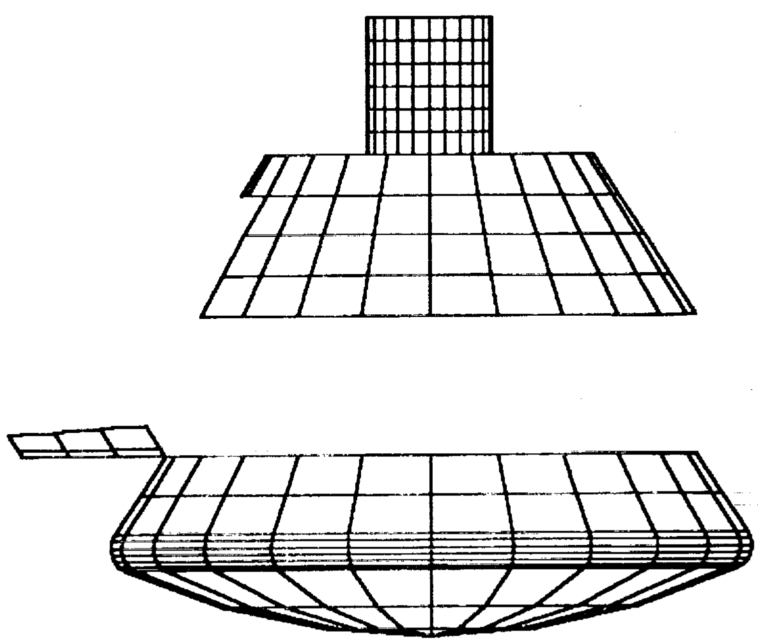


Figure 4.2.1 Low Horizontal Sectioning

4.3 BACK DOOR SECTIONING

The interior of the model is accessed by a back door sectioning method. This allows a large, hinged section of the model on the side opposite the hatch to be opened (Figure 4.3.1). Back door sectioning provides an opening sufficient to admit the egress couch and allow moderate visibility in the interior of the craft. The location is positioned high on the model to minimize the need for a water-tight seal, but this compromises the accessibility of the interior space, and the visibility as well. Making the door larger positions the lower edge nearer the water line and decreases the overall strength of the shell, making it more susceptible to failure.

Chapter 5.0 SEALS

Since the model is sectioned and has a working hatch, seals are needed to prevent any water intrusion. Four types of seals considered are weatherstripping, gaskets, appliance, and O-Ring.

5.1 WEATHERSTRIPPING

Weatherstripping (Figure 5.1.1), provides an inexpensive way to seal the sections of the model. It is readily available, but provides only a moderate seal. Weatherstripping material is relatively thick and results in a gap between the sections.

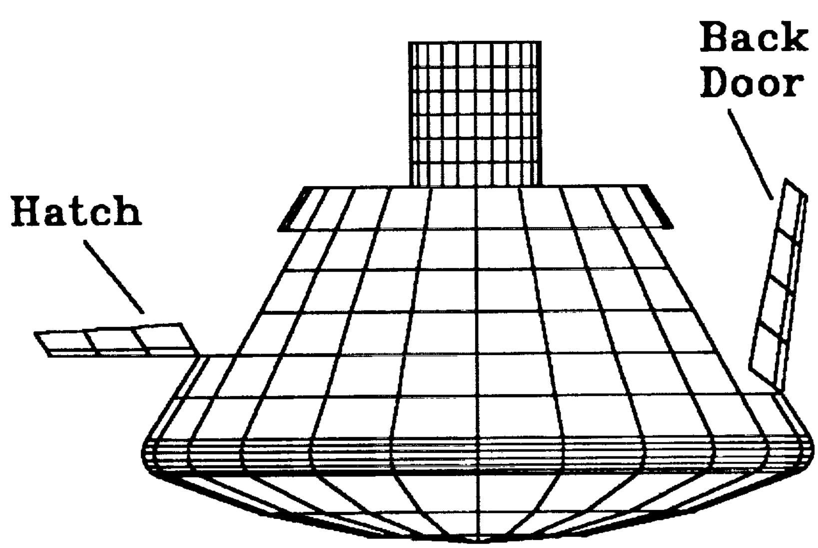


Figure 4.3.1 Back Door Sectioning

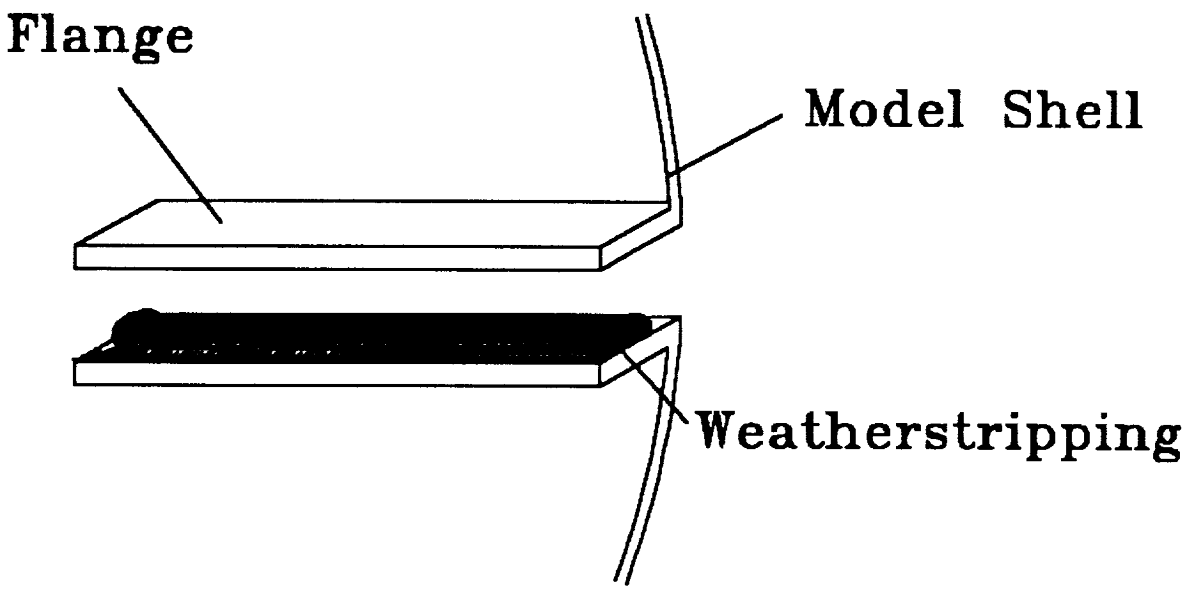


Figure 5.1.1 Weatherstripping

5.2 GASKETS

Gaskets (Figure 5.2.1), are another material for sealing the model. They provide a good seal if even pressure is applied along their surface. Gasket material, cork or fiber, can be obtained in sheet form and is inexpensive.[12]

5.3 APPLIANCE SEALS

Appliance seals, such as those used to seal dishwasher doors, are inexpensive and are widely available. However, they only provide a moderate seal. Appliance seals (Figure 5.3.1), are the thickest of the sealing alternatives and leave a large gap between the model sections.

5.4 O-RINGS

O-Rings (Figure 5.4.1), are potential seals for the model. O-Rings are made of several types of materials, yield the best sealing quality, and require uniform compression to form an adequate seal.

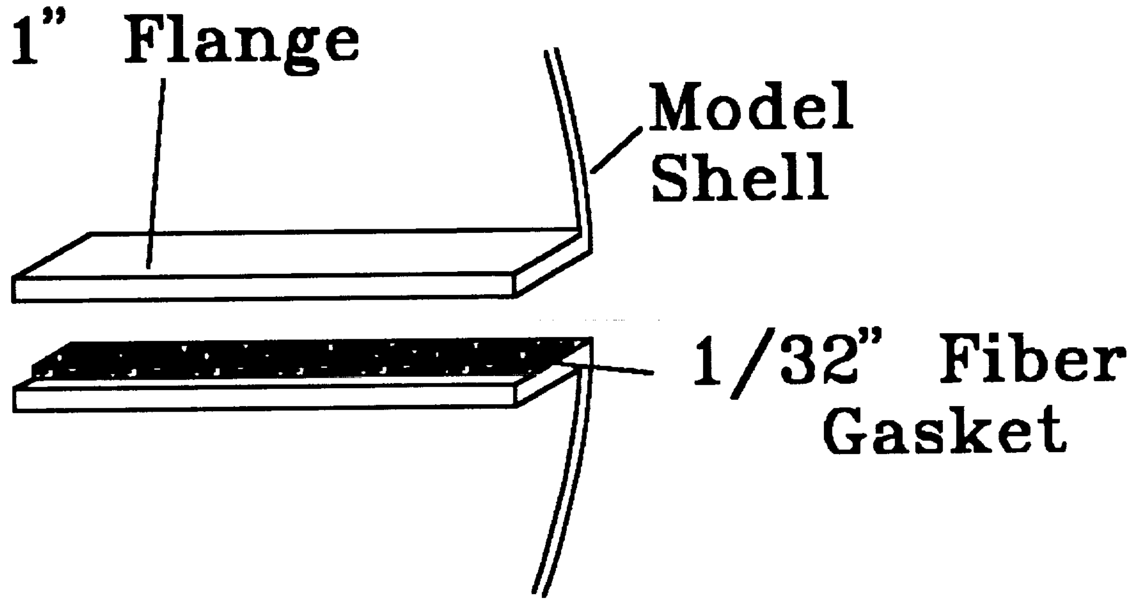


Figure 5.2.1 Gasket

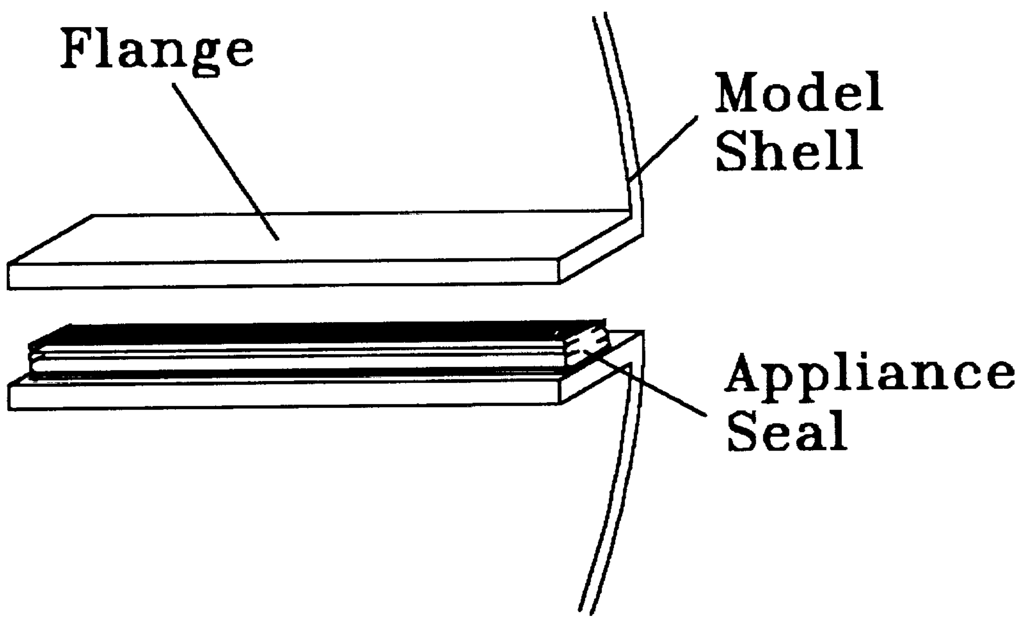


Figure 5.3.1 Appliance Seal

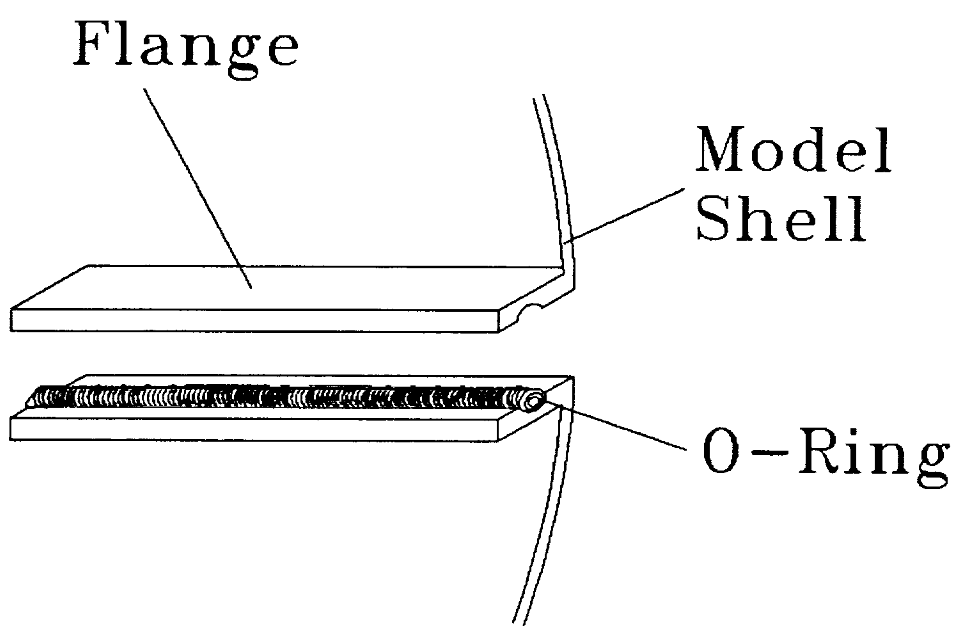


Figure 5.4.1 O-Ring

Chapter 6.0 CENTER OF GRAVITY & MOMENT OF INERTIA

The center of gravity (CG) and mass moment of inertia (MI) of the model must simulate those of the ACRV. After initial values of the CG and MI are determined for the model, its mass system is altered to simulate the values provided for the ACRV. The major consideration in modeling the CG and MI is their interdependence. A second consideration is the need to incorporate the flotation system and working egress mechanism into the model. Methods used to change the CG and MI values include:

1. Radial mass system
2. Flat plate system
3. Peripheral weight system
4. Combined system

6.1 RADIAL MASS SYSTEM

The radial mass system for varying the CG and MI of the model consists of cylindrical mass shapes on horizontal radial rods (Figure 6.1.1). These rods, which swivel around a vertical axis and are capable of vertical height adjustments, are located in both the top and bottom of the model. A configuration of one or more rods in either location can be used at any time. The weights are positioned along the radial rods and the rods are arranged at any angle required to place the weights in the correct location within the model.

The flexibility of this system is an advantage. It is easy to change the weight positions to adjust the CG and MI. The disadvantage of the radial mass system is that there is limited vertical area in which to move the rods due to the incorporation of the egress mechanism. This restricts the rods to below the floor level and above the operating range of the egress couch. Another disadvantage of this system is the need for either telescoping rods or several rods of varying lengths to take advantage of the variation of the shell diameter with height.

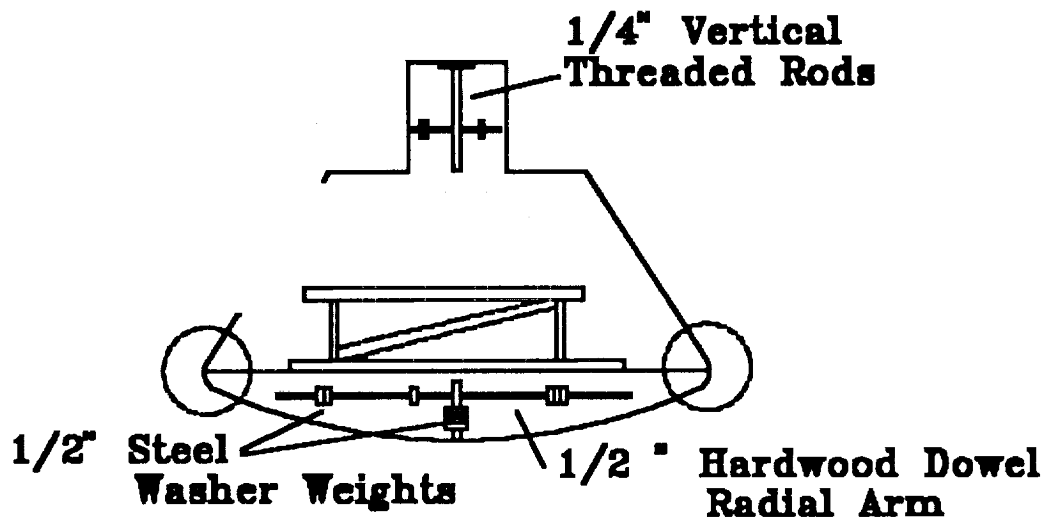


Figure 6.1.1 Radial Mass System

6.2 FLAT PLATE SYSTEM

Another way of changing the CG and MI is a system of weights in the shape of flat plates (Figure 6.2.1). These weights are fastened under the floor and to the top of the model above the egress mechanism working area. The relative weights of the plates and their positions determine the CG. The radial distribution of the weight of the plates determine the MI.

This system has two advantages. First, the plates are as heavy or as large radially as needed to model the center of gravity and moment of inertia. Second, symmetry causes the center of gravity of a flat plate to be about the vertical axis through the center of the plate. The moment is also symmetrical about this same axis, which simplifies mathematical modeling of the system. There are disadvantages associated with using a flat plate system. The plates must be machined very carefully and there must be a wide variety of sizes and weights available to obtain the proper weight distribution within the model. Another disadvantage is the limited area for mounting these plates.

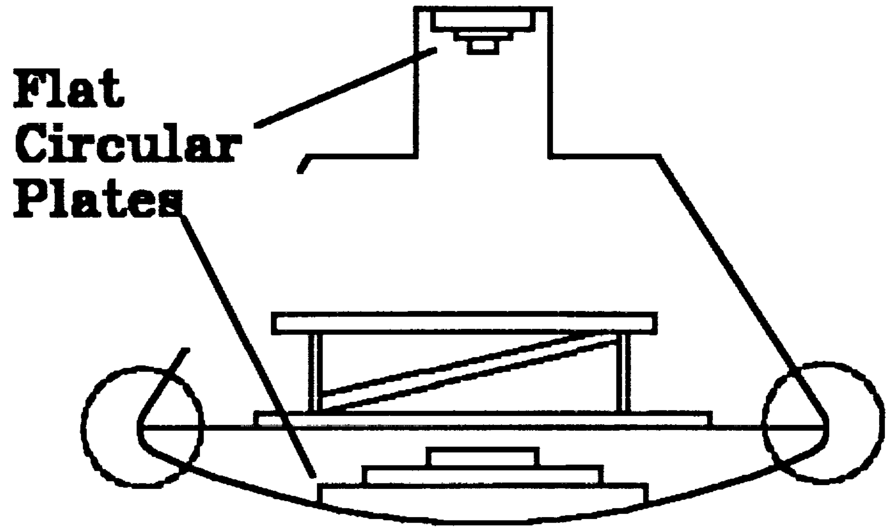


Figure 6.2.1 Flat Plate System

6.3 PERIPHERAL WEIGHT SYSTEM

Varying the MI independently of the CG simplifies the modeling of the vehicle. The use of a peripheral weighting system (Figure 6.3.1) changes the MI virtually independent of the CG, as long as the weights are placed symmetrically about the CG. The weights are of any consistent shape since it is not a critical factor for this method. This makes it easy to obtain weights. Most of the weight is located on the shell and does not interfere with the operation of the egress mechanism. A disadvantage to this system is that locating all the weights at such large distances from the CG could cause the required MI to be exceeded before the overall weight requirement for the model is met.

6.4 COMBINATION SYSTEM

Due to the interdependency of the CG, MI, and overall weight, modeling of these parameters with only one type of weighting arrangement becomes difficult due to the spatial limitations of the craft. Using a system as shown in Figure 6.4.1, which combines the features of all the discussed methods of modeling the CG and MI, maximizes system flexibility. The disadvantages of such a combined system are its complexity and expense.

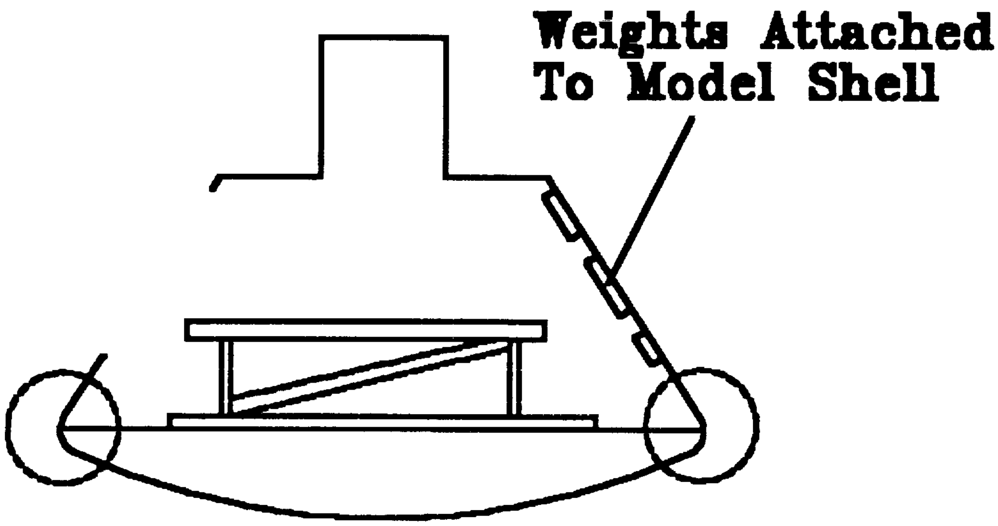


Figure 6.3.1 Peripheral Weight System

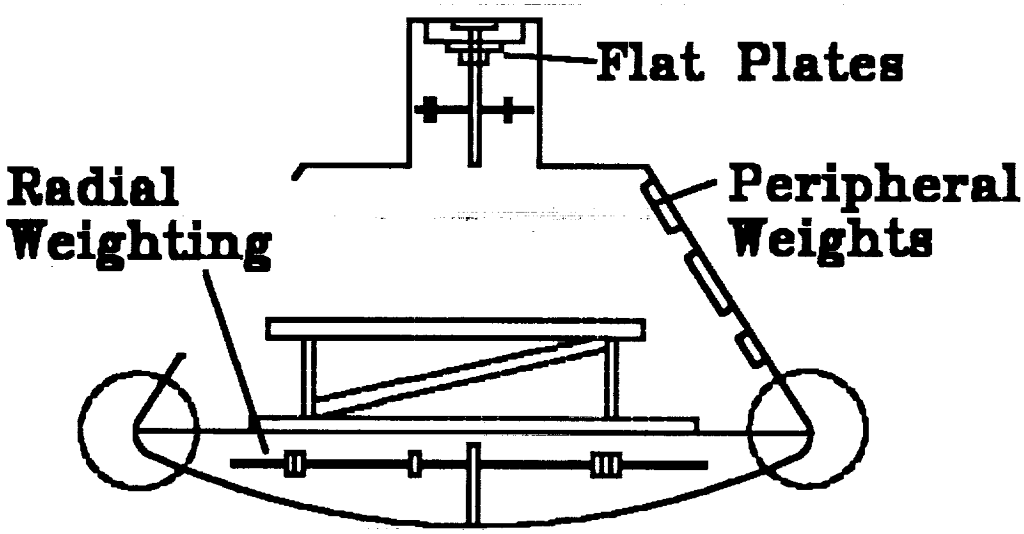


Figure 6.4.1 Combination System

Chapter 7.0 LIFT ATTACHMENT POINTS

All lift attachment points (LAP's) considered for the model are capable of being applied to the ACRV. Methods considered for lifting the model are:

1. Single pickup
2. Multiple pickup
3. Net pickup

7.1 SINGLE POINT PICKUP

The use of a single lift attachment point pickup (Figure 7.1.1), is the simplest method of retrieving the model. However, this system has no built in back-up should the attachment point fail. This is not especially important for the model, but is of great concern when considering the ACRV.

7.2 MULTIPLE POINT PICKUP

Another system considered is the multiple LAP. These points are placed high or low on the vehicle as long as the attachment points are above the center of gravity and are not located on the access tunnel. Either angled or vertical lifts can be accomplished.

7.2.1 High Attachment Points

LAP's located high on the craft make it more stable because the attachment points are located well above the center of gravity. Locating the LAP on the upper deck (Figure 7.2.1.1) takes advantage of the fact that the deck section is reinforced to withstand a 4g force generated when the parachutes open before splashdown.[13] However, with high attachment points the rescue personnel will have difficulty attaching the lift cables.

7.2.2 Low Attachment Points

Attachment points placed low on the vehicle, as seen in Figure 7.2.2.1, make it easier for the rescue personnel to attach the cables to the craft. The lower the points are placed, however, the more unstable the system becomes. The LAP's must be above the flotation area or the flotation devices must be removed.

7.2.3 Angled Attachment Points

Lifting the vehicle in an angled position (Figure 7.2.3.1) helps to drain any water that may have collected within the vessel. This reduces the cable load. Should this water become contaminated with fuel residue, the toxic mixture would be drained into an area below the craft.[14] This area needs to be cleared of personnel before angled lifting begins.

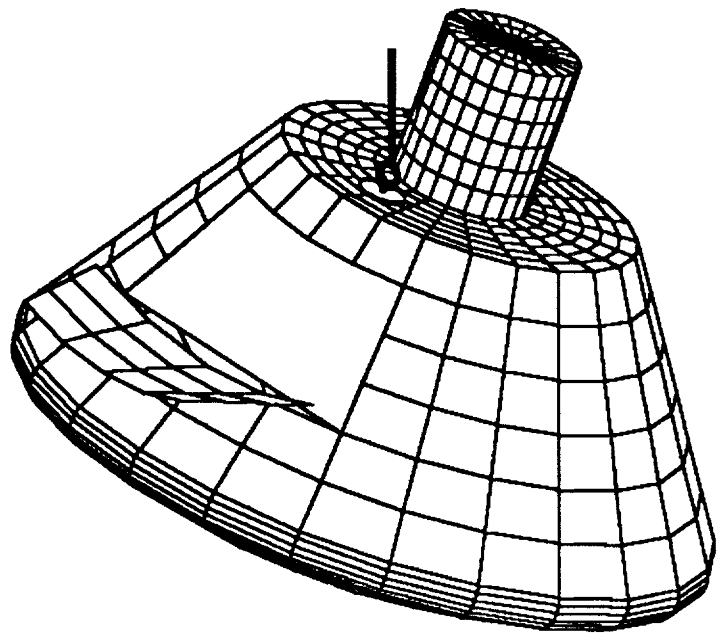


Figure 7.1.1 Single Point Pickup

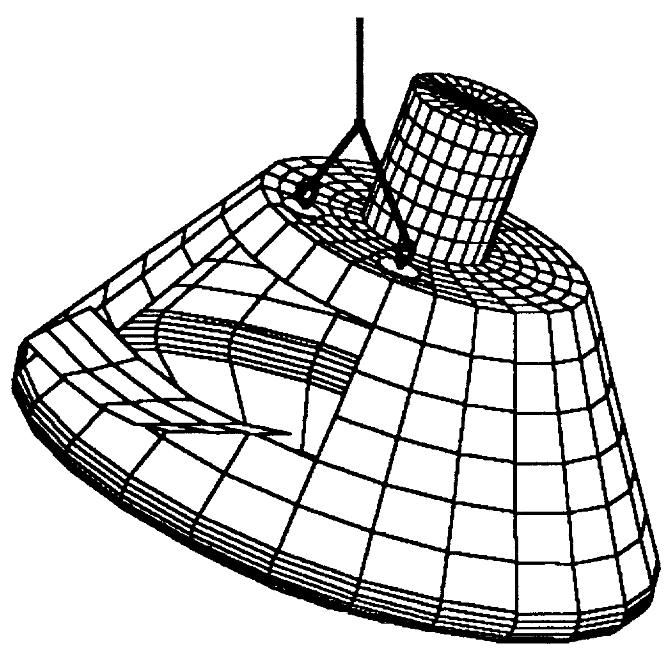


Figure 7.2.1.1 High Attachment

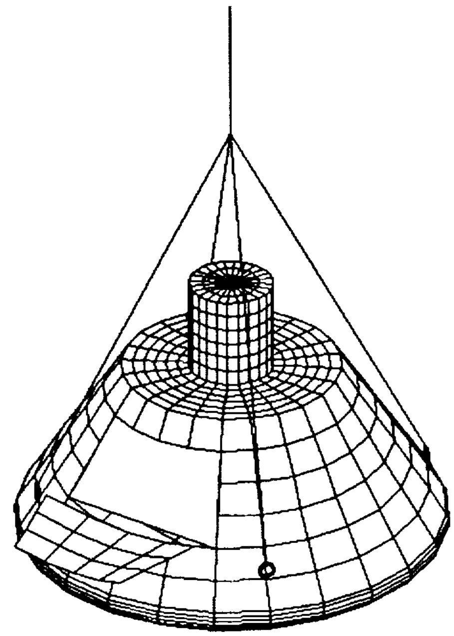


Figure 7.2.2.1 Low Attachment

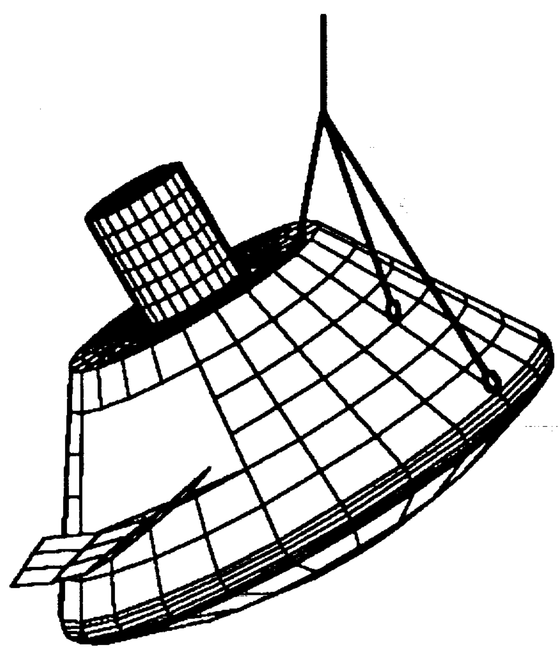


Figure 7.2.3.1 Angled Lift

7.2.4 Vertical Attachment Points

Lifting the vehicle vertically (Figure 7.2.4.1) prevents toxic liquid drainage, but makes it harder for the craft to be lifted if extra water weight is present. The ACRV can take on significant amounts of water.[15] Also, if the craft is lifted vertically, a method must be determined for disposal of the toxic water-fuel mixture. Disposal options may include dumping into the ocean once the area is clear, or storing on-board the transport vessel for hazardous waste personnel to handle at a later time.

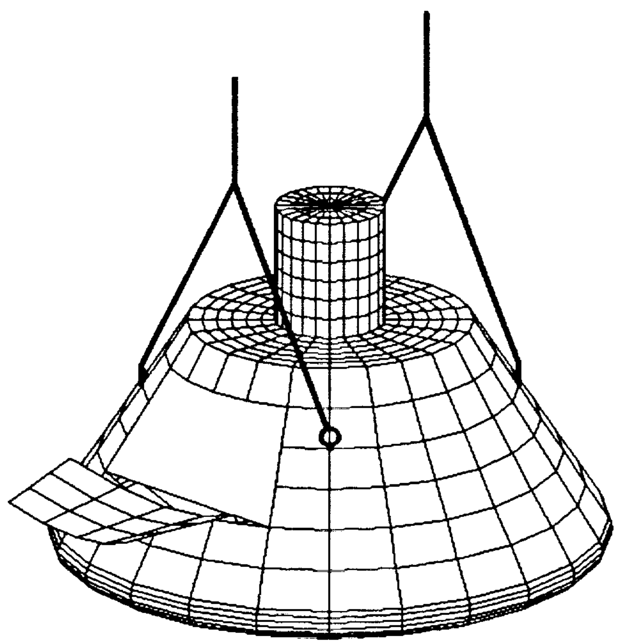


Figure 7.2.4.1 Vertical Lift

7.3 NET PICKUP

A large cargo-type net is used to retrieve the vehicle (Figure 7.3.1). This method is used if the LAP's fail or the craft is floating in a position such that the LAP's are not accessible. Removal or deflation of flotation equipment is required before lifting to prevent the net from damaging the flotation system. This method of retrieval provides no control over the position of the craft as it is lifted.

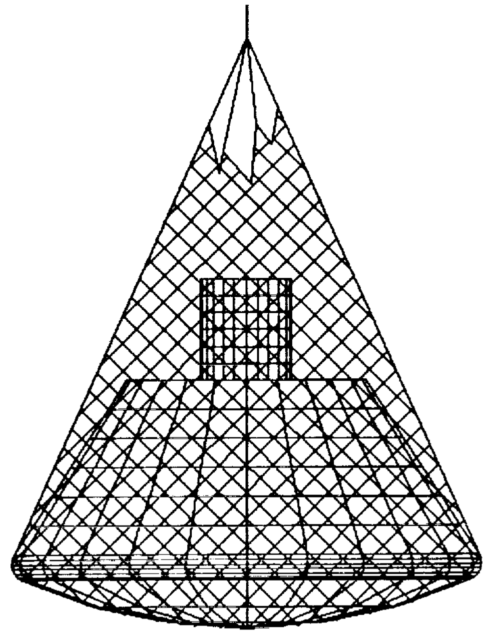


Figure 7.3.1 Net Pickup

Chapter 8.0 CHOSEN SOLUTION

8.1 MATERIALS

After construction of a decision matrix, shown in Appendix B, Figure B-1, the material found to be best suited for the construction of the model is fiberglass. A fiberglass model is waterproof, and simple to construct and repair. These features allow student involvement during the model construction phase. A fiberglass model requires construction of plugs and molds before forming and assembling of the shell.

8.1.1 Plug Construction

Plugs are used for shaping the plaster molds. As shown in Figure 8.1.1.1, a two-section wood frame is built of 3/4 inch thick marine grade plywood. The bottom portion of the wood frame is constructed from plywood beams cut to the radius of curvature required for the bottom of the model. The plywood beams are attached to a circular plywood section. The circular sheet has a diameter 4 inches larger than is desired for the model. The excess wood allows a 2 inch external flange to be formed on the mold. The upper portion of the plug is constructed from three circular sections of plywood joined together by 3 inch wide plywood beams.

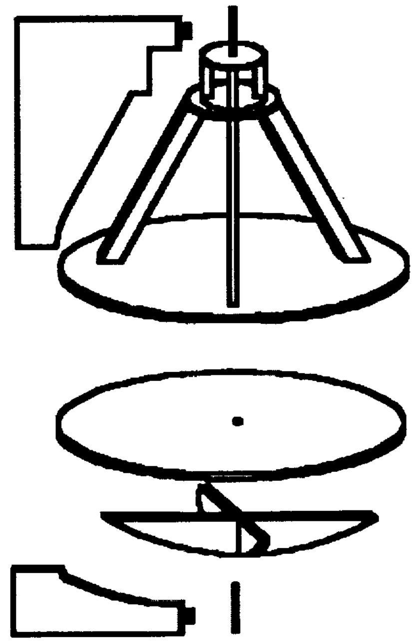


Figure 8.1.1.1 Wood Frame and Stencils

Two stencils, one shaped for each plug section, are made of 3/4 inch thick marine plywood cut to the dimensions of the model. These stencils are mounted on 1/2 inch diameter steel rods which pass through the centers of each plug frame. The stencils are capable of rotating 360 degrees.

Once the wood frame for a plug is complete it is wrapped with a wire mesh and covered with burlap. The burlap is soaked in molding plaster before it is applied to the frame. Layers of plaster are applied to the wire mesh and burlap to build the plug up to the model dimensions. During this process, the forming plug is checked frequently with the stencils shown in Figure 8.1.1.2. Plaster is added or sanded away as needed to obtain the exact model dimensions required.

Before the plaster is allowed to dry, sections are carved out to the dimensions required for the flotation system and hatch (Figure 8.1.1.3). Carving out the hatch pattern to a depth of 3/16 inch allows the formation of an inner flange on the model which supports the hatch in its closed position. After the plaster dries it is coated with several layers of shellac. The shellac keeps the plaster from absorbing water during the mold construction phase. After the shellac dries, a layer of paste wax is applied to the plug as a releasing agent to allow removal of the mold once it is completed.

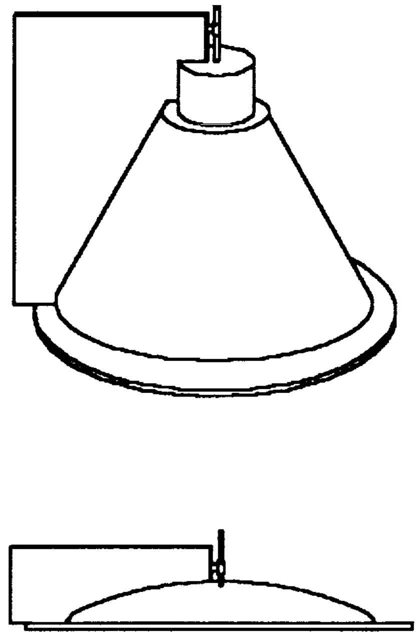


Figure 8.1.1.2 Plaster Plug

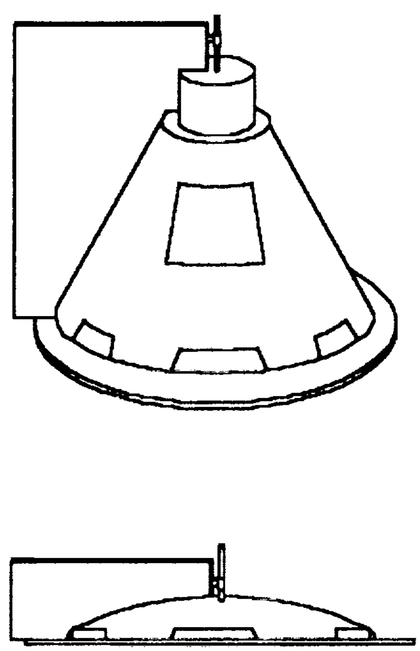


Figure 8.1.1.3 Carved Plug Sections

8.1.2 Mold Construction

To begin construction of the mold, a plywood ring is attached to the plug at the level where the model is sectioned for the access area (Figure 8.1.2.1).[16] This ring forms an external flange on the mold. The large circular plywood sections at the base of each plug form an external flange on the mold. These flanges provide an area to attach the two sections of the mold together allowing this part of the model shell to be constructed as one piece. The mold pieces are separated to release this section of the shell when it is completed.[17]

The sections carved open for the flotation system are filled with plaster in a separate operation from that for the main mold. These plaster sections are allowed to dry and removed. They are sealed with shellac and treated with paste wax. This forms removable molds of the insets, called fill plugs (Figure 8.1.2.2). These separate pieces are necessary to allow the mold to be removed from the plug when it is completed. These fill plugs are later fitted into slots on the main mold before the shell is constructed. The same technique is used for filling the carved area where the hatch is to be located.

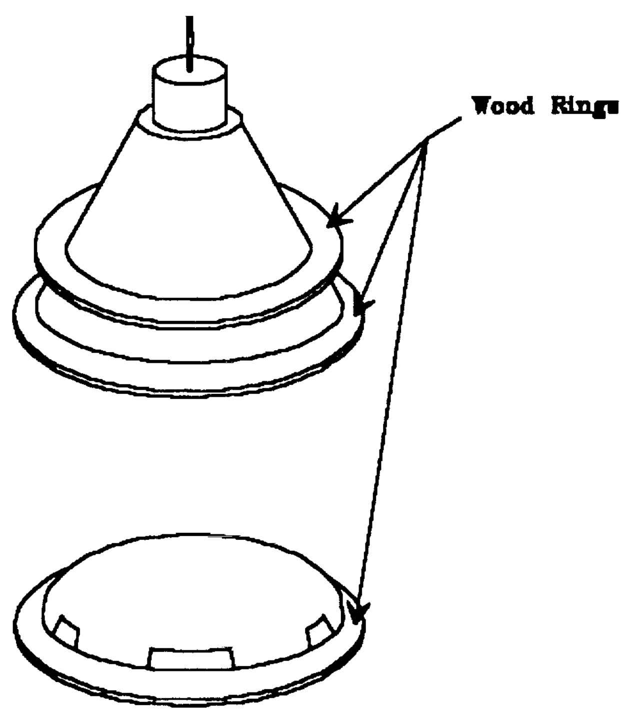


Figure 8.1.2.1 Wood Rings on Plug

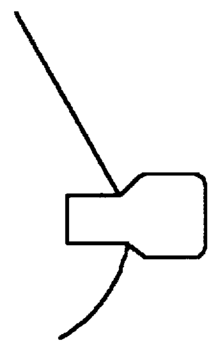


Figure 8.1.2.2 Flotation Fill Plug

Once the fill plugs have been finished and reinserted into the plug, additional plaster is layered over the entire assembly to a thickness of about 2 inches. When the shell molds are completed and dry, they are removed from the plug and sealed with several layers of shellac. The insides of the molds are coated with several layers of releasing agent before the bottom and center sections of the molds are fastened together. The flotation fill plugs are then placed in their respective slots in the mold. A plywood ring is fastened to the top part of this assembly and a similar ring is added to the bottom portion of the upper mold. This area forms the model access section and the rings allow construction of the inner flange required on each shell piece for gasket placement areas. After the molds have been completed, shell construction can begin.[18]

8.1.3 Shell Construction

To form the model shell, polyester resin and 1 1/2 ounce chop strand fiberglass are layered on the inside of the molds. The first layer is a thick coat of polyester resin. This ensures a smooth exterior finish on the model. Next, alternating layers of fiberglass sheets and resin are applied until the desired thickness of 1/8 inch to 3/16 inch is obtained. After each section of the shell is completed and allowed to dry, the molds are taken apart and removed. To form the hatch, the small section of mold which was used to form the indented hatch area is reused. It is coated with resin, then layered with fiberglass and resin to the same thickness as the rest of the model shell. When this small separate section is dry, it is removed from the mold and used as the hatch.[19]

The three separate pieces of molded fiberglass, the lower section, upper section, and hatch, are assembled to form the model shell.

8.2 HARD POINTS

Forces on fittings attached to the model cause large amounts of stress to be applied to small areas of the shell. Since fiberglass has a low shear strength, this stress must be distributed over a larger area using reinforcements, or hard points. These hard points consist of 1/8 inch pieces of balsa core cut into 3 inch squares.[20] These pieces of wood are incorporated into the shell interior with layers of resin. This technique increases the strength of the section by distributing the stress applied to the region over the entire surface area of the wood reinforcement. For further stress distribution, all fittings attached to the model have large washers placed between the model hard points and the nut securing the fitting (Figure 8.2.1).

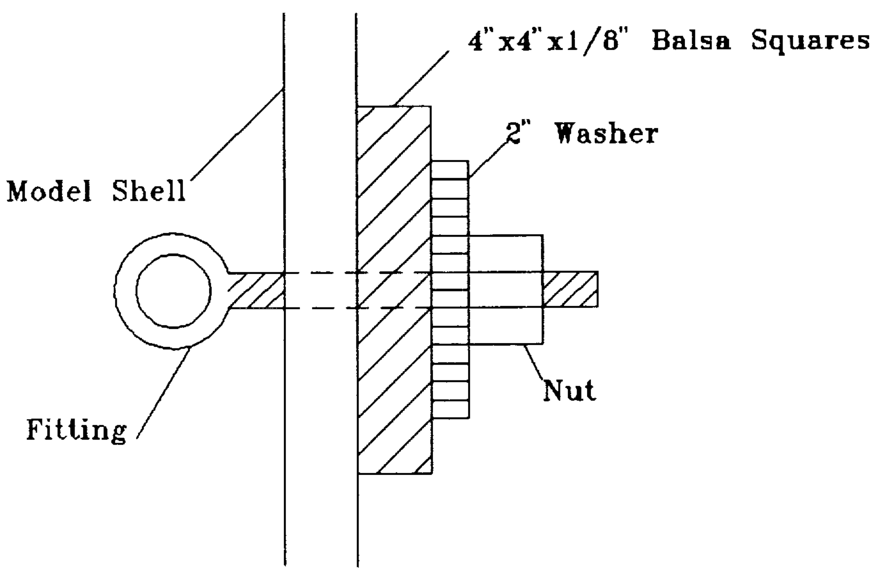


Figure 8.2.1 Hard Points

8.3 SECTIONING

The low horizontal method of sectioning the model was determined to be the optimal method after construction of the decision matrix (Appendix B, Figure B-2). As shown in Figure 8.3.1, the model is sectioned at the bottom of the hatch. This gives an opening of 24.6 inches which allows easy access to the interior of the craft for placement of the floor, egress couch model, and all interior equipment.

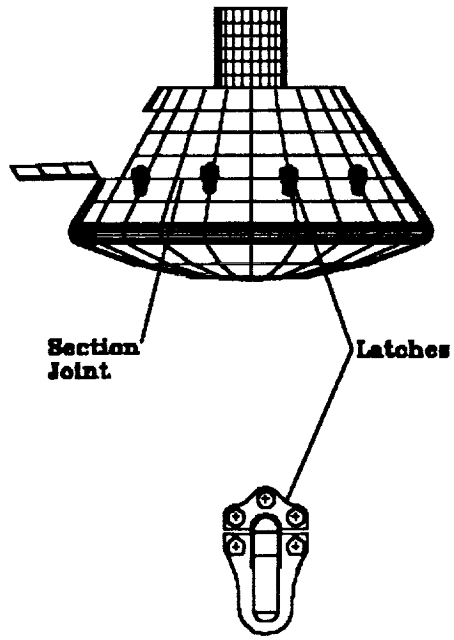


Figure 8.3.1 Sectioning

The two sections of the model lock together with eight 2 3/4 inch aluminum chest latches, spaced evenly around the vehicle. Hard points are provided for the latches. The latches allow quick and efficient access, and provide the pressure required to seal the model as discussed in the following section.

8.4 SEALS

Once the model has been constructed, it must be sealed to prevent water leakage during testing. Several types of seals are considered and, after construction of the decision matrix (Appendix B, Figure B-3), gaskets are chosen as the best seal for the model. A 1/32 inch fiber gasket material (Figure 8.4.1) is used. The gasket material comes in 9 inch by 36 inch sheets and must be cut into the shape required. It needs to be pieced by cutting the ends so that they fit together to maintain the quality of the seal. The shaped gasket material is placed on the flange between the model sections and around the shell side of the hatch opening. The gasket material is layered to make a thicker seal if there are enough discrepancies in the model construction to warrant varying the seal thickness.

Those sections of the shell that have been penetrated by fittings need to be permanently sealed. A silicone based sealant is used for this purpose.

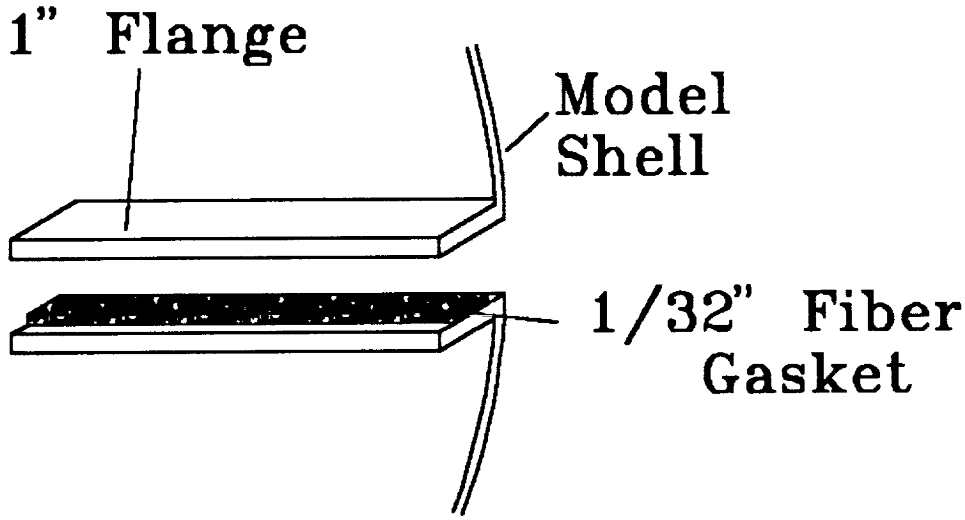


Figure 8.4.1 Gasket

8.5 HATCH

The hatch is attached to the model using a 2 inch strap hinge. When the hatch is closed it rests against a small seal-bearing flange around the shell perimeter. The hatch is locked closed using 1 3/4 inch turn buttons. The turn buttons are attached in three positions on the model. One turn button at the top of the hatch and one on each side keep the hatch tight against the gasket seal. A small ornamental knob is attached to the outside of the hatch to pull it open. A curved lid support is attached to the inner side of the hatch. The pin portion of the hinge is attached to a reinforced area of the shell interior. This pin-guided lid support (Figure 8.5.1) locks in its fully extended position to prevent hatch movement during testing with the deployed egress couch model. It also provides support for the hatch should it be required to bear weight during testing procedures.

8.6 FLOOR

The floor on which the egress couch is placed is constructed of 1/4 inch reinforced fiberglass. As shown in Figure 8.6.1, the floor is supported by 1 inch corner braces attached to the model walls. The corner braces are attached to the sections of the model walls that form the smallest diameter on the interior of the shell. These sections are the interior portions of the shell offset by the flotation system. One corner brace is attached to each flotation section inset. For clearance, the floor must be 1/2 inch smaller in diameter than the diameter offset by the flotation system. Turn keys attach the flooring to the corner braces.

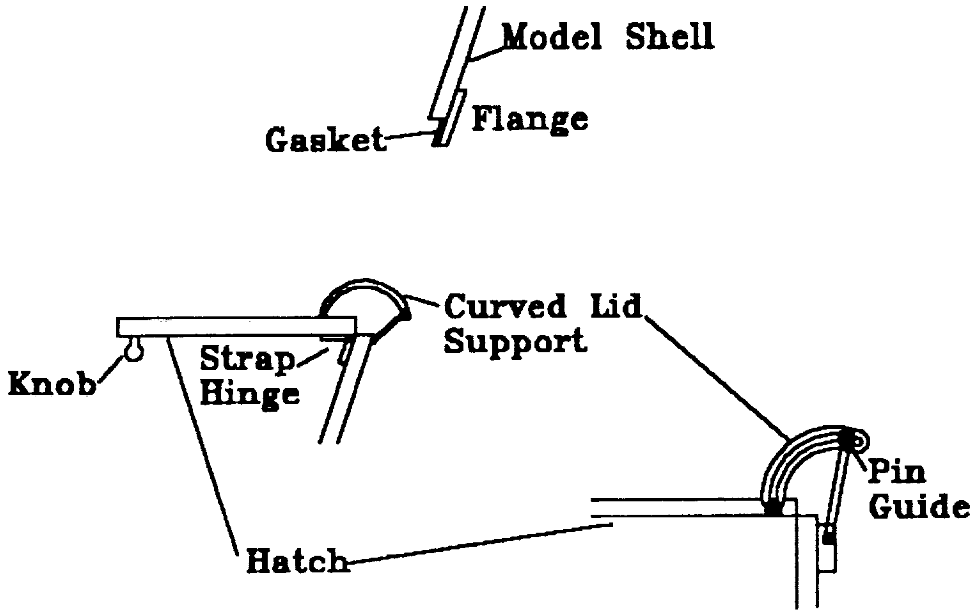


Figure 8.5.1 Hatch Hardware

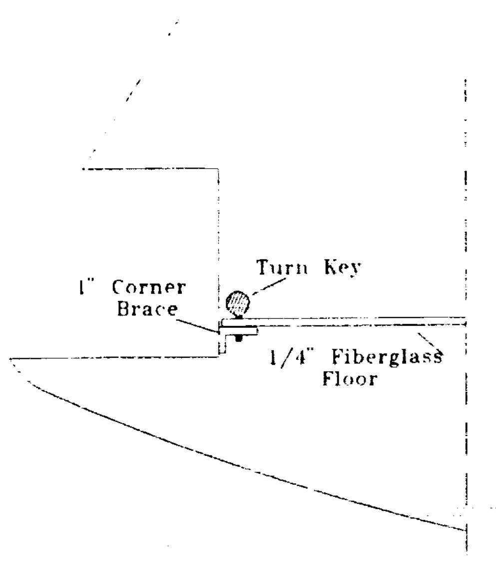


Figure 8.6.1 Floor

8.7 CENTER OF GRAVITY / MOMENT OF INERTIA DETERMINATION

Once the model has been built, and all the subsystems incorporated, its actual CG and MI are determined. Several methods are considered. Mathematical modeling is used, but yields only approximations because math modeling assumes uniform material density and weight distribution (Appendix C, Figure C-1). There are several methods available which determine the CG but not the MI. One method found to determine both the CG and the MI is the "swing" method,[21] (Figure 8.7.1). The completed model is suspended from a single point and set into motion. Its period is measured. The model is then suspended from another single point and the procedure is repeated. Since the period of a pendulum is related to its characteristic length, and the suspended model is considered to be a compound pendulum, the CG is determined. The period is also used with vibrational theory equations to determine the mass moment of inertia.[22] Once the actual CG and MI have been determined, the parallel axis theorem is used to approximate the required amount of weight and its position to shift the CG and MI values. After adjustments have been made to the chosen mass system, the "swing" method must again be employed to determine the effects of the changes. This trial and error method allows the CG to be positioned and the MI to be adjusted to the values required.

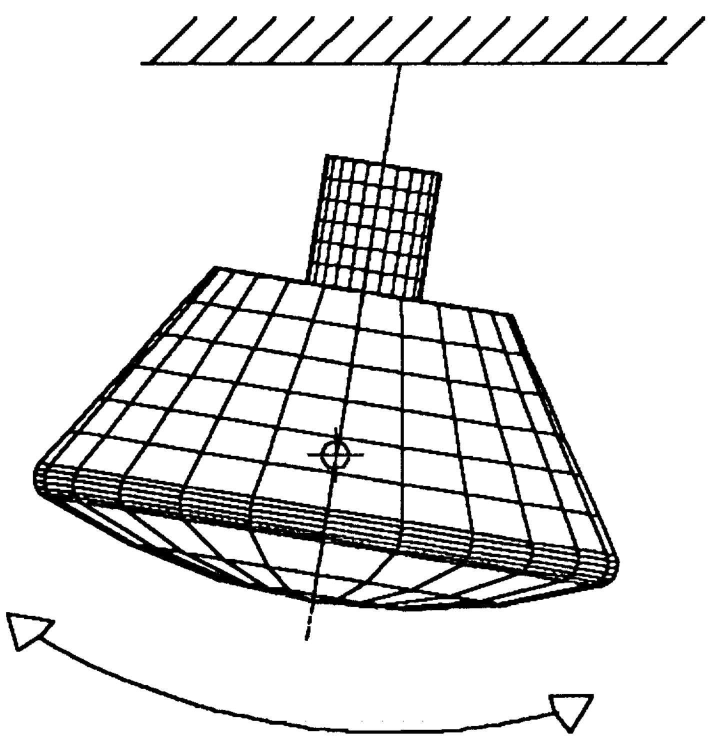


Figure 8.7.1 Swing Method

8.8 CENTER OF GRAVITY / MOMENT OF INERTIA ADJUSTMENT

The model systems considered for simulating the ACRV center of gravity/moment of inertia are the flat plate, peripheral, radial, and combination systems. After construction of the decision matrix for the systems (Appendix B, Figure B-4), it is determined that the radial system is the optimal one for the model (Figure 8.8.1).

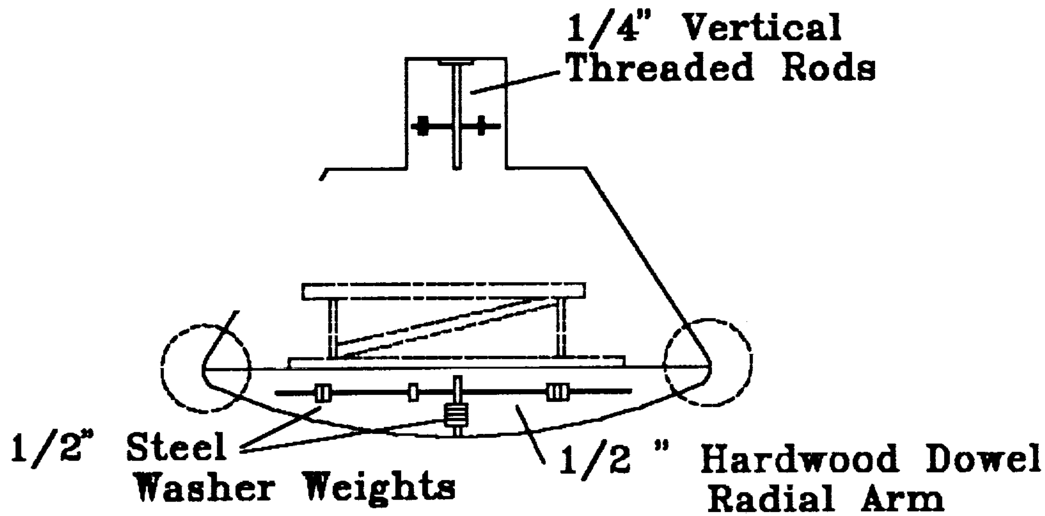


Figure 8.8.1 Radial Mass System

The radial system consists of two vertical 1/4 inch threaded rods. One rod is placed in the top access hatch area and one in the bottom of the model, under the floor. The rods are limited to these areas because of the large amount of operating space required for the egress couch mechanism. The areas of the shell where these vertical rods are attached are reinforced. These hard points incorporate threaded nuts as attachment points for the vertical rods. Radial arms are made of 1/2 inch hardwood dowels with a 5/16 inch hole drilled through their centers. This allows the radial arms to be light weight, yet rigid. 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 each side of the washer group. These weights are repositioned along the radial arms, as needed.

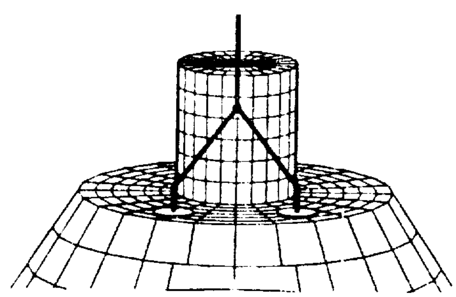
The radial arm positions are varied along the vertical rods. By varying the weight amounts and positions, and rotating the radial arms to any angle required, the center of gravity and moment of inertia are changed as required for accurate simulation.

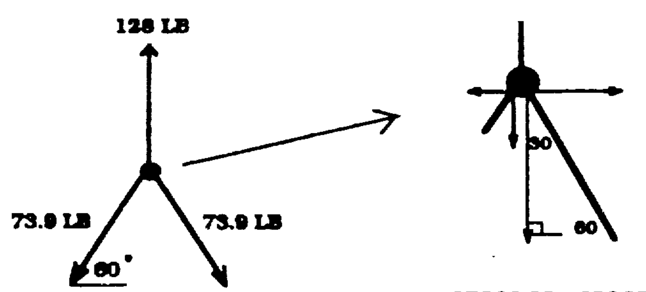
To bring the total model weight up to the 128 pounds required, additional weight is added. This is accomplished by positioning weights along the vertical threaded rods and fastening them in place with lock nuts. Mathematical modeling indicates the amounts and positions of such weights to keep the CG and MI as specified.

8.9 LIFT ATTACHMENT POINTS

The location of the lift attachment points is important. The lift attachment points used on the model simulate placements on the ACRV. Therefore, the most important requirement for lift attachment point placement is that the site(s) chosen be logical for both the model and the ACRV. All the lift attachment systems considered meet this requirement. These designs include single attachment, multiple attachment, angled lift, vertical lift, and net options. From the decision matrix (Appendix B, Figure B-5), it is seen that the lift attachment design that best met the requirements is the dual attachment system with an angled lift.

The dual attachment points offer redundancy. There are two attachment points, each with its own sling, but both are attached to a single lifting cable.[23] The sling angle that offers the least force on the attachment points, and the least tension on the cables, is 60 degrees[24] (Figure 8.9.1). The cable from the crane is strong enough to support the overall weight.





$2T\cos 30 = 128$ LB

$T = \frac{128}{2} \times \frac{1}{\cos 30}$

$T = 73.9$ LB

Figure 8.9.1 Force Analysis

Placing the lift attachment points high on the vehicle with respect to its center of gravity provides a more stable lift. It is also important to locate the attachment points in an area sufficiently reinforced to support the load imposed by the weight of the craft. As suggested by Rockwell, the ideal area of the ACRV for lift attachment points is on the upper deck area.[25] This area has been reinforced to withstand the forces generated by the parachutes that open upon re-entry. Since this location is so suitable for the ACRV, this is the lift attachment point site chosen for the model. The model's dual attachment system is, therefore, attached to the upper deck and provides an angled lift (Figure 8.9.2).

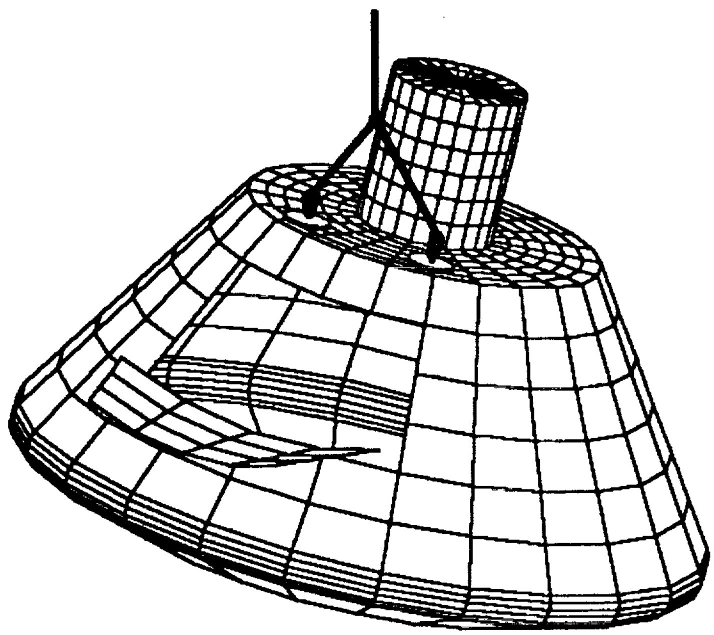


Figure 8.9.2 Dual Upper Deck Angled Lift

The final phase in constructing the lifting mechanism is the fitting that is affixed to the model. This portion of the lifting mechanism could be considered the most important. In any crane, or lifting device, the fitting is the weakest part of the system. This is the area where failure occurs first.[26]

Strength, weight, and security of attachment are the most important features considered. Since one of the characteristics of the eye-bolt is its strength to size ratio, the eye-bolt is the fitting which best meets the requirements.

There are two types of eye-bolt mechanisms, a nut type and a threaded type, that is screwed directly into the material. The nut type is the type which is used on the model, because the thin fiberglass shell does not provide a secure attachment for the threaded type unless thick wood hard points are used.

The position in which the eye-bolt is placed is also an important consideration. There have been studies, as shown in the chart[27] in Appendix D, Figure D-1, that indicate the force that can be safely applied to the fitting in different positions. The chart also includes the allowable forces for the various sizes of the eye-bolt. Because the weight of the eye-bolt is a consideration, it is best to find an eye-bolt that can support the load and still be as light as possible. Using these considerations and the force study as a guide, an adequate eye-bolt is chosen. Upon completion of the study, it is found that the Drop Forged Steel, 5/16 inch eye-bolt, with a nut mechanism best meets the requirements.

Chapter 9.0 OBSERVATIONS & RECOMMENDATIONS

MATERIALS

1. The use of a fiberglass mold instead of a plaster mold is recommended. Fiberglass is more durable, which proves important if multiple models are to be built.

2. A mounting mechanism for the stencil needs to be designed.

FLOOR

3. Depending on the weight of the egress couch, the planned fiberglass floor section may not be strong enough. A stress test is recommended to see if plywood or another material should be considered as an alternative.

LAP

4. Hard points should be installed to accommodate LAPs in areas other than the upper deck. This allows observation of the effects of alternate LAP placements on the lifting characteristics of the craft.

CG/MI

5. To support the heavier weights required for adjusting the CG and MI, it is recommended the drilled hardwood dowels be replaced by 1/2 inch PVC pipe lengths for the radial arms.

6. If reinforcing the bottom of the model sufficiently to support the vertical threaded rods with their attached radial arms is not possible, the lower vertical rod may be attached to the bottom of the floor. This requires reinforcing the fiberglass floor material or switching to a plywood floor.

HATCH

7. A recommended alternative to the curved lid support for the hatch is the use of a full overlay hinge which locks into position.

8. Due to the limited area available for the hatch opening, the couch may need to be lowered by removing the shims added last year.

ACRV

9. To prevent the drainage of toxic water-fuel mixtures, it may be necessary to consider plugging the RCS jet ports before the craft is lifted from the water. Plugging the ports contains the toxics and allows proper disposal by hazardous waste personnel at a later time.

SECTION II

ACMD FLOTATION AND ATTITUDE MODEL

DESIGN PHASE

- FLOTATION SYSTEM
- ATTITUDE SYSTEM
- MATERIALS
- INFLATION METHOD
- OPTIMAL SOLUTION
- OBSERVATIONS AND RECOMMENDATIONS

SECTION II. APOLLO FLOTATION AND ATTITUDE MODEL

INTRODUCTION

The ACMD Flotation Model team designed a one-fifth scale flotation and attitude system for the ACMD ACRV. The system models the full-scale flotation and attitude system. Both systems move rigidly with the craft after deployment and satisfy storage space requirements. The flotation system maintains buoyancy and provides stability by increasing the surface area at the water line. It also allows for current structural limitations such as the Reaction Control System (RCS). The attitude system counters the moment caused by the extension of the Emergency Egress Couch (EEC) and maintains correct orientation of the craft. Four areas incorporated into the design of this model were: (1) flotation, (2) attitude, (3) materials, and (4) inflation.

Four flotation methods considered for the ACMD were spheres, continuous ring, multi-chambered continuous ring, and a segmented ring. Storage of the Flotation System (FS) was a major consideration in the design of the flotation system. Several designs were considered for the Attitude System (AS). They include an attached raft, a mattress, a lattice support structure, and telescoping beams. The materials considered for FS and AS were butyl rubber, coated Kevlar™, coated canvas and coated nylon. The inflation method for the model did not need to model full scale behavior. Four design option were explored, a compressor, compressed gas canisters, pyrotechnics, and a hand or foot pump.

The design efforts of the ACMD Flotation and Attitude Model team are presented in this section. Specifications (Appendix F) for the model and descriptions of the design options for each system follows. A more detailed description of the optimized system will be presented along with observations and recommendations. The model was not built or tested due to higher priorities.

DESIGN PHASE

Chapter 10.0 FLOTATION SYSTEM

The flotation options considered are based on several criteria. First, the design must allow for placement of additional equipment. Second, the flotation system must move rigidly with the ACRV.[28] The flotation system must be redundant, and buoyant enough to support the weight of the craft and payload.[29] Finally, it must inflate to rigidity to provide a solid work surface and increase stability.

Four flotation methods are considered: 1) Spheres, 2) Continuous Ring, 3) Multi-chambered continuous ring and 4) Segmented Ring. The multiple sphere concept consists of spheres or partial spheres uniformly spaced about the ACRV. The continuous ring is a one-piece, doughnut-shaped device that encircles the ACRV. The multi-chambered continuous ring is comparable to the continuous ring except that it contains multiple gas-filled tubes inside the ring for redundancy. The segmented ring is composed of three or more separate ring sections each extending around a portion of the circumference of the ACRV. Each design option is detailed below.

10.1 SPHERES

The proper flotation of the craft is achieved through the use of flotation spheres (Figure 10.1.1). Spheres, or partial spheres, are uniformly spaced about the ACRV. This design does not require a continuous circumferential storage chamber around the craft but a finite set of storage pockets. The current design option is partial spheres with one-third of their volume submerged. The construction consists of air-tight partial spheres. These partial spheres are stored circumferentially around the ACRV along the water line. Compressed gas inflates the partial spheres and expands them out of the storage cavity. In the one-fifth scale model a valve on the outside of the model fills the individual chambers with air.

The advantages of this system are its redundancy and minimal storage space requirement. A number of partial spheres are used such that if a leak occurs in one sphere, the remaining spheres function to support the craft. However, the spheres lack rigidity due to the small contact area with the ACRV.

10.2 CONTINUOUS RING

Another design option considered is a continuous tubular flotation ring that entirely encircles the craft (Figure 10.2.1). This system is similar to the one used in the original Apollo vehicle. The construction of the ring consists of a gas tight chamber which is stored along the water line circumferentially around the ACRV. Compressed gas inflates the ring and causes it to expand from the storage cavity.

This ring system offers proven functionality and simplicity. It also provides a rigid work surface around the entire circumference of the ACRV. The continuous ring design serves to increase the surface area at the water line which decreases the pitch of the craft. In addition, this design has a greater craft contact area than the spheres, making it rigid with the craft. A disadvantage of the single chamber design is its lack of redundancy. If a leak occurs in the ring the system fails. A lack of storage space in the ACRV prevents multiple backup rings. Another disadvantage is that the current design of the ACRV does not allow storage space for a continuous ring because of the Reaction Control System (RCS) locations.

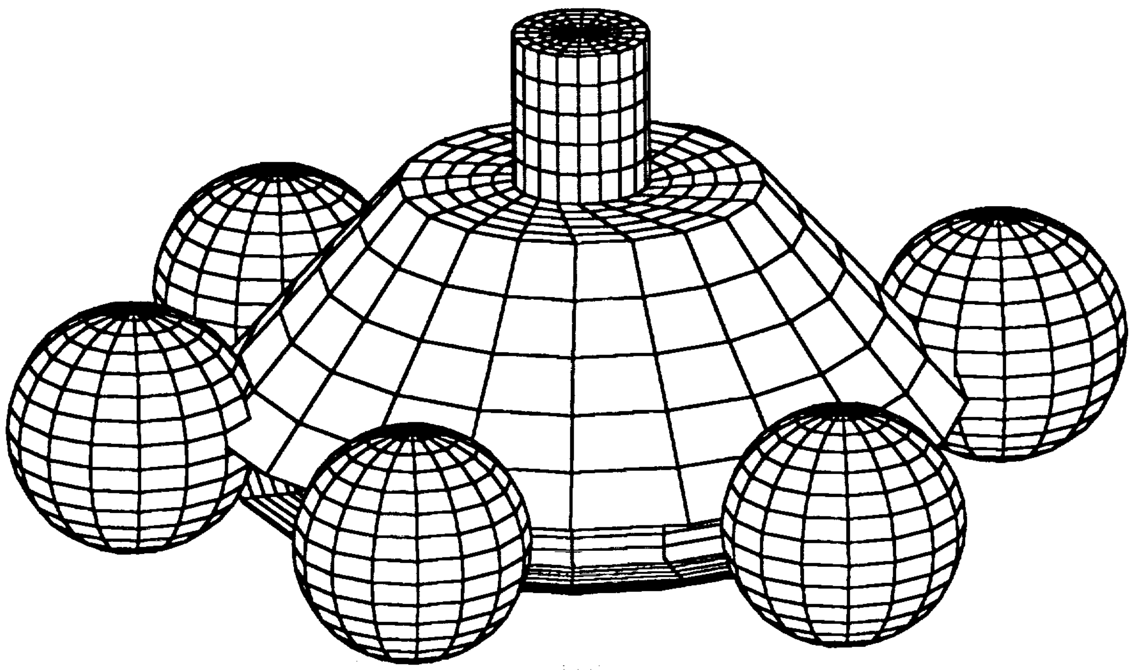


Figure 10.1.1 Spheres

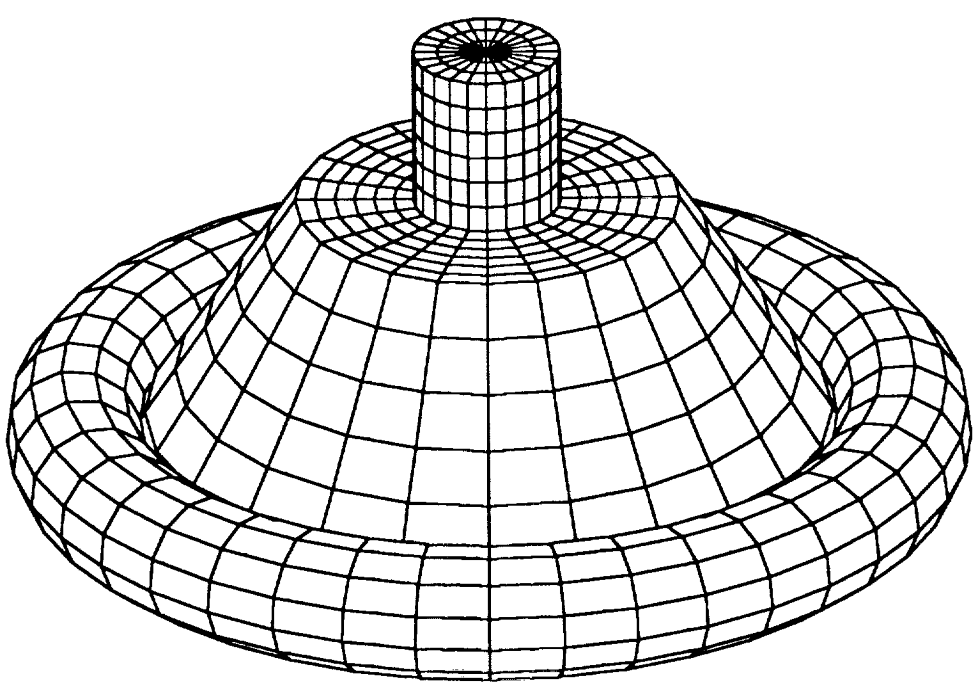


Figure 10.2.1 Continuous Ring

10.3 MULTI-CHAMBERED RING

The multi-chambered ring is comparable to the continuous ring except that it contains individual tubes (Figure 10.3.1). The tubes are individually inflated and encased in a nylon sheath. The nylon sheath contains the tubes and maintains a uniform shape.

Because the tubes are encased, if one or more of these tubes were to fail the rest would maintain buoyancy. This makes the system redundant. Like the continuous ring the multi-chambered continuous ring increases the surface area at the water line, improving stability. However, the system requires more storage space than the continuous ring, and inflation is more complicated.

10.4 SEGMENTED RING

A segmented ring design is another design considered. This system is similar to the single chambered ring, except the ring is segmented (Figure 10.4.1). This ring may be composed of three or more separate sections, each extending around a portion of the ACRV along the water line. Compressed gas inflates the segments and causes them to expand from the storage cavity.

This system has the advantage of redundancy which is provided by the multiple chambers. If a leak occurs in one chamber, the rest of the ring supports the craft sufficiently. This design also serves to increase the surface area at the water line. The segmented ring design provides a rigid work surface and greater attachment area for increased rigidity. The position of the sections is flexible, which means their location around the ACRV can be determined by the location of other pieces of important equipment. A disadvantage of this design is that it requires more storage space than the sphere design, although considerably less space than the continuous ring.

10.5 STORAGE OF THE FLOTATION

Storage is a major consideration of the flotation system. Each design option is stored in a region of specific volume cut away from the side of the craft. The full-scale inflation system must be stored in an exterior compartment of the ACRV. If the main inflation system fails, a manual backup system must be available. The manual backup allows a crew member to trigger the inflation of the ring from the crew cabin if the automatic system fails. In the one-fifth scale model the inflating gas and valve can be stored remotely. For simplicity, the spheres, ring, or ring segments are stored along the water line of the craft. Deflation for each design is accomplished with a controllable valve.

Appendix G, Figure G-1 compares the four flotation design options. The matrix is a numerical comparison of the criteria mentioned above. The heavily weighted factors are feasibility, dependability, rigidity and operational performance. Other considerations include simplicity, cost, redundancy, simplicity of construction, and maintenance.

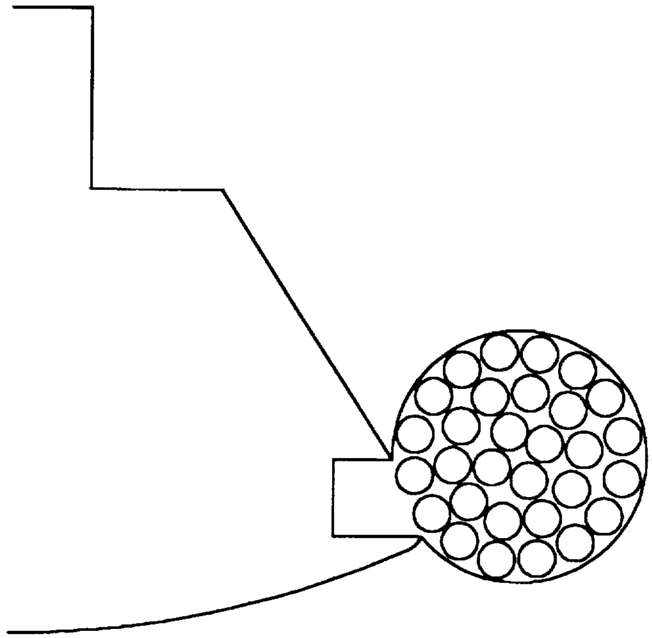


Figure 10.3.1 Multi-Chambered Continuous Ring

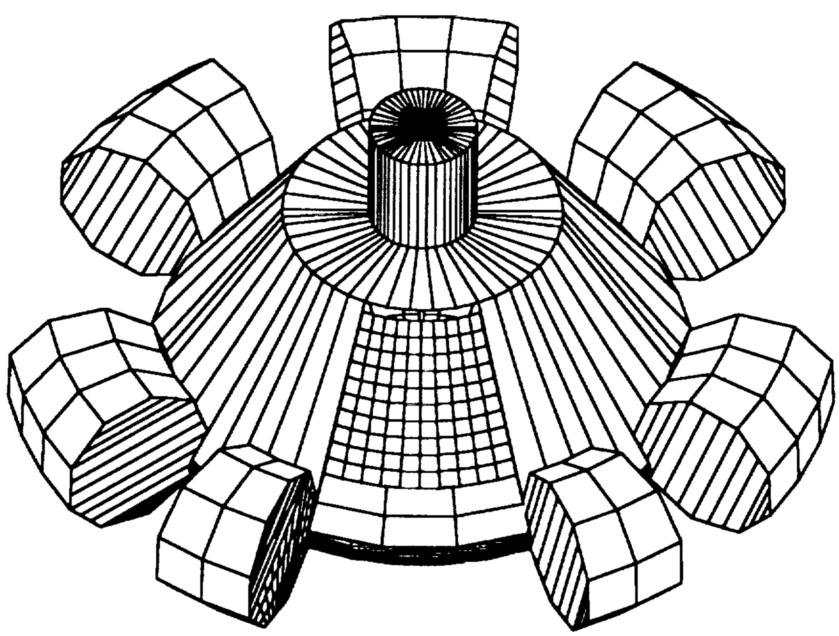


Figure 10.4.1 Segmented Ring

Chapter 11.0 ATTITUDE SYSTEM

The attitude options considered are based on requirements imposed by the physical structure of the EEC. First, the system must be designed to maintain the proper orientation of the ACRV during extension of the EEC. The EEC causes a moment on the ACRV that is compounded by the pitching of a rough ocean. The Attitude System (AS) can only counter this moment if it is rigidly attached to the ACRV. The one-fifth scale dimensions of the AS are 12 inches wide by 20.4 inches long. The full-scale maximum expected moment is the weight of the EEC times the distance to the center of the arm;

$$3.5ft.*600lbs.=2100ft\text{-}lbs.$$

However, the motion of the rough ocean greatly increases the stresses on the AS and EEC. There are secondary considerations. A variable length to test dynamic affects in the wave pool is desirable. The attitude system must provide a rigid work surface. Several AS design options with their associated advantages and disadvantages are discussed in this section. The options include an inflatable boat that is attached to the ACRV and systems deployed from the ACRV. Of the systems deployed from the ACRV, an inflatable mattress, lattice support structure and telescoping beams were considered.

11.1 ATTACHED RAFT

One design option is to attach an inflatable raft to the one-fifth scale ACRV (Figure 11.1.1). Rafts of the size and type desired are common in most United States rescue and recovery teams. In this scenario, an area under the hatch is removed, and the raft is manually attached to the craft.

Using an external raft for the stabilization system reduces the weight of the ACRV and leaves space inside the ACRV for storing equipment. An external raft has fewer design restrictions than an internal one, it may be designed to any size or shape desired. On the other hand, it is difficult to rigidly attach a raft to the craft, especially in rough sea conditions. Furthermore, in the full-scale, the raft must be carried by all rescue forces. The cost and logistics of supplying this equipment are major disadvantages.

11.2 MATTRESS

Another design option is an attitude control mattress deployed from a storage space under the hatch door (Figure 11.2.1). The mattress manually extends and inflates or mechanically deploys. This occurs independently of the FS, and before the EEC is extended.

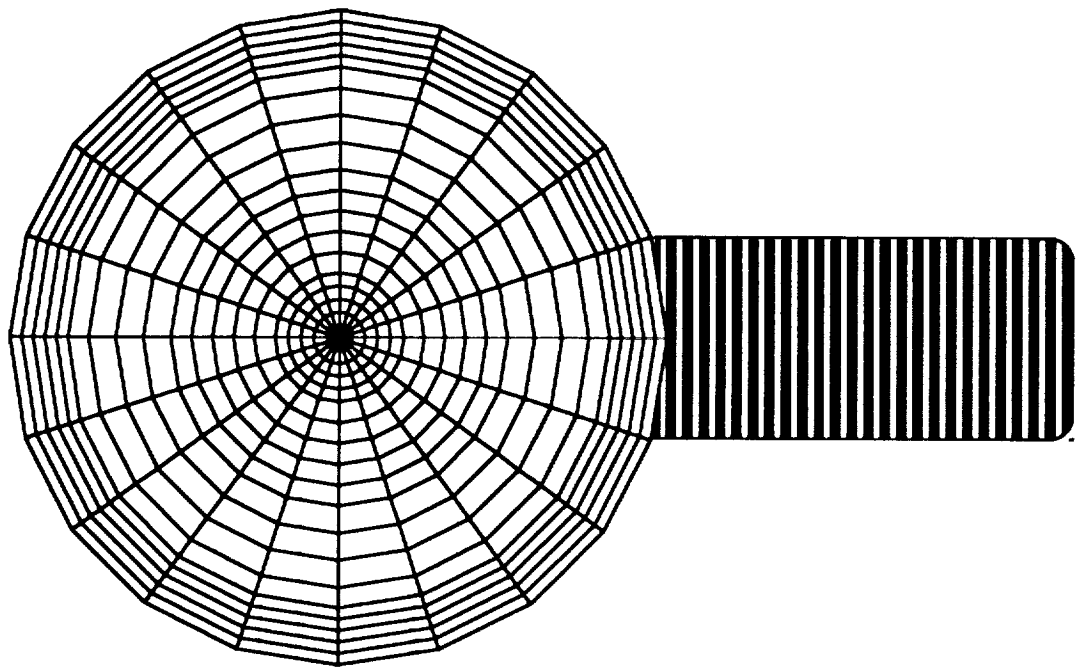


Figure 11.1.1 Attached Raft

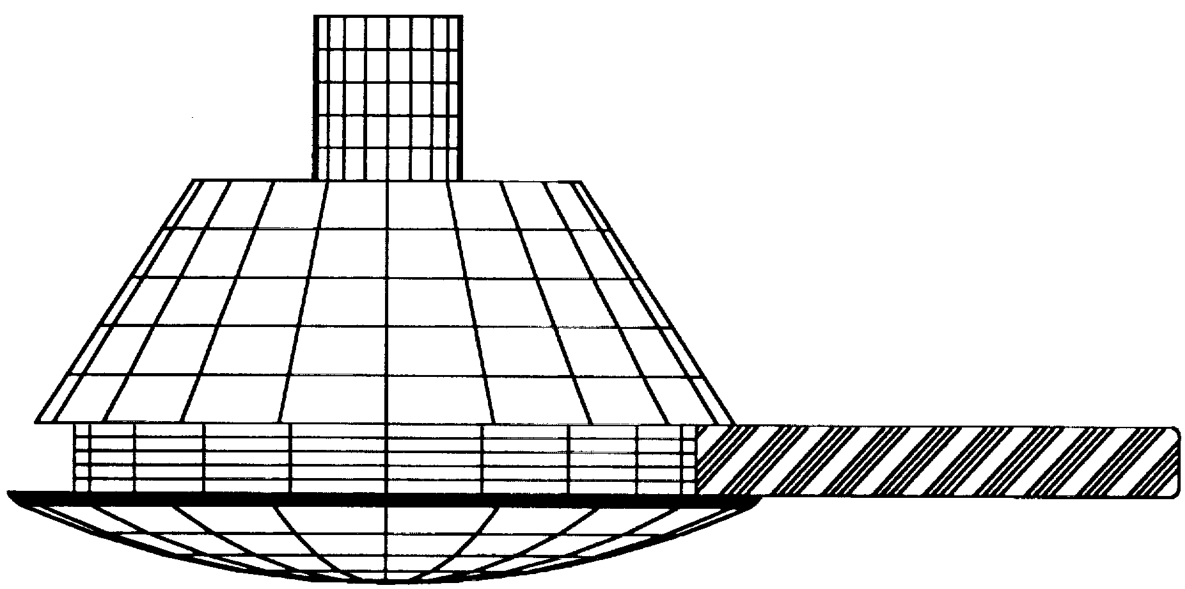


Figure 11.2.1 Mattress

The advantages of this method are increased rigidity, since a portion of the attitude raft is anchored inside the craft. Another benefit is that in the full-scale ACRV, the rescue personnel would not need any special equipment. Also, in the full-scale ACRV, the surface is able to support the weight of rescue personnel. A disadvantage is that the storage space requirements increase. The potential for error increases if the mechanical system is used, and system redundancy is complicated. The overall weight of the attitude system increases as a result of the deployment mechanism and the extra materials.

11.3 LATTICE SUPPORT STRUCTURE

A third design is a lattice support structure that unfolds from the ACRV shortly before the EEC extends (Figure 11.3.1). The lattice is an extending mechanism made of long, slender, flat pieces of aluminum. These pieces attach together as shown. The top, bottom, and two side sections, connect to provide a rigid structure when fully extended.

The lattice support structure provides rigidity in all directions. This system provides a rigid work surface, however, the structure decreases in width as it extends from the ACRV. It is heavy and expensive to fabricate.

11.4 TELESCOPING BEAMS

Telescoping beams are box beams that rotate ninety degrees from their storage position inside the ACRV, then telescope out to a specified length (Figure 11.4.1). An inflatable cylinder that is attached to the end of the beams is inflated. The work surface rolls out from a storage area above the beams and fastens to the beams. The beams bolt to the craft to provide rigidity. One of the benefits of this system is that the length is adjustable. The inflated cylinder provides a buoyant force which counters the moment caused by the EEC, and telescoping beams provide ample rigidity with the craft. However, the system is not redundant.

Appendix G, Figure G-2 compares the four attitude design options. The main criteria are feasibility, dependability, size, weight and operational performance. Also considered are safety, cost, redundancy, simplicity in fabrication and maintenance. It should be noted that none of the systems presented provide redundancy. However, this could be offset by improving the reliability.

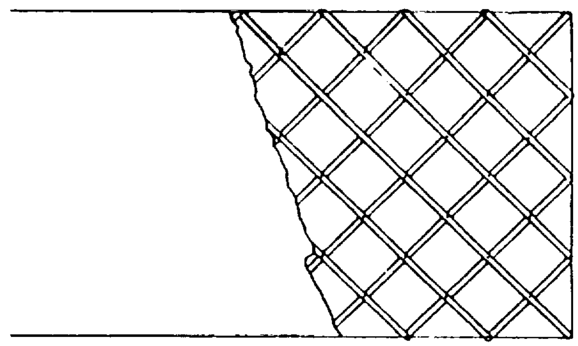


Figure 11.3.1 Lattice Support Structure

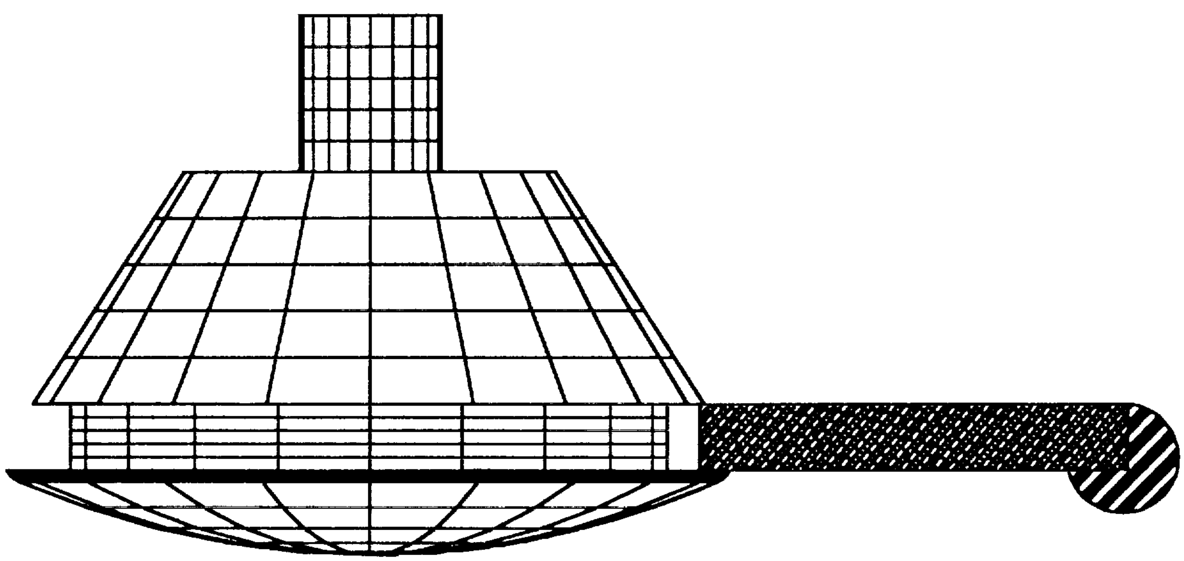


Figure 11.4.1 Telescoping Beams

Chapter 12.0 MATERIALS

There is a wide range of materials which might be employed for the construction of a one-fifth scale ACRV FS and AS. To narrow this range, certain material characteristics are defined. The material used must be capable of accurately modeling the actual FS and AS characteristics. For this to occur, the material's ability to fill to rigidity is examined. The material must be resistant to puncture and must be stored in, and deployed from, the craft. An inflatable material takes up approximately two percent of the volume when deflated that it uses when inflated. It is also necessary that the material be automatically deployed. The materials considered were butyl rubber, coated Kevlar™, coated canvas and coated nylon.

12.1 BUTYL RUBBER

The first material option is butyl rubber, a material commonly used in inner tubes. This material is flexible, non-porous and easy to work. A gas-filled chamber made of rubber can attain the buoyancy required to support the model.

Butyl Rubber effectively simulates the flexibility of the full-scale flotation and attitude systems. This material easily deploys from the craft. Butyl rubber is inexpensive and is purchased in thin sheets. However, butyl rubber is susceptible to puncture. The resistance to puncture is minimized by the use of a fabric covering, but the possibility of leakage still exists. Attachment may also prove to be difficult. Finally, increasing pressure in the chamber causes the material to expand without gaining rigidity.

12.2 KEVLAR™

Kevlar™ was developed by Dupont as a material for belted tires. It is a strong, light-weight fiber that can be woven into a fabric with a high tensile strength. Kevlar™ cloth can be coated with a flexible, non-porous material such as butyl rubber. A flotation device made with Kevlar™ can be inflated to a high pressure.

Coated Kevlar™ fabric is strong, light-weight, flexible and non-porous. The increased pressure that Kevlar™ allows provides increased rigidity (Figure 12.2.1). It is puncture resistant and durable. However, it is not as flexible as other textile materials, and therefore is difficult to store in the allotted area. Furthermore, Kevlar™ is more expensive than the other material options.

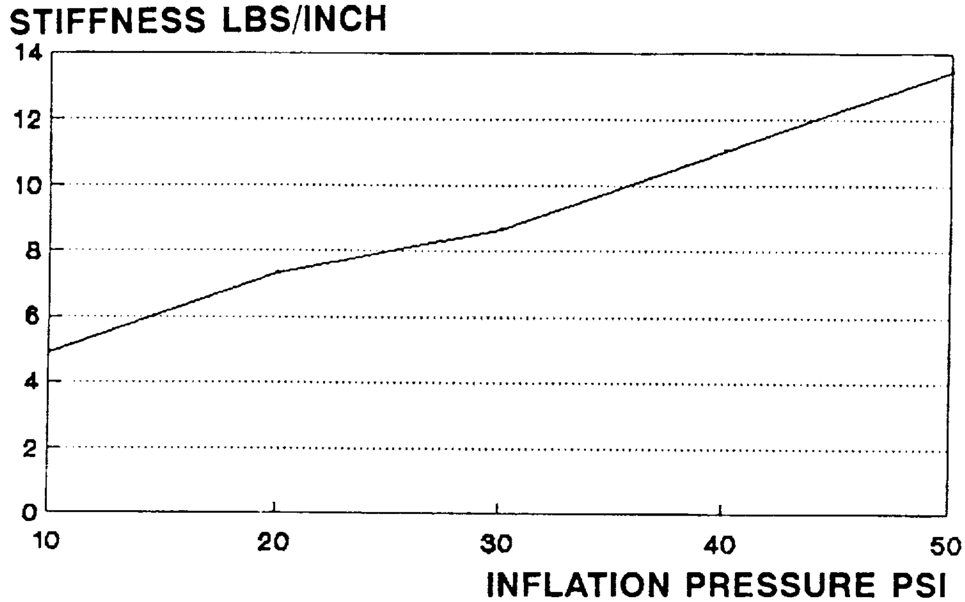


Figure 12.2.1 Kevlar™ Stiffness vs. Inflation Pressure

12.3 COATED CANVAS

Another design option is a light canvas fabric similar to that used to make light inflatable rafts. It is sewn into the proper shape then sealed by coating it with a non-porous sealer such as Butyl rubber. The material is attached and folded into limited storage space and deployed from the model.

Coated canvas is puncture resistant, becomes rigid with increased pressure and attaches easily to the model. The material easily configures into different forms, and can be stored in a small area. This material could be repaired should it become punctured. Gas-filled chambers made of light coated canvas accurately model full-scale behavior. However, coated canvas is known to deteriorate with age, and crack along bends or edges. This deterioration does not affect the one-fifth scale model.

12.4 COATED NYLON

Another textile under consideration is coated nylon. Coated nylon is constructed in the same manner as coated canvas. Coated nylon has the advantages of coated canvas with the addition of higher tensile strength and less susceptibility to aging. The increase in tensile strength allows inflation to a higher pressure for increased rigidity.

Appendix G, Figure G-3 compares the four material options. The main considerations include attachability, workability, ability to hold air, and ability to fill to rigidity. The options are also compared with respect to weight, strength, durability, repairability, and availability.

Chapter 13.0 INFLATION METHOD

A method of inflating the FS and AS must be considered for the one-fifth scale ACRV. Because the purpose of the FS and AS are to model dynamic behavior in the wave pool, it is not necessary that the inflation method model full-scale behavior. However, an inexpensive, reliable method of inflating the systems must be found. Four design options were explored:

* a compressor of the type used in the past to fill the attitude spheres on top of the Apollo return vehicles,
* compressed gas canisters such as the ones used to fill inflatable boats,
* pyrotechnics such as that used in automobile airbags,
* a hand or foot pump.

13.1 COMPRESSOR PUMP

One method of inflation is to use a compressor on the ACRV model to pump ambient gas into the flotation cells. In the past, a compressor filled the attitude spheres on top of Apollo capsules. The experience gained in past missions shows the use of a compressor is effective. The compressor pumped continuously until the attitude spheres obtained the correct pressure, then was shut off manually or by a regulator system.

A benefit of the compressor system is that it is versatile. It is automatically or manually operated. The disadvantage of the compressor is that it is heavy, which limits the size of compressor that is used. Because of this size limitation, it takes considerable time to fill the FS and the AS. The pump is also expensive compared to compressed gas canisters or a hand or foot pump.[30] For the compressor to be redundant it requires at least two pumps which adds weight to the ACRV.

13.2 COMPRESSED GAS

Another method of inflation is the use of a compressed gas canister stored in an outer compartment of the model. When the FS is deployed, the high pressure in the container is released into the FS which is completely inflated in seconds.[31]

Compressed gas is a relatively simple and inexpensive option. However, there is the possibility that the cartridge could leak and have no gas available to fill the system. There is also the problem of filling the system to the required pressure. A regulator is necessary to keep the system from overfilling and possibly rupturing.

13.3 PYROTECHNICS

The most common chemical found in pyrotechnics is Sodium Azide-Copper Oxide. This chemical is used in automotive air bags. It burns quickly causing the volume to fill rapidly. Pyrotechnics are reliable and easy to ignite. However, pyrotechnics may be difficult to control on the ACRV model. The amount of TAL1101, a form of Sodium Azide Copper Oxide, necessary to fill an automotive air bag costs approximately three hundred dollars. Finally, the heat of combustion may destroy the flotation material.

13.4 HAND/FOOT PUMP

A hand or foot pump is a manual compressor. The type of pump needed for the ACRV model is a bicycle pump. It has the advantage of being simple, inexpensive, easy to use, and safe. In addition, it is reusable without added expense. A disadvantage in this device is that it is not an integral part of the vehicle. However, since deployment is not being modeled, this is inconsequential.

Appendix G, Figure G-4 compares the four inflation methods under consideration for the model. As mentioned above, the primary concerns are feasibility, safety, dependability and operational performance. Also considered are cost, redundancy, and simplicity.

Chapter 14.0 CHOSEN SOLUTION

Though each system performs its individual task, it is through integrated designing that a successful flotation/stabilization system is established. The full-scale sequence of events begins after splashdown and after the correct attitude has been attained. The FS is deployed and the craft remains in this condition until rescue personnel arrive. The attitude mattress is deployed by the rescue personnel. After this point the hatch is opened and the Emergency Egress Couch (EEC) is extended.

The focus of the flotation design group is modelling from the time the flotation system is filled to the time the EEC is extended. The objective is to make the flotation and attitude systems simple while achieving all design objectives.[32]

14.1 FLOTATION SYSTEM

The decision matrix for the flotation system (Appendix G, Figure G-1) indicates the segmented ring configuration is the optimal system. One reason is the placement of the FS is restricted by the position of the RCS jets. The segmented ring allows for this restriction. Furthermore, it is a redundant system. Finally, one of the basic requirements was that the systems move rigidly with the craft. This is achieved by attaching the flotation device to the ACRV inside the storage compartment (Figure 14.1.1 and Figure 14.1.2), and by pressurizing the segments to rigidity. Attachment is achieved by bolting mounting tabs to reinforced sections of the ACRV using one-quarter inch bolts.

The volume of air needed to keep the ACRV afloat is calculated from Archimedes' principle:

$$F_b = \rho * g * V_{disp}$$

where

$$\rho * g = 62.4\,lb_f/ft^3$$

The one-fifth scale ACRV weight (F_b) equals 128 lb_f, so 128 lb_f of water must be displaced by the FS. Therefore, calculating the volume:

$$V_{disp} = F_b/\rho * g = 2.05 ft^3$$

This is the total volume of air needed to keep the craft afloat. To achieve this volume, the radius and length of each module was adjusted to iteratively arrive at a solution. Based on these calculations, a radius of 4.6 inches, and a combined length of 46.3 linear inches of tube are adequate. The segment positions along with the RCS locations are depicted in Figure 14.1.3.

The system is stored in compartments along the water line of the ACRV (Figure 14.1.4). The volume of the stored material is approximately 1/50 of its inflated volume.[33]

14.2 ATTITUDE SYSTEM

The decision matrix for the Attitude System (AS) (Appendix G, Figure G-2) indicates the telescoping beam configuration is the optimal system. This configuration extends from the craft, is configurable into different lengths, and is strong. This configuration also incorporates safety, low cost, dependability, and simplicity.

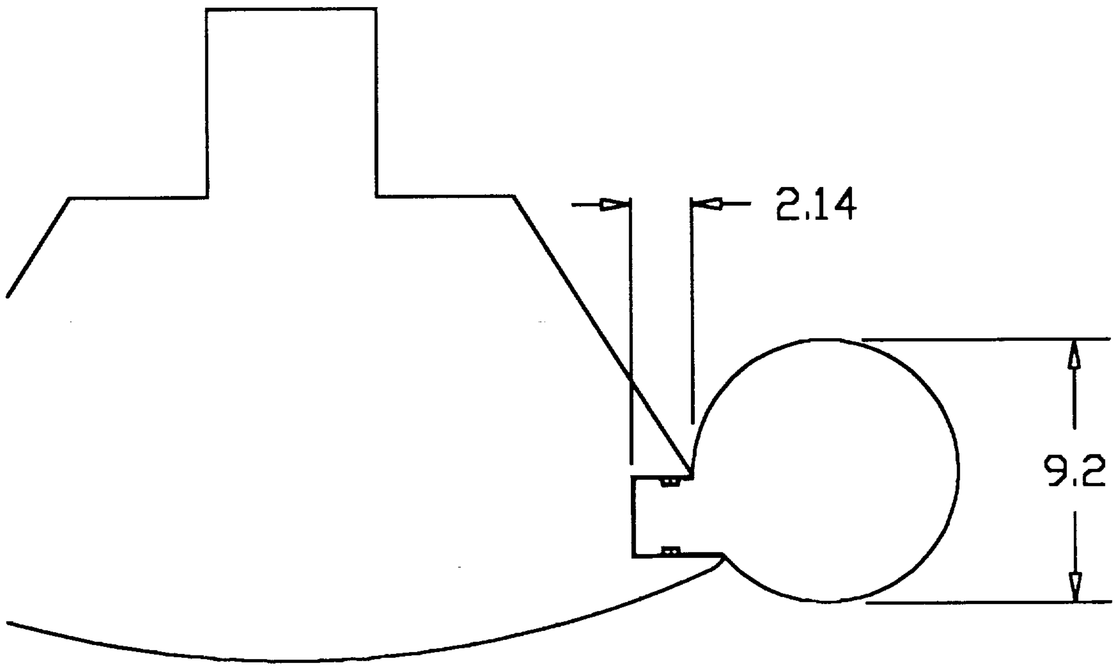


Figure 14.1.1 Side View of Segmented Ring

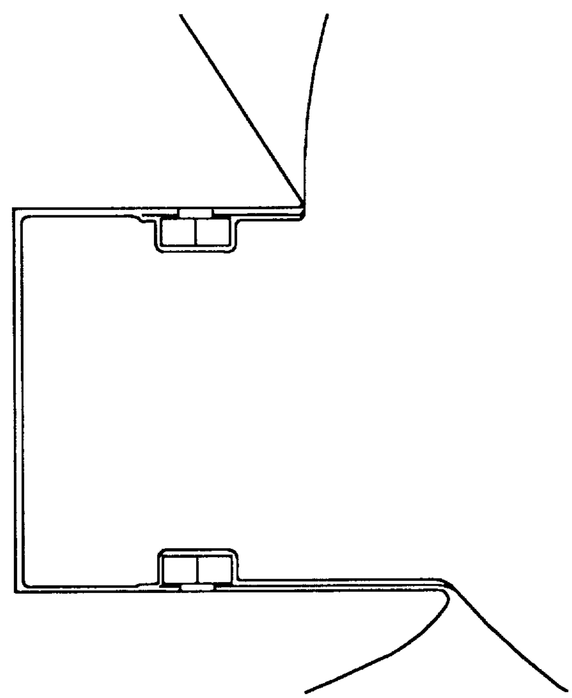


Figure 14.1.2 Detail of Flotation Attachment

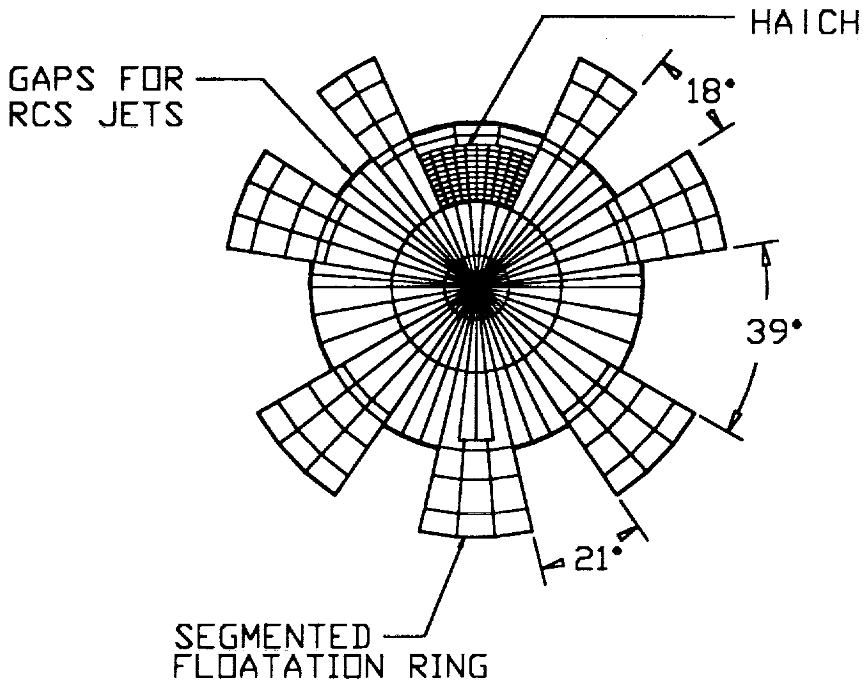


Figure 14.1.3 Detail of Segmented Ring and RCS Locations

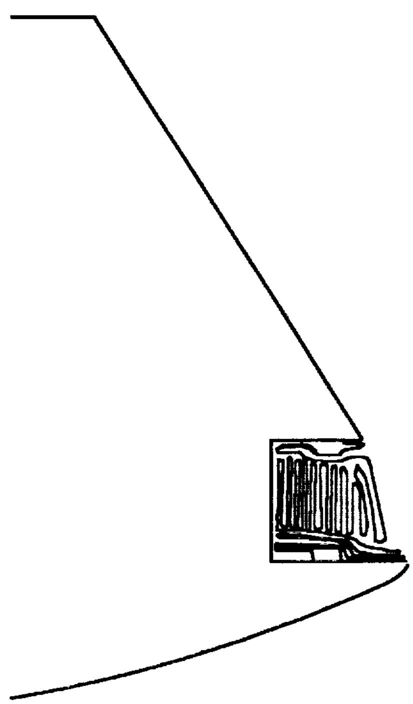


Figure 14.1.4 Detail of Floatation Storage

The basic purpose of the AS is to counter the static force caused by the EEC extended from the craft. The forces imparted on the craft in the water are depicted in Figure 14.2.1. Summing the forces about the center of gravity of the ACRV gives the buoyant force necessary. The required buoyant force is calculated to be 2.4 pounds.

To determine the strength required for the AS it is necessary to consider the dynamic effects of sea-state four waves. Two times the static buoyant force of the AS is a reasonable estimate of the impulsive load at the end of the attitude system. If 4.8 pounds is used as the maximum force on the end of the AS, and the maximum moment arm is 2.6 feet, the resulting moment at the base of the arm is 12.48 ft-lb. This moment is used in the stress analysis to evaluate material requirements. Stress analysis will be discussed in the materials portion of this section.

Included in the dynamic analysis of the system is vortex shedding. It is important that the natural frequency of the craft not be near the frequency created when wind or water causes vortices (Figure 14.2.2). The extension of the AS and the couch could function as a spoiler to reduce these affects if they trail the craft as expected.[34] To model these effects in the wave pool, the AS is made variable in length.[35]

Deployment of the Attitude System is shown in Figure 14.2.3. The AS pivots on one-quarter inch steel bolts that connect the beams at the top and bottom of the storage compartment (Figure 14.2.4). Two beams have three telescoping sections extending from 1 foot to approximately 2 1/2 feet in the ACRV model (Figure 14.2.5). This is comparable to from 5 feet to 13 feet in the full-scale model. The couch extends to 1.4 feet in the ACRV model. The beams fold out one by one and lock into place. They are extended to the desired length and locked into position with a pin. A cylindrical balloon at the end of the beams is inflated to maintain the correct attitude. Finally, a rigid surface is rolled out and pinned to the beams. This functions as a work surface on the full-scale ACRV.

The material used for the AS telescoping beams must be strong to counter the applied stresses and remain within size constraints. For these reasons, the telescoping beams of the AS are 1/2 inch by 3 inch aluminum boxbeams with 1/16 inch walls. These dimensions satisfy the size constraints imposed by the available storage space. The beams are attached to the ACRV by two 1/4 inch bolts each (Figure 14.2.6). The stress concentrations are located where the bolts go through the box-beams. The stresses are calculated by summing the moments about the base of the beam; this force is calculated to be 2.08 pounds. The resulting stress is calculated by summing the moments about the pivot point, then translating this moment into a stress on the beam. The resulting stress for this geometry is calculated to be 1584.8 psi, which is considerably less than 44,000 psi, the yield stress for aluminum.[36] This leads to a factor of safety of 28 for the 1/16 inch aluminum tubing. To spread the stress concentration at the head of the bolts, fender washers are recommended.

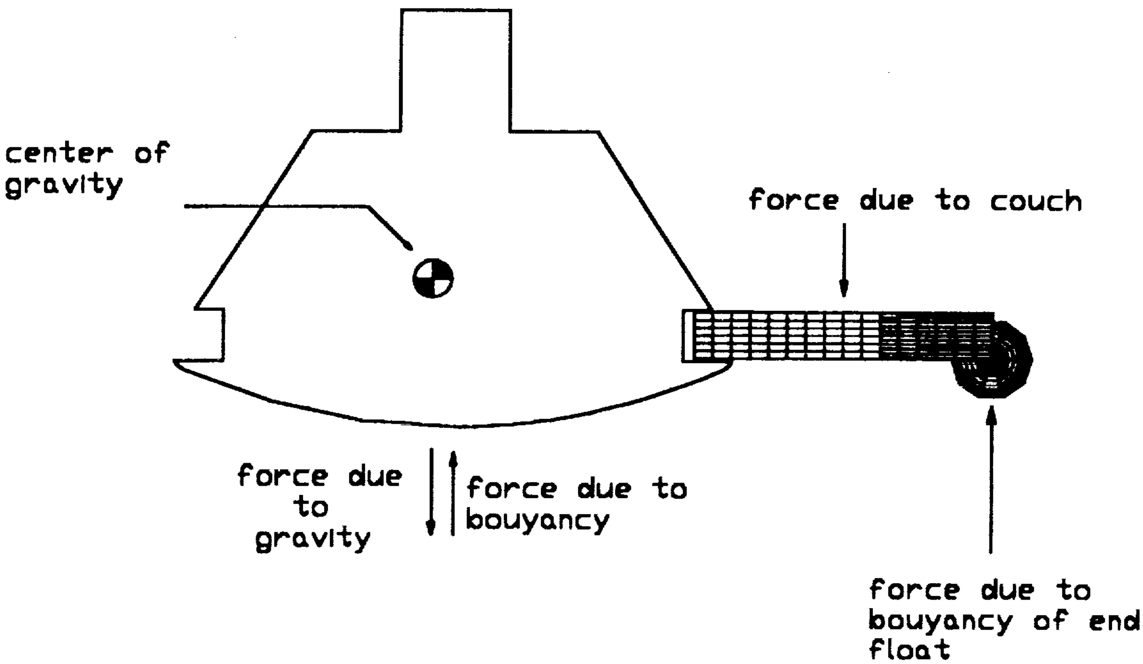
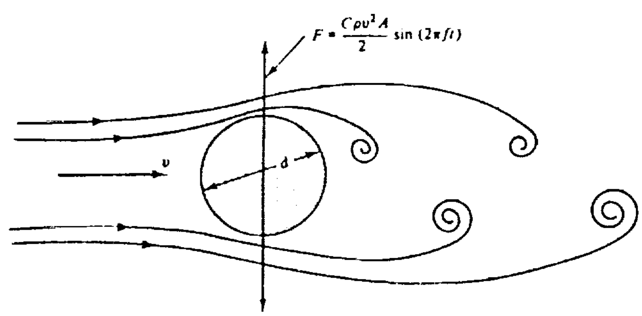


Figure 14.2.1 Attitude System Static Force Analysis



$$f = \frac{Sv}{d}$$

where S = *Strouhal* number (dimensionless)
d = diameter of cylinder (ft, m)
v = velocity of fluid (ft/s, m/s)

Figure 14.2.2 Vortex Shedding

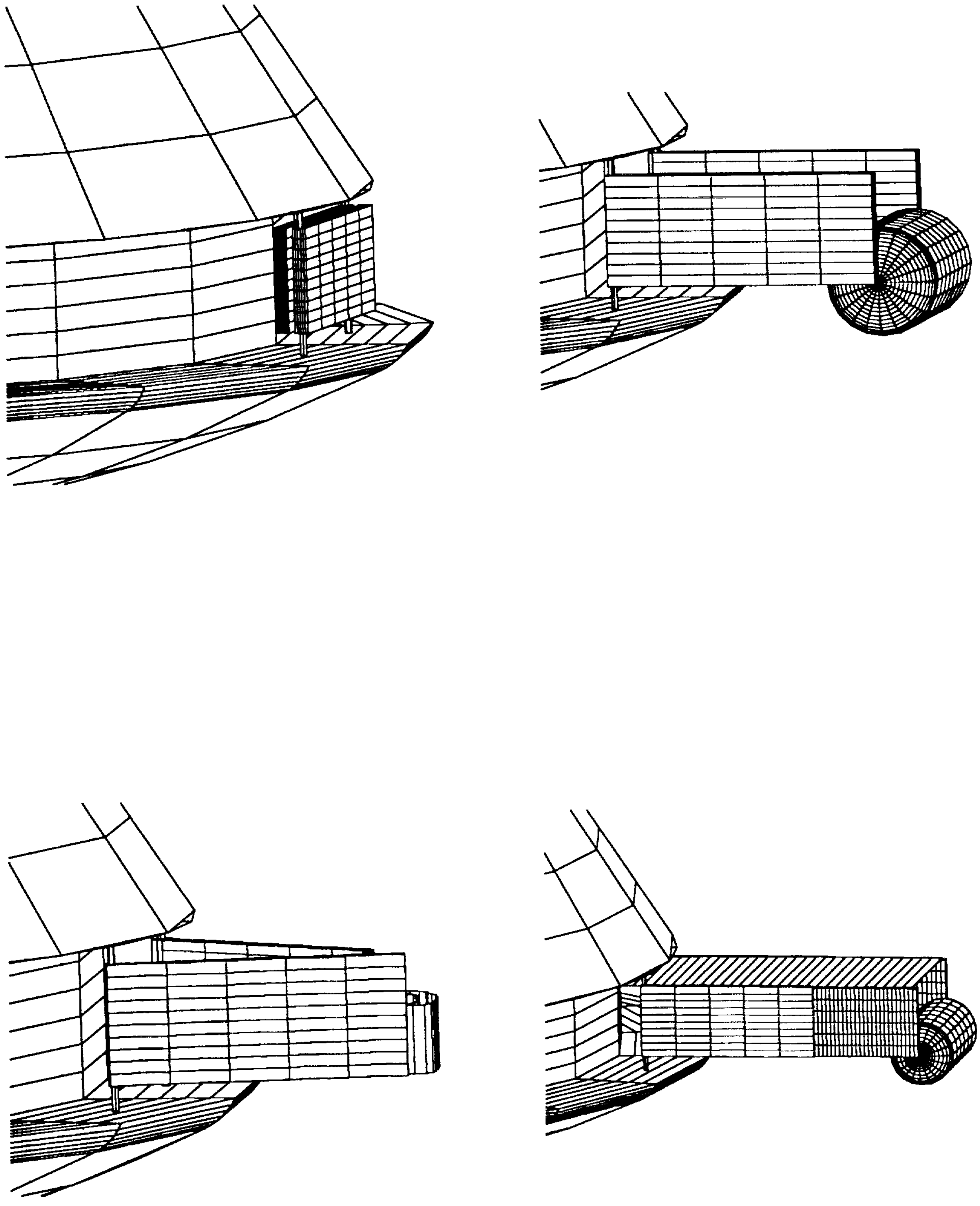


Figure 14.2.3 Detail of Extension

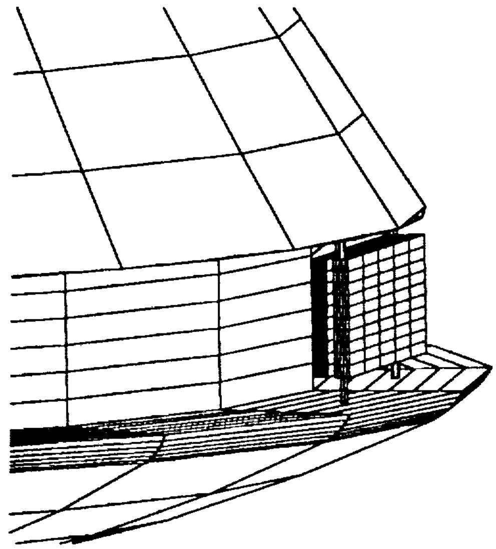


Figure 14.2.4 Detail of Storage

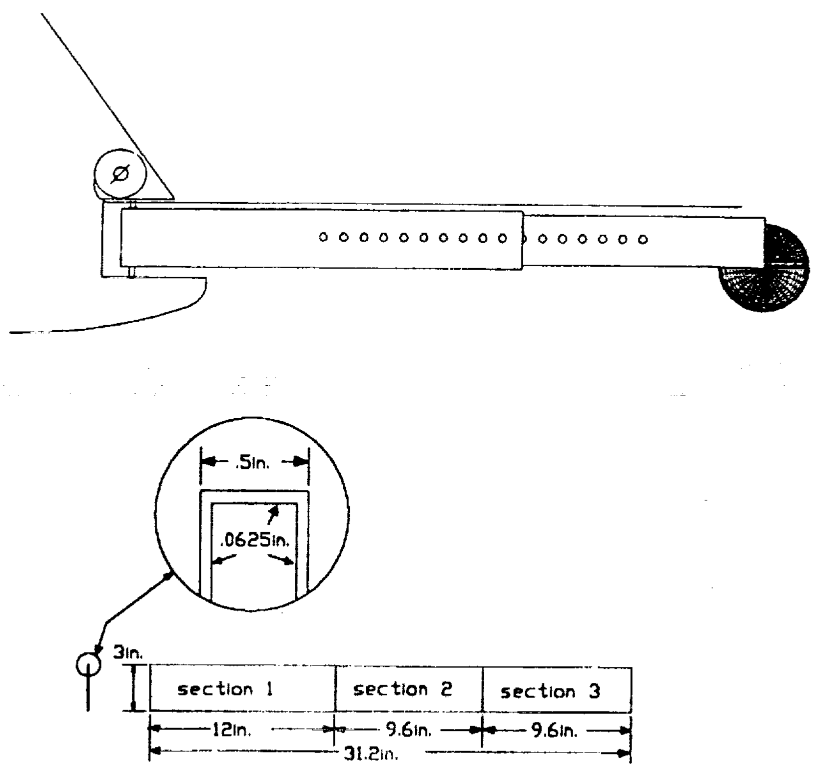
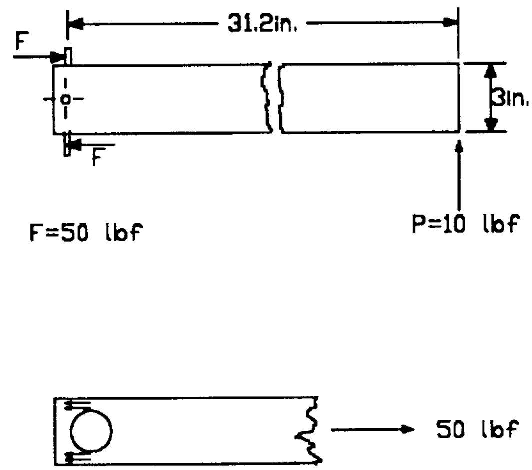


Figure 14.2.5 Detail of Telescoping Beams

Yield strength of Aluminum=44 Ksi
Yield strength of Steel=71 Ksi



stress in bolt=2.5 Ksi
stress in arm at pivot hole=3.2 Ksiz

Figure 14.2.6 Beam Stress

14.3 MATERIALS

The optimum inflatable material, based on the material matrix (Appendix G, Figure G-3) and associated discussion, is tightly woven nylon fabric coated with butyl rubber. Coated nylon accurately models the material to be used on the full-scale ACRV. It is light, flexible, strong, and non-porous. The coated nylon that works for this application is readily available from suppliers.[37] In the small quantity needed for the ACRV model, complimentary samples are available.[38]

The coated nylon is both sewn and glued at seams and attachment points. All sewn seams use an overlap configuration for both strength and to reduce air loss. After a seam has been sewn, another strip of the material is glued across the seam to ensure an air-tight joining. Attachment points are sewn to the float and sealed on the inside using the aforementioned method. The strips of material used for attachment receive special attention. These pieces have holes for the attachment bolts. The attachment bolts cause stress concentrations at the holes. To compensate for the higher stresses, these pieces are double sewn for reinforcement.[39]

14.4 INFLATION METHOD

In the full-scale ACRV, the deployment of the flotation system is of concern. The purpose of the model is to test the effects of the fully inflated FS and AS, and not the method of deployment. Therefore, the best method is the simplest and least expensive. Referring to the decision matrix (Appendix G, Figure G-4) the hand or foot pump meets the criteria. The device is easier to operate than a compressor, less expensive than CO_2, and considerably safer than pyrotechnics.

For the inflation of the FS and AS in the one-fifth scale model, a threaded valve similar to that used for automobile tires is attached to the flotation devices. The material around the valve is reinforced by doubling the fabric. The valve is placed through a 3/8 inch hole in the material. A washer is placed around the stem of the valve and a nut is clamped down on top of the washer. The cost for this type of valve is approximately three dollars.[40] Since there are seven individual segmented rings and one cylinder at the end of the arm, eight valves are required. Each segment is inflated individually using a hand or foot pump. The effects of different air pressures in the segments require testing. The air pressure is measured using a tire pressure gauge.[41]

Chapter 15.0 OBSERVATIONS AND RECOMMENDATIONS

The design work performed in the Fall 1991 semester preceded planned fabrication and testing during Spring 1992. Testing of the ACRV scale model will at a wave research laboratory was also planned. The model allowed for a number of operational tests, and provided an inexpensive way to study the effects of different configurations and weather conditions. In particular, study plans included, the dynamic effects of different lengths of the Attitude System (AS). Tests to study the effects of varied pressures on the Flotation System (FS) along with system redundancy were also planned.

Researching the flotation and attitude system for the one-fifth scale ACRV model, recommendations for a full-scale ACRV flotation and attitude system were made. It is recommended that a segmented ring be used for flotation, for the same reasons that it was suggested for the model. Each segment is rigidly attached to the ACRV and stored in a compartment at the waterline of the ACRV. Deployment is accomplished by blowing out a section of the outer shell of the ACRV. CO_2 cartridges or pyrotechnics are used to inflate each segment. Upon inflation a portion of the volume of each segment is inside the storage compartment and a large surface area is in contact with the craft. Each segment should be inflated independently of the others so that, if the inflation of one segment fails, the inflation of the remainder would not be affected.

It is recommended that Kevlar™ fabric coated with butyl rubber be used for the flotation system material. Coated Kevlar™ is light, strong, flexible, non-porous, and resistant to tears and punctures. Coated Kevlar™ fulfills all requirements needed for use as an air chamber for the full-scale ACRV. As seen in Figure 12.2.1 Kevlar™ increases in stiffness with increased pressure. This increased stiffness improves system rigidity.

Due to the design requirements of a rigid system for the AS, the design options are limited. It is recommended that the full-scale ACRV use telescoping beams that are stored on the craft. Telescoping beams can be stored in a small area, they are strong, rigid, and can be easily deployed. A number of materials may be used for construction. Aluminum, for example, withstands the stresses that would be placed upon the arm in sea-state four. Although aluminum is adequate, a lighter material may be available. A carbon fiber composite, titanium alloy, or other light material may be desirable.

There are options for inflating the FS in the full-scale. CO_2 gas is a reasonable method of inflation in the full-scale ACRV as well as pyrotechnics or a compressor. Before a final decision is made, however, more information should be collected and studied. For instance, the effects of microgravity and prolonged space exposure need to be investigated.

It is recommended that the air chamber at the end of the AS be manufactured from the same material as the flotation system. Although this may seem obvious, the systems are separate and require separate inflation systems. This chamber could be inflated in the same manner as the FS, however, the logistics of the AS system may be prohibitive. It is recommended that the AS air chamber be inflated by the rescue personnel.

SECTION III

ACRV SCRAM CONFIGURATION MODEL

DESIGN PHASE

* CENTER OF GRAVITY AND MASS MOMENT SYSTEMS
* HEAT SHIELD SHROUD
* LIFT ATTACHMENTS POINTS
* MATERIALS
* OPTIMAL SOLUTION
* OBSERVATIONS AND RECOMMENDATIONS

BUILDING PHASE

* SCHEDULING
* CONSTRUCTION

TESTING PHASE

* TEST PLAN
* PRESENTATION OF TEST RESULTS
* OBSERVATIONS AND RECOMMENDATIONS

SECTION III. SCRAM CONFIGURATION MODEL

INTRODUCTION

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. A beneficial characteristic of the SCRAM design concept is the space between the crew compartment and the heat shield.[42] This space allows for a "free flood" region between the crew compartment and the heat shield. This accumulated water will provide "dynamic damping" of the SCRAM's movement with respect to the wave motion. Four areas were researched during the design process: (1) Center of Gravity and Mass Moment Systems, (2) Heat Shield Shroud, (3) Lift Attachment Points, and (4) Construction.

To model the SCRAM configuration dynamically, the Center of Gravity (CG) and Mass Moment of Inertia must be modeled. A subsystem was designed to model the weight, CG and mass moment of inertia. The designs investigated were; concentrated mass, peripheral weight, suspended mass, mass on a vertical rod, flat circular plates, and an adjustable rotating weight system.

To determine the flotation characteristics of the model with an open heat shield and with a closed heat shield, a heat shield shroud was designed. This system seals the area between the edge of the heat shield and the crew compartment. The methods considered were a flat shroud, an inclined shroud, or inflatable balloons.

The Lift Attachment Point (LAP) system simulates a lift attachment location and methods of lifting the full scale ACRV. The systems consist of retrieval cables of different lengths and lift attachment points. The design options considered include: a sea sling LAP centered on the roof, three LAPs on the roof, three LAPs on the side of the crew compartment, two LAPs on the roof, and two LAPs on the roof with one on the heat shield.

Several materials were considered for the construction of the model. These materials include door skin, sheet metal, plastic, and fiberglass composite. The material chosen determined the construction technique that was used to build the model.

After the model was designed, the project continued with building. Scheduling techniques used to insure the project completed on time include work breakdown structures, logic charts, and Gantt charts. The model was constructed in three major assemblies: the crew compartment, the heat shield, and the Adjustable Rotating Weight System (ARWS)

A test plan was constructed to coordinate the conduct of the testing. Testing of the model was completed in three phases. Pre-testing was completed to verify the model satisfied the specifications. Static testing consisted of tests to determine the static draft and water tightness of the model, as well as the durability of the LAP system. Dynamic testing took place at Offshore Technology Research Center at Texas A & M University in College Station, Texas. This testing was done to evaluate the SCRAM configuration's flotation characteristics and various methods of craft recovery. The wave and lift 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.

The Design Phase details the design activities leading to the development of the ACRV SCRAM configuration model. Specifications for the model are presented in Appendix H. Descriptions of the design options for each system follows. A more detailed description of the optimized system will be presented along with observations and recommendations. The Building Phase details the scheduling procedures used and the construction of the model. Included in the Testing Phase are the test plan, the test results and observations and recommendations.

DESIGN PHASE

Chapter 16.0 CENTER OF GRAVITY AND MASS MOMENT SYSTEMS

To achieve geometric and dynamic similitude with the full scale SCRAM model, the one-fifth scale SCRAM model must geometrically and dynamically simulate the Assured Crew Return Vehicle (ACRV) design concept.[43] To accomplish this the SCRAM model must have an adjustable center of gravity and mass moment of inertia. The center of gravity of the SCRAM model must be adjustable both with respect to the axis of symmetry and the vertical distance from the crew compartment.[44] To achieve these results, six options were considered: concentrated mass, peripheral weight, suspended mass, mass on a vertical rod, flat circular plates, and mass suspended on blades.

16.1 CONCENTRATED MASS

A simple means of positioning the center of gravity is to place a concentrated mass at the required location. The amount of mass and its location is used to change the center of gravity (Figure 16.1.1). Additionally, a mass hanging from a system of peg boards throughout the crew compartment changes the center of gravity both horizontally and vertically. This alternative is simple to fabricate and use. It cannot, however, adjust the vertical center of gravity and vertical mass moment independently. It also requires space in the center of the crew compartment which may limit the model's utility in the future.

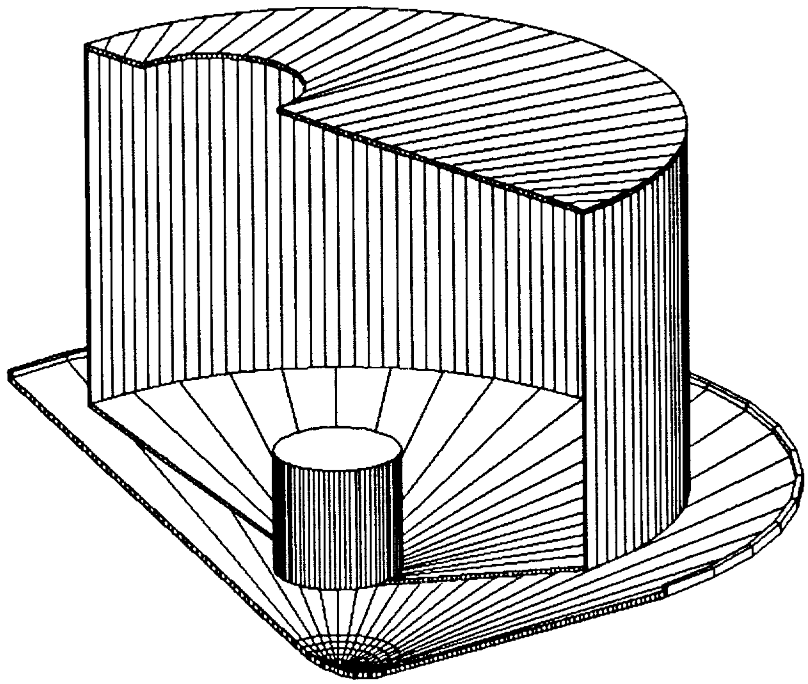


Figure 16.1.1 Concentrated Mass

16.2 PERIPHERAL WEIGHTS

A proper placement of weights on the interior of the shell makes it possible to adjust both the center of gravity and the mass moment. A system of shelves is installed in the crew compartment to facilitate the distribution of mass (Figure 16.2.1). These shelves do not interfere with the use of the center of the crew compartment, are simple to fabricate and are easily adjusted. This peripheral placement of weights, however, creates a large mass moment.

16.3 SUSPENDED MASS

Another alternative consists of a fixed mass supported by a mechanically adjustable structure (Figure 16.3.1). This structure would is made up of several rods that are adjusted to correctly locate the center of gravity. This system allows for flexibility and accuracy in the placement of the center of gravity, but the moment of inertia cannot be adjusted independently of the CG. It is also difficult to fabricate and would be complicated to adjust precisely.

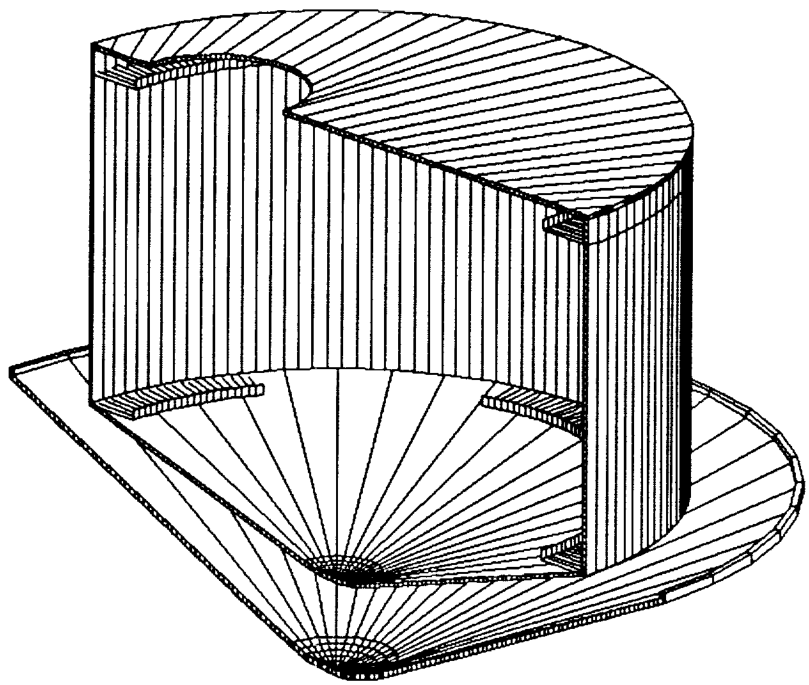


Figure 16.2.1 Peripheral Weights

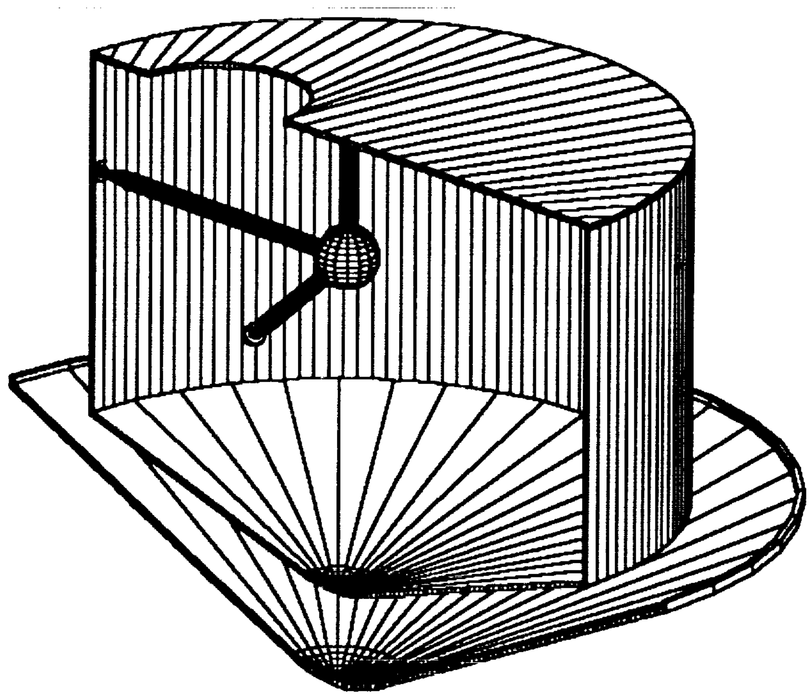


Figure 16.3.1 Suspended Mass

16.4 MASS ON A VERTICAL ROD

The mass on a vertical rod consists of a moveable weight on a threaded vertical rod on the X-axis center line of the model (Figure 16.4.1). This provides a means of moving a volume of mass vertically to obtain the desired center of gravity. A pegboard system is used to adjust the center of gravity with respect to the horizontal plane. This system is adjustable and easy to fabricate. As with the other concentrated mass systems, the moment of inertia cannot be adjusted independently of the center of gravity. It is also placed in the middle of the crew compartment making the interior unusable for future modification.

16.5 FLAT CIRCULAR PLATES

A flat circular plate system was developed during 1990-1991 to adjust the center of gravity and mass moment of the Apollo model. To overcome the limitations imposed by simply distributing the weight vertically, the weight can be distributed horizontally as well as vertically (Figure 16.5.1). A thin, flat plate mounted to a horizontal peg board provides adjustability of the center of gravity both horizontally and vertically by the use of holes and spacers. A circular plate provides a uniform mass moment about any horizontal axis through the center of gravity.

This system provides an inexpensive means to obtain the desired center of gravity. It also reduces inconsistencies during testing due to oscillation of the center of gravity. Since this system was used previously, insight could be gained from the previous effort. The plates require special machining to create the required moment of inertia.

16.6 ADJUSTABLE ROTATING WEIGHT SYSTEM (ARWS)

The Adjustable Rotating Weight System is shown in Figure 16.6.1 This design relies on a movable blade configuration to change the center of gravity and the mass moment of the SCRAM model . There are two blades; one on top of the crew compartment and the other at the bottom. The blades have the capability to move the mass both horizontally along the blade and vertically above and below the blade. The moment and center of gravity are adjusted independently to a larger range of values with this system than with the other alternatives. A disadvantage, however, is that its fabrication and use is complicated.

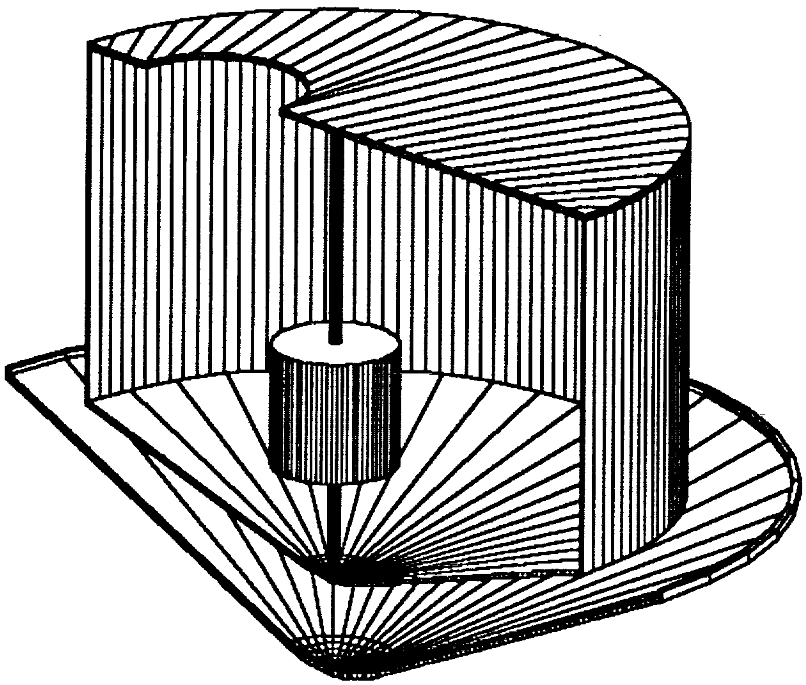


Figure 16.4.1 Mass on Vertical Rod

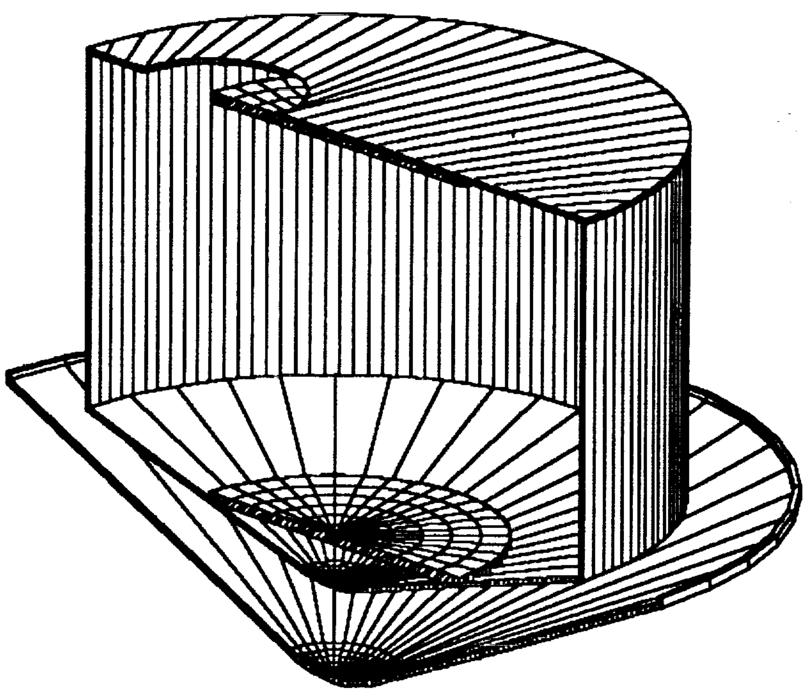


Figure 16.5.1 Flat Circular Plates

C-2

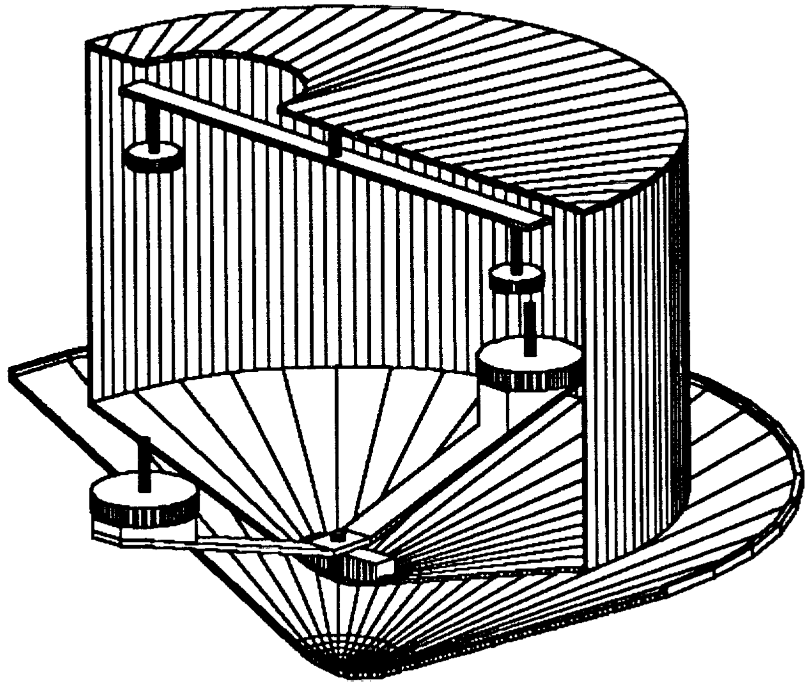


Figure 16.6.1 Adjustable Rotating Weight System

Chapter 17.0 HEAT SHIELD SHROUD

An inherent difficulty in the SCRAM design concept is the free flood region between the crew compartment and the heat shield (Figure 17.0.1). This amount of water positions the center of buoyancy higher on the vehicle causing it to sit low in the water.[45] Additionally, the accumulated water adds significant mass to the vehicle, making its recovery difficult. To alleviate these problems, an attachable shroud from the body of the crew compartment to the edge of the heat shield is added to the model. The function of the shroud is to prevent the flow of water into the space described above. The options considered to test the feasibility of a heat shield shroud are a flat shroud, an inclined shroud, or inflatable balloons.

17.1 FLAT HEAT SHIELD SHROUD

A simple approach is to provide a sealing surface by using a flat piece to seal the gap (Figure 17.1.1). This shroud is a single washer-shaped piece which is fitted over the crew compartment. The sealing surfaces are the inside radius of the washer against the crew compartment and the outside radius against the heat shield. This configuration is a simple geometry making it easy to fabricate. A potential problem of this design is that it is difficult to seal.

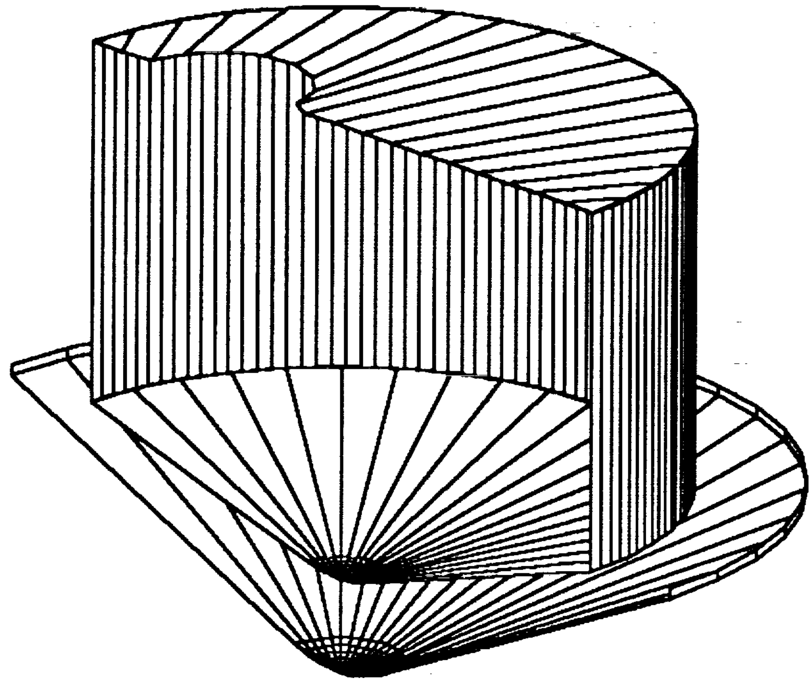


Figure 17.0.1 No Shroud

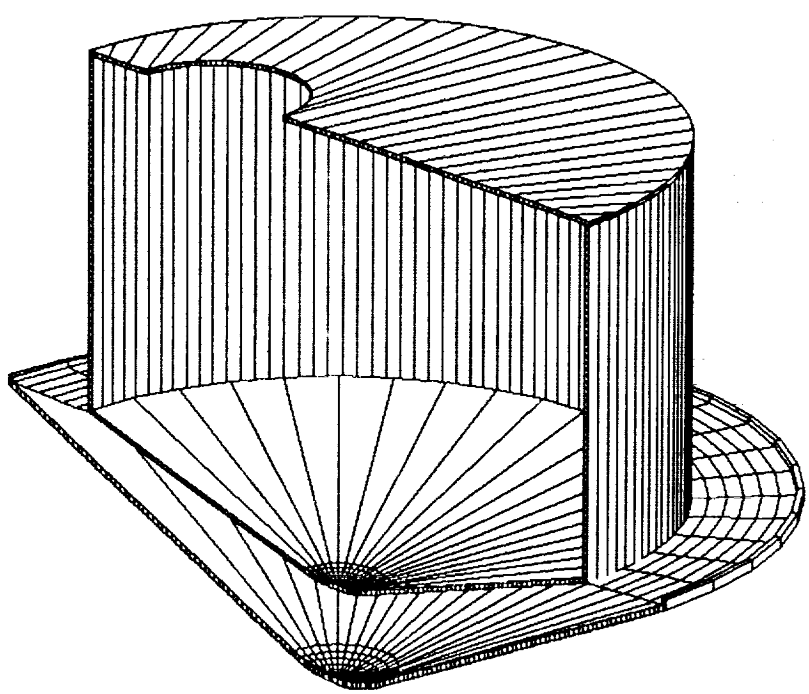


Figure 17.1.1 Flat Shroud

17.2 INCLINED SHROUD

An inclined shroud is similar to the flat shroud but would slope upward as it seals to the crew compartment (Figure 17.2.1). The construction consists of a number of formed plates which are affixed to the crew compartment, the heat shield, and each other. This configuration provides no surface for standing water and ensures no water is taken on. The formed surfaces required for this system are difficult to construct and to seal.

17.3 INFLATED BALLOONS

Another possibility is to use an inflated membrane to displace available volume between the crew compartment and the heat shield (Figure 17.3.1). This membrane is initially deflated leaving the heat shield flooded. The flooded heat shield causes the model to sit lower in the water, giving it greater stability. When required, the membrane is inflated to displace the flooded volume of the heat shield and make the vehicle lighter and easier to recover.

An inflated membrane makes it possible to reduce water accumulation in the heat shield and its solution does not require a change in the SCRAM's shape. It can also be inflated or deflated at different times to optimize the SCRAM's buoyancy characteristics during the different phases of the mission. A disadvantage to this system is that it requires a mechanism to inflate the membrane on demand. Further, a model would be difficult to fabricate.

Chapter 18.0 LIFT ATTACHMENT POINTS

The Lift Attachment Point (LAP) subsystem is designed to meet the following requirements:

1. The lift attachment subsystem must be positioned above the center of mass of the SCRAM.

2. The system and its components must be able to support 180 pounds, providing the necessary 1.4 safety factor.

3. The system has the potential to solve the problem of accumulated water in the heat shield.

4. The SCRAM model LAP system must meet the physical constraints of the proposed SCRAM/ACRV prototype.

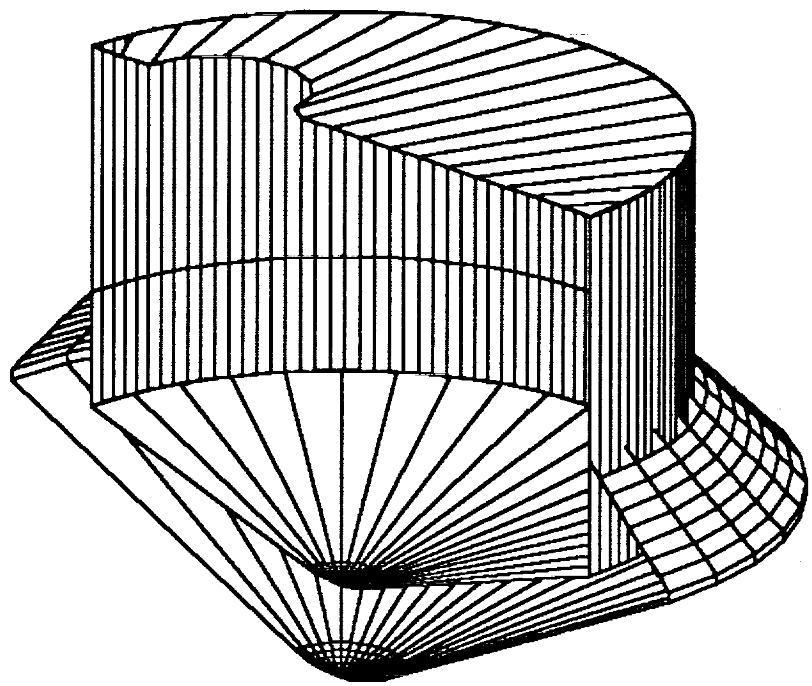


Figure 17.2.1 Inclined Shroud

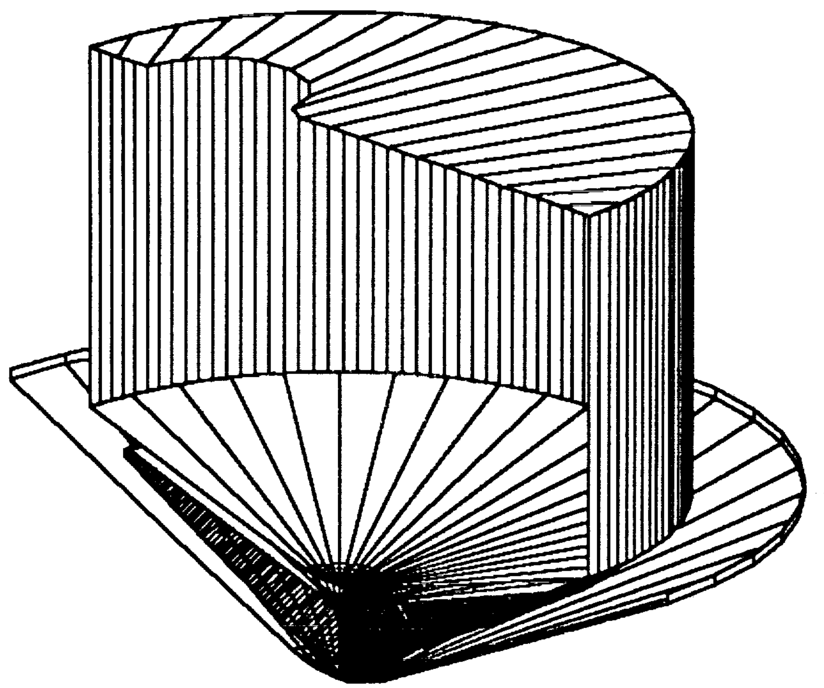


Figure 17.3.1 Inflated Balloons

In addition to the objectives mentioned above, the LAP system is considered a design alternative to draining the heat shield during recovery. The design options considered were: a sea sling LAP centered on the roof, three LAPs on the roof, three LAPs on the side of the crew compartment, two LAPs on the roof, and two LAPs on the roof with one on the heat shield.

18.1 CENTRAL LAP ON THE ROOF/SEA SLING

The central LAP on the roof/Sea Sling is shown in Figure 18.1.1. This system consists of a loop, hook, or other attachment device mounted on the center of the roof, possibly on the same structure as the parachute tethers. This design solution is straightforward. The proposed SCRAM/ACRV is required to have hard points for the parachutes centered on the roof that can withstand 3 g's. A LAP that coincides with these points meets the subsystem objectives and the SCRAM/ACRV physical constraints. The stress is concentrated on the roof and requires reinforcement of the vehicle's top section.

18.2 THREE LAPS ON THE ROOF

This system uses three attachment couplings mounted at 120 degree intervals in the plane of the roof perimeter (Figure 18.2.1). Each of these points is designed to support the entire weight of the SCRAM model. Since there are three LAPs, each point is subject to less stress. The multiple LAP system has the advantage of providing redundancy and stability during recovery operations. However, the redundancy exists only to the cable gathering point. This system ignores the reinforced center parachute point, therefore, reinforcement of these points is necessary.

18.3 THREE LAPS ON SIDE

This design is similar to the three LAPs on the roof, but each LAP is on the side of the crew compartment. The feature of this design is the three recessed couplings on the upper outside perimeter spaced at 120 degree intervals in the horizontal plane (Figure 18.3.1). A side LAP provides better stress distribution than a LAP mounted on the roof. Each coupling would be designed to support the entire weight of the SCRAM model while achieving the most efficient stress distribution. This system gives better stability and offers redundancy during recovery operations. Putting LAPs on the crew compartment side adds complexity to the model design, ignores the center parachute point .

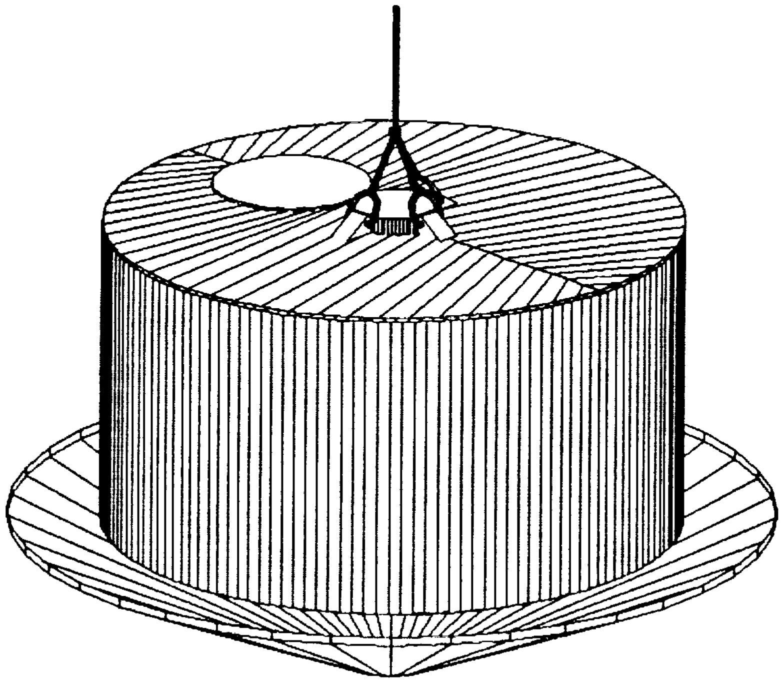


Figure 18.1.1 Sea Sling

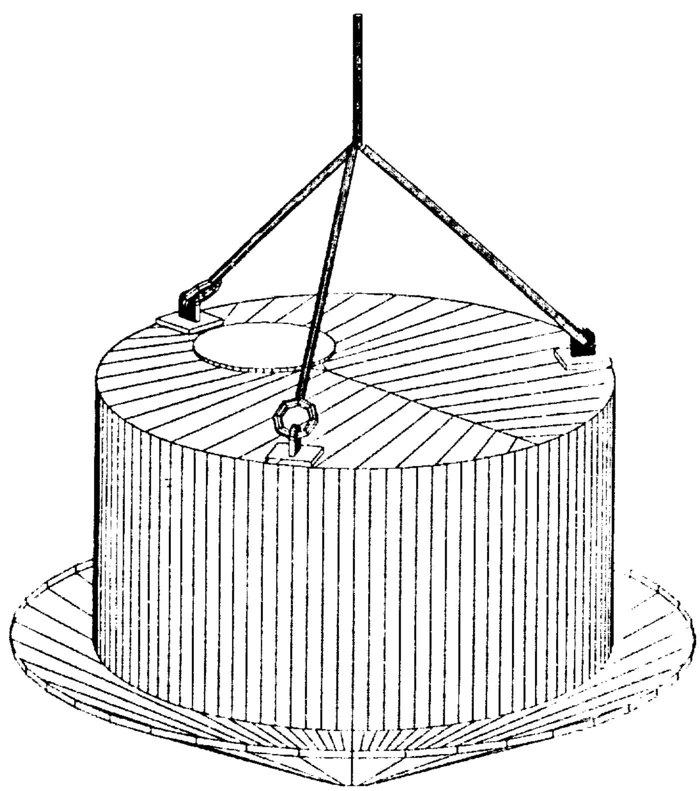


Figure 18.2.1 Three Lift Attachment Points on the Roof

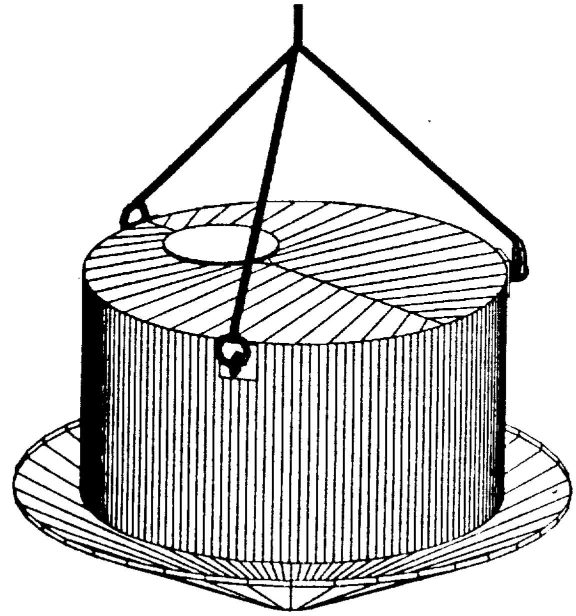


Figure 18.3.1 Three Lift Attachment Points on the Side

18.4 DUAL OFFSET LAPS

This system consists of two attachment couplings with a horizontal angular spacing significantly less than 90 degrees. These LAPs would be mounted on the top of the crew compartment to one side (Figure 18.4.1). This arrangement provides a means to remove accumulated water in the heat shield during recovery operations. As the craft is lifted up, the mass of the vehicle, in conjunction with the offset LAPs, provides a moment to tip the SCRAM 20 to 30 degrees allowing the water to drain. Greater redundancy is provided by the Dual Offset LAP system than by the single LAP system. However, two offset LAPs subject the outside surface of the crew compartment to greater stress concentrations than a three LAP system.

18.5 TWO LAPS ON ROOF AND ONE ON HEAT SHIELD

This design is similar to the previous design but an additional single LAP is extended to the heat shield (Figure 18.5.1). This configuration provides a greater moment on the craft during recovery operations. Again, this moment tips the craft so water can drain easily from the heat shield. While it does provide redundancy, it is difficult to design it to meet the physical constraints of the proposed SCRAM/ACRV prototype. This option requires considerable reinforcement of the heat shield at the point of attachment. Care must be taken to ensure that this arrangement does not allow the crew compartment to rub against the lifting wire. All three LAPs are subject to considerable shear stress.

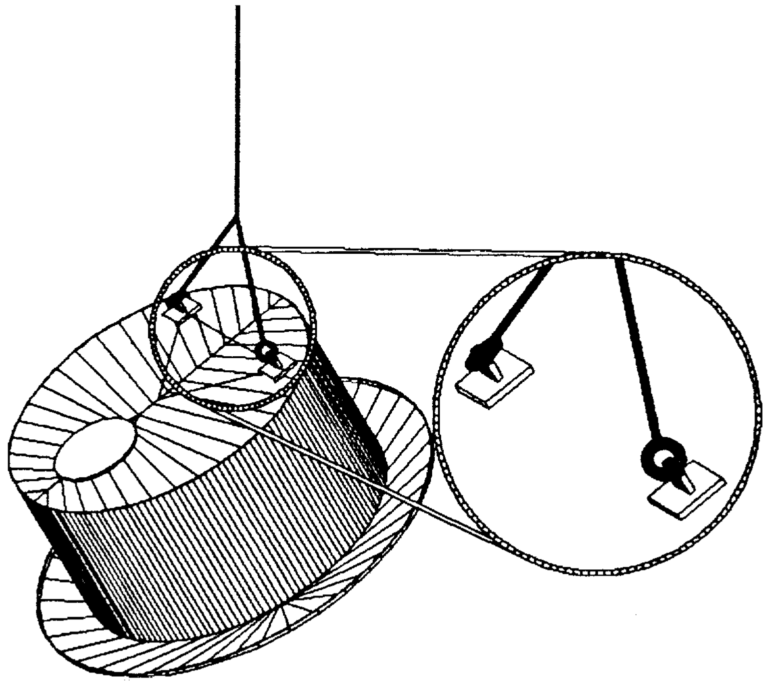


Figure 18.4.1 Dual Offset Lift Attachment Points

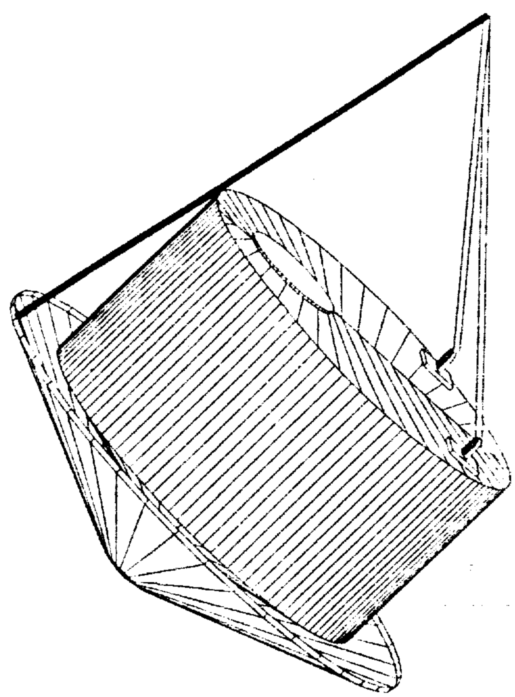


Figure 18.5.1 Two Lift Attachment Points on Roof One on Heat Shield

Chapter 19.0 MATERIALS

Several materials for the construction of the model are evaluated. The design criteria for the construction materials are as follows:

1. The SCRAM model must be constructed from a material which is able to withstand a simulated oceanic environment.

2. The crew compartment must not leak an undue amount of water.

3. The construction materials should not be so heavy as to limit the adjustability of the center of gravity and mass moment system.

4. The material used must be easy to work with.

The options under investigation for construction materials are: door skin, sheet metal, plastic, and fiberglass.

19.1 DOOR SKIN

Door skin is a type of thin plywood used in the construction of doors. It is flexible, inexpensive and easy to work with. Door skin is a building material usually made of thin layers of wood which are glued together with moisture resistant glue. These layers, called pliers or veneers, are arranged so that the grain direction is at right angles to that of the layer next to it.[46] In addition to being flexible, inexpensive and easy to work with, door skin is readily available, easy to repair, and strong and stiff along the grain. Door skin provides a straightforward and simple fabrication process. However, door skin requires extensive water proofing, is easily damaged, and needs a frame for support and strength.

19.2 SHEET METAL

Using sheet metal to construct the SCRAM model was considered. A frame for the heat shield and crew compartment is made from wood. After the fabrication of the frame, sheet metal is formed around it to produce the model. Thin sheet metal is easy to shape and work with, while being very strong and durable.[47] Sheet metal, adds weight to the model both in the metal itself and in the frame it requires. This excess weight reduces the amount of weight available for the center of gravity and mass moment adjustment subsystem. Metal also requires corrosion protection.

19.3 PLASTIC

Plastics are a varied group of synthetic materials which are processed by forming or molding into shape a polymerizing material. Plastics require curing time to make a form and retain their shape after curing. Most plastics are composed of long chains of carbon atoms covalently bonded together in the main molecular chain.[48] Plastic provides a lightweight material with strength obviating reinforcement. In fabrication, plastic is difficult to work with and requires some expertise. Since the model is large, fabrication with plastic may lead to a significant thinning of the material during construction. Plastic expands with temperature, has a low relative stiffness, and its mechanical properties are significantly reduced over other types of materials. Other disadvantages are flammability, notch sensitivity, and easy absorption of moisture.

19.4 FIBERGLASS COMPOSITE

Glass fiber is the most common reinforcement for polymer composites. The trade name is Fiberglass. The glass fiber is made by forcing molten glass through tiny holes in dies. Fiber diameters usually range from 0.0002 to 0.001 inch. There are two types of glass configurations which can be used, mat cloths and weaves. Weaves are interwoven layers of glass fibers and mat cloths are made from randomly intertwined, discontinuous fibers of intermediate length. The bonding is completed with the addition of a resin to the polymerizing copolymer.[49]

There are two types of glass, E-glass and S-glass. E-glass is essentially a borosilicate glass named for electrical applications and it is lower in cost than the S-glass. S-glass is a magnesia/alumina/silica material with a higher tensile strength than E-glass. The 1990-1991 UCF Apollo model was made from a composite which used S-glass.

Fiberglass provides: light weight, good rigidity, ease of repairs, ability to modify, and no need of a frame. Also, Fiberglass is durable in a water environment, fatigue resistant, and absorbs impact energy that would puncture most materials. Fiberglass requires a mold to be fabricated first and is difficult to work with. The construction would be labor intensive, time consuming, and would require some knowledge and expertise to achieve good results. Once the mold has been fabricated, though, the model can be reproduced whenever necessary. Fiberglass is strong in tension but weak in shear. Hard points require additional reinforcement for model assembly.

Chapter 20.0 CHOSEN SOLUTION

This section contains the design alternatives which were chosen. Each optimal subsystem alternative is discussed in detail. Decision matrixes were used as tools to choose the optimal design alternative for each subsystem (Appendix I).

20.1 MODEL CONSTRUCTION

20.1.1 Crew Compartment Construction

The best combination of construction properties is achieved with the use of a fiberglass composite for the model shell (Appendix I, Figure I-1). A mold infrastructure is made out of wood to the specific dimensions of the crew compartment. A formica skin is then stapled on the infrastructure and this determines the shape of the crew compartment. A coat of silicone is applied to the formica before the fiberglass and resin is applied. The silicone is a "mold release" agent. A "mold release" agent is used to release the model from the mold as easily as possible.

The first coat is gelcoat. The second layer is a strong fiberglass multi-directional matting, called a "gel coat". The third layer is 1/8" thick, 1" x 1" balsa wood squares, on a layer of fiberglass, called "balsacore". The balsacore gives the fiberglass matrix enormous strength and durability. A layer of biaxial fiberglass is applied to the balsacore as an outer coat. These four layers make up a fiberglass matrix system which is ultra strong and supports the weight of the SCRAM model

20.1.2 Lid Construction

The lid is made of the same fiberglass matrix as the crew compartment. However, three 2 foot long, 1 x 1/2 inch wood ribs are placed radially from the center at even intervals and secured with wood screws into fiberglass lid (Figure 20.1.2.1). Structuring the lid in this manner gives it the necessary strength to test the LAP subsystem. Eight 1/4 inch holes must be drilled to accommodate the lid securing latches.

20.1.3 Crew Compartment Lid Attachment

There are eight lid securing latches located symmetrically around the lid (Figure 20.1.3.1). The latches are constructed of 1 x 3/4 x 1/8 inch aluminum flat stock. There is a 1/4 inch tapped hole located in the center of the width 1/4 inch from one end. This flat stock enables a 1/4 x 3/4 inch galvanized bolt to secure the lid to the crew compartment. The latch fits under a fiberglass lip which encircles the inner circumference of the crew compartment.

A 26 inch diameter, 1/8 inch thick neoprene gasket is placed on the top of the fiberglass lip to prevent water from entering the crew compartment. The gasket material is easily obtained and cut to required dimensions.

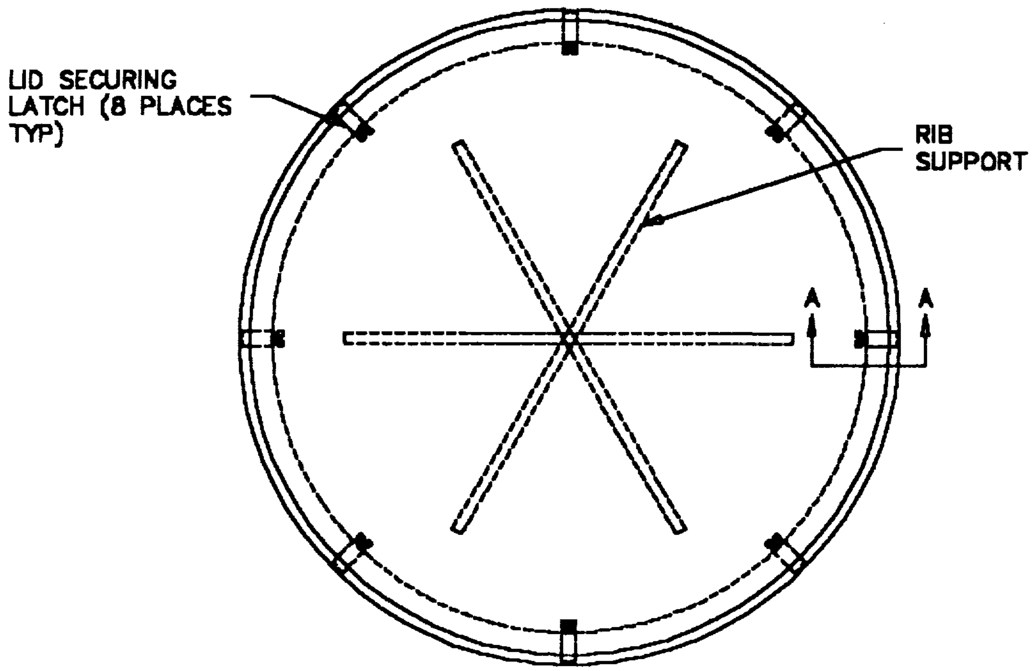


Figure 20.1.2.1 Crew Compartment Lid Securing Latches

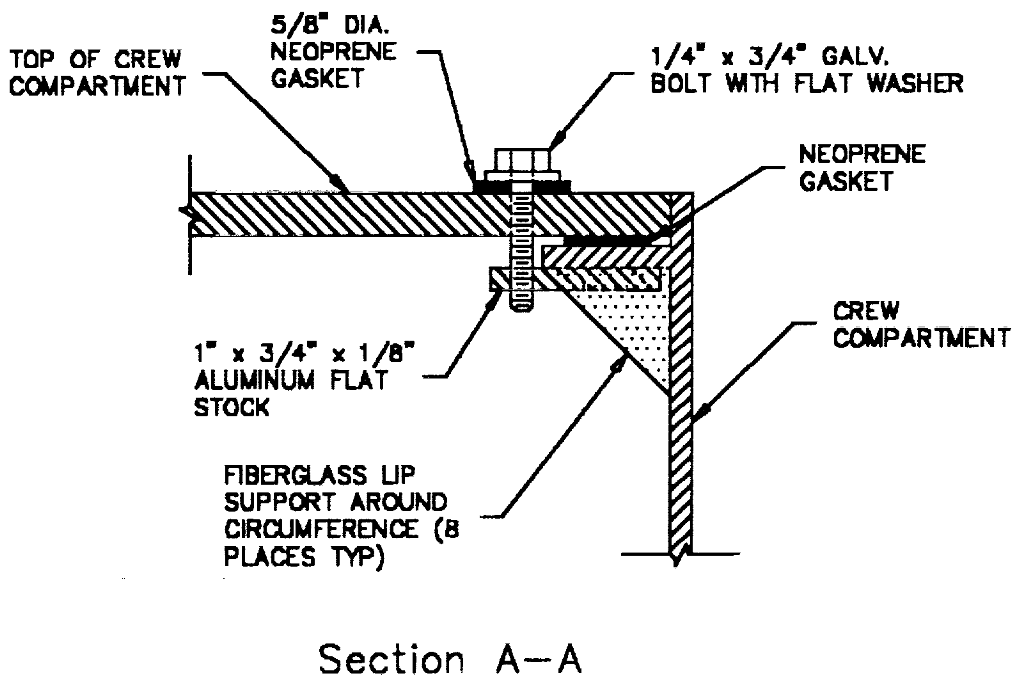


Figure 20.1.3.1 Crew Compartment Lid Attachment

20.1.4 Heat Shield Construction

The heat shield of the model is constructed separately and fabricated in the same manner as above. It is secured to the crew compartment as described in the "Crew Compartment to Heat Shield Attachment" section below. The heat shield's shape is an inverted cone with a rounded tip.

20.1.5 Compartment to Heat Shield Attachment

The method of attachment described below allows the heat shield to be removed from the crew compartment. This allows the crew compartment to be water tested unaccompanied by the heat shield. The method of attachment of the crew compartment to the heat shield is four attachment points located symmetrically around the crew compartment (Figure 20.1.5.1).

20.1.6 Attachment Construction

There are four, 6 x 1 1/2 x 1/8 inch aluminum flat stock, sections bolted to the crew compartment (Figure 20.1.5.1). A 2 x 2 inch aluminum angle, 2 inches in length is bolted to the heat shield and bolted to the flat stock on the crew compartment. All bolts are 1/4 x 1 inch galvanized round head bolts.

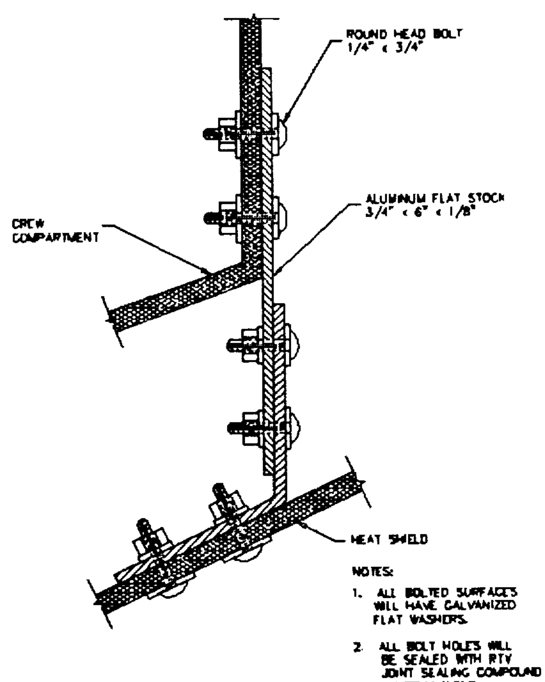


Figure 20.1.5.1 Crew Compartment Heat Shield Joint

20.2 CENTER OF GRAVITY AND MASS MOMENT SYSTEM

There are several alternatives which model the center of gravity and the mass moment of inertia. The most feasible and adjustable subsystem to be used to model the center of gravity and mass moment is the Adjustable Rotating Weight System (ARWS). This subsystem is the most versatile of the alternatives(Appendix I, Figure I-2).

20.2.1 ARWS Construction

The ARWS is constructed of 1 1/2 x 1/8 inch aluminum flat stock which is bent into required shape. Weights are used to create the desired center of gravity and mass moment of inertia. Each weight is machined, to specific dimensions. There are ten, one pound, weights and four, five pound, weights. Also, there are at least four, ten pound weights. These weights are constructed out of machined steel.

The weight system structure has a 1/2 inch threaded steel shaft, which enables the weighted structure to be rotated 360 degrees. The shaft is fixed at the base to a 2 x 4 inch wooden block and backed with an 1/8 inch aluminum plate, which is used for strength. The weight system structure has a 1/2 inch hole to accommodate the threaded shaft. As the rotating weight system reaches the calculated angle needed to model the CG and the moment of inertia, it is bolted securely in place (Figure 20.2.1.1).

20.3 LIFT ATTACHMENT POINTS

Several alternatives were conceived to meet the necessary criteria for lifting the ACRV during retrieval. The optimization matrix for the LAP subsystem (Appendix I, Figure I-3) determined the parachute lift attachment points or the "Sea Sling", as the optimal solution. The Sea Sling LAP is structured to withstand 3 g's. It has a three point redundancy and also lifts the vehicle at an angle to allow excess water contained in the heat shield to be drained.

20.3.1 LAP Construction

The three lift attachment points are hardened steel eyelets and are bolted to hard-points on the crew compartment lid. The hard points are made of 1 1/2 inch angle iron bolted to the lid at two points (Figure 20.3.1.1).

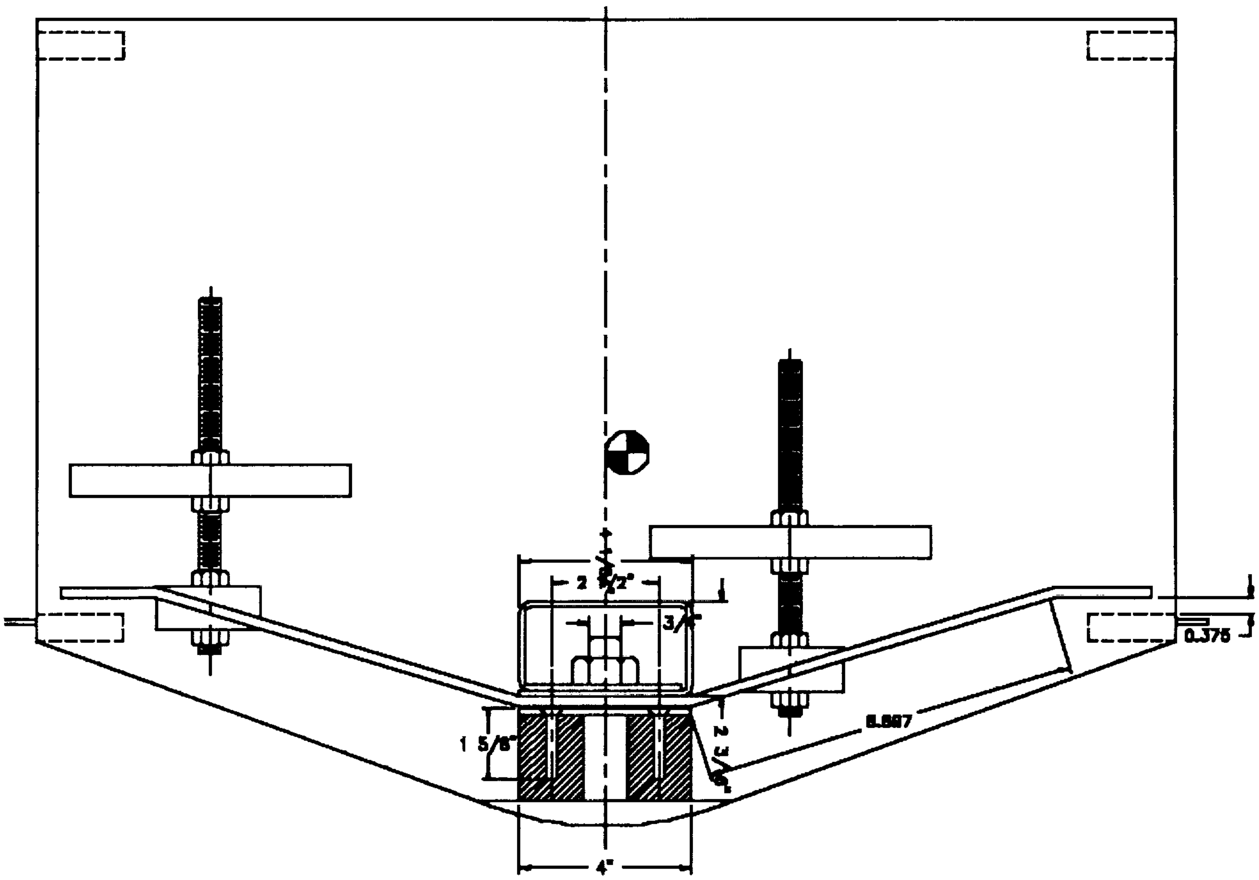


Figure 20.2.1.1 Adjustable Rotating Weight System

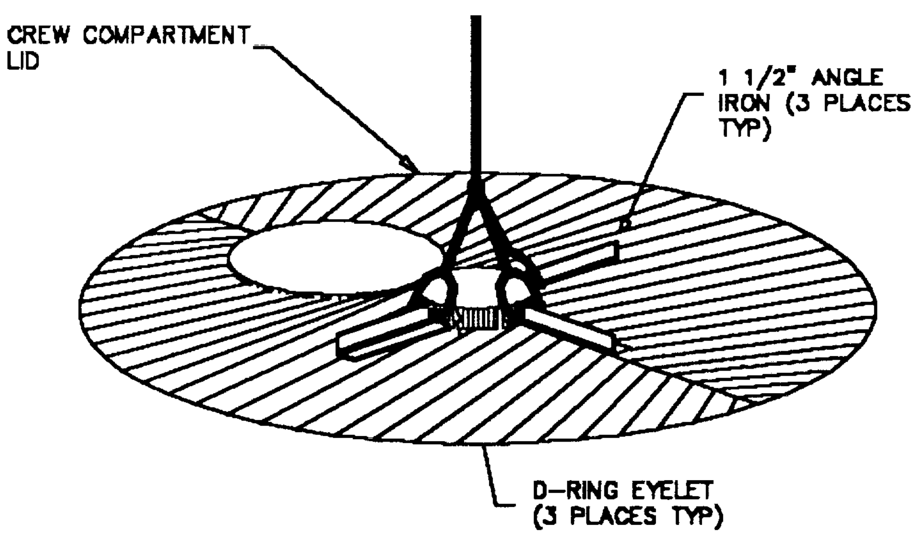


Figure 20.3.1.1 Lift Attachment Point Construction

20.4 HEAT SHIELD SHROUD

The heat shield of the SCRAM model overlaps the crew compartment by a length of four inches. That is, the crew compartment's diameter is smaller than the heat shield's largest diameter. The void between them allows water to flood the area below the crew compartment. The flooded void causes the vehicle to sit low in the water, which could make the side hatch unusable during SAR operations. A heat shield shroud can be used to prevent water from entering this area. The flat heat shield shroud is the chosen design (Appendix I, Figure I-4). It is easy to fabricate, remove and apply. This subsystem is used as a comparative test after the vehicle has been water tested without the heat shield shroud.

20.4.1 Heat Shield Shroud Construction

The heat shield shroud is fabricated of biaxial fiberglass with a strong fiberglass undercoat. It is a rigid subsystem easily removed by slipping it over the crew compartment. The shroud is secured in place by banding an integral neoprene seal around the crew compartment and bolting around the circumference (Figure 20.4.1.1). The heat shield side of the shroud is sealed at the edges with a neoprene gasket to prevent leakage.

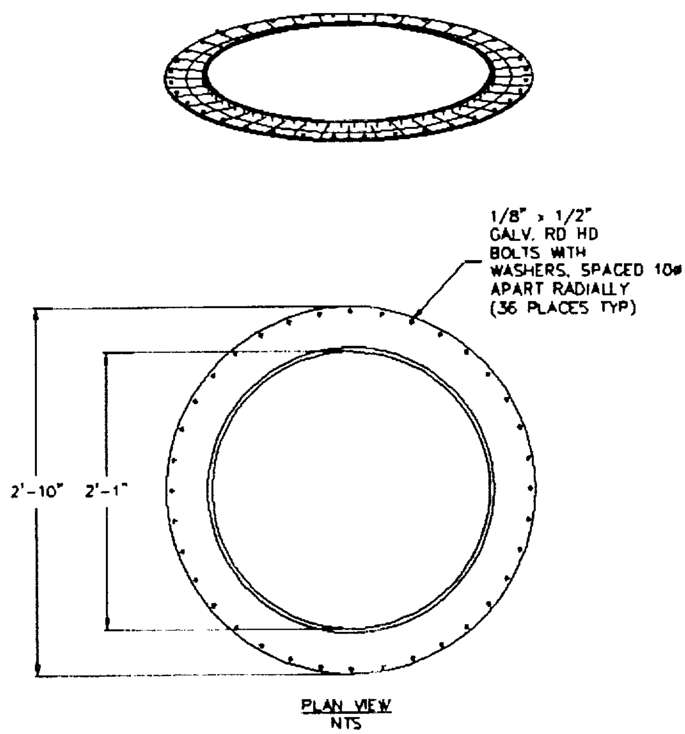


Figure 20.4.1.1 Heat Shield Shroud

20.5 DATA ACQUISITION SYSTEM

The data acquisition system consists of three subsystems:

1) accelerometer signal generators
2) data transfer cross link
3) data interpolation and display system

Accelerometers consist of three elements: the transducer body, the sensing element, and the seismic mass. The sensing element is pre-loaded between the transducer body and the seismic mass by a pre-loading element. Because of the constant seismic mass, the force acting on the measuring element is proportional to the acceleration of the accelerometer.[50] An electrical charge is generated proportional to the impulse force and hence the acceleration. Accelerometers with their inherent characteristics of low mass, high rigidity, and subsequent high resonant frequency are ideally suited for application to the SCRAM model. Accelerometers were used in 1990-1991 on the ACM configuration scale model.

The accelerometers are mounted in the model with respect to three perpendicular axes (see Appendix H for the specific axes orientation). Access to the accelerometers is gained through the crew compartment lid. These accelerometers are used to monitor the vehicle's dynamic motion in a simulated ocean environment (pitch, heave, and yaw). The data transfer cross link provides the means by which the accelerometer signal is transferred and amplified to the data interpretation and recording device. The data transfer cross link consists of electrical cables to connect the accelerometers and a signal amplifier. The data interpolating and recording subsystem consists of a device which displays and records the signals generated by the accelerometers.

Chapter 21.0 OBSERVATIONS AND RECOMMENDATIONS

During Fall semester extensive effort was devoted to the design of the SCRAM model. Some of this knowledge can be applied to the full scale prototype. The specific areas of concern addressed here are:

1) the need for hard point reinforcement.

2) the heat shield shroud may preclude the advantages afforded by the SCRAM design in a water environment.

3) inherent weakness in using a suspended heat shield design.

4) crew extraction in a water environment.

There is concern that the hard points on the SCRAM model will require extensive reinforcement similar to the wood blocks used on last years UCF ACM model. This may prove unnecessary and the weight used in this reinforcement could be more effectively used in the center of gravity and mass moment system. A controlled experiment will be performed to quantitatively determine the amount of reinforcement necessary. Based on this experiment the model will be reinforced as needed.

A heat shield shroud is intended to provided a safer atmosphere for crew rescue operations. The heat shield shroud prevents flooding of the void between the heat shield and the crew compartment lowering the center of buoyancy. This provides additional buoyancy which raises the craft. While making the rescue operation easier and safer, a heat shield shroud ruins the intended effect of dynamic damping in water. The JSC patent application is specific in the motivation for the use of the SCRAM design because of its inherent flotation characteristics due to the suspended heat shield design. The effect of "dynamic damping" is a very attractive characteristic with crew members on board for an extended amount of time in water.

A solution on the full scale SCRAM would be to incorporate a heat shield shroud that has provisions for ballasting and de-ballasting the void between the crew compartment and the heat shield. This could be accomplished with a valve and stored energy system that functions similar to a submarines ballast system. When the SCRAM lands, the valves on the heat shield shroud open to allow flooding of the space between the crew compartment and the heat shield. Prior to SAR operations a stored energy system expels the accumulated water. After the water is blown overboard the valves are shut to maintain the positive ballast. This solution provides the "dynamic damping" envisioned by the JSC design team and also gives a safer environment for SAR and recovery operations.

In considering the SAR operation, there is concern for the safe removal of the crew. Concern for the potential of flooding the craft and extracting the crew from a pitching craft are considered most important. Ideally a helicopter extraction would be performed away from the craft to prevent the crew member from being struck by the craft during assent. This is an unacceptable solution for a deconditioned, injured, or ill crew member. It is recommended the extraction of the crew be accomplished by a hinge hatch at the top edge on the side of the crew compartment. This gives the best configuration to prevent loss of the capsule due to flooding.

BUILDING PHASE

The tools used to schedule the project are; a Work Breakdown Structure (WBS), Logic and Gantt charts. The scheduling tools provided the structure to monitor the progress of the project and assure that it was completed on time. Construction drawings and methods are presented. This section serves as a description of the steps leading to the testing phase.

Chapter 22.0 SCHEDULING

Scheduling techniques used include the WBS, logic, and gantt charts, and provide the means by which the SCRAM group's progress is scheduled and monitored. The functional relationships between the design tasks are delineated in the WBS. The sequence of design tasks and the critical path are represented in the logic charts. The scheduling sequence is given in the gantt charts.

22.1 WORK BREAKDOWN STRUCTURE CHARTS

The construction of the model was divided into its most basic tasks in the Model Fabrication WBS (Figure 22.1.1) with a brief definition of each task in the WBS Dictionary (Appendix J). The first task listed was the information search (1.1) which divided into three sub-tasks. The first sub-task was a document search (1.1.1) for all needed information. The second sub-task (1.1.2) was to write the necessary reports to document the team's progress. Finally, there was a presentation of the team's findings (1.1.3). The second task in the fabrication WBS was to create the final design drawings (1.2). Dimensioned drawings of the SCRAM (1.2.1), mold construction (1.2.2), Adjustable Rotating Weight System (ARWS), (1.2.3), and detail drawings of the various systems (1.2.4) were included. The third sub-task was the acquisition of all necessary components (1.3). Data acquisition instruments (1.3.1) were acquired, materials to fabricate joints, fasteners (1.3.2), LAP's (1.3.3), and the ARWS (1.3.4) were purchased. The final task was the actual model fabrication (1.4). The specific items that were fabricated include the shell (1.4.1), the ARWS (1.4.2) the LAP's (1.4.3), and the joints (1.4.4). The last sub-task was to put all parts together in the final assembly (1.4.5).

A WBS was also made for the testing phase (Figure 22.1.2), and is divided into three tasks. The first of these tasks was to delineate the necessary procedures (2.1) for model testing. The procedures section was divided into determining the model's requirements (2.1.1), writing the procedures to meet these requirements (2.1.2), and the closeout (2.1.3). Pre-testing (2.2) was the next task. A pre-test of the material's strength (2.2.1) was performed before building. After construction, further pre-tests confirmed leak tightness (2.2.3), the ability to float (2.2.4), and the ability of the LAPs to support the model's weight (2.2.7). The center of gravity and mass moment system were also pre-tested to insure accurate modeling of the dynamic constraints (2.2.2). The data acquisition system was pre-

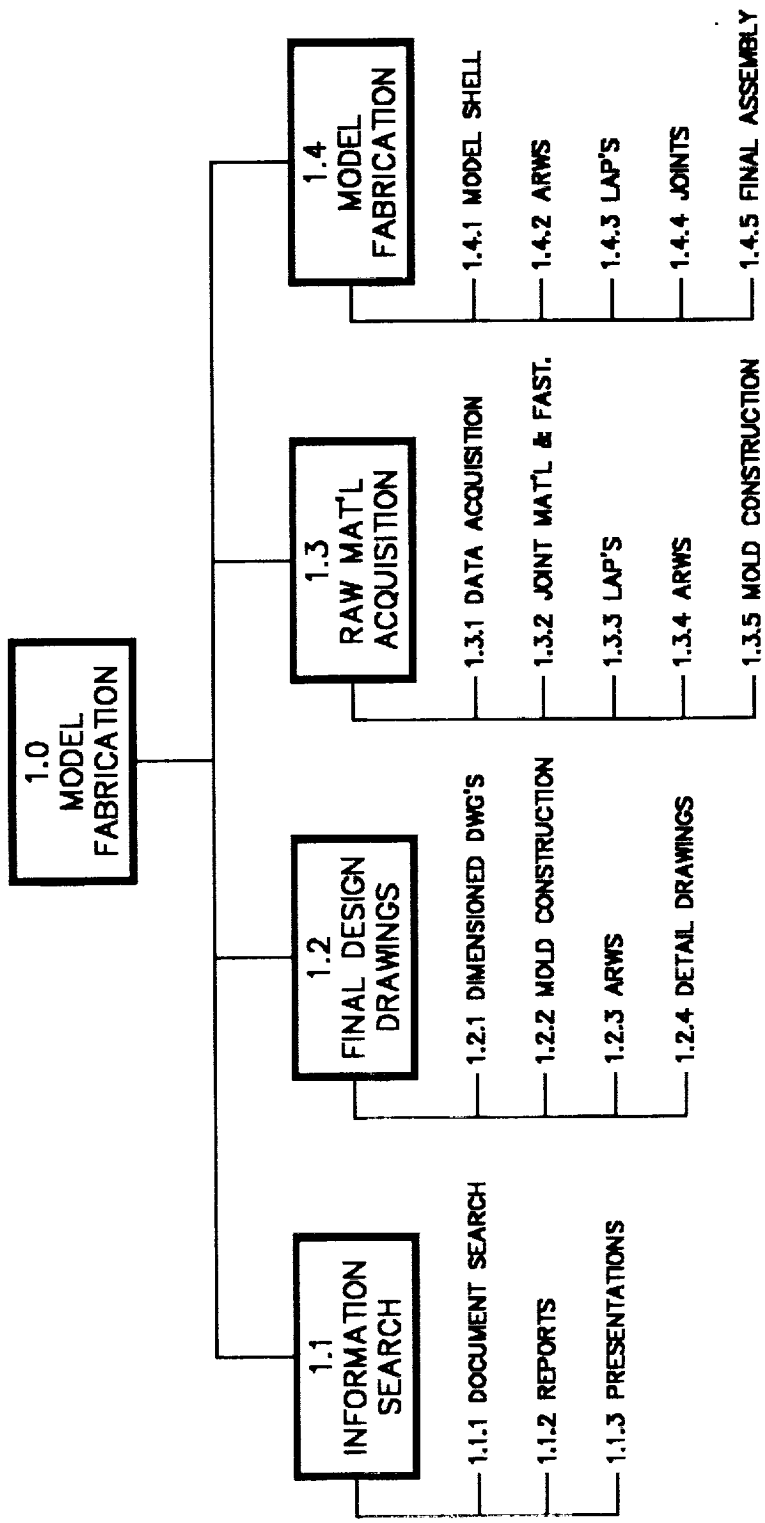


Figure 22.1.1 Model Fabrication WBS

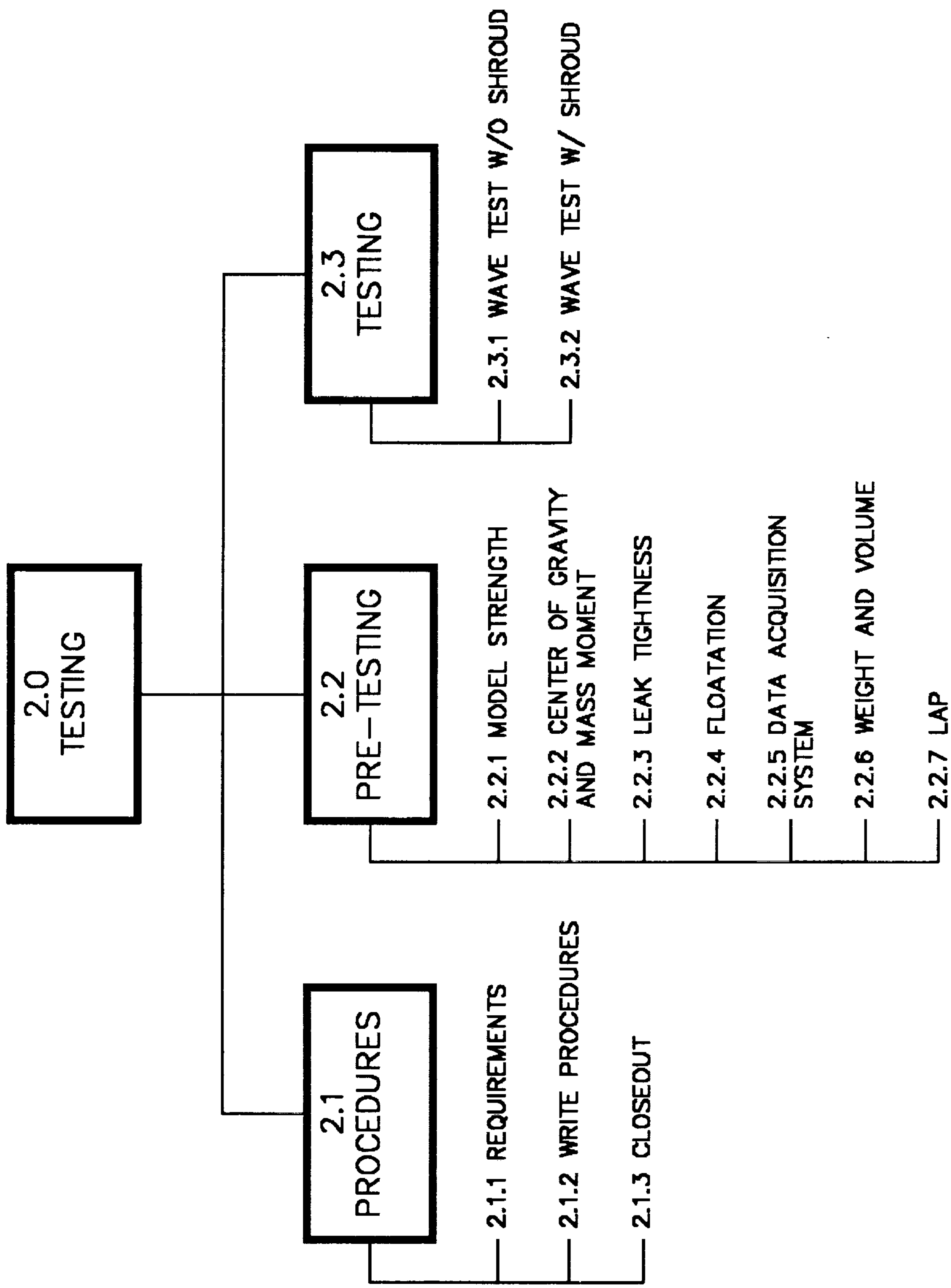


Figure 22.1.2 Testing WBS

tested to verify accurate data measurement (2.2.5). Finally, the weight and volume were measured for correct geometric scaling (2.2.6). The final task was the testing of the finished model (2.3). This task was divided into two sub-tasks: lifting and wave tests without the shroud (2.3.1) and lifting and wave tests with the shroud (2.3.2).

22.2 LOGIC CHARTS

While a WBS is convenient for determining and listing the necessary tasks involved, it does not provide for a sequence of events. The logic chart shows an orderly flow of sub-tasks and the dates in which they should be performed. On each chart the critical path is denoted by bold lines. The critical path is the sequence of events which requires the most time. The master logic chart lists all the necessary sub-tasks for the entire project (Figure 22.2.1). Since this chart is rather cumbersome, it is broken down into a fabrication logic chart and a testing logic chart.

The first task in the Model Fabrication Logic Chart was the document search (1.1.1) (Figure 22.2.2). Next, all necessary drawings were created (1.2.1 through 1.2.4). Actual material acquisition began before the drawings were fully complete and continued into the beginning of the fabrication. The acquisition dates are given on the logic charts (Figure 22.2.2, steps 1.3.1 through 1.3.5).

Early phases of the shell and ARWS construction began at the end of January (1.4.1 and 1.4.2). The shell construction is on the critical path because it involved lengthy work with an outside company and several different phases of construction. Building for the other subsystems began in early March (1.4.3 and 1.4.4). Construction of all of the subsystems was completed by the end of March and the final assembly was completed on March 28, 1992 (1.4.5).

The testing was performed according to the testing logic chart (Figure 22.2.3). The first tasks completed were the determination of the requirements (2.1.1) and writing the test procedures (2.1.2).

The first pre-tests to be done on the model were the material strength tests (2.2.1), however, these tests were not completed due to reasons stated in the pre-testing results section. After construction, the model was checked to assure durability during handling, and transport. After the strength tests were completed, the model was tested for geometric similarity (2.2.6). Next, the model's leak tightness (2.2.3) and ability to float (2.2.4) were tested. The LAP subsystem was tested for its ability to support the weight of the model (2.2.7), and the ARWS was tested for its adjustability, stability, and accuracy (2.2.2). The last pre-test confirmed data acquisition system operation (2.2.5). After the pre-tests were completed the model was ready for the wave tests. The first wave tests were performed with the heat shield shroud off (2.3.1). Later, wave tests were performed with the shroud on (2.3.2). The final phase, was the closeout (2.1.3) in which the test data was evaluated.

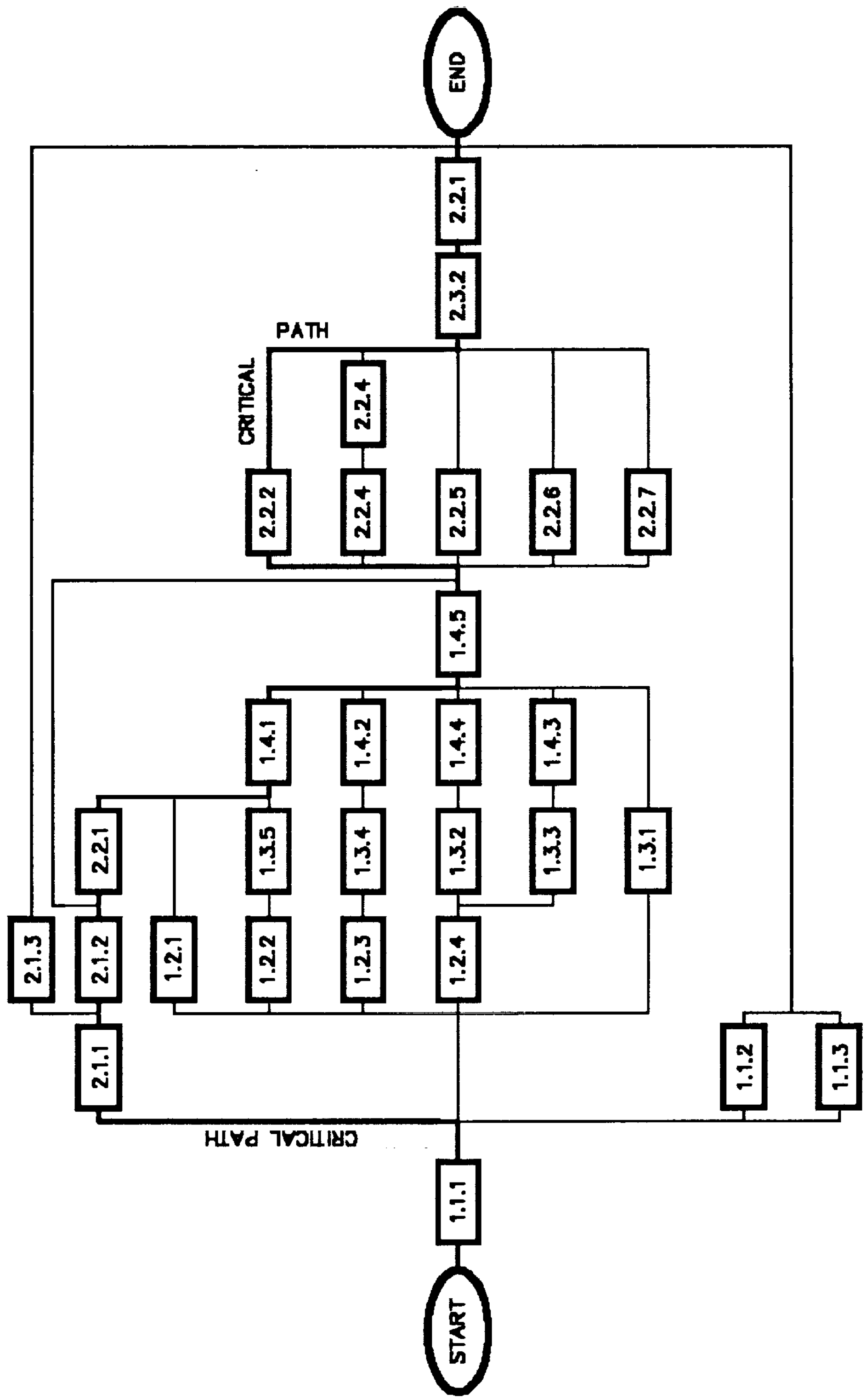


Figure 22.2.1 Master Logic Chart

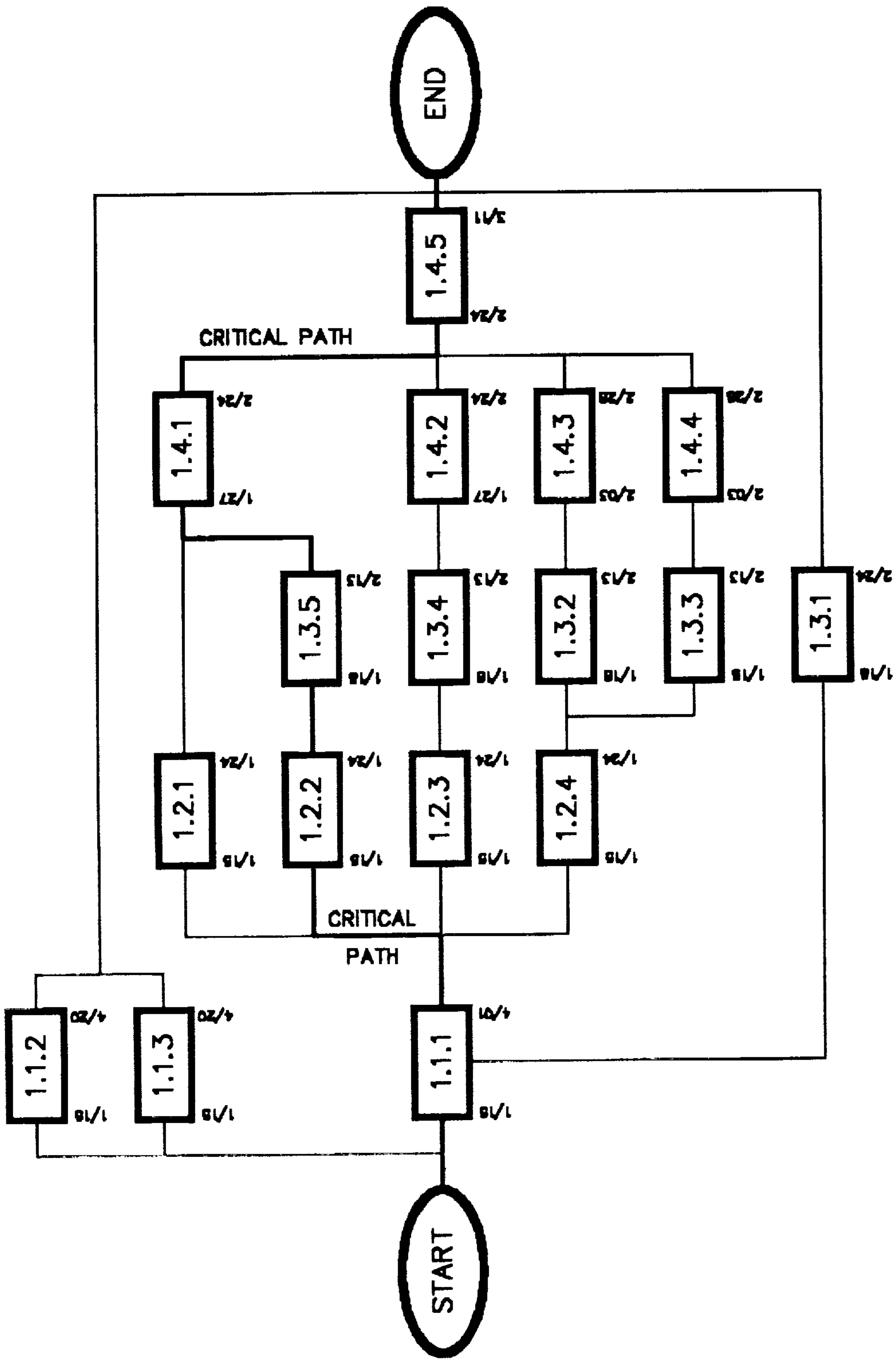


Figure 22.2.2 Model Fabrication Logic Chart

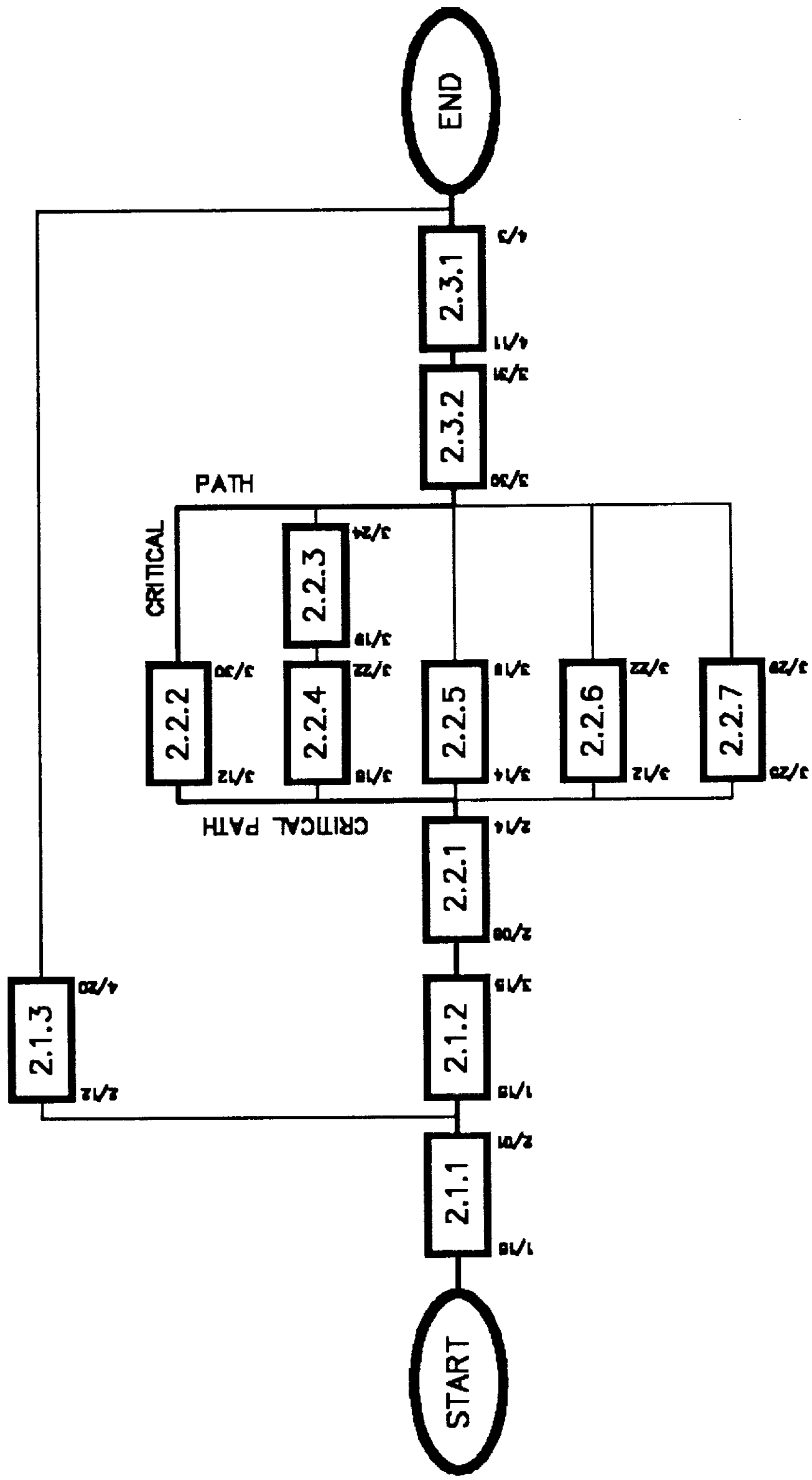


Figure 22.2.3 Testing Logic Chart

22.3 GANTT CHARTS

An overall graphical view of all scheduling deadlines is given in the Master Gantt chart (Figure 22.3.1). It is accompanied by a legend of major milestones (Table 1). The Master Gantt chart is divided into a Fabrication Gantt chart (Figure 22.3.2) and a Testing Gantt chart (Figure 22.3.3).

22.4 SCHEDULING SUMMARY

Scheduling enabled the construction and testing of the one-fifth scale SCRAM model in a timely manner. Three tools were employed for this task. The first was the Work Breakdown Structure which divided the projects into several tasks and sub-tasks. Each of these sub-tasks were put in sequential order and given a start and end date on the logic charts. Finally, gantt charts were made from the logic charts to present a clear, concise work schedule to track work progress and insure completion by the testing deadline. This section marks the path the design team took to complete the building and testing of the model ACRV/SCRAM configuration.

Chapter 23.0 CONSTRUCTION

Described in this chapter are the methods of construction used to assemble the SCRAM model. The model was constructed in three major assemblies: the crew compartment, the heat shield and the Adjustable Rotating Weight System (ARWS).

23.1 CREW COMPARTMENT CONSTRUCTION

The crew compartment is the largest section of the SCRAM/ACRV model. Its shape is a short cylinder with a conical bottom. The crew compartment was constructed by Guard Lee Model Building Company in three sub assemblies: the lid, the conical bottom section, and the cylindrical main body.

23.1.1 Crew Compartment Lid

The lid of the crew compartment (Figure 23.1.1.1) is a fiberglass "sandwich." It is constructed by laying up glass fiber sheets into a plywood mold shaped to the desired configuration. First, the mold was waxed to prevent sticking during curing. The bottom of the mold was then coated with a thin layer of polyester resin mixture. The resin consists of a base polymer and its hardener. This made the sandwich a hard durable matrix. The next step was to apply the first layer of fiberglass. Resin was added to the fiberglass to begin the foundation of the matrix. The procedure was repeated for each successive layer.

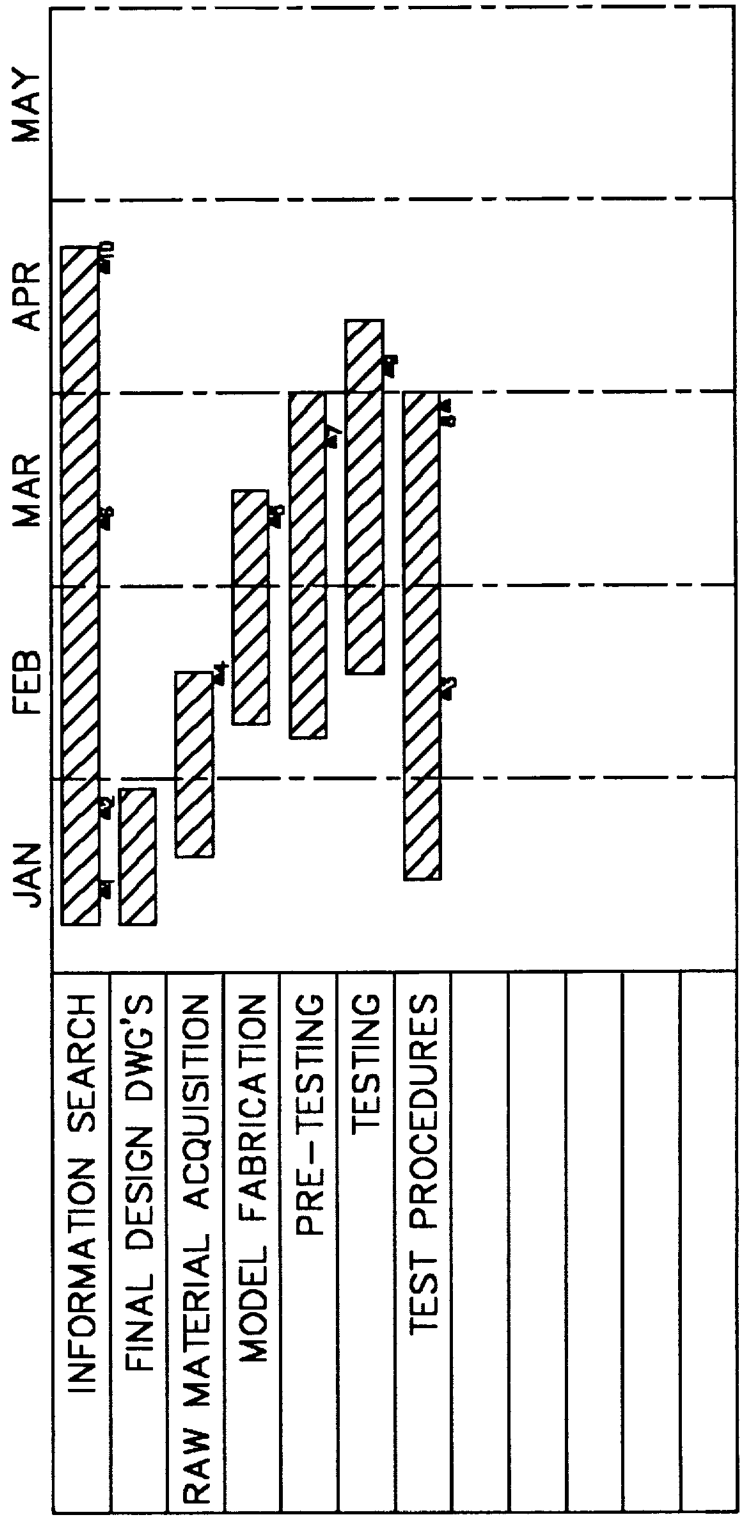


Figure 22.3.1 Master Gantt Chart

	TASK	DEADLINE
1	Work Breakdown Structure	01/15/92
2	Info Search Completed	01/25/92
3	Strength of Materials Test	02/14/92
4	Material Acquisition	02/24/92
5	Completed Model	03/11/92
6	Midterm	03/18/92
7	Pretest	03/24/92
8	Final Pretest	03/30/92
9	Final Test	04/03/92
10	Final	04/20/92

Table 1 Deadline Dates

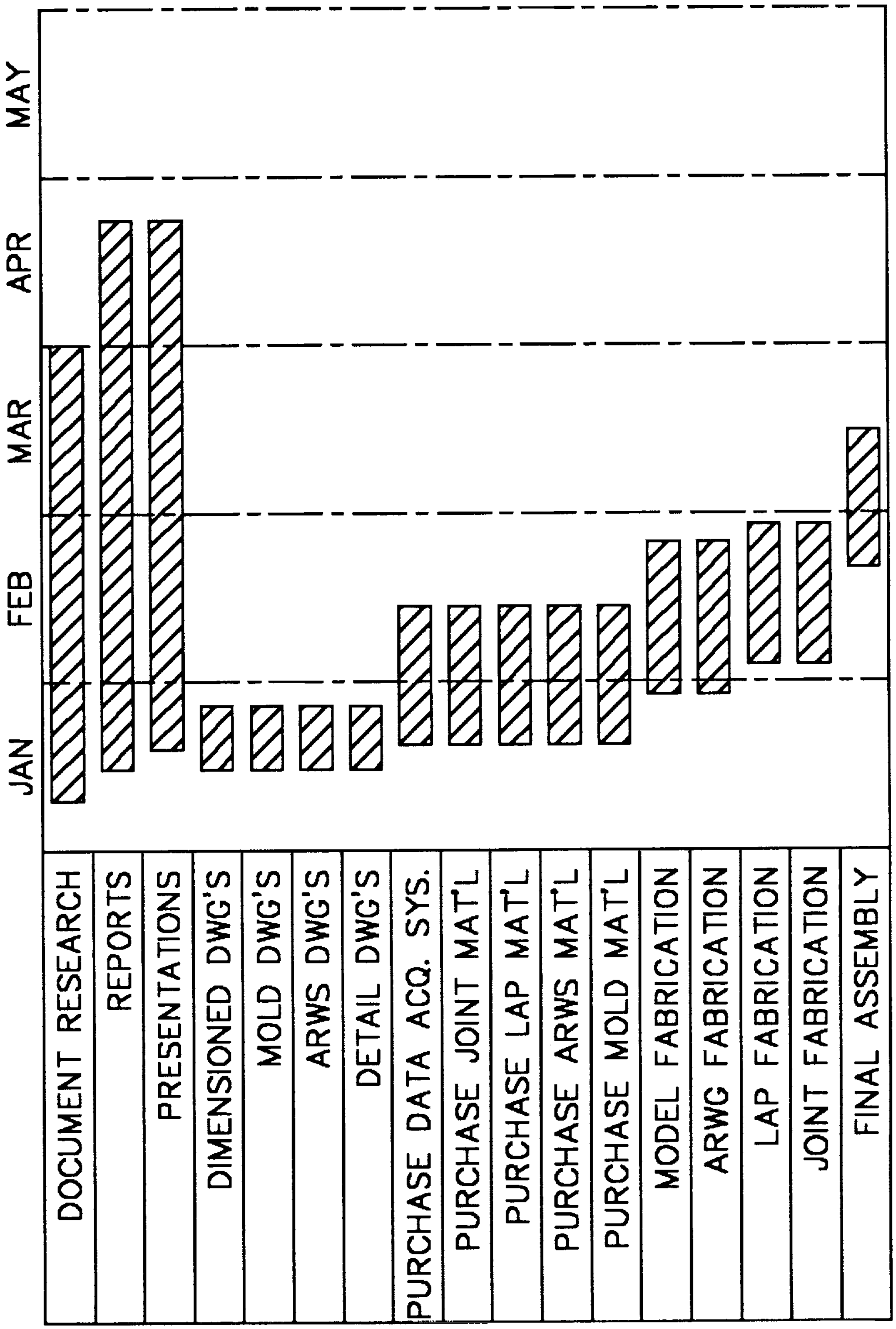


Figure 22.3.2 Model Fabrication Gantt Chart

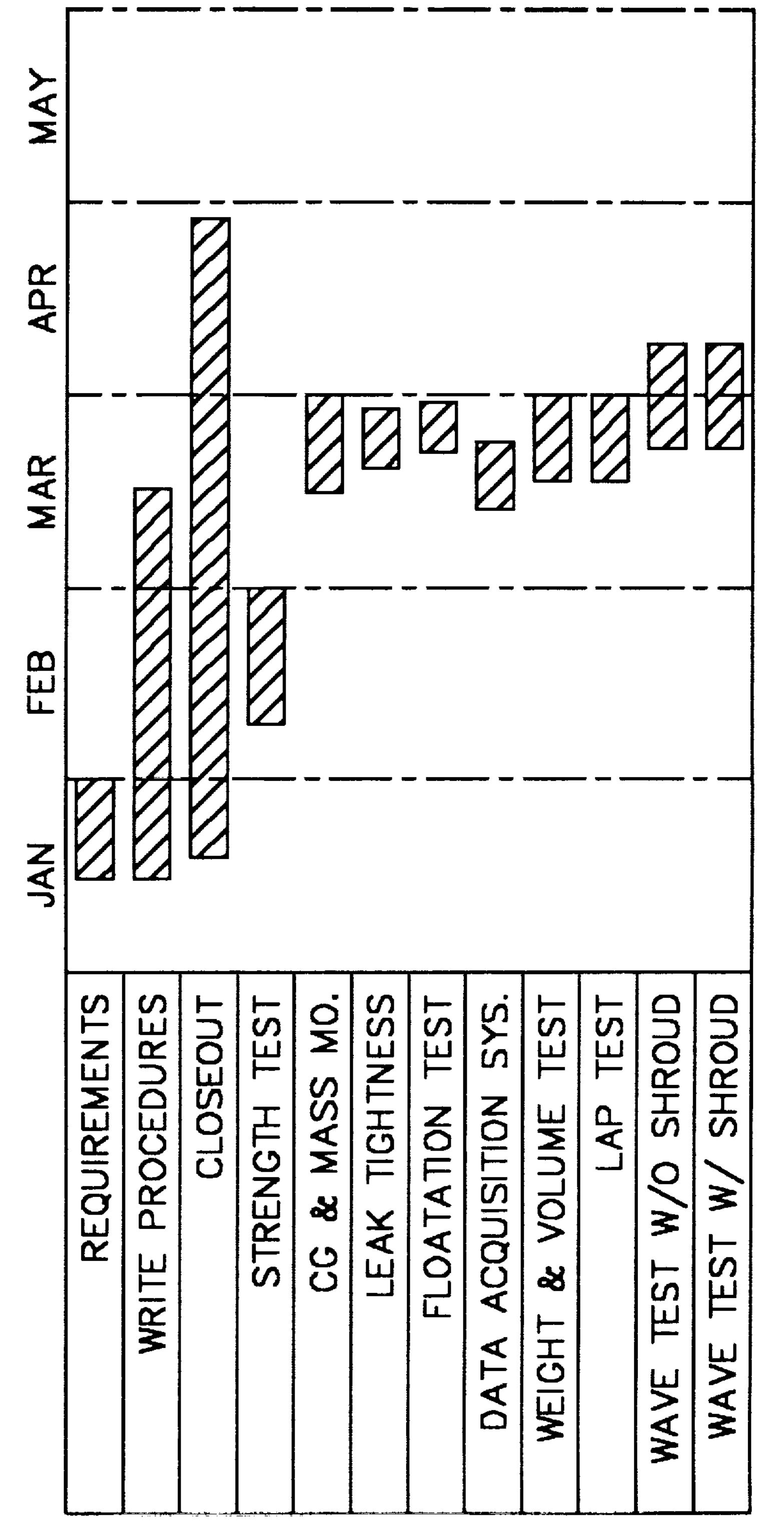


Figure 22.3.3 Testing Gantt Chart

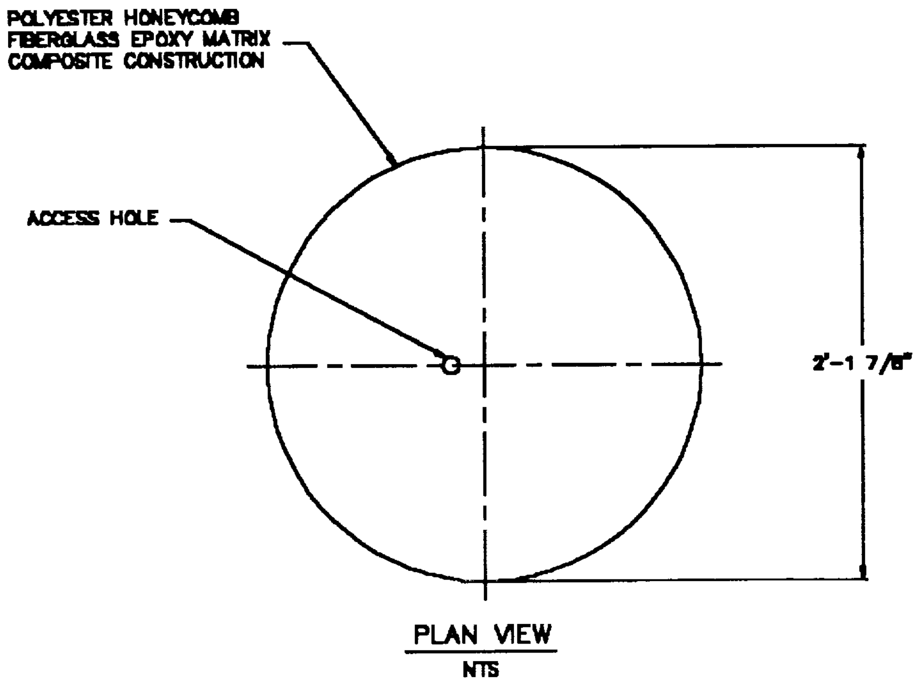


Figure 23.1.1.1 Crew Compartment Lid Dimensions

The first four layers are of 1 1/2 ounce fiberglass matte made of chopped glass fiber. The fifth layer is a 3/8 inch honeycombed polypropylene material that adds both strength and resiliency to the lid. Next, there is another layer of 1 1/2 ounce matte. The final layer of the lid is 6 ounce fiberglass cloth, which is used to create a region of high strength and form a smooth surface. After smoothing the top ply, the top of the form was placed on the matrix formed above. Weight was put on the top and the entire assembly was allowed to harden overnight. The final step in this sub-assembly's construction was to prepare the surface for painting. Guard Lee applied primer paint and the SCRAM group applied the topcoat paint.

23.1.2 Lift Attachment Points

Attached to the crew compartment lid is the Lift Attachment Point sub-assembly. The purpose of this subsystem is to assure safe retrieval of the SCRAM model. The sub-assembly (Figure 23.1.2.1) was constructed of 3 pieces of 1 1/4 inch angle iron 6 inches long placed 90 degrees apart on center. Multiple holes drilled into the upper portion of the angle iron allow for different angles in the lift attachment lines.

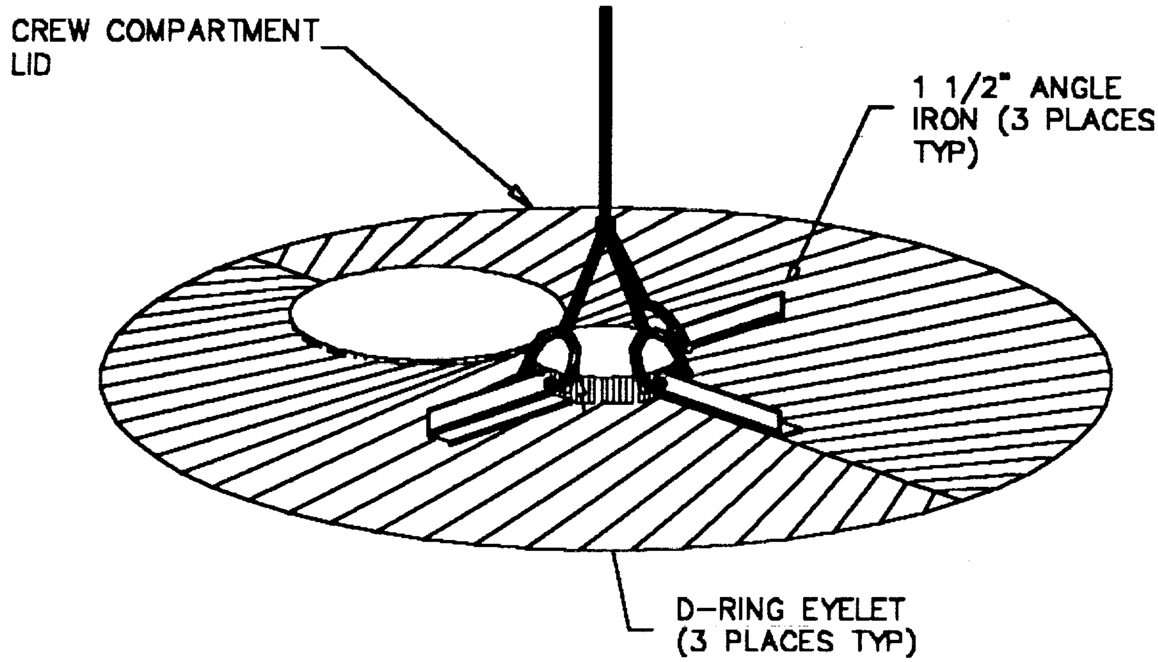


Figure 23.1.2.1 Lift Attachment Point Construction

The attachment was accomplished with three D-rings attached to the holes in the angle iron. The D-rings were also attached to the ends of three cables which are clamped together at one central cable. This central cable was then attached to the lifting apparatus. The angle iron was attached to the lid of the crew compartment by bolts running through holes drilled in the lid and the angle iron. Locking washers were used to avoid crack propagation from the bolt holes.

23.1.3 Lid Attachment

The lid was fastened to the top of the crew compartment by eight 2 inch long 1/4 inch bolts. Bolt holes are positioned at regular intervals one inch from the outside edge of the crew compartment lid. Threaded inserts, which match the thread pattern of the bolts, are positioned in the upper lip. The lid was attached by aligning the lid bolt holes above the insert holes and tightening the two inch bolts.

23.1.4 Crew Compartment Bottom

The crew compartment bottom (Figure 23.1.4.1) was made of fiberglass. The first step in construction was to make a template of the profile of the model's exterior. This template, was made of sheet aluminum welded to a small section of tubing that projects 1/2 inch past the bottom edge of the template. Next a wooden mold frame was constructed to hold the mold for this section. When the mold frame was completed, plaster was added to the frame. The projecting tube of the form was placed in the center of the plaster and the form was rotated. This generated the hollow conical profile of the section to be made. When the surface of the plaster was smooth, the template and rod were removed and the plaster was allowed to dry overnight.

After the mold was fully dry it was waxed and the fiberglass sandwich was formed as in the lid procedure. Unlike the lid procedure, however, the mold was not weighted. The crew compartment bottom is constructed of four layers of 1 1/2 ounce matte and the polyester resin that is required to bind it. Its final thickness is approximately 1/8 inch. The final step in this construction was once again to prepare its surface and paint it as above.

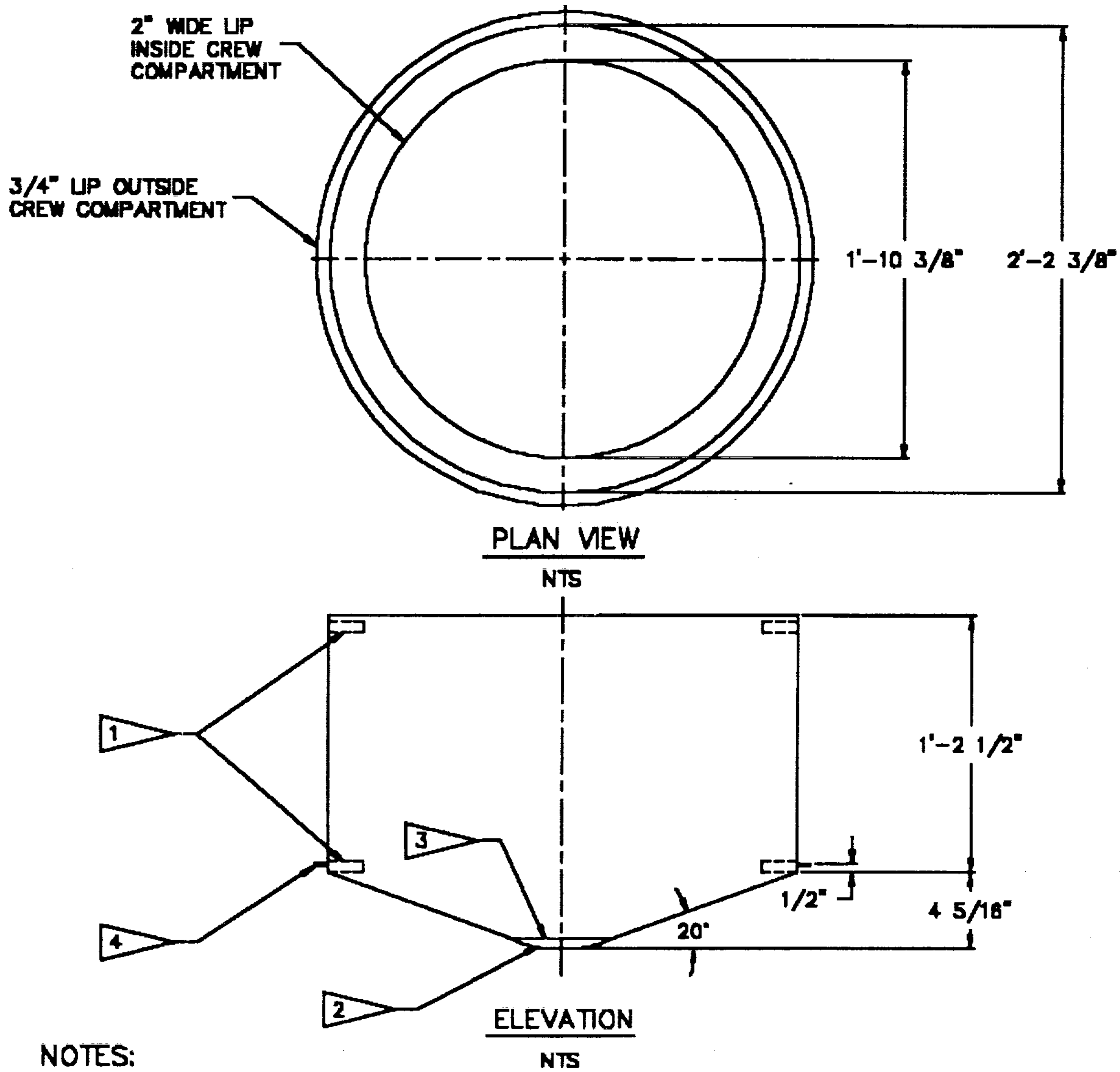
23.1.5 Crew Compartment Body

The next step in construction was the fabrication of the crew compartment body. The crew compartment body has the shape of a hollow cylinder. It has a large lip for the lid mounting on top and a small lip on its bottom for assembly with the crew compartment bottom.

First a plug was assembled having the exterior characteristics of the body. From this plug the mold for the body was made of plaster. To prevent shrinkage and cracking of the mold during drying, it was formed in sections. After the two molds are dry, the fiberglass was formed as above. These sections are constructed of four sheets of 1 1/2 ounce matte and the necessary polyester resin-and hardener-mixture. After these sections hardened, they were taken off their molds and assembled with a few small sections of glass matte and polyester mixture onto two 1/2 inch thick plywood rings (Figure 23.1.4.1). This section was then bonded to the crew compartment bottom by clamping together the lips of each section and adding polyester mixture to bond them. The final step was surface preparation and painting.

23.2 HEAT SHIELD CONSTRUCTION

The next portion of the SCRAM model constructed was the heat shield (Figure 23.2.1), and heat shield shroud. This assembly is a detachable part of the model. The shield's shape is a hollow conical section, with a small lip on its upper edge. The shroud is a flat washer-shaped ring.



NOTES:

1. 2" WIDE LIP MADE OUT OF 1/2" PLYWOOD. FIBERGLASS INTO CREW COMPARTMENT AS SHOWN. (2 TYP)
2. BOTTOM OF CREW COMPARTMENT SHALL BE ROUNDED TO 7 3/4" DIA.
3. 6" DIA. FIBERGLASS FLAT PLATFORM. LOCATED AT BOTTOM OF CREW COMPARTMENT.
4. 3/4" LIP AROUND OUTSIDE OF CREW COMPARTMENT. FIBERGLASS THICKNESS SHALL BE 1/8".

Figure 23.1.4.1 Crew Compartment Dimensions

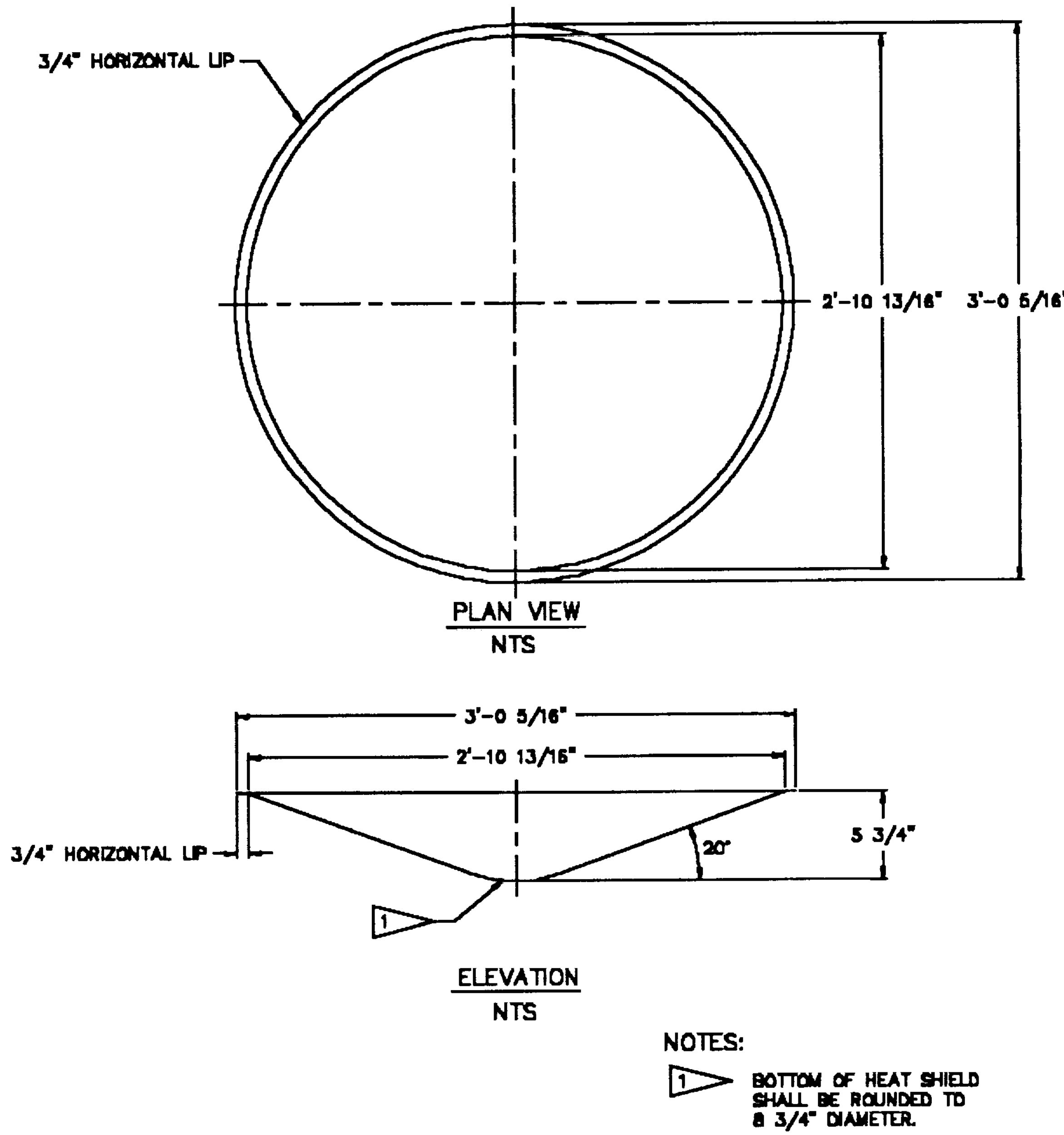


Figure 23.2.1 Heat Shield Dimensions

23.2.1 Heat Shield

The heat shield was constructed similarly to the crew compartment bottom. A template was formed and a mold was constructed. The sandwich of the shield is three layers of 1 1/2 ounce fiberglass matte and one layer of 6 ounce fiberglass cloth. Its outer surface was finished, primed, and painted.

23.2.2 Heat Shield Shroud

The heat shield shroud (Figure 23.2.2.1) was cut from 1/8 inch sheet aluminum. The shroud was cut with a sabre saw to an outside diameter 36 5/16 inch and an inner diameter of 26 5/8 inch. It is placed over the top edge of the heat shield to extend to the lip on the outside of the crew compartment body.

23.2.3 Heat Shield and Shroud Fastening

The heat shield is fastened to the crew compartment body by four symmetrical joints. Each joint (Figure 23.2.3.1) consists of a piece of 1 1/4 x 1/8 x 6 inch aluminum flat stock, six 1/4 x 3/4 inch round head bolts, twelve locking washers, and six nuts. Once the model sub-assemblies were finished, the attachment joints were constructed. The model sub-assemblies were aligned in their proper place and hole locations were marked. Next the holes were drilled as marked. The final step was to assemble and tighten the fastening joints.

The shroud was attached to the lip of the heat shield and the lip at the bottom of the crew compartment's cylindrical section. Bolt holes were drilled through the shroud and the lips. Eighteen 1/8 inch bolts were inserted and tightened. This assembly is removable.

23.3 ARWS CONSTRUCTION

The ARWS sub-system (Figure 23.3.1) allows the adjustment of the total weight, center of gravity, and mass moment of inertia in the model. The ARWS is mounted on a 4 x 4 inch wood block which has a 1 x 1 x 1 3/4 inch deep hole in the center of its top face. This block is fiberglassed to the bottom center of the crew compartment. A 3/4 inch threaded spindle holds the ARWS in place.

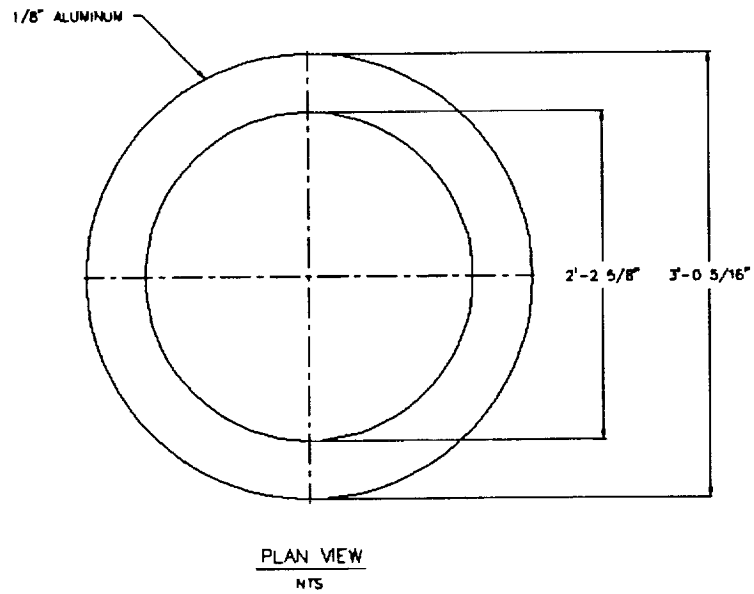


Figure 23.2.2.1 Heat Shield Shroud Dimensions

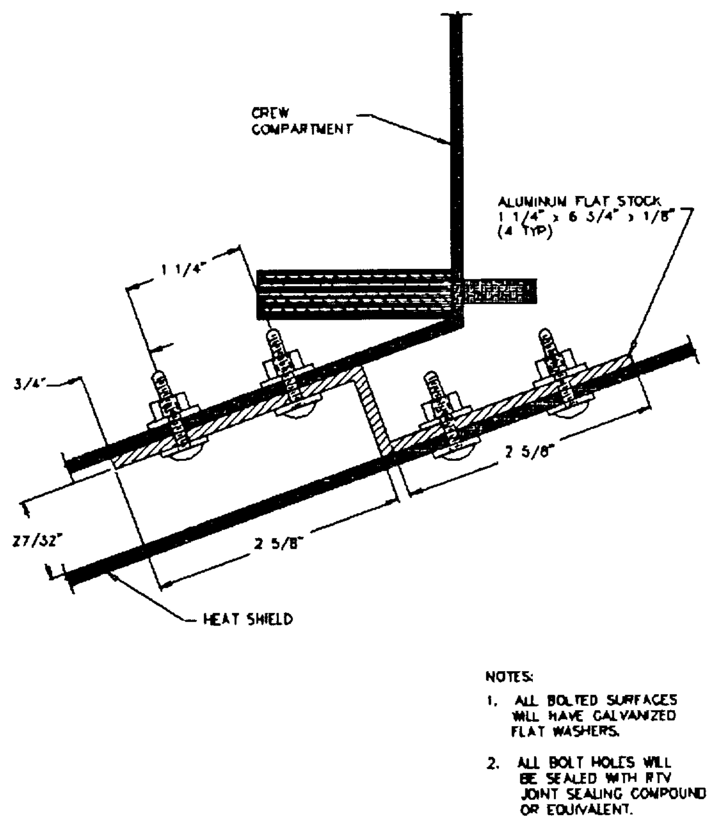


Figure 23.2.3.1 Crew Compartment Heat Shield Joint

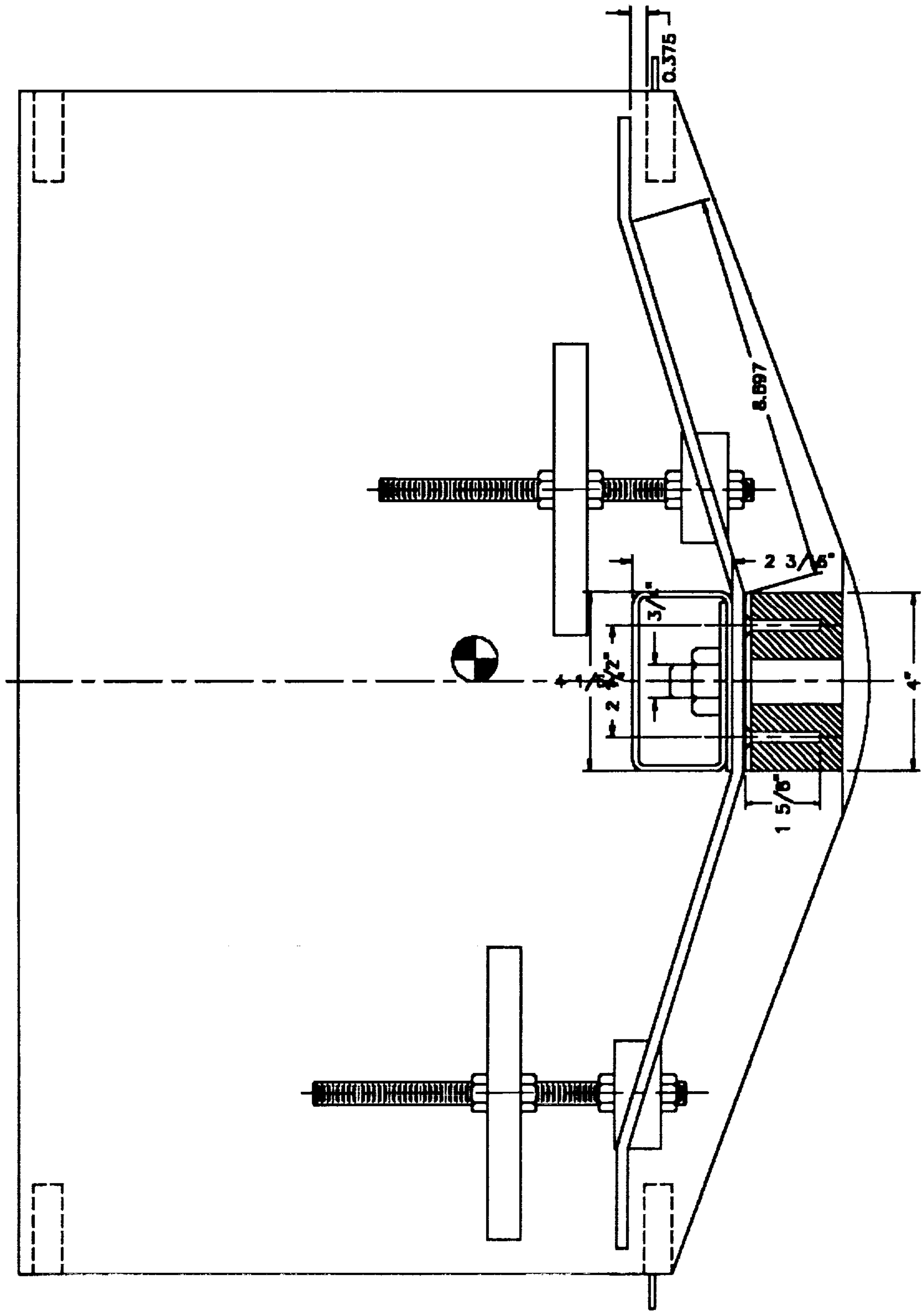


Figure 23.3.1 Adjustable Rotating Weight System

23.3.1 ARWS Sub-Components

The blades of the ARWS are formed with a 1/4 x 2 x 24 inch piece of aluminum flat stock. The flat stock was bent on each side 2 inches from the center to 18.43 degrees upward and 10.7 inches from the center 18.43 degrees downward. Next, 1/2 inch slots were machined into the 10.7 inch blade sections, and a 3/4 inch hole was drilled through the center of the bar. Four wedge-shaped compression blocks were cut out of 3/4 inch aluminum sheet metal (Figure 23.3.1.1). The wedges are 2 inches wide, 2 1/4 inches long, and 3/4 inch high. They were formed by cutting a 2 1/4 inch piece from 2 inch x 3/4 inch flat stock aluminum, and then cutting across opposite edges of the piece perpendicular to the 2 inch side. A 1/2 inch hole was drilled through the center of each wedge.

The spindle was formed by turning a 1 x 1 x 5 inch square aluminum rod on a lathe to round it from the top to 1 3/4 inches from the bottom. The 3/4 inch diameter rounded portion was then threaded. The bottom section was left square.

The next pieces fabricated were the two risers upon which the weights are placed (Figure 23.3.1.1). These risers were made of 1/2 inch threaded aluminum rod. They were completed by cutting rod stock into 8 1/4 inch pieces, and de-burring the cut ends with steel wool.

The final part of the ARWS is the spindle retention plate. This plate is a 4 x 4 inch piece of 1/8 inch aluminum sheet metal. After cutting this piece, a 3/4 inch hole was drilled in its center. It was then lined up on top of the wood block fiberglassed into the crew compartment bottom. One quarter inch holes were drilled for wood screws.

23.3.2 ARWS Assembly and Installation

ARWS assembly was started by placing the spindle in the block hole and securing the retention plate with the wood screws. Next, the blade was placed on the spindle through its center hole. A washer and nut and were then threaded on the spindle and tightened.

The final step was to assemble the weight risers. First, one nut was threaded on an end of each riser. Next, a wedge was placed on each riser by putting a riser through the wedge's center hole. The risers were then put through the slots in the blade, and a second wedge was placed on the riser. A nut was threaded down and tightened on the top wedge. A support nut was threaded down on the spindle to hold the weight in place. The weight desired was added and a nut was threaded and tightened on top of the weight.

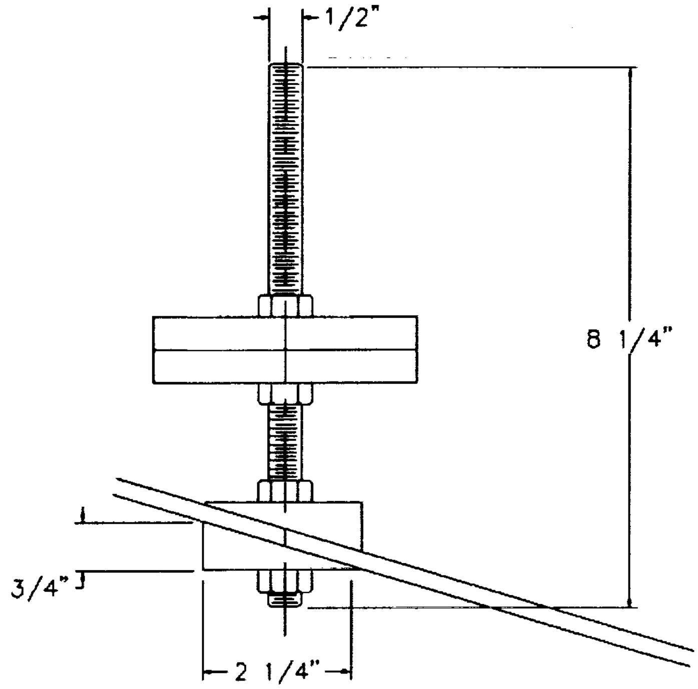


Figure 23.3.1.1 Wedge and Riser Detail

23.4 FINAL MODEL CONFIGURATION

After the ARWS sub-system was assembled and installed, the model was configured to its final state (Figure 23.4.1). The crew compartment was assembled to the heat shield and the heat shield joints tightened. The shroud was installed. The ARWS sub-system was assembled, installed, and clamped to the lower lip on the inside of crew compartment. The lid was installed and tightened.

The ARWS subsystem provides the capacity to reconfigure the model in different combinations of total weight, center of gravity, and moment of inertia. The model can also be tested with and without the heat shield shroud. This ability allows the evaluation of the dynamic damping effect of the original design concept. In the final analysis of this construction effort, the SCRAM/ACRV model fulfills the intent set forth in the original design by meeting the geometric constraints and providing for a versatile test article.

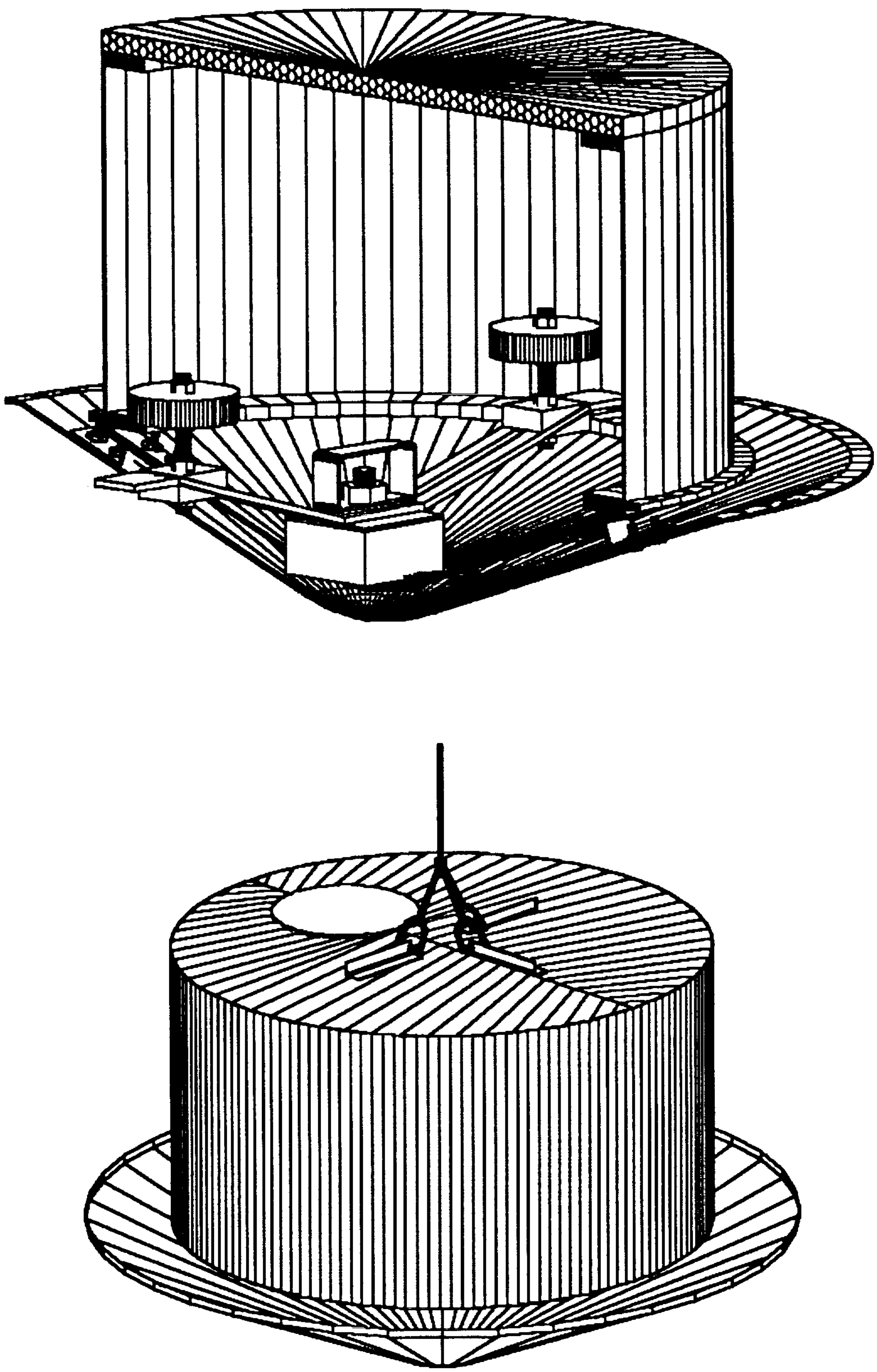


Figure 23.4.1 SCRAM 1/5 Scale Model

TESTING PHASE

Chapter 24.0 TEST PLAN

When the fabrication of the model was complete, it was evaluated to determine the scaled characteristics of the basic design. The evaluation was conducted in three phases:

1) Phase I (Pre Testing) - Pre testing consisted of tests that demonstrate the model met specifications outlined in UCF-SPEC-391. Each pre-test was conducted in of the engineering building at UCF.

2) Phase II (Static Testing) - Static testing consisted of a static water leak tests and initial evaluation of all subsystems. The water test was conducted at a local pool and all other static tests were conducted at UCF.

3) Phase III - Dynamic testing was done to evaluate the model's flotation characteristics and various methods of recovery. The dynamic testing was conducted at the OTRC facilities at Texas A & M University.

24.1 FACILITIES DESCRIPTION

PHASE I: Pretesting and Evaluation

Location: CEBA 1, Room 370
University of Central Florida
Orlando, FL

Senior Engineering Tech.: Greg Bealer

PHASE II: Static Water Evaluation

Location: CEBA 1, Room 168
University of Central Florida
Orlando, FL

Senior Engineering Tech.: Greg Bealer

Equipment and uses:

1. 4 x 12 x 2.5 feet deep water trough

2. Data collection devices
   - Oscilloscope
   - Strain gage instrument

3. Data collection
   - Accelerometer
   - Strain Gauge

PHASE III: Dynamic Wave Evaluation

Location: Offshore Technology Research Center (OTRC, Figure 24.1.1)
Texas A&M University
College Station, TX

Facility Manager: Pete Johnson

Equipment and uses:

1. Overhead crane - 5 ton capacity

2. Crane operators

3. Computer controlled (GEDAP™ software) wave generator

4. Tank 150 x 100 x 19 feet deep
   - Deep pit 30 x 15 x 55 feet
   - Motorized Instrumentation Platform

5. Data collection (Figure 24.1.2)
   - Optical tracker
   - Accelerometer
   - Inclinometer
   - Feedback Transducer
   - Run-up Wave Probes

6. Data analysis
   - VaxStation 3500™ CPU
   - NEFF System 620™
   (Analog to Digital Conversion)

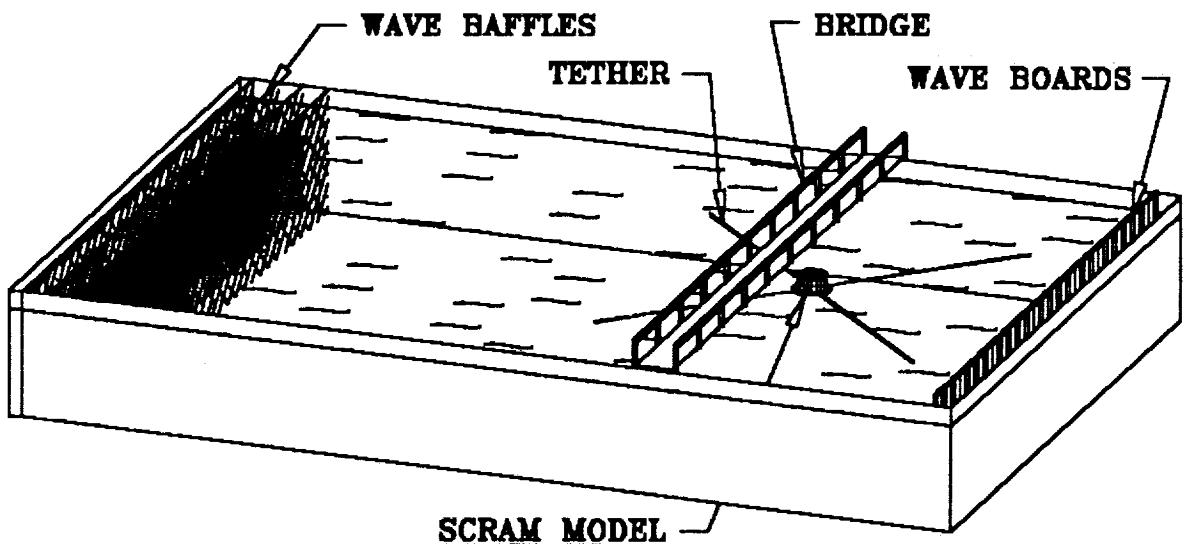


Figure 24.1.1 Offshore Technology Research Center, Texas A & M University

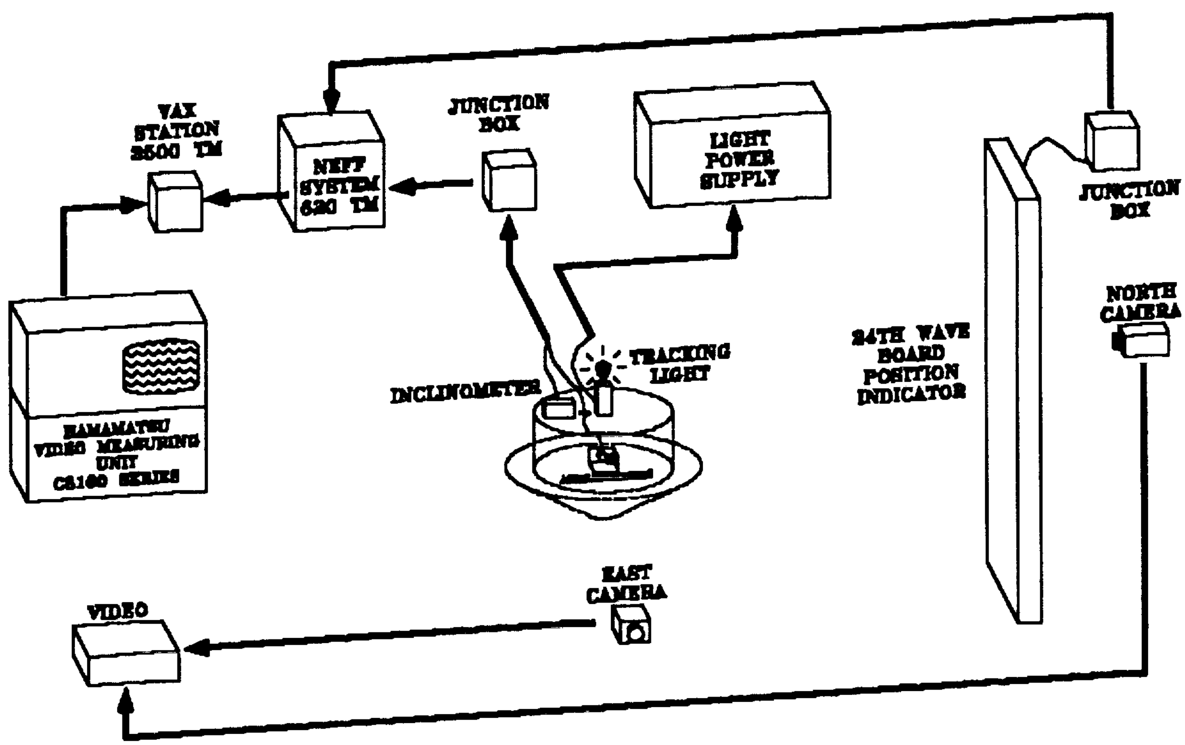


Figure 24.1.2 Data Acquisition System Flow Diagram

- Analog filtered at 5 Hz
- Digital sampling on each channel at 20 Hz
- HAMAMATSU C3160™ (Video Measuring Unit)

24.2 ENGINEERING PRE-TEST PLAN

This series of pre-tests was to confirm the SCRAM model meets the specifications required in UCF-SPEC-391 (Appendix I). These specifications were met prior to dynamic water testing at the OTRC facility. Four essential areas for pre-testing were: geometric similitude, ease of transportation, CG and mass moment of inertia adjustability, and the rapid and accurate positioning of the ARWS. The satisfactory performance of the model in these proof tests established the model meeting the intent of the design. Each pre-test included a test objective, materials list, procedure, and the specifications.

24.2.1 Engineering Pre-Test Goals

1. Confirmation of the model shell dimensions against specifications.
2. Confirmation that the model can be readily transported.
3. Confirmation of the CG and mass moment of inertia required by specification.
4. Confirmation of rapid configuration changes in the ARWS.

24.3 ENGINEERING STATIC TEST PLAN

The static portion of the SCRAM/ACRV test plan was designed to determine the basic flotation characteristics (leak tightness and static draft) and to establish a base line for wave testing at OTRC. This section contains three areas of pre-testing. These areas are: static flotation, static draft, and the LAP subsystem.

The leak tightness test was designed to insure the effects of leakage are negligible. The leak test and the static draft measurement were performed at the same time. The static draft was measured and recorded during the 30 minute duration of the leak tightness test.

A failure of the system at the OTRC facility would have limited testing of the model. Therefore, the system was tested at the maximum design weight (1.4 safety factor included) prior to dynamic testing. Additionally, a "jerk" test was conducted to verify the system's ability to withstand a drop distance equal to the maximum wave height.

24.3.1 Engineering Static Test Goals

1. To determine the static flotation characteristics of the model.
2. To demonstrate the soundness of the LAP subsystem.

24.4 ENGINEERING DYNAMIC TEST PLAN

This phase of testing was designed to investigate the dynamic flotation characteristics of the SCRAM/ACRV. The response of the full scale SCRAM/ACRV design in an oceanic environment was simulated by subjecting the model to controlled scaled wave shapes. The dynamic response of the model is assumed to be analogous to the wave response experienced by the full scale SCRAM/ACRV.

A benefit of the ACRV/SCRAM design is dynamic damping. When the weight of water in the heat shield interacts with the motion of the heat shield, dynamic damping occurs. A result of the flooded heat shield is a craft which sits low in the water. To evaluate the dynamic damping effect, the model was tested with and without the shroud. One benefit of the shrouded condition is that the model sat higher in the water.

Another aim of this phase was to determine the best method of recovering a waterborne SCRAM/ACRV with a LAP subsystem similar to the ACM. These tests varied conditions (i.e. heat shield shroud, CG, and relative length of sling cables) to determine the best method of craft recovery.

24.4.1 Engineering Dynamic Test Goals

1. Evaluate the one-fifth scale SCRAM/ACRV model flotation characteristics in a simulated oceanic environment.
2. Identify the dynamic responses for different CG's at different wave configurations.
3. Evaluate different methods of model lifting and recovery in a dynamic wave environment.

24.4.2 Dynamic Testing Variations

The dynamic testing of the one-fifth SCRAM/ACRV model involved a number of changes to its configuration and to the wave environment. Configuration parameters were established and sea state conditions were set during development of the model and the JSC full scale mockup conditions. Since all possible combinations of critical parameters could not be evaluated, only extreme combinations were employed. This is a "bracketed" method of evaluation. The parameters evaluated were: weight, CG, open/closed heat shield, and sea state. The "normal" CG was found for the empty model, and is reported in section 25.1 (Pretesting Results).

1. Two weight configurations were evaluated:

   a. Mid weight (76 pounds)
      - corresponding to the maximum mockup weight of 9500 pounds

   b. High weight (120 pounds)
      - corresponding to the maximum design weight of 15000 lbs

2. Two vertical CG locations were evaluated:
   - High (1.2 inches above the normal CG)
   - Low (1.2 inches below the normal CG)

3. Two offset CG locations were evaluated:
   - Small (1.2 inches from the axis away from the hatch - aft)
   - Large (1.2 inches from the axis toward the hatch - forward)

4. Three wave states were evaluated:
   - Intermediate (0.52 foot height, 1.252 second period, regular wave shape)
     - corresponds to the maximum JSC mockup wave condition (wave test identifier - RG2)

   - Sea State 4 (1.2 foot height, 2.22 second period, regular wave shape)
     - corresponds to the Sea State 4 wave condition
     (wave test identifier - RG1)

   - Intermediate random (0.334 foot average wave height, 1.118 second average significant period, random wave shape)
     - corresponds to the maximum JSC mockup random wave condition
     (wave test identifier - RN)

A testing matrix (Appendix K) is used to show the tests completed.

Terms used in the testing matrix and in the subsequent analysis are explained as follows:

1. Each identifier is explained in Appendix L.

2. The hatch of the model is considered the bow and stern is 180 degrees from the hatch.
3. Static angle is the model's steady state flotation angle.

Chapter 25.0 PRESENTATION OF TEST RESULTS

The testing was conducted in accordance with the test plan. The results are divided as follows: pre-testing, static testing, and dynamic testing at the OTRC facilities.

25.1 PRE-TESTING RESULTS

1. The model met its geometrical constraints. The diameter of the heat shield is 2 feet 10 13/16 inches. The height of the model is 1 foot 7 15/16 inches.

2. The model assembly and disassembly times are 12 minutes and 15 minutes respectively and the model can be readily transported.

3. The model's "normal" CG was determined. The CG is .15 inches forward of the vertical axis of symmetry, and 6 inches above the bottom of the heat shield.

4. The required CG offsets were determined to be 1.2 inches measured perpendicular to the axis of symmetry. The large horizontal offset is 1.2 inches toward the hatch, and the small horizontal offset is 1.2 inches away from the hatch. The two vertical offsets are 1.2 inches above and below the normal model CG.

25.2 STATIC TESTING RESULTS

1. The model (no heat shield shroud and 120 pound) floated with no crew compartment leakage. The draft for this configuration is seven inches.

2. The model (heat shield shroud installed and 120 pound) floated with no heat shield leakage. The draft for this configuration is 6 1/4 inches.

3. The model, with its total weight at 208 pound, was suspended for two minutes. An investigation of the lid and the crew compartment showed no signs of cracking.

4. The model, with its total weight at 120 pound, was supported on its LAP's by cables. It was then lifted to and dropped from a height of 16 inches. An investigation of the lid, showed no signs of failure.

25.3 DYNAMIC TESTING RESULTS

A significant amount of data was collected at the OTRC facility on the pitch, heave, surge, yaw, and lift forces of the model and is available upon request. The data obtained will require extensive analysis to fully describe the flotation characteristics of the model, however, some insight to the behavior of this design is given.

25.3.1 Natural Frequency without Shroud (Test Runs 1-5)

In calm water, the front end of the SCRAM was manually pushed down and the model was allowed to freely pitch This was repeated three times to obtain the pitch natural frequency. The heave natural frequency tests were performed by manually pushing the model straight down and recording its free oscillations up and down. All of these tests were performed both with and without the mooring lines attached. The model's oscillations were strongly damped. A contributing factor may be the motion of water through the space between the heat shield and the crew compartment. The surge natural frequency tests were preformed by attaching the mooring lines and displacing the model from its steady state position and recording its movements.

25.3.2 Natural Frequency with Shroud (Test Runs 29-33)

The shrouded natural frequency tests were performed the same as the unshrouded natural frequency tests. The test showed the shrouded model is also a highly damped system in heave and pitch. When the model was manually excited it returned to static draft quickly, but not as quickly as the unshrouded model. This effect was evident in both heave and pitch.

25.3.3 Natural Frequency Determination

To confirm the assumption that the model's frequency under dynamic wave conditions closely approximates its natural frequency, the damping coefficient must be examined. By performing the derivation described in Appendix M, an expression relating the damping coefficient to the natural angular frequency, period, and successive wave amplitudes is obtained. If the damping coefficients for both the pitch and heave are less than 0.2, the model's frequency is approximately equal to its natural forced frequency. Using the data obtained from the natural frequency tests, values for the damping coefficient are determined as:

$$\xi_{Heave} \approx 0.0651$$

$$\xi_{Pitch} \approx 0.1244$$

Since these values are less than .2, it can be assumed that the motion of the model closely follows the motion of the incident waves.

25.3.4 Wave Tests without Shroud (Test Runs 6 - 17)

The model showed greater pitch with the CG in the higher position. With the CG toward the waves, that is, the bow facing down into the waves, the model pitched less than with the CG aft.

25.3.5 Wave Tests with Shroud (Test Runs 34 - 45)

The wave conditions were the same in tests with and without the shroud. The model floated higher and at a lower angle of inclination with the shroud on. Only during tests in which the center of gravity faced the waves, did water reach the bottom edge of the hatch. During tests in which the center of gravity was opposite the waves, the water line stayed significantly below the hatch bottom.

25.3.6 Heavy Weight without Shroud (Test Runs 55 - 60)

The model was set to the 120 pounds (15,000 pounds full scale) configuration. The CG was configured for a low vertical offset and a large horizontal offset. The model floated statically with the water line approximately 1/3 up the hatch. As the waves struck the model, the hatch was completely covered with water. If the hatch were opened in this configuration on the full scale model the SCRAM would fill with water.

25.3.7 Yaw Testing (Test Runs 61 - 65)

Yaw testing was completed when the model was configured for the 76 pounds weight, large horizontal offset and small vertical offset. The model was free floating during all yaw tests. The center of gravity (CG) was positioned at the up stream side of the wave direction on the first test run and the model moved in the same direction as the waves. In the second test, the model was positioned with the CG down stream of the waves. As the waves struck the model, it rotated approximately 10 degrees clockwise about the vertical axis. The model then took an approximately 30 degrees lateral movement from the wave direction. The lateral movement of the model was in the opposite direction of the CG. This particular test was run a second time with translational movement to the opposite side. This translational movement was the result of a counter-clockwise rotation about the vertical axis. The model moved laterally opposite to the CG in these two test runs.

25.3.8 LAP Tests

25.3.8.1 Static Lift without Shroud (Test Runs 18 - 28)

During this part of the testing, the model's lifting characteristics in the wave state RG1 were evaluated. To determine the peak stresses during lifting, the model was evaluated while hanging at different heights less than the wave amplitude. Then the model was lifted at four inch increments and tested (until the model was lifted above the wave amplitude).

25.3.8.2 Lift Tests (Test Runs 46 - 54)

These tests were performed both with and without the heat shield shroud attached. The model was first positioned in the wave tank with the lifting hook attached. The model was horizontal as it was lifted out of the water. This test was performed three times. Then two lift cables were lengthened to lift the model at an angle. The block and tackle on the main lifting cable was then lengthened for the final set of tests.

25.3.8.3 LAP Test Analysis

In examination of each of the lift test configurations, angled and level with the heat both shield on and off, the maximum tension value (or tension spike) yielded significant results. Comparison of these values, aids in the determination of the optimal lifting setup.

Looking at the orientation of the model as the first parameter, it can be seen that the lifting of the model at an angle produced the smallest tension spike. When the model was lifted in a level orientation, the lifting cable tensions reached maximum values of 19 kilopounds (kips) shroud on and 22 kips with the shroud off. In contrast, when the model was lifted at an angle, the tension plots shows spikes of 20 and 16 kips with the shroud on and off respectively.

For the next parameter, the presence of the heat shield shroud is considered. By observation, the state in which the heat shield shroud is in place can be perceived as having the smallest tension spike.

Coupling the effects of the tilt angle and the heat shield shroud, the optimal configuration is determined to be lifting the model at an angle without the shroud in place. This setup gave a tension spike of 16 kips while, in contrast, the level orientation without the shroud has a spike of 22 kips.

Chapter 26.0 OBSERVATIONS AND RECOMMENDATIONS

Two semesters have been spent producing a model and testing it in a wave tank to provide insight into the feasibility of the SCRAM configuration for the water landing ACRV. Tests were performed spring semester and results are:

1) Lift attachment point stresses
2) The response of the model to a wave environment and the location of the hatch relative to the water
3) Free yaw response

The stresses experienced by the lift attachment points while the model was being lifted from a wave environment were measured. The crane at the wave facility was unable to lift the model out of the water in only one wave cycle. This meant that several waves hit the vehicle as it was being lifted. Each wave would pick the vehicle up and allow it to drop causing jerk stresses on the LAPs that were over twice the weight of the model. These stresses could be reduced by using a crane which can remove the model rapidly to prevent it being hit by several waves. After being lifted straight up, several tests were performed by picking the model up at an angle. This significantly reduced the jerk stresses on the LAPs. In either case, the LAPs need to be designed to withstand stresses much greater than the weight of the vehicle.

When put in the water at the wave tank, the SCRAM model proved to be very buoyant with only a small fraction of it sitting below the water level. At the 76 pound configuration with the shroud off, the model floated with the water line 1 1/2 inch above the crew compartment lip. The hatch also sits well above the water in a static environment. In the large wave states, the SCRAM "rode" the waves very well and kept nearly the same orientation with the water as in the static state. The smaller waves, however, had a much higher frequency and the model could not react fast enough to stay on top of them. Because it could not follow the water line, water tended to splash up over the sides and the hatch opening. When the CG was in the direction of the hatch, causing the hatch to pitch down, the waves would come up over it and would have filled the crew compartment-sinking the vehicle if the hatch had been open. The hatch remained further from the water line when the CG was located on the opposite side from the hatch, causing it to pitch up. This is the recommended location to keep the hatch dry when it is open.

The yaw tests provided the most unusual results of the wave experiments. When allowed to yaw freely, the 1990-1991 Apollo model would rotate until its CG was pointed downstream of the waves. The SCRAM model, however, did just the opposite; it rotated until the CG was upstream. In addition, when it was oriented in a preferred position the model would translate with the waves much quicker than with the CG pointed downstream. When the CG was offset to one side relative to the waves, it would cause the model to translate in the direction the CG was pointed.

Further free yaw testing, with different CG configurations, is required to evaluate the model's yaw rotation fully. In addition, free yaw tests need to be performed with the shroud on to determine the effect of the heat shield on the SCRAM model.

SECTION IV

EEC CONFIGURATION MODEL

DESIGN PHASE

* HUMAN WEIGHT MODELLING
* MEDICAL EQUIPMENT WEIGHT SYSTEM
* VARIABLE HEIGHT SECTIONS
* SLING AND ATTACHMENT POINTS CONFIGURATION
* FLOTATION
* DATA ACQUISITION
* COVER
* MATERIALS
* SYNOPSIS
* OPTIMAL SOLUTION
* OBSERVATIONS AND RECOMMENDATIONS

BUILDING PHASE

* SCHEDULING
* CONSTRUCTION

TESTING PHASE

* TEST PLAN
* PRESENTATION OF TEST RESULTS
* OBSERVATIONS AND RECOMMENDATIONS

SECTION IV EEC CONFIGURATION MODEL

INTRODUCTION

The current rescue operation uses a helicopter pararescue team. The Emergency Egress Couch (EEC) is extended out the hatch of the ACRV where Pararescue Jumpers (Pjs) attach it to a helicopter hoist. The EEC is then hoisted, retrieved, and secured in the helicopter[51].

The dynamic and geometric characteristics of the EEC that best suit this rescue operation are currently to be determined. The maximum weight and geometric data is known. The EEC can weigh no more than 400 pounds and must not exceed the geometric constraints of 7 × 2 × 1 feet. The requirements of the full scale Emergency Egress Couch Model (EECM) are:

- Variable Weight (300 - 400 lbs)
- Variable Center of Gravity (0 - 2 ft)
- Variable Moment of Inertia
- Variable Flotation Characteristics
- Lift Attachment System[52]

The EECM has the capability of modelling a variety of configurations to meet these requirements. First, it simulates a basic litter and weight of an incapacitated crewmember. The addition of medical equipment to the EEC is simulated by attaching a weight system to the basic litter. Thus, a weighted medical couch model is created. Along with this weight system, additional height is added to produce a full size medical couch model. Finally, a cover and sling attachment system are incorporated to create the complete medical couch model. The current design of the EECM is divided into eight subsystems:

- Human Weight
- Medical Equipment Weight System
- Variable Height Sections
- Sling and Attachment Configuration
- Flotation
- Data Acquisition
- Cover
- Materials

The human weight system models the dynamic characteristics of a person in the EEC. Design concepts investigated include a dummy, a weight system, and the "do nothing" alternative. The medical equipment weight system varies the dynamic characteristics of the EECM. A peg system, a rail system, a worm gear system, a rail and worm gear system, and weight blocks were considered for the medical weight subsystem. The increase the height of the EECM, variable height sections were designed. Concepts include blocks, layers, and inflatable sections. The sling and attachment points system provides connection of the EECM to the helicopter hoist. Methods considered were perimeter and specific area attachment. Hardware considered for this system includes a compression collar, fixed ring and swing-way hook. The flotation subsystem maintains the EECM in an upright position. External floats, internal inflatable floats, solid internal flotation and a mattress are design concepts of this subsystem. Methods of data acquisition are considered. Different cover configurations are discussed. Materials investigated include aluminum, steel, fiberglass, styrofoam, pvc, canvas and wood.

After the model was designed, the project continued with building. Scheduling techniques used to insure the project completed on time include work breakdown structures, logic charts, and Gantt charts. The model was completed in four phases. The basic litters and Lift Attachment Points (LAPs) were constructed in the UCF Engineering R & D Shop. The layers, cover and medical weight system were constructed by the design team. The medical weights were purchased from an outside vendor and the human weight system was acquired from the Navy.

A test plan was written to coordinate data collection for the test report. Testing of the model was completed in three phases. Phase I was performed in the UCF Senior Design Lab and consisted of a series of pre-tests to confirm that the EECM met its specifications. Phase II 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 EECM. Phase III was performed at the UCF pool. This testing phase consisted of flotation tests.

The Design Phase details the design activities leading to the development of the EEC configuration model. Specifications for the model are in appendix N. Descriptions of the design options for each system follows. A more detailed description of the optimized system is presented along with observations and recommendations. The Building Phase details the scheduling procedures used and the construction of the model. Included in the Testing Phase are the test plan, the test results and observations and recommendations.

DESIGN PHASE

Chapter 27.0 HUMAN WEIGHT MODELLING

A weight modelling system to simulate a human body is necessary. This system simulates weight extremes of a fifth percentile female to a ninety-fifth percentile male. The weight, mass moment of inertia, and center of gravity are accurately modelled by this system.

27.1 DUMMY

A dummy simulates the actual dynamic and geometric characteristics of a human body. This dummy can be placed in the basic litter and secured. Using weight distribution data from medical references, the dummy accurately models the desired dynamic characteristics. The geometric characteristics of a human are also modelled by using a dummy.

27.2 WEIGHT SYSTEM

This system models only the dynamic characteristics of the human body. Weight modelling of the injured crewmember involves placing weights within the EECM to simulate a human on the couch. The resultant weight, center of gravity, and mass moment of inertia of a human body are modelled using a simple stack of weights.

There is relatively no manufacturing cost in this system. Weights can easily be added or removed to vary the modelled victim. This system lacks realism in that the weights do not geometrically resemble the human body.

27.3 DO NOTHING

In this system, the human dynamic characteristics are not modelled for testing. No weight is placed in the basic litter. The data collected from EECM during testing can then be corrected.

This system is easy to operate during testing and there is no cost incurred in modeling the human body. Construction is uncomplicated since nothing extra is needed. This system does not accurately model the EEC because the human weight is not considered. The data corrections are tedious and inaccurate. Furthermore, no human factors can be determined during testing. A base line on the basic litter can not be obtained since there is no human modelling. Rescue tests on the empty litter would therefore be worthless.

Chapter 28.0 MEDICAL EQUIPMENT WEIGHT SYSTEM

The weight distribution subsystem models the weight of the EEC and the medical equipment within it. The placement of the equipment and the weight of the EEC effects the dynamic characteristics of the EEC. The best configuration can be determined by changing the dynamic characteristics of the EECM during testing. Changing the center of gravity is accomplished by moving weights in the horizontal direction. The mass moment of inertia is changed by altering the distribution of weights along the horizontal axis. An increase in the total weight of the couch is accomplished by adding more dead weight to the system. Options for the medical weight system include:

- PEG SYSTEM
- WEIGHT BLOCKS
- RAIL SYSTEM
- WORM GEAR
- RAIL AND WORM GEAR

28.1 PEG BOARD

The Peg Board system consists of threaded vertical rods attached to a base plate (Figure 28.1.1). Weights of various amounts are placed onto the peg and then locked down by a nut. The rods are evenly spaced about the plate. These various securing points allow the center of gravity and mass moment of inertia to be changed.

This system has a low manufacturing cost and is simple to operate. Locking the weights in place is easy and reliable using the threaded rods. This method limits the placement of weight to those locations where a rod exists. Calculation of the center of gravity and mass moment of inertia is difficult.

28.2 WEIGHT BLOCKS

An attachment to the basic litter with compartments to store various weight blocks allows the dynamic characteristics of the couch to be changed (Figure 28.2.1) Blocks are constructed of various weights. By using these various weights and leaving selected compartments empty, the center of gravity and mass moment of inertia are altered.

The placement of the weight contains no moving parts. This placement facilitates the construction of the EECM. The cost of such a system is minimal. However,to achieve an accurate and wide range of tests, many blocks must be produced. Calculations of the dynamic characteristics of this system are complicated.

28.3 RAIL SYSTEM

One or more weight platforms on a rail system are used to change the center of gravity and mass moment of inertia. The center of gravity easily changes by moving the

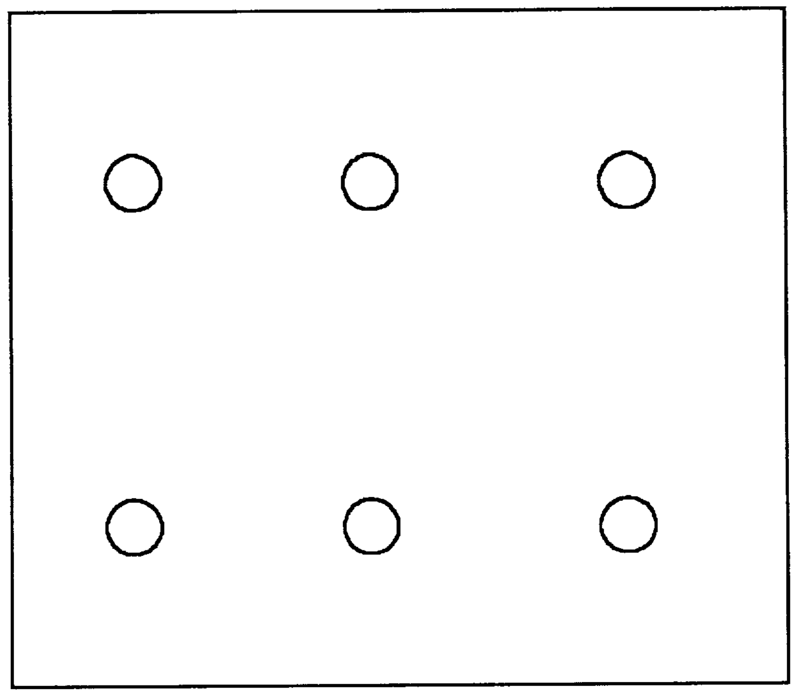


Figure 28.1.1 Peg Board

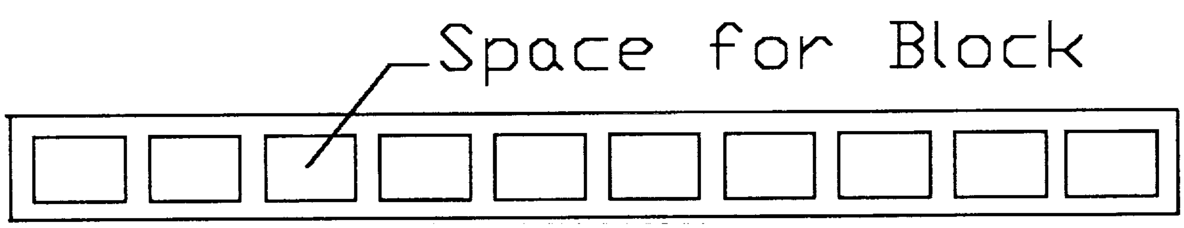


Figure 28.2.1 Weight Blocks

weights along the rails in the desired direction (Figure 28.3.1). Two weight platforms are needed to change the mass moment of inertia. This is accomplished by separating or moving the platforms closer to each other.

Moving the weights in this system is easy, however, locking the weight platforms down is difficult. This system is also expensive and hard to construct.

28.4 WORM GEAR

This system is similar to the rail system, but instead of moving along rails, the weight platform is moved using a worm gear. Turning the worm gear moves the threaded weight platform to the desired position (Figure 28.4.1).

The inherent characteristics of a worm gear creates a locking system allowing easy and precise placement of the weights. However, the worm gear is expensive and hard to construct. Two worm gears are necessary if two platforms are used.

28.5 RAIL AND WORM GEAR

This alternative combines both the rail system and the worm gear. In this combination, the rails allow easy movement while the worm gear is the driver (Figure 28.5.1).

Again, this system has an inherent locking ability. It also incorporates the advantages of the separate systems. This system is costly and difficult to construct.

Chapter 29.0 VARIABLE HEIGHT SECTIONS

The maximum height of the EECM without the cover is established at one foot. It is not known if this height is plausible. For this reason, the EECM must have the capability to vary its height. The minimum height of the EECM is that of a basic litter, approximately six inches. A system is required to change the height, in increments, from this basic litter height to the maximum height of one foot. This system allows for both a maximum height constraint and an optimal EEC height to be determined.

The variable height system attaches to and detaches from the basic litter and weight system as needed. These sections need to be able to lock quickly and safely to the EECM. They must also be capable of supporting the full weight of 600 pounds in both compression (when placed beneath the weight system) and tension (when placed above the weight system).

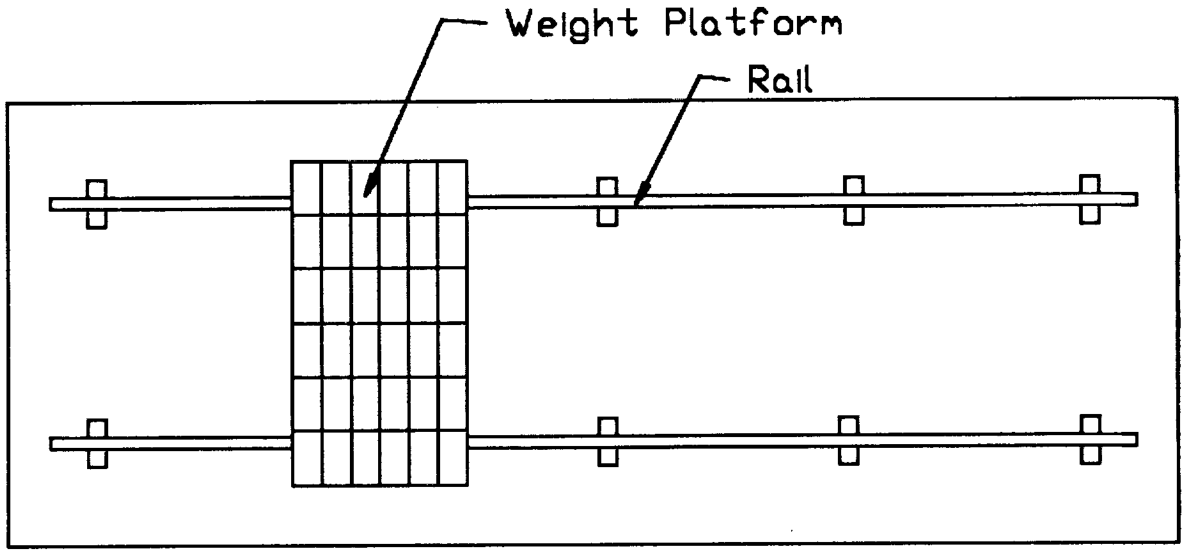


Figure 28.3.1 Rail System

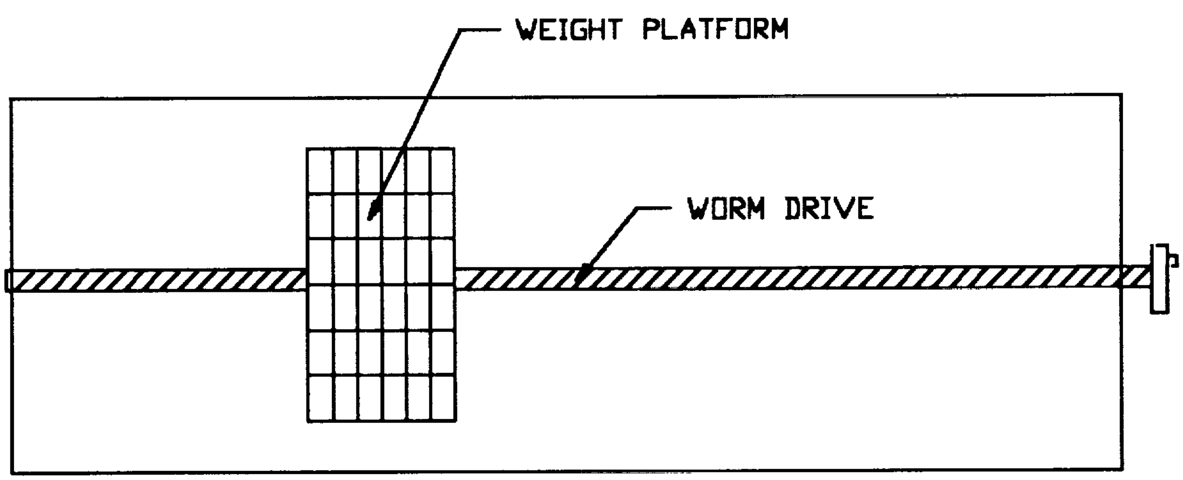


Figure 28.4.1 Worm Gear

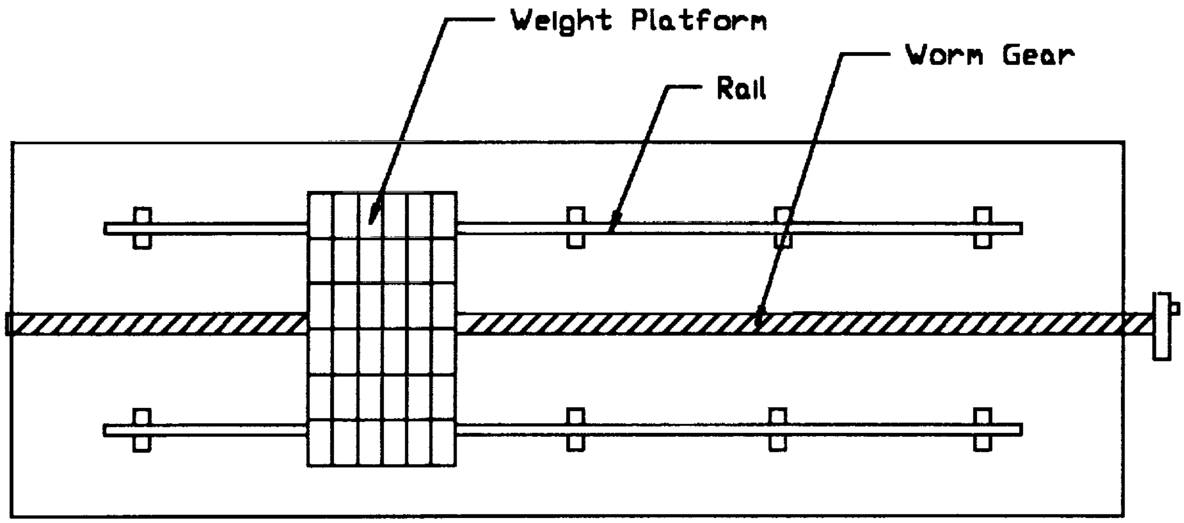


Figure 28.5.1 Rail and Worm Gear

The variable height sections are also used to determine the flotation stability of the EECM. To accomplish this, The height sections are placed at different heights in relation to the weight system providing buoyancy at various height. Thus, the center of gravity is varied in the vertical direction. The variable height subsystem is extremely important to the success of the EECM since it determines the critical dimension of the actual EEC. Options for varying the height include:

- BLOCKS SYSTEM
- LAYERS SYSTEM
- INFLATABLE SECTIONS

29.1 BLOCK SYSTEM

The first design concept of variable height sections is a block system. Blocks of various sizes are combined to produce different heights of the EECM (Figure 29.1.1). By attaching these blocks in various configurations, the geometric and dynamic characteristics of the EECM are changed.

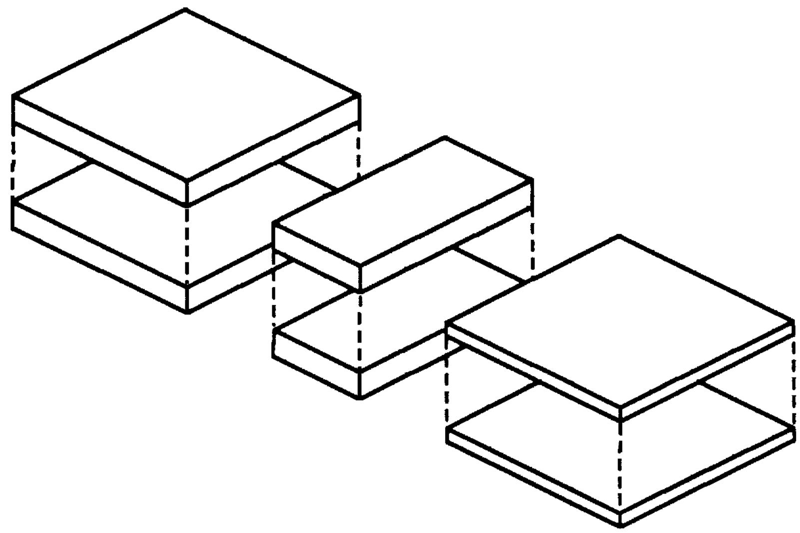


Figure 29.1.1 Block System

The block system is versatile in changing the geometric and dynamic characteristics of the EECM. The weight system is incorporated into the blocks for accurate weight modelling. This system is complex and reconfiguration is time consuming. Manufacturing costs of this system are high.

29.2 LAYERS

The second design concept of variable height sections is layers. Individual layers of dimensions seven feet long by two feet wide are added to increase the height of the EECM (Figure 29.2.1). Layers of various heights are constructed.

These layers are easily and quickly assembled for rapid reconfiguration during testing. This system has few components, therefore, it is not a complicated model. A weight system is incorporated within the layers to simplify the EECM system further. Layers are low in cost and keep the construction of the EECM simple.

29.3 INFLATABLE SIDES

The sides of the EECM are fabricated with a bladder that is filled with air. The bladder is segmented into independent vertical sections which allow various heights to be obtained by inflating the necessary section (Figure 29.3.1). The area in the center is left hollow to allow for the weight system.

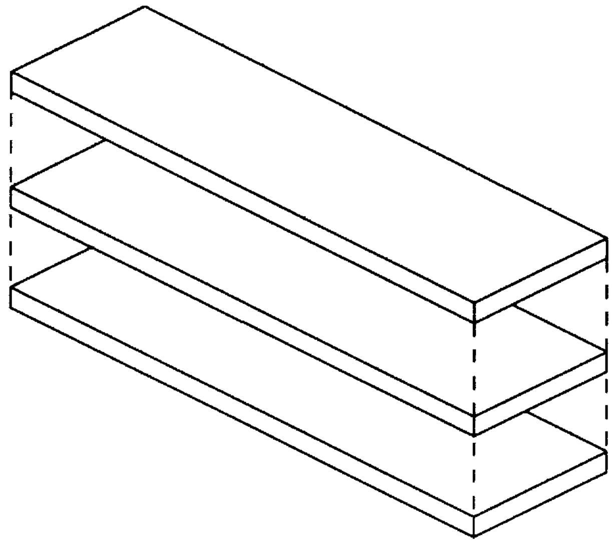


Figure 29.2.1 Layers

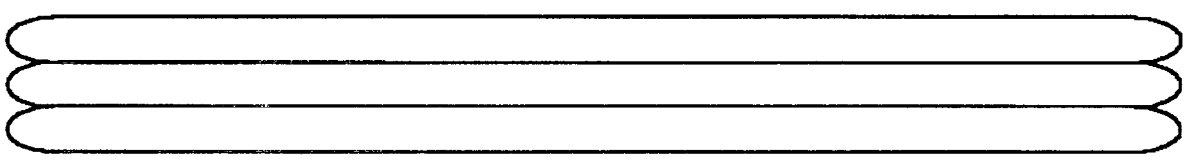


Figure 29.3.1 Inflatable Sides

The bladder of this system aids in the flotation of the EECM. The problem with the bladder is that it lacks the rigidity which is necessary to support the full weight of the EECM. Since the bladder is susceptible to puncture, it does not fulfill the requirement of durability. Manufacturing costs of this system are high.

Chapter 30.0 SLING AND ATTACHMENT POINTS CONFIGURATION

A method of attaching the EECM to the helicopter hoist must be designed. The helicopter hoist consists of a 250 foot steel cable with a D-ring on the end. The sling includes four cables that connect the EECM to the D-ring. The location of the sling attachment points governs the stability of the system. Thus, variable attachment points need to be incorporated within the EECM. Several different methods are considered to accomplish this objective.

- PERIMETER SYSTEM
- SPECIFIC AREAS

- COMPRESSION COLLAR
- FIXED RING
- SWING-WAY HOOK

30.1 ATTACHMENT POINT POSITIONS

30.1.1 Perimeter

Attachment points are placed along the entire perimeter of the EECM. This provides a variety of connection points all around the couch (Figure 30.1.1.1).

A perimeter configuration allows for a maximum number of sling attachments to be tested. While having attachments along the entire perimeter yields the freedom of different test configurations, it is over designed. Equipping the entire couch with attachment points is costly, difficult, and bulky.

30.1.2 Specific Area

Attachment points are confined to only four areas on the couch, two on each side (Figure 30.1.2.1). Having only four attachment areas facilitates the construction of the couch, yet allows for an adequate number of locations to be tested. Sound engineering judgment is needed to determine the necessary areas to be outfitted with attachment points. Cost and construction time are both reduced by only placing the attachment points in specific areas. With fewer attachment points to interfere, the other subsystems are easily incorporated. The couch is simple and safe to handle. Variations of sling configurations are obviously limited to the range of areas selected.

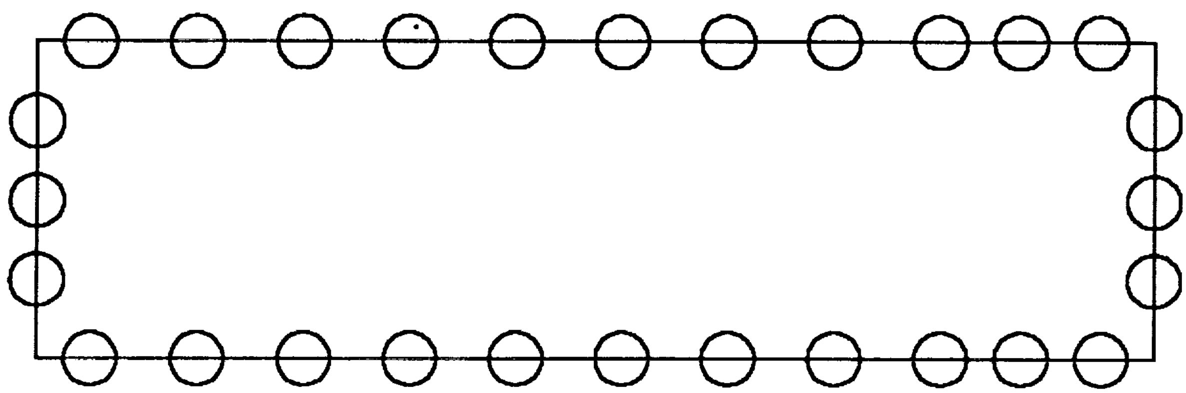


Figure 30.1.1.1 Perimeter

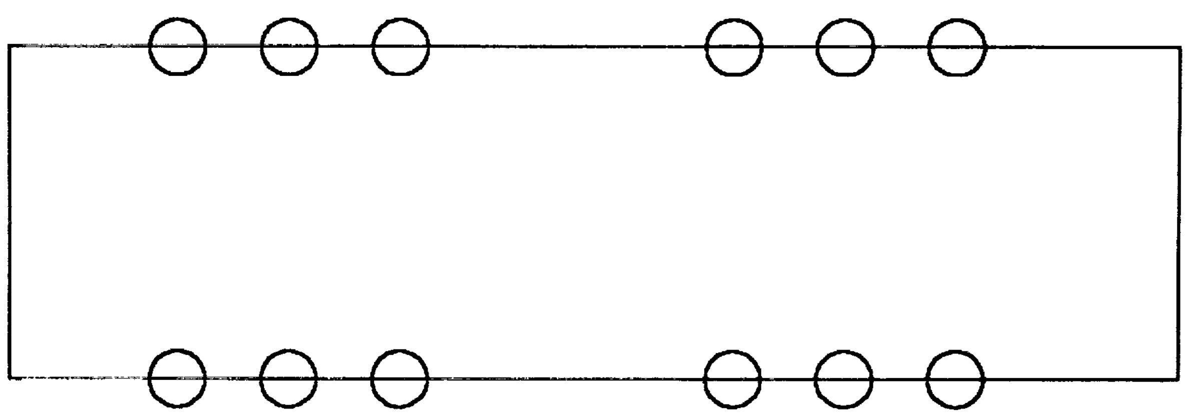


Figure 30.1.2.1 Specific

30.2 SLING ATTACHMENT EQUIPMENT

30.2.1 Compression Collar

The sliding compression collar is a rectangular-shaped clamp that uses pressure to prevent motion (Figure 30.2.1.1). The collar is shaped around the frame of the simple litter and tightened by way of two bolts. A ring attached above the two bolts holds the sling.

This configuration enables flexibility of movement and ease of attaching the sling to the EECM. The system is easily locked in place using the pressure of the ring against the rail. Construction of the collar requires precise machining, therefore, it is expensive to make.

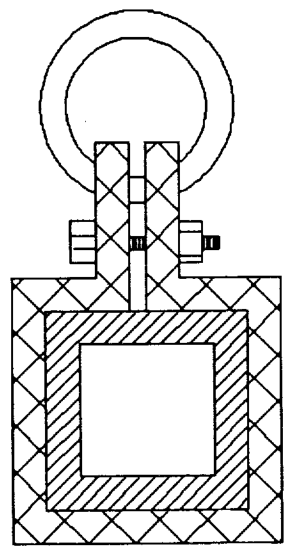


Figure 30.2.1.1 Compression Collar

30.2.2 Fixed Ring

A fixed ring system consists of a ring connected directly to the side of the EECM (Figure 30.2.2.1). The ring is permanently attached to the EECM through welding or bolting.

A fixed ring is strong and easy to use. However, the fixed ring must be placed at each point where attachment is being considered allowing no flexibility in placement.

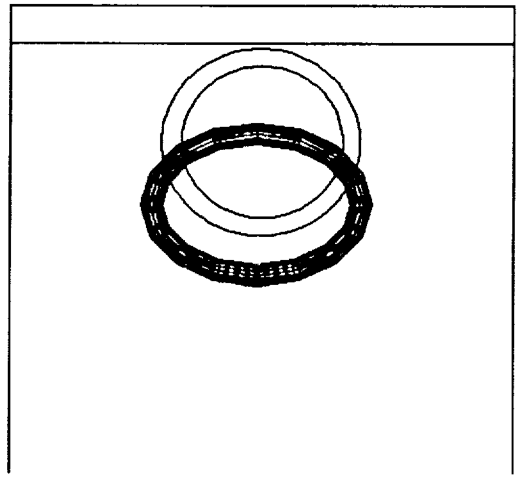


Figure 30.2.2.1 Fixed Ring

30.2.3 Swing-Way Hook

A spring activated hook is used in this system. This hook swings flush with the side of the EECM when not in use (Figure 30.2.3.1). The safety requirement is satisfied since the hook is only protruding from the couch while it is in use. This type of system is easy for the PJ's to use. However, it is more complex than some of the other systems since it is not out and ready to use. A backup system needs to be designed in case the spring system fails. The strength of the hook needs to be analyzed and a safety factor incorporated.

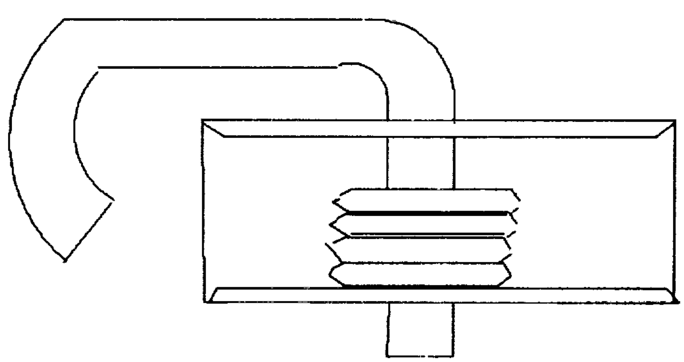


Figure 30.2.3.1 Swing-Way Hook

Chapter 31.0 FLOTATION

The flotation subsystem maintains a stable orientation of the EECM in a water environment. It is required that this system keep the crewmember above the water line and perform under weather conditions from sea state 1 to sea state 4. The following design concepts are considered for performing this purpose:

- MATTRESS FLOTATION
- INTERNAL INFLATABLE FLOTATION
- EXTERNAL FLOTATION
- SOLID INTERNAL FLOTATION

31.1 MATTRESS FLOTATION

The mattress design concept consists of a seven foot long by two foot wide mattress constructed of a solid foam type material (Figure 31.1.1). The height of the mattress is available in one point five inch increments.

The mattress serves the dual purpose of a flotation device and a cushion for the crewmember. It is easily attached to the couch with straps. However, the mattress is not capable of holding the maximum weight of the couch.

31.2 INTERNAL INFLATABLE FLOTATION

The internal inflatable float consists of a bladder within a section of the couch (Figure 31.2.1). For the bladder to fit inside the section, the size is dependent upon the section dimensions. The bladder is inflated by a CO_2 cartridge and may be inflated all the time or when required.

Since this system is internal, it does not contribute to the outer dimensions or hinder in the handling of the couch. The bladder and section can also be designed to ensure adequate flotation of the couch. However, the space required for the storage and use of the internal inflatable float could be used for other purposes. It is difficult to confirm if inflation is hampered since the bladder is enclosed.

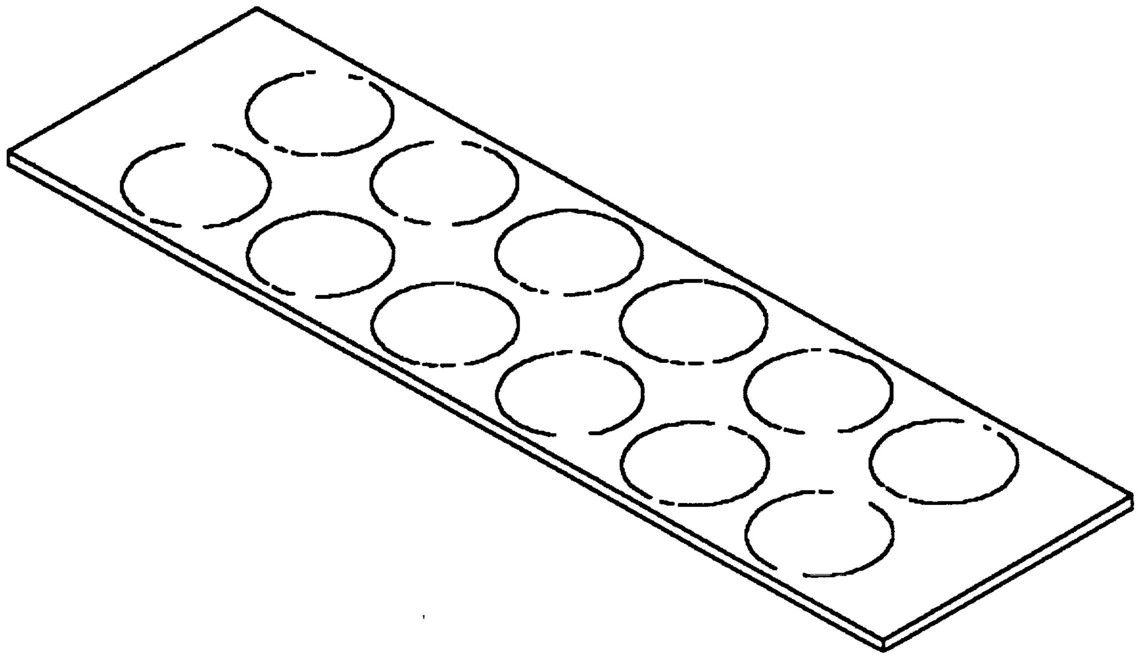


Figure 31.1.1 Mattress Flotation

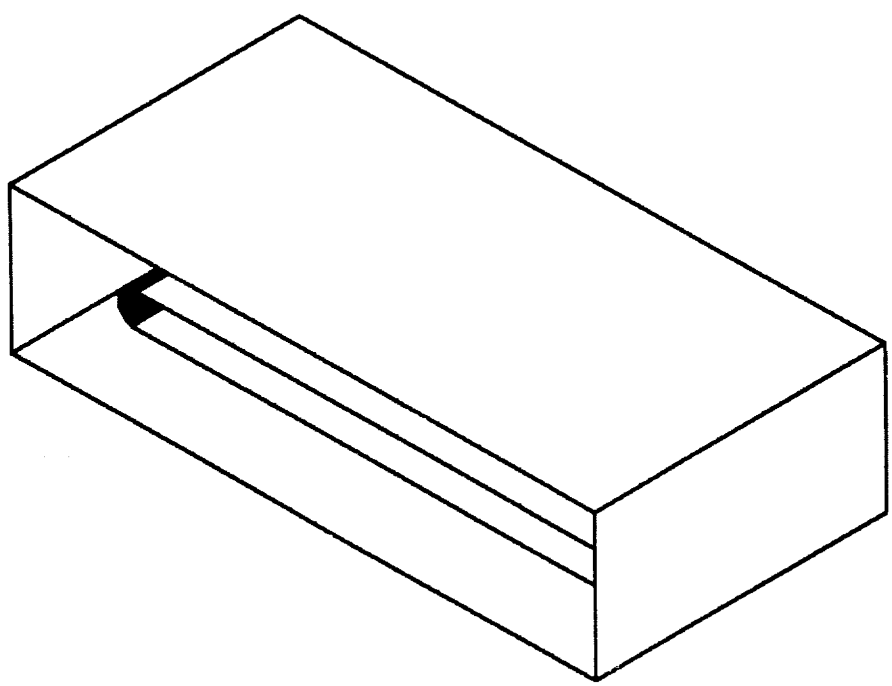


Figure 31.2.1 Internal Inflatable Flotation

31.3 EXTERNAL FLOTATION

The external solid flotation is similar in size to the inflatable floats (Figure 31.3.1). They are connected to the perimeter of the EECM at the head and feet areas. The floats are constructed of a solid material similar to styrofoam. This concept is similar to what is used on a Stokes litter. The shape of the floats are circular, but they may be constructed as rectangles to fit the EECM more accurately.

This system is more reliable than others because of its solid construction. It is also able to support the maximum weight of the EECM and is easily attached through the use of straps or bolts. The design of this system increases the outer dimensions of the couch, thus interfering with the handling of the EECM during retrieval.

31.4 INTERNAL SOLID FLOTATION

The internal solid flotation system consists of solid material similar to the solid external flotation system. The material is placed in the areas around the person in the top portion of EECM (Figure 31.4.1). The material height is equal to the depth of the top portion of the EECM where the person lies.

This system is completely internal so it does not interfere with the handling of the EECM. However, the amount of material required to maintain the stability of the couch may exceed the area limits in the top portion of the couch.

Chapter 32.0 DATA ACQUISITION

The data acquisition subsystem is responsible for monitoring the motion of the EECM. During retrieval there are three directions of concern for the EECM: pitch, yaw, and heave (Figure 32.0.1). To monitor this motion, the use of accelerometers are considered. Accelerometers provide a simple and accurate system of monitoring the acceleration in the directions of concern. Accelerometers are small and require little room to function, thus they can be placed in any area of the couch.

An additional consideration for data acquisition is the visualization of the EECM during testing. A system using a video camera with the capability to superimpose a grid on the picture is available. The grid provides a method to measure the EECM's angles of rotation.

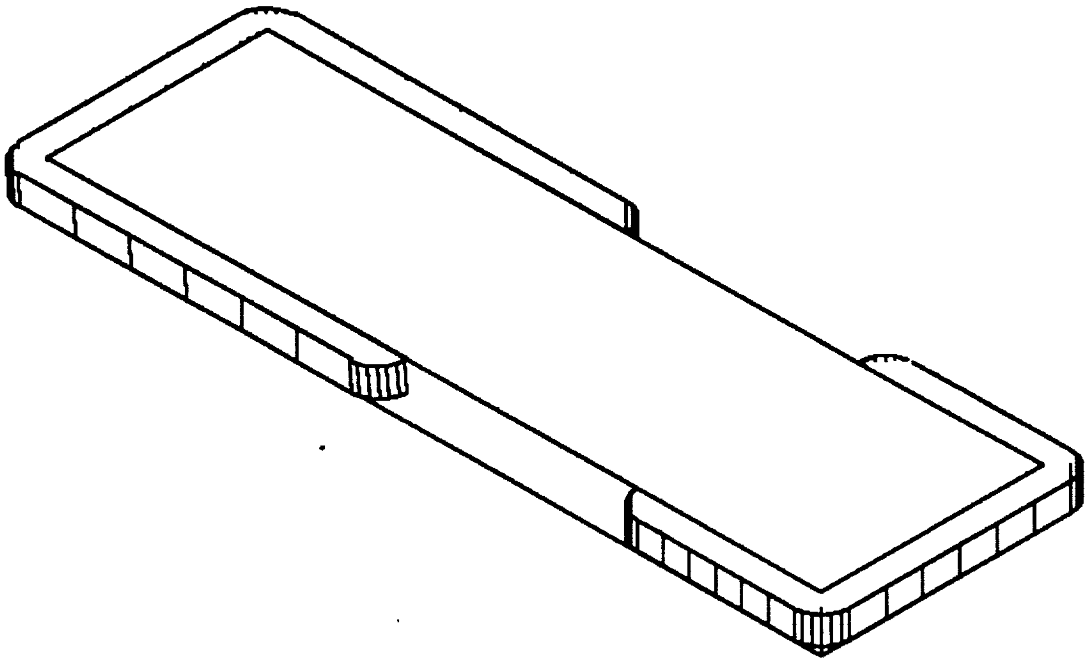


Figure 31.3.1 External Flotation

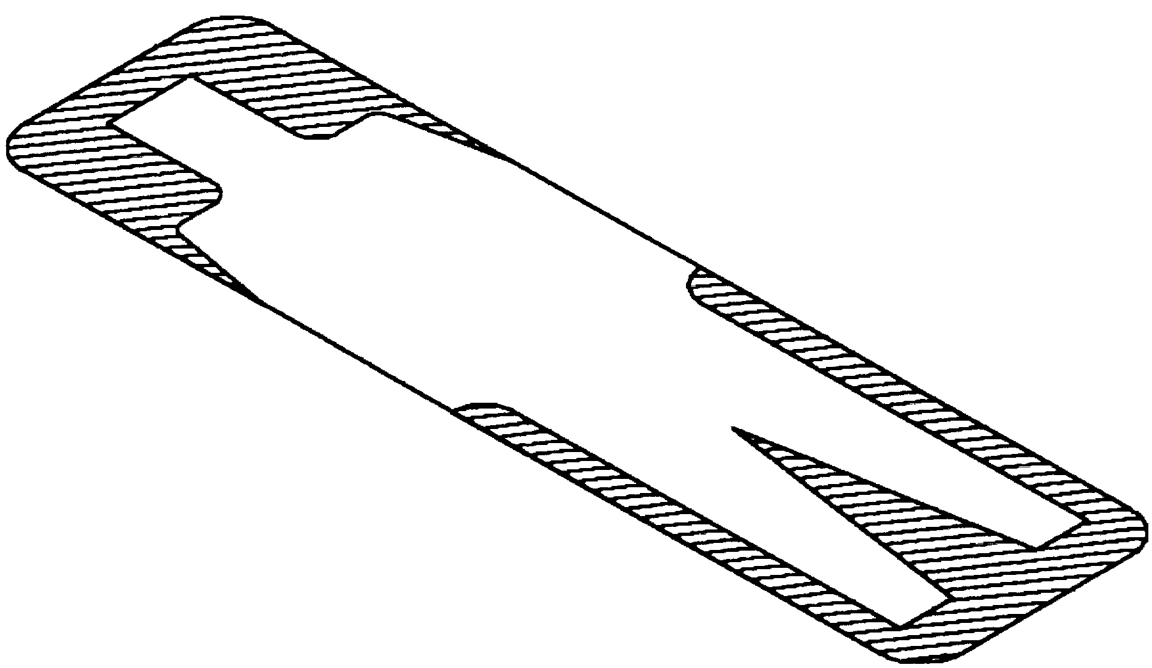


Figure 31.4.1 Internal Solid Flotation

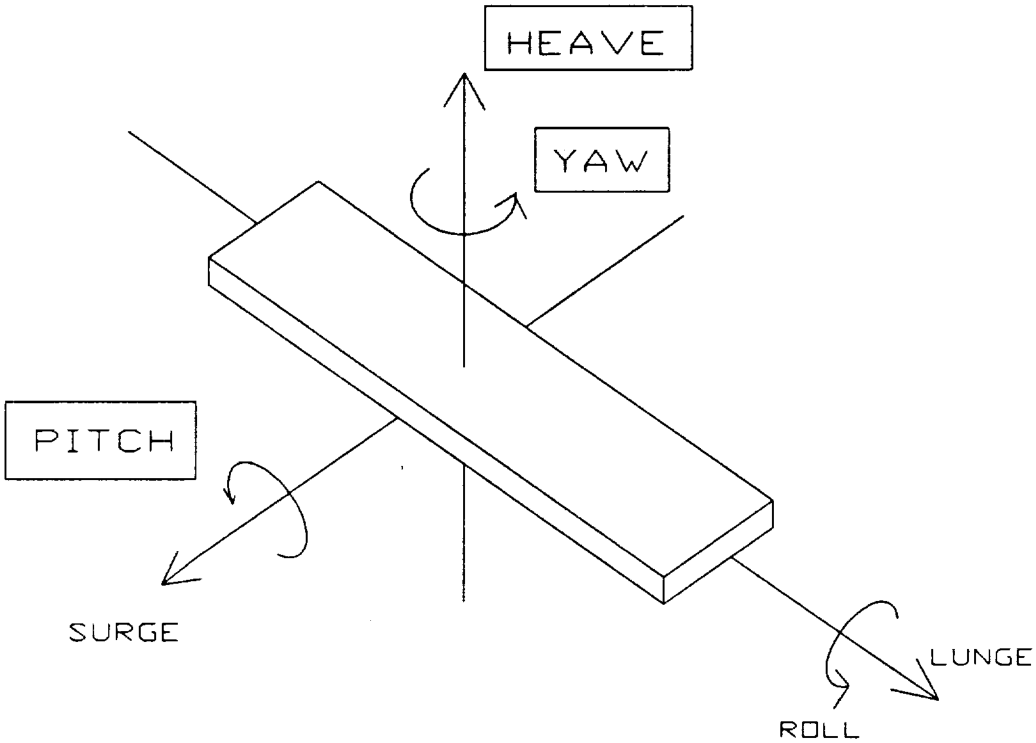


Figure 32.0.1 Critical Motion Directions

Chapter 33.0 COVER

The cover subsystem simulates the covering for the actual EEC. This cover is used to determine any interference with other subsystems such as the sling attachments. Another consideration is how the cover affects the process of retrieving the EECM into the helicopter. The effect of the helicopter downwash on the cover is also under consideration. Three design concepts for the cover are circular, angled, and triangular (Figure 33.0.1).

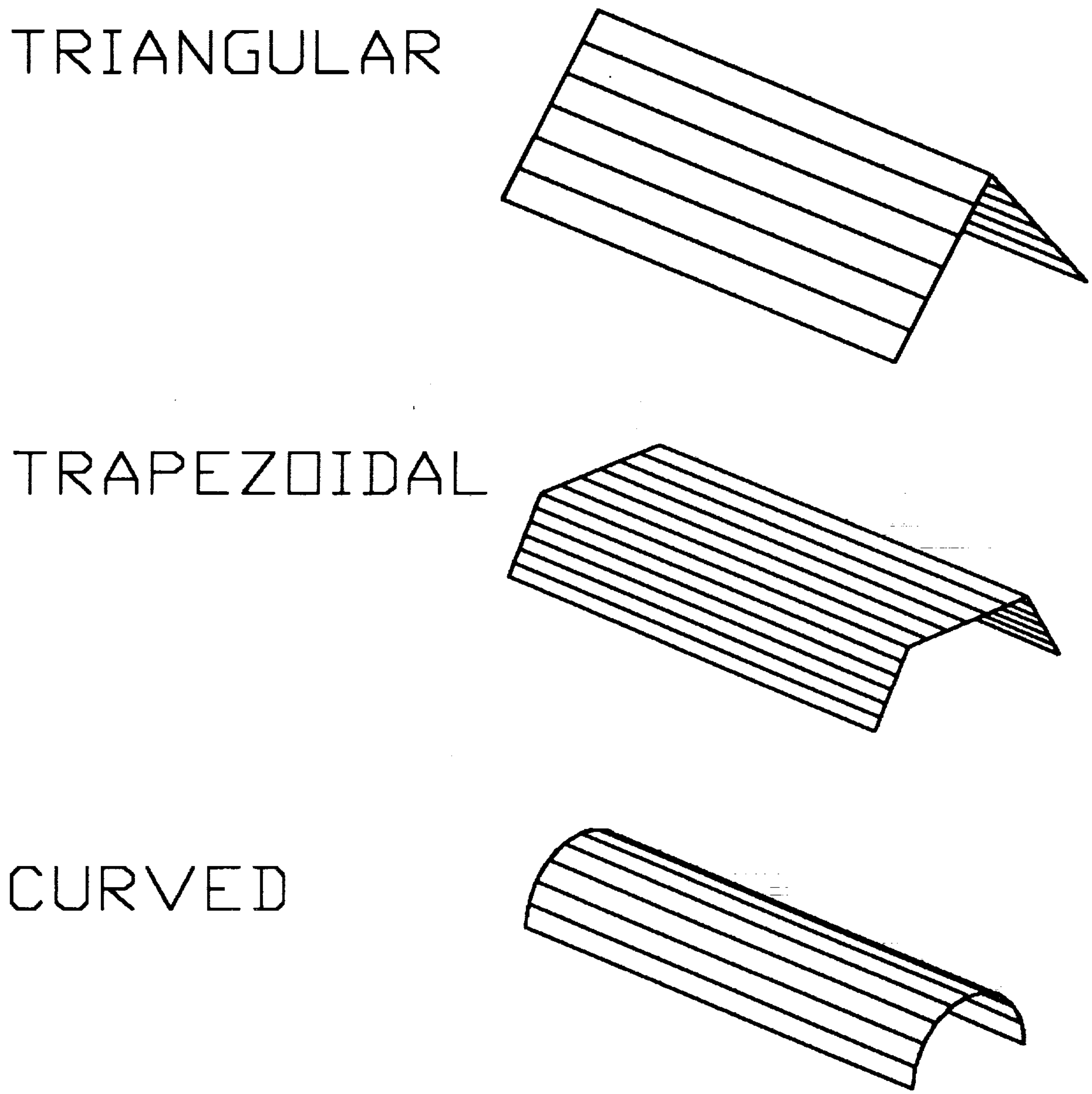


Figure 33.0.1 Curved, Trapezoidal, and Triangular Covers

Chapter 34.0 MATERIALS

Material selection for the construction of the EECM must meet several criteria (Appendix O, Figure O-6). The most important is strength. The material must withstand the maximum weight test parameter of four hundred pounds. The next criteria is light weight. The material must not exceed the parameters of the basic EECM without working weights added. The material must be efficient to work with and must withstand corrosion due to salt water. Cost is the last criteria that must be addressed. The following materials are considered:

- WOOD
- ALUMINUM
- STEEL
- FIBERGLASS
- STYROFOAM
- PVC
- CANVAS

34.1 WOOD

Wood can be used as the main construction material for the EECM. Wood is a strong material, has a low cost, and is easy to work with. The strength of wood is directly proportional to the density of the wood, thus the heavier the wood the stronger it is. Wood absorbs water which causes the wood to warp and increase in weight.

34.2 ALUMINUM

Aluminum is considered for the main construction material of the EECM. Aluminum satisfies the strength requirement and is a light weight material. Aluminum also does not corrode due to salt water. However, aluminum is not easy to work with and it is expensive.

34.3 STEEL

Steel is another material considered for the main construction material of the EECM. Steel is high in strength and costs less than aluminum. Steel is high in weight, not easy to work with, and is susceptible to salt water corrosion.

34.4 FIBERGLASS

The EECM can be constructed from fiberglass. Fiberglass is high in strength, light weight and economical. It is not affected by salt water, but working with fiberglass is difficult.

34.5 STYROFOAM

Styrofoam will not be used for the main construction because it has relatively no strength. Styrofoam is very inexpensive and easy to work with. Styrofoam has excellent flotation characteristics. Height variation spacers are constructed from sheets of the material.

34.6 PVC

PVC piping can be used in various areas of the EECM. It is inexpensive and easy to use. The available types of connectors for PVC provide flexibility in construction of the EECM. PVC is relatively weak in long sections. It does not have shock resistance and tends to break under impacting loads.

34.7 CANVAS

Canvas is a thin material. It can be used as a covering for the frame of the EECM. Different types of canvas are available locally. Canvas is both easy to use and is lightweight. On the other hand, it has low strength and tears easily.

Chapter 35.0 SYNOPSIS

The following is a synopsis of the systems under consideration:

WEIGHT SUBSYSTEM

DUMMY

Advantages	Disadvantages
☺ Accurate Modeling	⊗ Difficult to Construct
☺ Shows Human Factor	⊗ Expensive

WEIGHT SYSTEM

Advantages
- ☺ Model Various Weights
- ☺ Easily Constructed

Disadvantages
- ⊗ No Human Factor

DO NOTHING

Advantages
- ☺ Not Complex

Disadvantages
- ⊗ Less Accurate
- ⊗ Data Interpretation

PEG BOARD SYSTEM

Advantages
- ☺ Easy to Use

Disadvantages
- ⊗ Limited Movement

WEIGHT BLOCKS

Advantages
- ☺ Flexibility
- ☺ Ease of Movement

Disadvantages
- ⊗ Number of Parts
- ⊗ Limited Placement

RAIL SYSTEM

Advantages
- ☺ Movement of Weight
- ☺ Easy to Use

Disadvantages
- ⊗ Difficult to Secure

WORM GEAR

Advantages
- ☺ Motion Control
- ☺ Easily Secured

Disadvantages
- ⊗ Cost
- ⊗ Operation

RAIL AND WORM GEAR

Advantages
- Ease of Movement
- Control

Disadvantages
- Cost
- Weight

VARIABLE HEIGHT SECTION

BLOCKS

Advantages
- Size
- Weight

Disadvantages
- Number of Parts
- Attachment

LAYERS

Advantages
- Height
- Large Working Area

Disadvantages
- Connecting Layers
- Handling

INFLATABLE SECTIONS

Advantages
- Easy to Use
- No Attachments

Disadvantages
- Low Rigidity
- Puncture Hazard
- Weight Capability

SLING ATTACHMENT POINTS DESIGN

PERIMETER

Advantages
- Placement Flexibility

Disadvantages
- Overdesign
- Large Area Required

SPECIFIC AREA

Advantages
- ☺ Simple

Disadvantages
- ⊗ Limited Range

COMPRESSION COLLAR

Advantages
- ☺ Versatility
- ☺ Range

Disadvantages
- ⊗ Strength
- ⊗ Reliability

SWING-WAY HOOK

Advantages
- ☺ Safety
- ☺ Ease of Use

Disadvantages
- ⊗ Strength

FLOTATION SUBSYSTEM

MATTRESS FLOTATION

Advantages
- ☺ Multi-functional
- ☺ Available

Disadvantages
- ⊗ Weight Support

INTERNAL INFLATABLE FLOTATION

Advantages
- ☺ Internal
- ☺ Supports Weight

Disadvantages
- ⊗ Space

EXTERNAL FLOTATION

Advantages	Disadvantages
☺ Reliable	⊗ Increases Dimensions
☺ Support	⊗ Interferes with Handling

INTERNAL SOLID FLOTATION

Advantages	Disadvantages
☺ Internal	⊗ Amount Required
☺ Supports Crewmember	

Chapter 36.0 CHOSEN SOLUTION

36.1 BASIC LITTER

To create a baseline for test results, the couch model must be capable of simulating a basic litter. In designing this basic litter it was decided to stay with a design similar to the current rescue litter, the Stokes litter (Figure 36.1.1). This choice allows the baseline to represent the present configuration. The desirable design characteristics of the Stokes litter are incorporated in the design of the basic litter. These characteristics include a tubular steel frame, wire mesh bottom, and the shape of the Stokes litter. Modifications are added to allow the basic litter to be fitted with the other systems of the EECM design. These changes include: flanges, for attachment to the weight system; peg attachment holes, to accommodate the weight modelling of the injured crewmember; and top rails compatible with the sling attachment system. Overall dimensions of the basic litter model is seven feet long by two feet wide by four inches high. Dimensions of the tubular frame are determined by a strength and weight analysis.

36.2 MODELLING THE HUMAN

A weight system, consisting of two moveable pegs and weight plates, is the optimal choice to model the dynamic characteristics of the injured crewmember (Figure 36.2.1). These dynamic characteristics are weight, center of gravity, and mass moment of inertia. This system is simple yet flexible, yielding a high operational performance. It is inexpensive and easy to construct (Appendix O, Figure O-1).

Two crewmember configurations are required to be modelled. These configurations are a ninety-fifth percentile male, weighing 220 pounds, and a fifth percentile female, weighing 95 pounds. The peg positions and the distribution of the weight plates to model

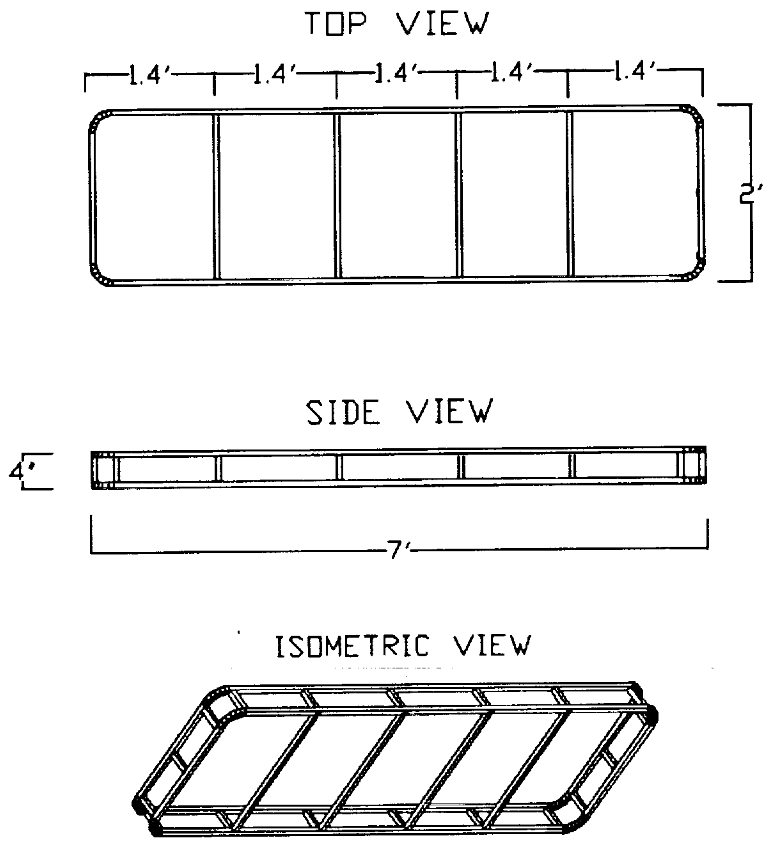


Figure 36.1.1 Basic Litter

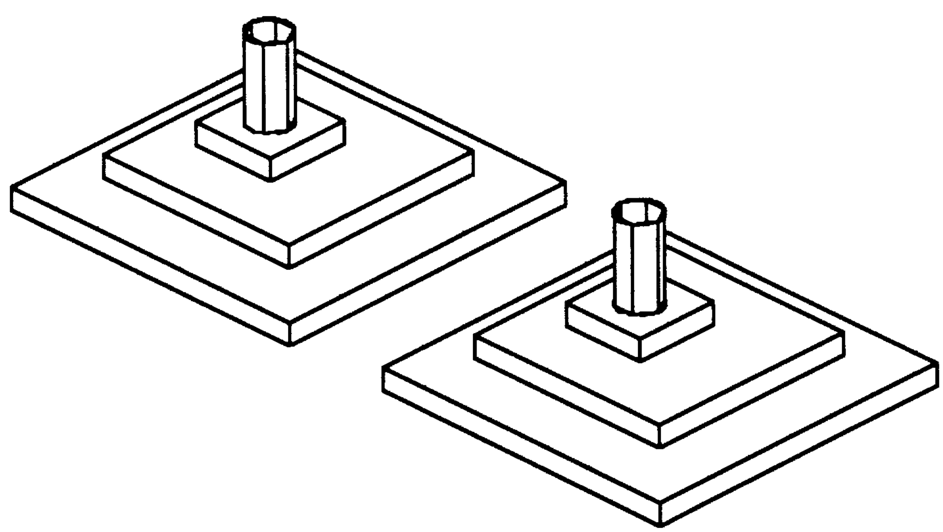


Figure 36.2.1 Human Weight System

both situations are calculated and incorporated into the basic litter. The four inch pegs are threaded 3/4 of an inch on the bottom. The center rail of the basic litter has four holes in the calculated positions. These four holes are machined to accept the threaded pegs. The upper four inches of the pegs are threaded, allowing a locking nut to be screwed on. The weight plates are rectangular and machined with a hole so that they can fit over the pegs. Locking nuts screw on the pegs to lock the weight plates in place.

36.3 MODELLING THE MEDICAL EQUIPMENT

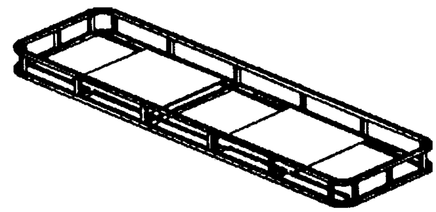
A dual weight platform/rail system is the choice to model the dynamic characteristics of the medical equipment (Figure 36.3.1). These dynamic characteristics are weight, center of gravity, and mass moment of inertia. This alternative achieves the required operational performance and flexibility with the least expense and complication. The dual weight platform/rail system is reliable (Appendix O, Figure O-2).

The weight platforms have threaded pegs, upon which weight plates are placed. These weight plates are locked in place by lock nuts. The weight platforms move along rails by means of a linear bearing assembly. Motion of the platforms is provided manually. The platforms are locked in place with a compression screw. Two rails run along the length of couch model and are seven feet long. The entire platform/rail system is enclosed in a tubular steel frame similar to the basic litter model frame. The dimensions of the frame are seven feet long by two feet wide by four inches high. Flanges are welded to the top and bottom rails of the frame to attach the medical equipment weight system to the other EECM systems.

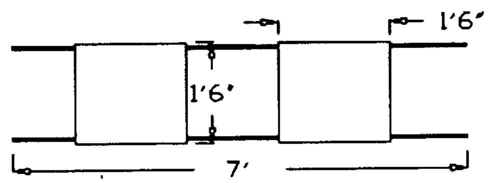
36.4 VARIABLE HEIGHT SECTIONS

Layers, along with the medical equipment weight system, are the optimal choices to vary the height of the EECM from the four inch high basic litter to the one foot high maximum height set by NASA (Figure 36.4.1). This alternative satisfies the design criteria (Appendix O, Figure O-3).

The minimum height of the medically equipped couch model is eight inches. This includes the combination of the basic litter and medical equipment weight system. In addition to this minimum height, three separate layers are added in one, two, three, or four inch combinations to vary the height of the medical couch model. Two of the layers have dimensions of seven feet long by two feet wide, by one inch high. The third layer is seven feet long, by two feet wide by two inches high. The layers are constructed of a wood frame, wood bottom and filled with styrofoam. The frame is drilled with appropriate bolt holes to attach it to the other EECM systems.



WEIGHT SYSTEM IN FRAME



WEIGHT SYSTEM

Figure 36.3.1 Rail System

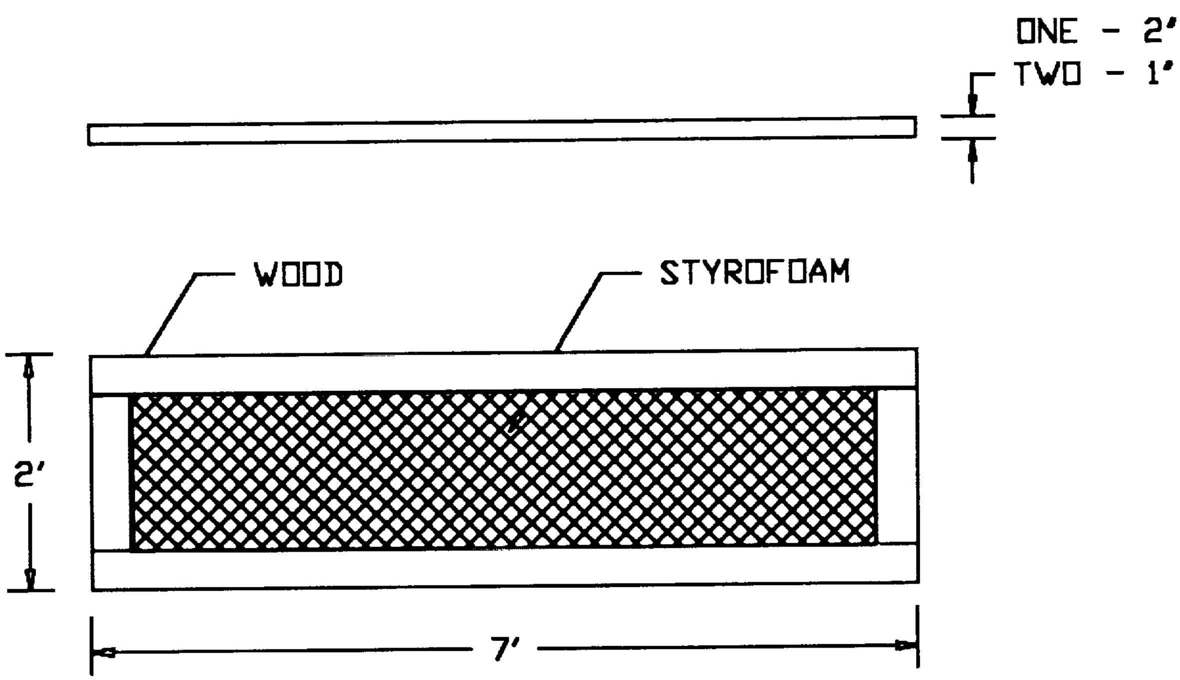


Figure 36.4.1 Variable Height Sections

36.5 SLING ATTACHMENT SYSTEM

Compression collars located in four specific areas are the choice for the sling attachment system. The compression collars allow flexibility. Using them in specific areas insures simplicity and ease of construction (Appendix O, Figure O-4). Compression collars are located on the top side rails of the basic litter model. When the compression bolt is loosened, the collar slides along the rail to the desired position. Upon tightening the bolt, the collar is locked into placed. A sling attachment ring is located above the bolt (Figure 36.5.1).

36.6 FLOTATION

Internal solid flotation (styrofoam) is the choice to determine the flotation characteristics necessary for the EEC (Figure 36.6.1). Styrofoam is inexpensive, easy to work with, and offers excellent flotation properties (Appendix O, Figure O-5). Styrofoam is placed both in the basic litter and in the variable height layers. The amount of styrofoam in the basic litter is varied. The flotation characteristics of the couch are changed by using different combinations of layer placements with respect to the medical weight system; the layers are placed above or below the medical weight system.

36.7 DATA ACQUISITION

A visual data system was used to collect data. This system consists of a video camera equipped with crosshairs in the eyepiece for alignment. The EECM was video taped during testing. When viewing the tape a scaled down grid was placed on the monitor and the EECM will be visible through it. By measuring the EECM against the grid, the motion of the EECM can be determined. Film speed was also be known. This can be used to determine the rate at which the EECM moves.

36.8 COVER

Three different cover configurations were considered for the EECM. The covers are easy, and inexpensive to construct. The three shapes considered were: circular, triangular, and trapezoidal (Figure 36.8.1). The triangular shape was constructed out of wood, using a light but strong veneer for the panels.

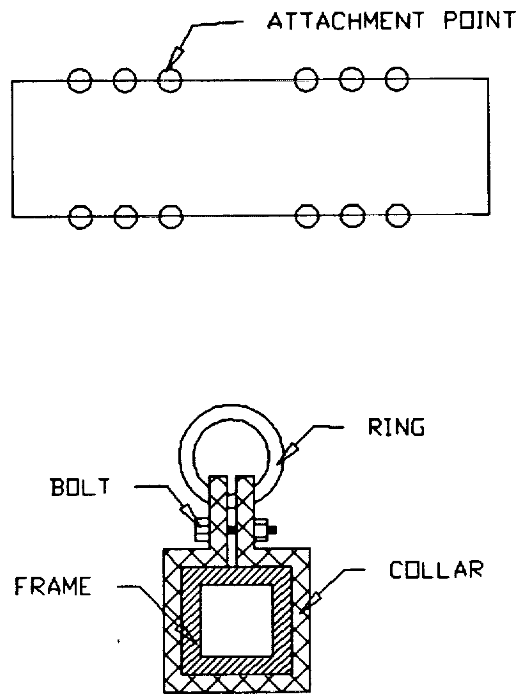


Figure 36.5.1 Sling Attachment System

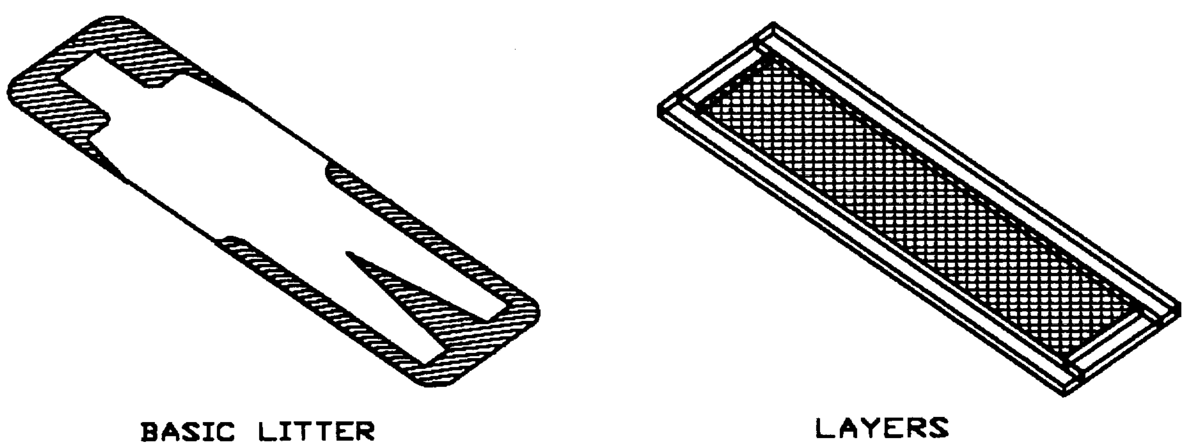


Figure 36.6.1 Flotation System

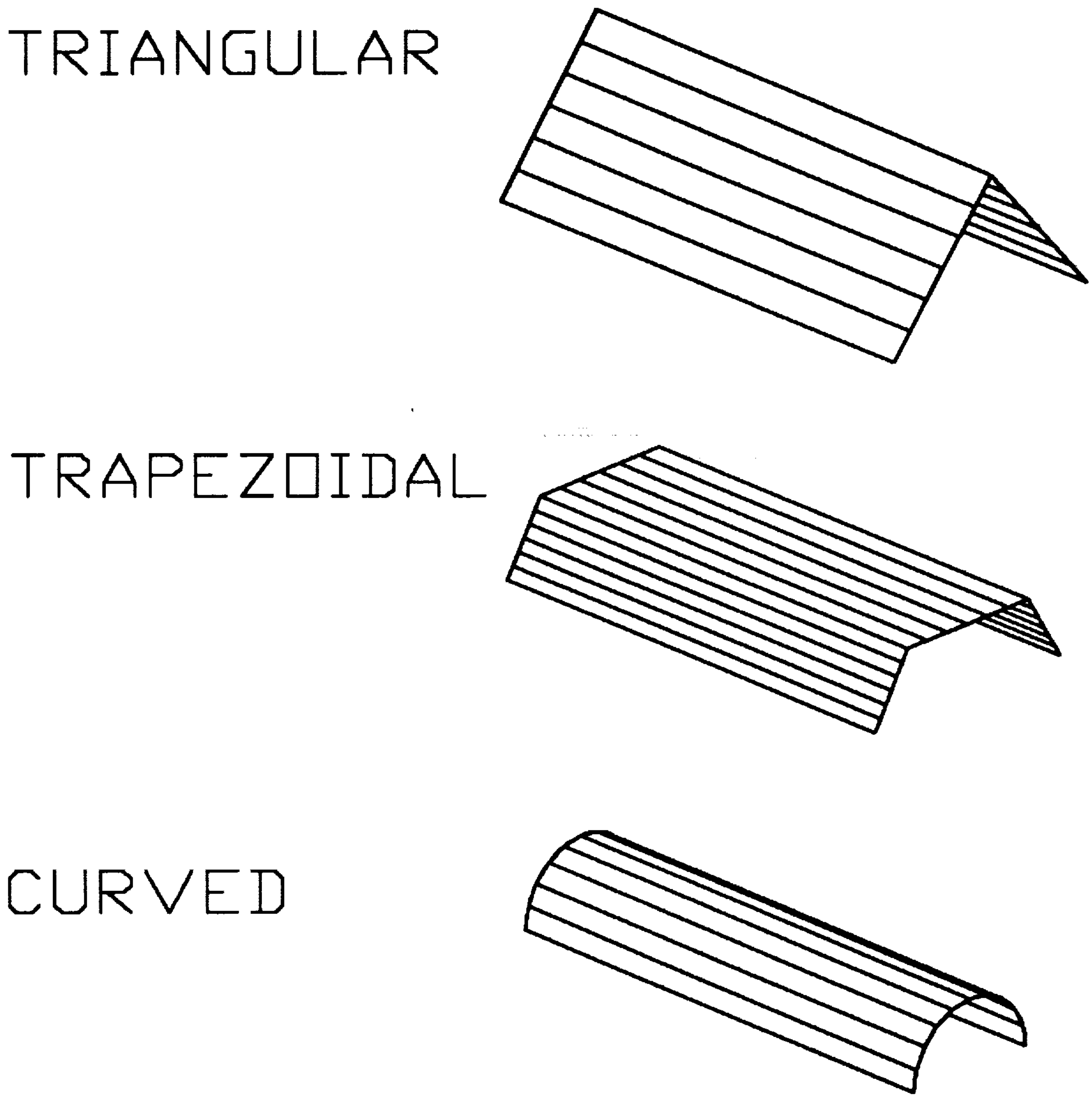


Figure 36.8.1 Cover Configurations

Chapter 37.0 OBSERVATIONS AND RECOMMENDATIONS

The two primary metals used in the design and construction of the EECM are aluminum and steel. While aluminum has a weight advantage over steel it lacks the strength and resilience. Thus, steel is used for high strength, and aluminum is used in areas where weight needs to be conserved. The ease of welding steel makes this metal most desirable in constructing the various frames.

Safety is a major biggest concern in designing the EECM. For this reason two pegs are used to secure each set of weight plates both in the human weight system and medical weight system. This provides redundancy to the securing of the weight plates, and eliminate rotation of the plates.

The layers are made as light as possible to increase their flotation properties. The attachment design of the layers must insure that they experience no tensile loads and limited compressive loads. The wood must be treated so that it withstands a water environment.

The sling attachment system must be extremely reliable. For this reason the sling attachment system and all components carrying the load of the EECM during a lift are designed with a high factor of safety in the range of three to four. There is some concern that the compression collars will experience fatigue due to the cyclical loading involved in securing them to the rails. For this reason the component is designed so that a minimum compressive load, and deflection achieves the necessary locking force. Wire rope slings with a high factor of safety are used to attach the compression collars to the helicopter hoist hook.

The styrofoam used in the EECM is protected in order to ensure durability. The flotation blocks in the basic litter are secured.

The center of gravity, mass moment of inertia, weight, and buoyancy characteristic of all the systems are calculated and recorded. Varying these values by means of the weight system is performed in a safe, quick, reliable, and accurate manner.

BUILDING PHASE

Chapter 38.0 SCHEDULING

Work Breakdown Structures, Logic Charts, and Gantt Bar Charts present the tasks and dates of completion. These charts and performance measuring tools serves as guides for the EECM design team.

38.1 Work Breakdown Structure

The Work Breakdown Structure (WBS) links objectives and tasks with resources. The WBS logically separates work-related units. These program units provide information necessary to evaluate and control the program[53,54].

The WBS for the EECM development phase is shown in Figure 38.1.1. The development process included drawings, purchasing, manufacturing, finishing, developing the governing equations, and writing the reports for the project. The drawing process consists of rough sketches, detailed drawings, and final working plans. Purchasing entails gathering construction materials, construction tools, and fasteners for the EECM. During the manufacturing process, sections of the EECM were fabricated and tested for compatibility. Components were assembled, necessary reworking completed, and the final assembly performed. The finishing step confirmed the completion of the final working model. Governing equations were developed to determine the center of gravity and moment of inertia of the EECM when the weights were varied. Reports presented during this project include the Scheduling Report, the Construction and Test Plan Report, the Test Results Report, and the Final Report.

The WBS chart for the testing phase is shown in Figure 38.1.2. The testing phase included both pretests and actual tests for optimization of the EEC characteristics. The requirements and procedures are shown in the WBS Dictionary (Appendix P). Pretesting verified that the dynamic and geometric characteristics of the EECM can be easily changed during the actual test phase. The dynamic characteristics of the EECM include weight, center of gravity, moment of inertia, and different locations for the lift attachment points. Variable height sections make up the geometric characteristics of the couch.

The testing phase determined the optimal dynamic and geometric characteristics of the EECM. This phase was conducted at Patrick Air Force Base. Dynamic characteristics determine the placement of the medical equipment, location of the center of gravity, amount of moment of inertia, and locations for the lift attachment points. Geometric and handling characteristics determine the couch height and use of the cover.

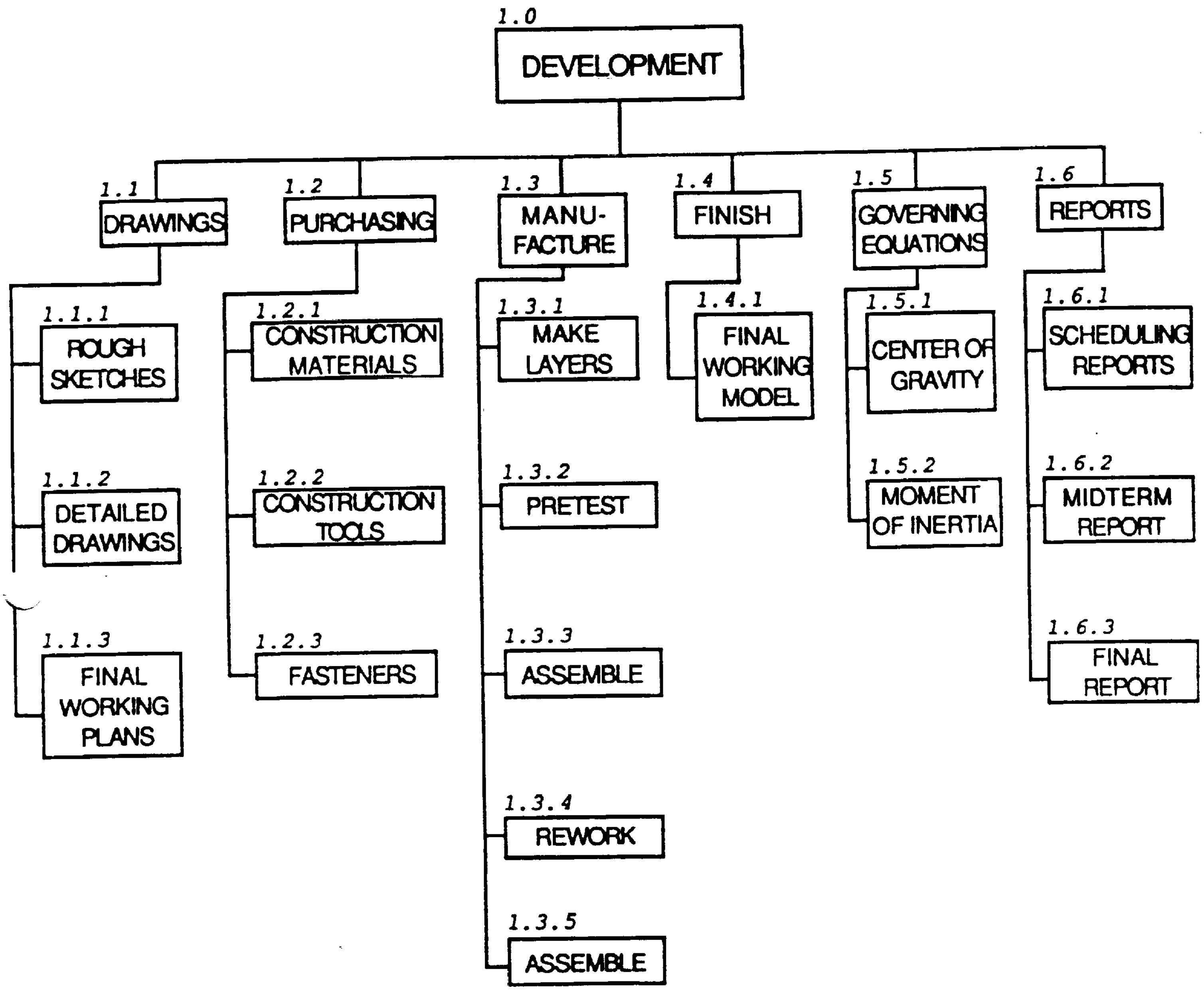


Figure 38.1.1 Development Phase Work Breakdown Structure

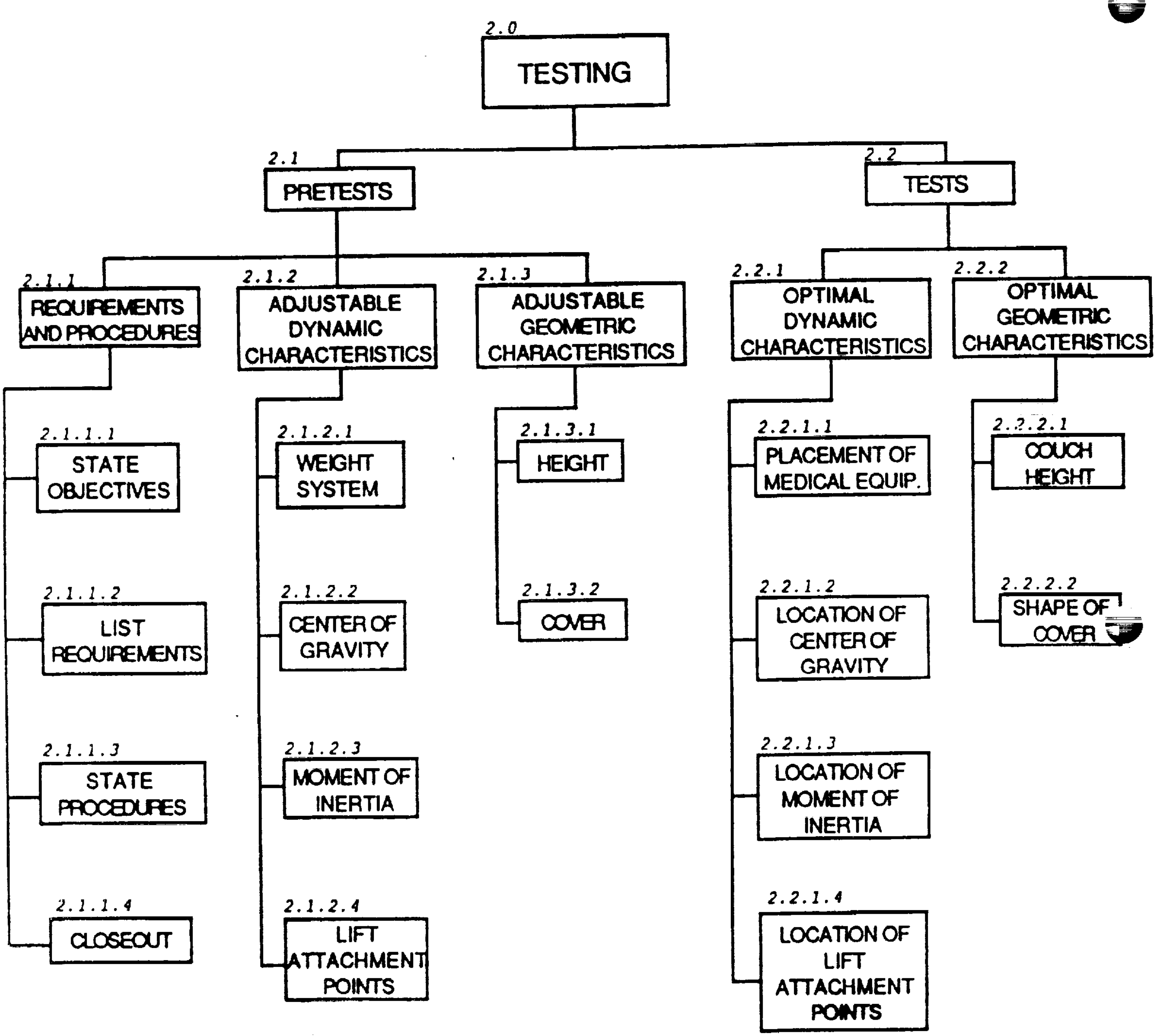


Figure 38.1.2 Testing Phase Work Breakdown Structure

38.2 LOGIC CHART

A Logic Chart is a network scheduling technique that forces the detailed definition of tasks, task sequences, and task interrelationships. It places emphasis on the critical activities or those requiring the greatest amount of time for completion. The critical path identifies tasks which may pose problems if schedule slippage occurs.[55,56] These tasks must be closely monitored and controlled throughout the program.

Logic charts show the critical path for the development phase of the project (Figure 38.2.1), the testing phase (Figure 38.2.2), and an overlay of both phases (Figure 38.2.3). The numbers in the boxes correspond to the tasks defined in Appendix P. The numbers to the bottom left and right of the box are the anticipated beginning and completion dates for each task.

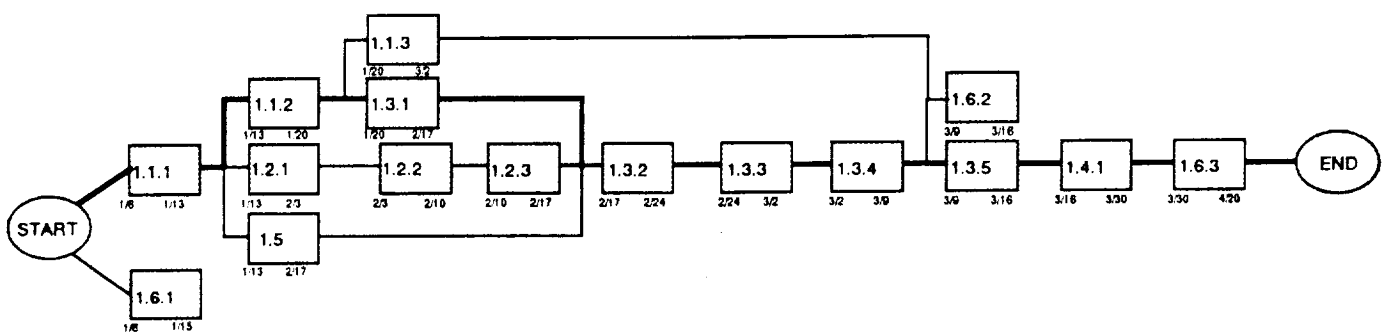
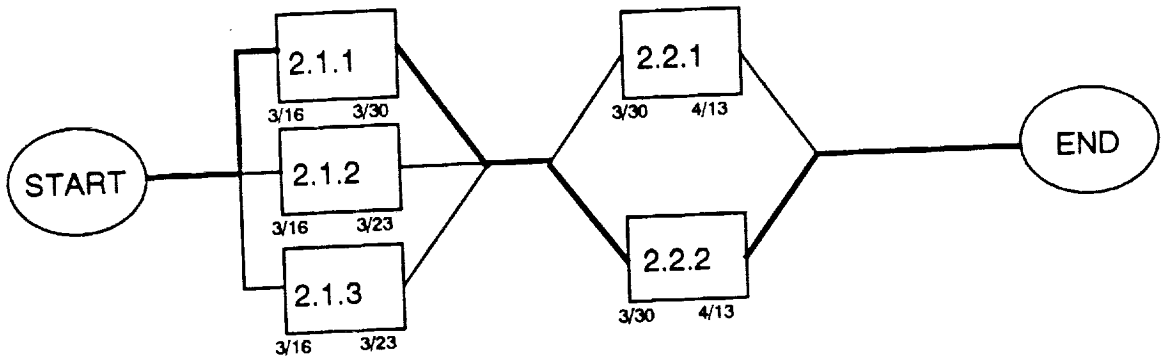
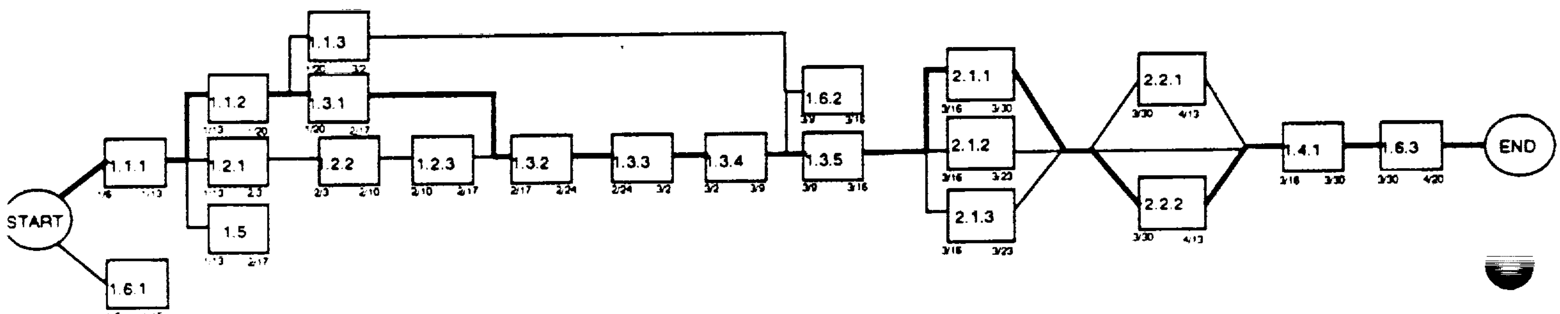


Figure 38.2.1 Development Phase Critical Path



BOLD LINE - CRITICAL PATH

Figure 38.2.2 Testing Phase Critical Path



BOLD LINE - CRITICAL PATH

Figure 38.2.3 Overlay of Development and Testing Critical Paths

38.3 GANTT BAR CHART

The Gantt Bar Chart projects task progress (in terms of work completed) against program activities and milestones. The chart acts as a performance measuring system. Deadlines and problem areas are easily identified through the use of this chart[57,58].

As shown in Figure 38.3.1, the task areas were: review requirements, generate drawings, purchase materials, manufacture model, do finishing touches, determine governing equations, write reports, pretest, and test the EECM. The subtasks are shown in Figure 38.3.2 and defined in Appendix P.

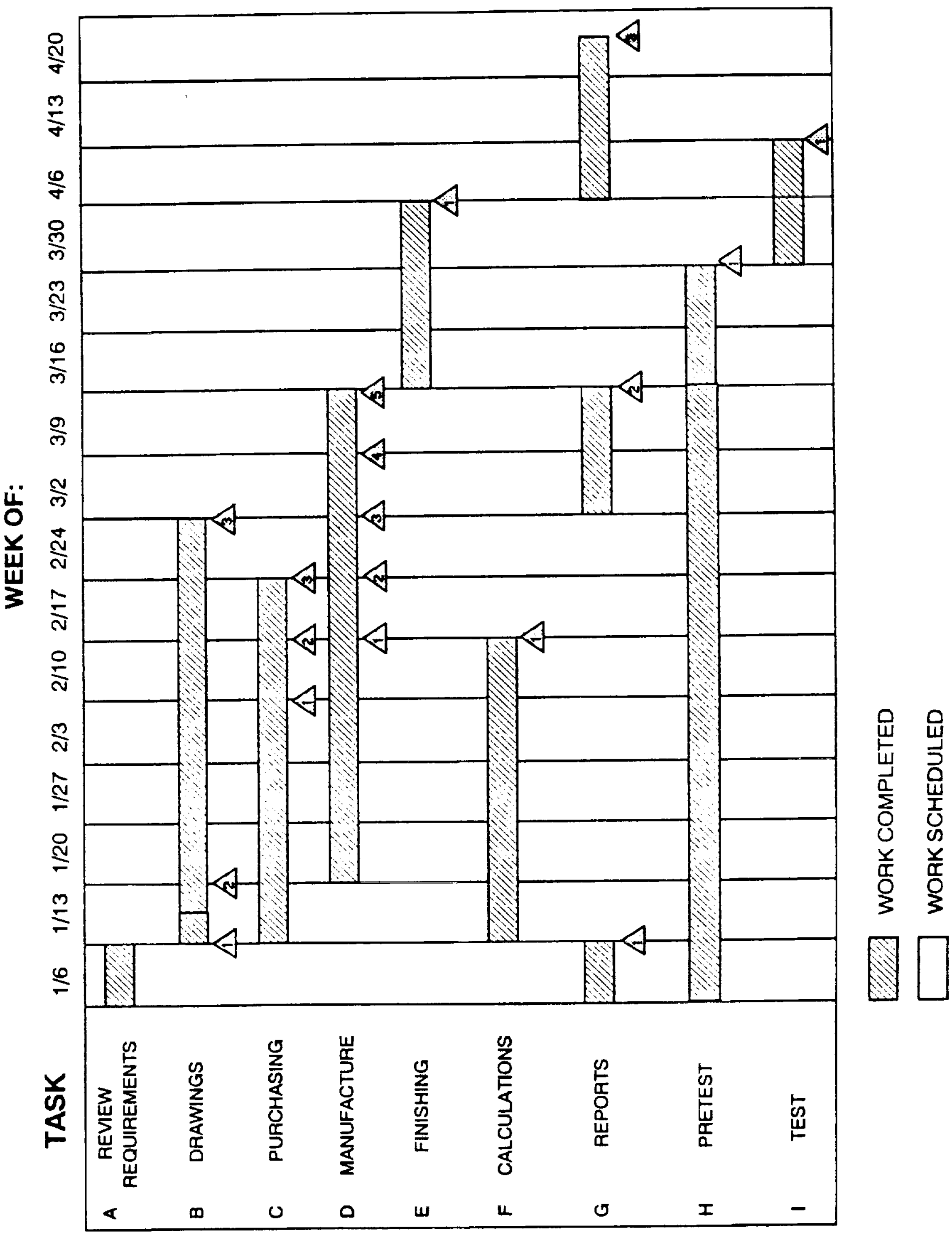


Figure 38.3.1 Gantt Chart Task Areas

A. REVIEW REQUIREMENTS

B. DRAWINGS
- B.1 ROUGH SKETCHES
- B.2 DETAILED DRAWINGS
- B.3 FINAL WORKING PLANS

C. PURCHASING
- C.1 CONSTRUCTION MATERIALS
- C.2 CONSTRUCTION TOOLS
- C.3 FASTENERS

D. MANUFACTURE
- D.1 MAKE LAYERS
- D.2 PRETEST
- D.3 ASSEMBLE
- D.4 REWORK
- D.5 ASSEMBLE

E. FINISH
- E.1 FINAL WORKING MODEL

F. CALCULATIONS
- F.1 CENTER OF GRAVITY
- F.2 MOMENT OF INERTIA

G. REPORTS
- G.1 SCHEDULING
- G.2 MIDTERM (CONSTRUCTION AND TEST PLAN REPORT)
- G.3 TEST RESULTS REPORT
- G.4 FINAL REPORT

H. PRETEST
- H.1 REQUIREMENTS AND PROCEDURES
- H.2 ADJUSTABLE DYNAMIC CHARACTERISTICS
- H.3 ADJUSTABLE GEOMETRIC CHARACTERISTICS

I. TEST (PATRICK AIR FORCE BASE)
- I.1 OPTIMAL DYNAMIC CHARACTERISTICS
- I.2 OPTIMAL GEOMETRIC CHARACTERISTICS

Figure 38.3.2: Subtask Requirements

Chapter 39.0 CONSTRUCTION

The construction phase including the method of fabrication for each subsystem, is described. The R & D Shop at The University of Central Florida built the EECM and its subsystems.

39.1 BASIC LITTER (TOP LITTER)

The EECM is comprised of five sections. The top litter simulates the basic Stokes Litter, currently used for shuttle rescue missions. The Human Weight System is contained in the top litter of the EECM to simulate the weight of the injured crewmember. The approximate weight of an empty Stokes litter is 15 pounds. The weight of a 95th percentile male is 220 pounds and the weight of a 5th percentile female is 100 pounds.[59] The top litter is made of chrome-moly steel tubing, with 1 inch outer diameter and 0.095 inch wall thickness.[60] The method of welding used was Tungsten-injected gas (TIG).[61]

39.1.1 Constructing the Frame:

39.1.1.1 Heat chrome-moly steel tube sections on one side and bend around a cylinder (the heated side is the outer radius of the bend). This forms the 4 inch radius corners of the couch.[62]

39.1.1.2 Cut two chrome-moly steel tubes into 6 foot 4 inch pieces.

39.1.1.3 Cut two chrome-moly steel tubes into 1 foot 4 inch pieces.

39.1.1.4 Weld the corner sections to the tubes to form the 7 × 2 foot EECM frame (Figure 39.1.1.4.1).

39.1.1.5 Repeat steps 39.1.1.1 through 39.1.1.4 to construct a total of two frames.

39.1.2 Constructing the Top Litter:

39.1.2.1 Cut 10 chrome-moly steel tubes into 3 inch pieces. End mill 1 inch diameter semicircles on each end (Figure 39.1.2.1.1). These are called "spacers".

39.1.2.2 Cut three chrome-moly steel tubes into 1 ft 11 in pieces. End mill 1 inch diameter semicircles on each end (Figure 39.1.2.1.1). These are called "runs".

TOP FRAME

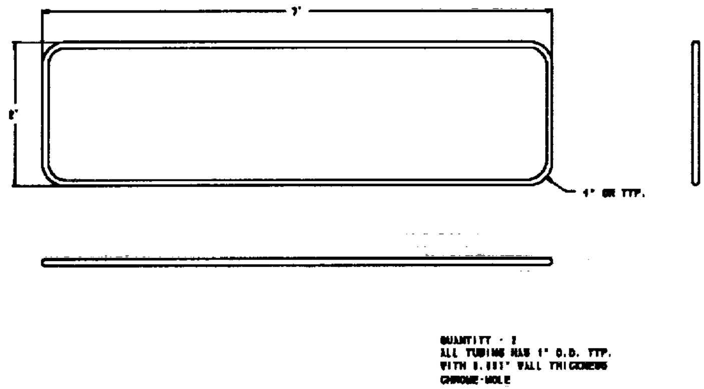


Figure 39.1.1.4.1 Top Frame of Top Litter

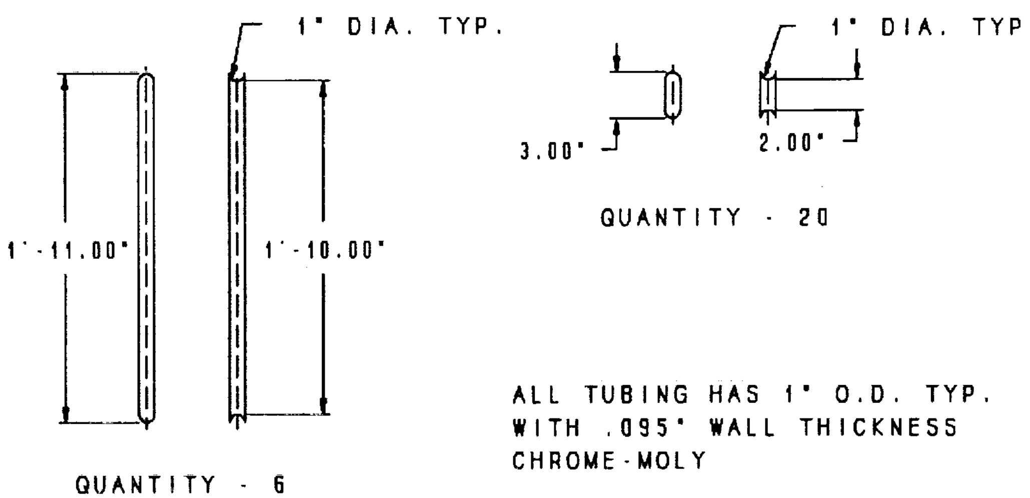


Figure 39.1.2.1.1 Runs and Spacers

G.3

39.1.2.3 Weld one run in the center of the frame. The other 2 runs are welded 1 ft 9 in apart on center from center run (Figure 39.1.2.3.1). This is the bottom frame of the top litter.

39.1.2.4 Weld 6 spacers between the two tubular frames, 1 ft 9 in apart.

39.1.2.5 Weld the remaining 4 spacers between the ends of the frames (two on each end), 1 ft 2 in at center apart. This completes the top litter (Figure 39.1.2.5.1).

39.2 WEIGHTED MEDICAL COUCH (BOTTOM LITTER)

The bottom litter contains The Medical Weight System. When attached to the top litter, the EECM represents a weighted medical couch. The medical equipment for the EEC weighs a maximum of 120 pounds. The minimum value for the medical equipment is 75 pounds. Therefore, the minimum total value of the weighted medical couch, when considering a 100 pound female, is 190 pounds. The minimum total weight when considering a 220 pound male is 310 pounds.[63] The maximum total weight the helicopter winch is capable of lifting is 600 pounds.[64] Like the top litter, the bottom litter was constructed from chrome-moly steel tubing, 1 inch in diameter with 0.095 inch wall thickness. TIG welding was also used.

39.2.1 Constructing the Frame

39.2.1.1 Repeat steps 39.1.1.1 through 39.1.1.5.

39.2.2 Constructing the Bottom Litter

39.2.2.1 Repeat steps 39.1.2.1 through 39.1.2.5 to complete the bottom litter.[65]

39.3 HUMAN WEIGHT SYSTEM

The Human Weight System simulates the weight of a human and is contained in the top litter. A weighted dummy with the same dynamic and geometric characteristics as a human was used. The dummy weighs 102 pounds with the CG corresponding to the CG of a crewmember. The dummy was secured by strapping it to the upper litter.

39.3.1 Acquisition

39.3.1.1 Obtain Dummy from Naval Training Center.

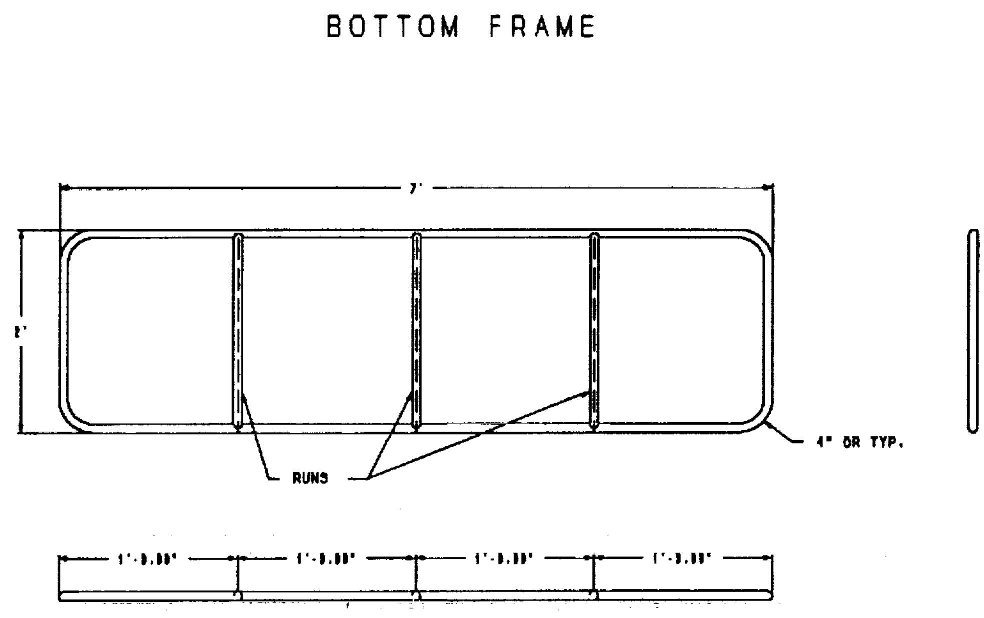


Figure 39.1.2.3.1 Bottom Frame of Top Litter

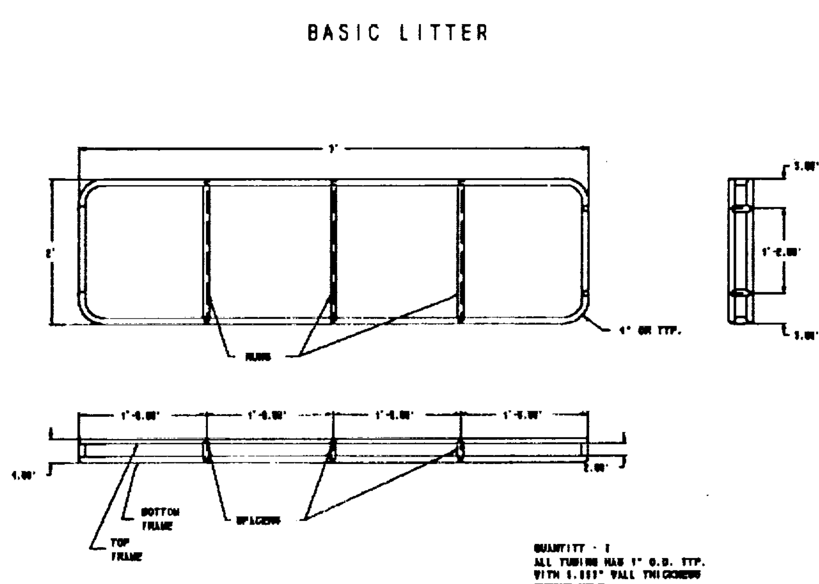


Figure 39.1.2.5.1 Basic Litter

39.3.2 Attachment

39.3.2.1 Place dummy in the top litter and strap securely in place using nylon straps (Figure 39.3.2.1.1).

39.4 MEDICAL WEIGHT SYSTEM

The Medical Weight System simulates the weight of the medical equipment and also functions to vary the overall CG of the couch and moments of inertia. This system is housed in the bottom litter and consists of two 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 EECM. The position of the weights can be varied as well by attaching the platforms along the support strips and bolting them in place.

39.4.1 Fabricating Weight Platforms

39.4.1.1 Purchase and/or cut two 1/4 inch thick aluminum platforms each 12 × 21 inch.

39.4.1.2 Drill two holes 5/8 inch diameter in each plate 4 inch from center to each lengthwise side and on width-wise center.

39.4.1.3 Drill two holes 7/16 inch diameter in each plate 2 inches in from each lengthwise end on width-wise center (Figure 39.4.1.3.1).

39.4.2 Fabricating Support Strips

39.4.2.1 Cut 2 aluminum strips each 3.5 × 55 inches. Drill holes to allow for bolts to secure platform in each configuration. Bolt to bottom litter.

39.4.2.2 Drill 6 - 7/16 inch diameter holes for each platform at L-Bracket to bolt plate to litter.

39.4.2.3 Drill 4 - 7/16 inch diameter holes for each support plate to secure the weighted plates.

39.4.2.4 Secure weights using bolts with oversized washers.

39.4.2.5 File rough edges (Figure 39.4.2.5.1).

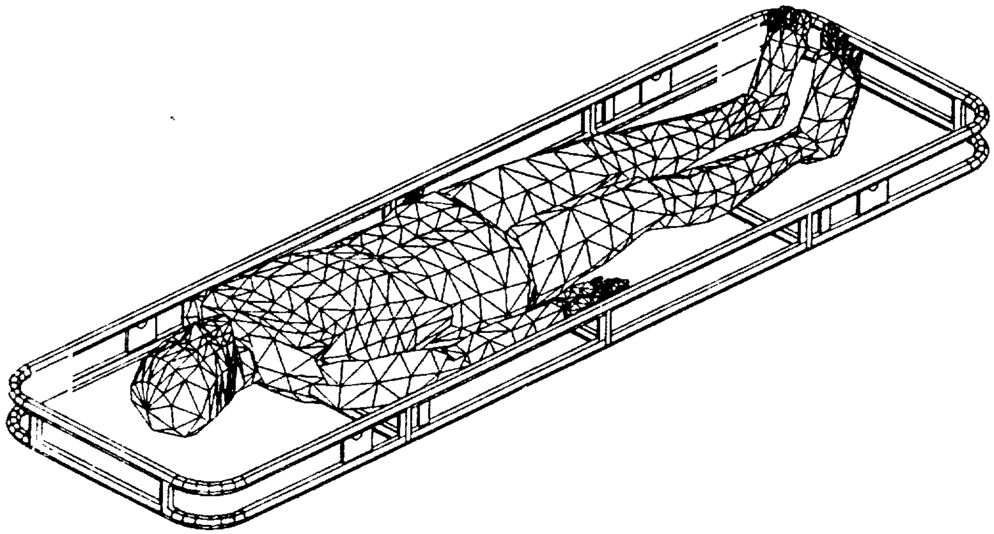
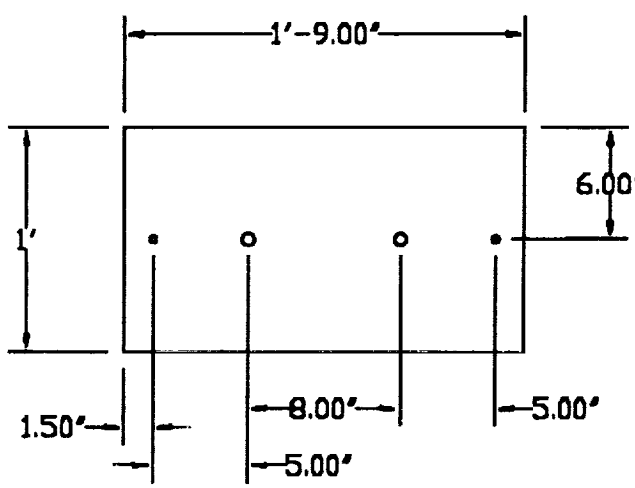


Figure 39.3.2.1.1 Human Weight System



QUANTITY: - 2
OUTER HOLES 0.375" DIA.
INNER HOLES 0.625" DIA.
MATERIALS 0.25" THICK ALUMINUM

Figure 39.4.1.3.1 Weight Platforms

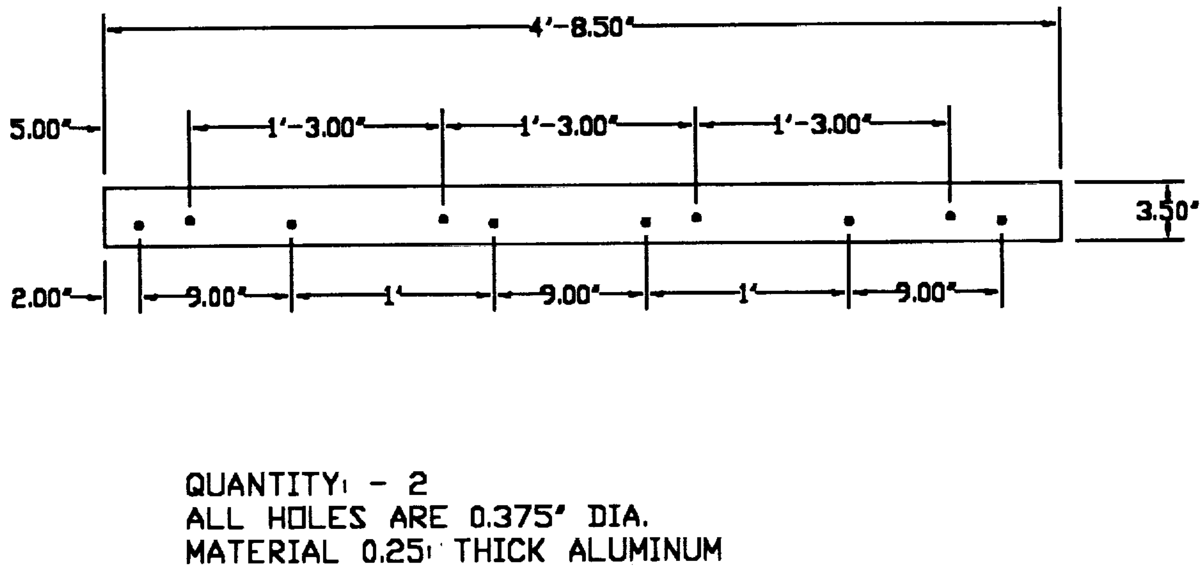


Figure 39.4.2.5.1 Support Strips

39.5 LAYERS CONTAINING FLOTATION ELEMENTS

The layers serve the dual purpose of augmenting the height of the couch to achieve the maximum of one foot and supporting the flotation system.[66] There are three layers: one with a 2 inch height and two with a 1 inch height. This allows for a great deal of flexibility when varying the EECM height.

The frames of the layers are made of 2 × 4 inch pressure treated wood that is planed to the proper heights, mentioned previously. A polystyrene sheet fills the center of the frame for flotation. The layers are 7 × 2 feet and attach between the top and bottom litter. The corners have a 4 inch radius for proper interface with the other EECM components and a 0.375 inch diameter hole to allow for the layer attachment system.

39.5.1 Constructing the Wood Frames for the Layers

39.5.1.1 Cut and plane wood into four 1 in × 4 in × 7 ft pieces and two 2 in × 4 in × 7 ft pieces.

39.5.1.2 Cut and plane wood into four 1 in × 4 in × 2 ft pieces and two 2 in × 4 in × 2 ft pieces.

39.5.1.3 Screw the 7 foot and 2 foot pieces together with 3 inch #8 wood screw to form the frame of the layer.

39.5.1.4 Sand the corners of the frame so they are rounded with a 4 inch turn radius.

39.5.1.5 Drill a 0.375 inch hole in each corner of the wooden frame to allow for the layer attachment system. The hole is located in the center of the wood, 5.5 inches in from the end of the frame.

39.5.1.6 Attach four 1 ft × 21 in half inch plywood to 1 inch top layer wood frame.

39.5.1.7 Attach four 12 × 21 × 1/2 inch to the upper 1 inch layer spaced so as not to interfere with runs using #8 - 3/4 inch wood screws.

39.5.1.8 Attach three 12 × 21 × 1/2 inch plywood to the bottom of the lower 1 inch layer. Space evenly using #8 3/4 inch wood screws (Figure 39.5.1.8.1).

39.5.2 Adding the Flotation Elements

39.5.2.1 Cut two polystyrene sheets for a tight fit 1 in × 1 ft 4 in × 6 ft 4 in.

39.5.2.2 Cut one polystyrene sheet for a tight fit 2 in × 1 ft 4 in × 6 ft 4 in.

39.6 LITTER ATTACHMENT

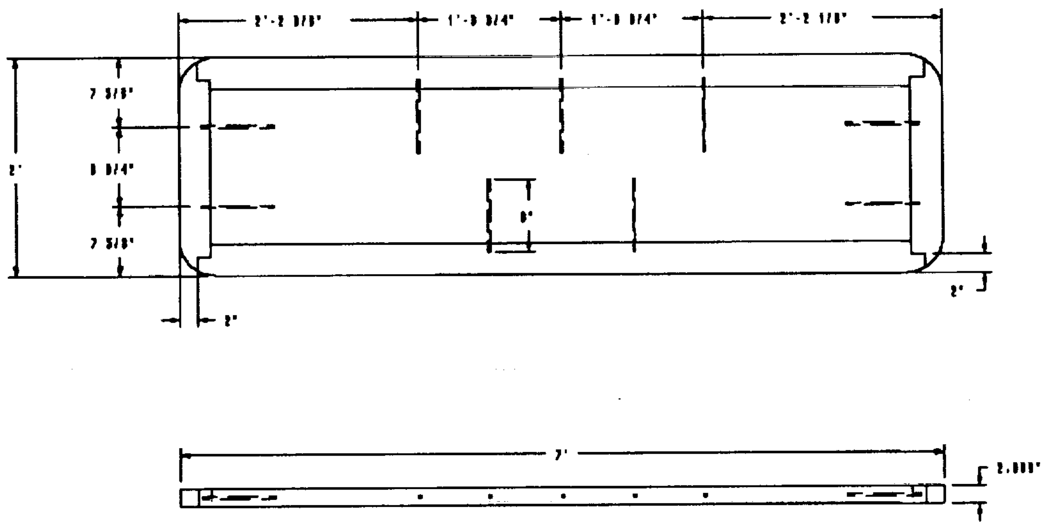
The EECM is composed of several sections, each serving a specific purpose. These sections must be securely attached to each other, yet be easily removed and replaced during testing[67]. The method employed uses four L-brackets made of angle iron and four 9 inch bolts placed in each of the corners of the EECM. The bolts pass through the angle iron from the bottom litter to the top litter and are secured by nuts and washers.

39.6.1 Fabricating the Attachment Brackets

39.6.1.1 Cut the 4 × 4 inch angle iron into eight 4 inch pieces.

39.6.1.2 Drill a 0.375 inch diameter hole in the center of the L-bracket, 1.5 inch from the inside (Figure 39.6.1.2.1).

2



QUANTITY - 1
ALL DIM. FOR RODS ARE ON CENTER
RODS ARE PLACED IN CENTER OF WOOD
ALL RODS ARE 8" LONG & 0.25" IN DIA.

Figure 39.5.1.8.1 Layer 2

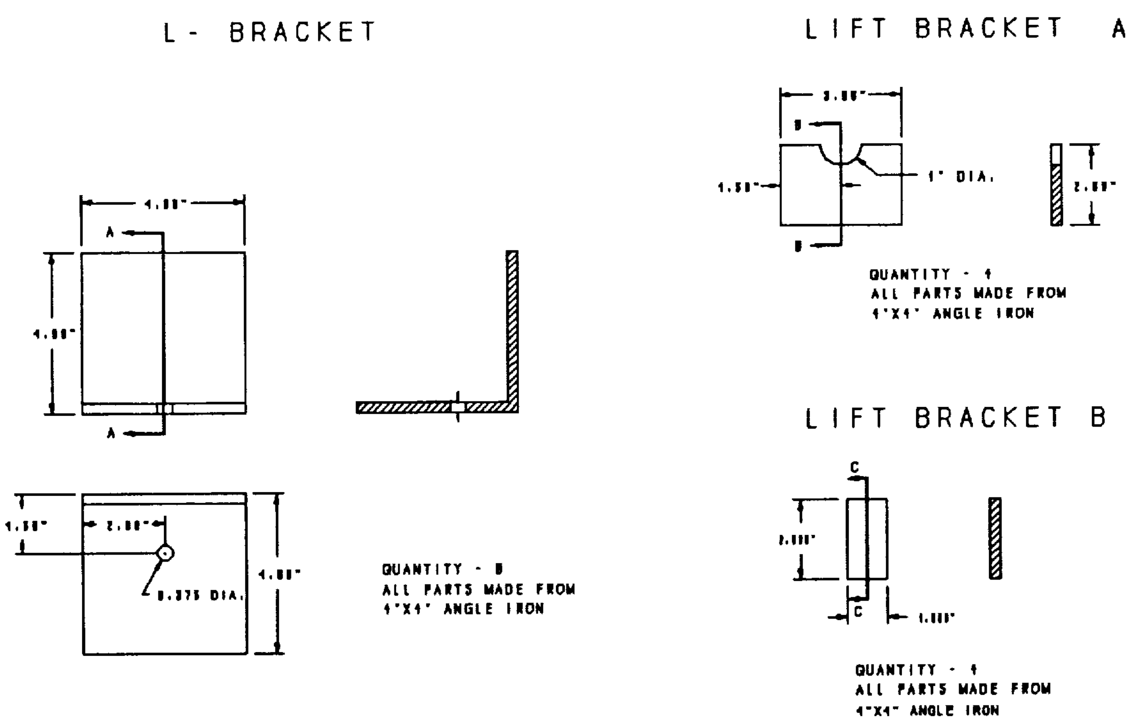


Figure 39.6.1.2.1 L-Brackets and Lift Attachment Brackets

39.6.1.3 Weld the brackets on the 7 foot sides of the top and bottom litters, 4 inches in from either end of the EECM (Figure 39.6.1.3.1).

39.7 LIFT ATTACHMENT POINTS (LAPs)

The LAPs vary according to the variation in CG to determine the configuration that provides optimal stability characteristics. The varying LAPs have different harness configurations. A harness consists of two cables that attach to the couch. Both ends of each cable are attached to each 7 foot side of the couch. The centers of each cable are drawn together to a point. This junction of the two cables is then attached to the helicopter cable. The device used to connect the cables to the EECM and to the helicopter hoist is a carabinier.

The EECM 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. A harness supplied by The 41st Air Rescue Squadron (PAFB) was used during testing.

The system that is implemented for the LAPs differs from the system that was described in the design optimization last semester.[68] Rather than rely on friction devices for securing the harness, a LAP bracket was developed. The first set of LAPs are small metal plates that are welded close to the spacers on the top litter. The carabinier fits securely between the spacer and the metal plate to prevent movement of the harness during testing. The second set of LAPs is designated by iron plates welded between the upper and lower tubular frames on the top litter. The carabinier is put through a semicircular opening cut in the iron plates and secured around the tubular frame.

39.7.1 Constructing the First Set of LAPs

39.7.1.1 Cut 4 × 4 inch angle iron into four 2 × 1 inch pieces (Figure 39.6.1.2.1).

39.7.1.2 Weld the 2 × 1 inch pieces to the top litter of the EECM, as per Figure 39.6.1.3.1.

39.7.2 Constructing the Second Set of LAPs

39.7.2.1 Cut four 2 × 3 inch pieces from the 4 × 4 inch angle iron.

39.7.2.2 Cut a 1 inch diameter semicircle at the top of each iron piece (Figure 39.6.1.2.1).

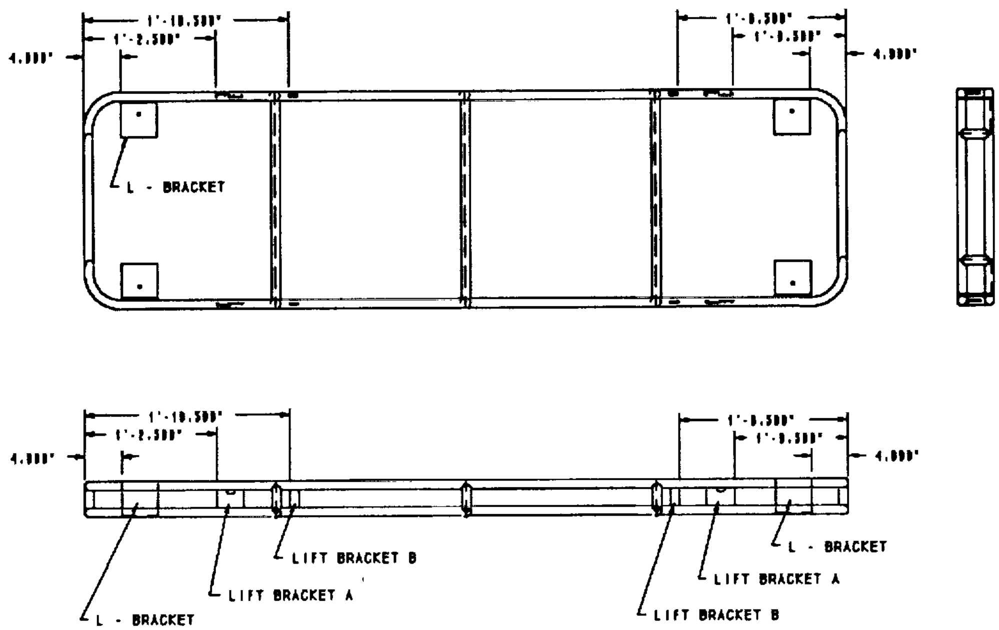


Figure 39.6.1.3.1 Locations of Layer Attachment Brackets

39.7.2.3 Weld these 2 × 3 inch pieces to the top litter of the EECM, as per Figure 39.6.1.3.1. This completes the LAPs. The harness can now be attached and secured through the brackets.

39.8 OVERALL CONSTRUCTION

The EECM consists of five sections. The top litter simulates a basic Stokes Litter and is made of chrome-moly steel tube. The Human Weight System is housed in the top litter and simulates the weight of a human. The weight system consists of a 102 pound dummy. The bottom litter, when added to the top litter, simulates a weighted medical couch. Like the top litter, the bottom litter is made of chrome-moly steel tube. The bottom litter contains the Medical Weight System, which simulates the weight of the medical equipment. This weight system incorporates support strips and two weight platforms. There are three wood layers attached between the top and bottom litters. These layers serve the dual purpose of augmenting the height of the EECM and supporting the flotation system. Polystyrene is used for the flotation system. The entire system is shown attached in Figure 39.8.1.

Other subsystems of the EECM include the litter attachment devices and the Lift Attachment Points (LAPs). Four L-brackets are welded to the top and bottom litters. Bolts pass through the sections and the L-brackets and are fastened by nuts. This provides a secure method of attaching the litters, yet is easily reconfigurable. There are two sets of LAPs. The first set is placed in the same location in the top litter as those in the Stokes litter. The second set is placed further out on the top litter and is for stability purposes during testing of the different EECM configurations.

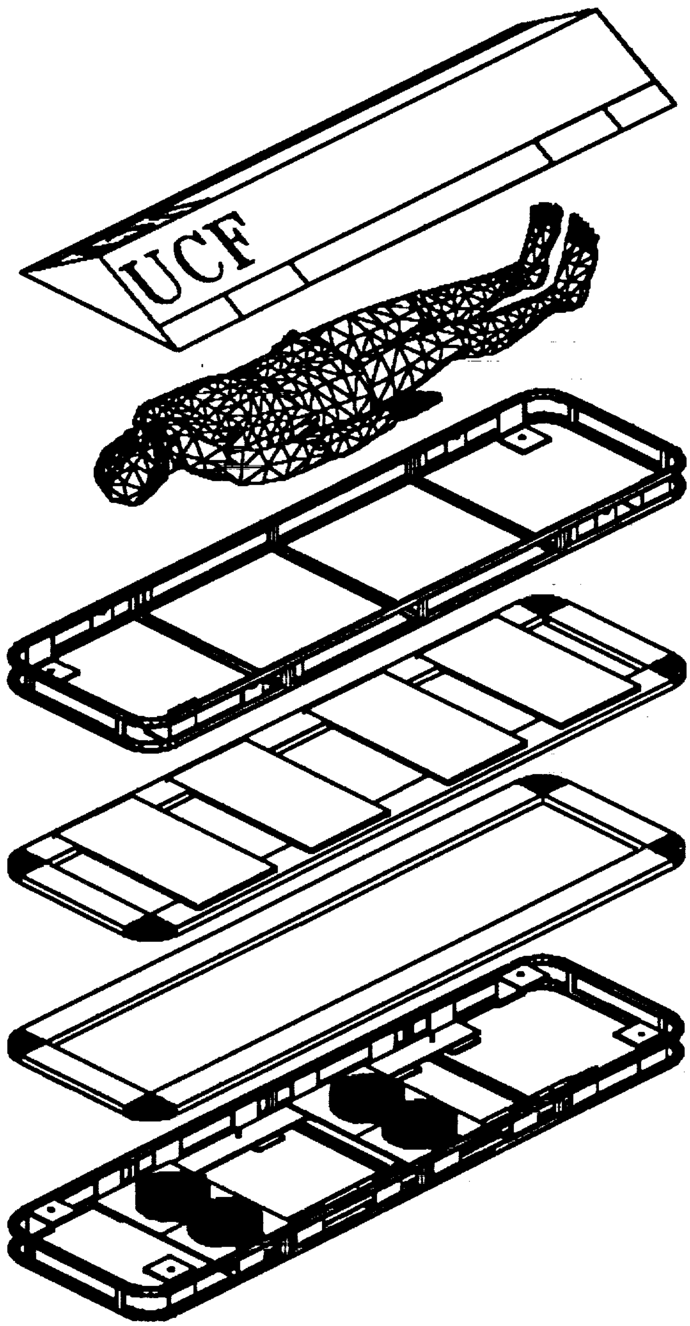


Figure 39.8.1 Complete Couch

TESTING PHASE

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 EECM met its specifications. The tests included verifying geometric constraints, weight, CG and mass moment of inertia variability, and safety. Phase II 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 EECM. Phase III testing was performed at the UCF pool. This testing phase consisted of flotation tests. The test plan and test results will be presented in this section.

Chapter 40.0 TEST PLAN

40.1 FACILITY DESCRIPTION:

PHASE I: Ground Evaluation	Engineering Building- Senior Design Laboratory University of Central Florida Orlando, FL 32826

Relevant Capabilities:

- Floor space for Phase I testing

PHASE II: Configuration Evaluation	Helicopter Hover Area Patrick Air Force Base Cocoa Beach, Fl 32931

Relevant Capabilities:

- H-3 Helicopter and Winch
- H-3 Helicopter Pilots
- H-3 Helicopter Flight Engineers
- H-3 Helicopter Pjs
- Viewing Area for Video Data Collection

PHASE III: Flotation Evaluation

UCF Pool
University of Central Florida Campus
Orlando, FL 32826

Relevant Capabilities:

- Swimming Pool - shallow end large enough to perform flotation testing
- Pool Deck - room for video equipment and configuration change

40.2 TESTING GOALS

1. Generate a Rating Sheet of geometric characteristics and have test operators give a rating for each (Appendix Q).
2. Identify the different dynamic characteristics of each EECM configuration for use in determining the optimum design of the EEC.

40.3 OBJECTIVES

40.3.1 Phase I - Ground Evaluation

1. Confirm that the EECM has no sharp edges.
2. Confirm that the length and width of EECM are 7 feet and 2 feet respectively.
3. Verify that the weights within the EECM can be fastened securely.
4. Verify changeable dynamic characteristics of the EECM (center of gravity and moment of inertia).
5. Ensure that the EECM can vary in height up to one foot.
6. Obtain weights of each section and ensure that the EECM can vary from 300 to 400 pounds.
7. Confirm that the EECM is capable of varying from a simple litter to a complex couch.

8. Ensure that the EECM components are fastened together securely.

40.3.2 Phase II - Configuration Evaluation

The tests performed during this phase will be completed for three EECM configurations. EECM-A weighs 296.5 pounds and has a height of 9 inches. EECM-B weighs 362 pounds and has a height of 10 inches. EECM-C weighs 400 pounds and has a height of 1 foot.

40.3.2.1 Compatibility Tests

1. Ensure that the EECM connections are secure.
2. Ensure that the EECM can be connected to the helicopter rescue cable.
3. Confirm that the harness configurations allow the EECM to be lifted higher than the floor of the helicopter.
4. Verify that each configuration of the EECM can be pulled into the helicopter by the flight engineer.

40.3.2.2 Spin Test

1. Ensure that each configuration (with cover) does not spin excessively while being raised by the helicopter.

40.3.2.3 Low Hover Test

1. During ascent to the helicopter, visually inspect the pitch of EECM-A, B, and C configurations (covered) with varying CGs, MoIs, and harness systems.
2. During ascent to the helicopter, visually inspect the yaw of EECM-A, B, and C configurations (covered) with varying CGs, MoIs, and harness systems.

40.3.2.4 High Hover Test

1. During ascent to the helicopter, visually inspect the pitch of EECM-A, B, and C configurations (covered) with varying CGs, MoIs, and harness systems.
2. During ascent to the helicopter, visually inspect the yaw of EECM-A, B, and C

configurations (covered) with varying CGs, MoIs, and harness systems.

40.3.2.5 Forward Flight Test

1. Visually inspect the stability characteristics of the EECM-A, B, and C configurations (covered) with varying CGs, MoIs, and harness systems as the helicopter performs slow forward flight.

40.3.3 Phase III - Flotation Evaluation

1. Verify that the EECM can float up-right with a maximum weight of 400 lbs.

40.4 TEST VARIATIONS

The tests involve a number of variations to the configuration of the EECM. A variety of testing was completed to determine the effects that each parameter has on the EECM (Figure 40.4.1).

1. Three test EECM configurations are evaluated:

   a. EECM-A: 296.5 lbs, 9 in high
   b. EECM-B: 362 lbs, 10 in high
   c. EECM-C: 400 lbs, 1 ft high

2. Three CG/MoI locations are evaluated per EECM configuration:

   a. <1> (CG at center: Platforms at center)
   b. <2> (CG at center: Platforms at ends)
   c. <3> (CG forward)

3. Two harness configurations are evaluated per EECM configuration:

   a. <H-1> (Uses inside LAPs)
   b. <H-2> (Uses outside LAPs)

It is not feasible to test all of the combinations of these variations in one day. Therefore, a test matrix was made to determine which tests would be attempted to provide a conglomeration of information (Figure 40.4.1). Results of combinations not tested will be deduced from results of those tested.

Run Number	EECM	CG/MoI	Harness
1	A	<1>	<H-1>
2	A	<2>	<H-2>
3	A	<3>	<H-1>
4	B	<1>	<H-1>
5	B	<2>	<H-1>
6	B	<3>	<H-1>
7	C	<1>	<H-1>
8	C	<2>	<H-1>
9	C	<3>	<H-1>

Figure 40.4.1 Test Matrix

40.5 EECM TEST SEQUENCE

The test plan sequence contains the basic outline of the flow of procedures for the EECM configurations. Detailed procedures are provided in the next section. Revisions to test conditions, configuration, or procedures may be made at any point to improve test results.

All data from each phase of the testing will be thoroughly reviewed before initiation of the next phase. This will insure that all the procedures, hardware, and data extraction are functioning properly and the EECM is up to specifications before entering a new facility.

A. Phase I - Ground Evaluation
   1. Verify integrity of all components
   2. Verify mass properties
   3. Perform all configuration changes

B. Phase II - Configuration Evaluation
   1. Perform compatibility tests
   2. Perform spin test
   3. Perform low hover test
   4. Perform high hover test
   5. Perform slow forward flight test

C. Phase III - Flotation Evaluation
   1. Verify flotation capability of EECM

40.6 EECM TEST PROCEDURES

40.6.1 Phase I - Ground Evaluation

1. Verify through visual and touch inspection that EECM edges are not sharp.

2. Confirm that the length and width of the EECM are 7 x 2 feet respectively by measuring them with a tape measure.

3. Verify, by moving and inverting the litters, that the weights within the EECM are securely fastened.
   a. Check Human Weight System
   b. Check Medical Weight System

4. Balance couch on a wedge to determine CG. Measure CG and MoI variation capability of EECM
   a. Measure CG locations on Medical Weight System with a tape measure
      (1) Determine location of CG at position 1
      (2) Determine location of CG at position 2
      (3) Determine location of CG at position 3
   b. Determine corresponding MoI for each CG location
      (1) Calculate MoI for CG at position 1
      (2) Calculate MoI for CG at position 2
      (3) Calculate MoI for CG at position 3

5. Measure height of EECM components with a tape measure, confirm total height of 1 foot
   a. Measure with tape measure height of top litter (H_1)
   b. Measure with tape measure height of bottom litter (H_2)
   c. Measure with tape measure height of wood layers (H_3,H_4,H_5)
   d. Confirm that $H_1+H_2+H_3+H_4+H_5 = 1$ ft

6. Weigh each section of the EECM on a scale, record data and confirm the weights of EECM-A, EECM-B, EECM-C
   a. Weigh top litter (W_1)
   b. Weigh bottom litter (W_2)
   c. Weigh 2" wood layer (W_3)
   d. Weigh 1" upper wood layer-1 (W_4)
   e. Weigh 1" lower wood layer-2 (W_5)
   f. Weigh Harness System (W_6)
   g. Weigh Weights incorporated in Weight Systems (W_7)
   h. Weigh EECM-A ($W_1+W_2+W_4+W_6+W_7$)
   i. Weigh EECM-B ($W_1+W_2+W_3+W_4+W_5+W_6+W_7$)
   j. Weigh EECM-C ($W_1+W_2+W_3+W_4+W_5+W_6+W_7$)

7. Confirm, by bolting the layers and litters together, that the EECM varies from a simple litter to a full-sized couch (7 x 2 x 1 feet).

8. Ensure that the EECM sections are fastened together securely by pulling at each section.

40.6.2 Phase II - Configuration Evaluation

40.6.2.1 Compatibility Tests

1. Confirm, through inspection, and by pulling and/or yanking, that the EECM harness connections are secure.

2. Ensure that the EECM can be connected to the helicopter rescue cable by physically hooking the harness system to the cable hook.

3. Confirm that the harness systems allow the EECM configurations to be lifted higher than the floor of the H-3 helicopter.
   a. Attach harness system-1 to helicopter hook and check, through visualization, that the EECM is above the floor of the helicopter.
   b. Repeat above step for harness system-2.

4. Verify that EECM-A, B, and C can be pulled into the helicopter by the flight engineer.
   a. Configure, hook up, lift, and pull in EECM-A
   b. Repeat for EECM-B
   c. Repeat for EECM-C

40.6.2.2 Spin Test

1. Ensure that the EECM does not spin excessively while being raised by the helicopter while a PJ performs a spin test.
   a. Configure, hook up and perform spin test on EECM-A
   b. Repeat for EECM-B
   c. Repeat for EECM-C

40.6.2.3 Low Hover Test

1. During ascent to the helicopter, record on videotape the pitch of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

2. During ascent to the helicopter, record on videotape the yaw of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

40.6.2.4 High Hover Test

1. During ascent to the helicopter record on videotape the pitch of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

2. During ascent to the helicopter record on videotape the yaw of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B

c. Repeat for EECM-C

40.6.2.5 Forward Flight Test

1. While hanging from the hoist of the helicopter performing slow forward flight, record on videotape the stability of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

40.6.3 Phase III - Flotation Evaluation

1. Verify that the EECM can float upright by placing it into a pool while in different configurations:

   First configuration:
   No weights in the Human Weight System or the Medical Weight System.

   Second configuration:
   180 lbs in the Human Weight System and no weight in the Medical Weight System.

   Third configuration:
   No weight in the Human Weight System, 40 lbs in the Medical Weight System.

   Fourth configuration:
   180 lbs in the Human Weight System and 40 lbs in the Medical Weight System.

40.7 SAFETY

Safety is a critical component of testing and has been integrated into the evaluation of the EECM. Each facility required for this test has safety and operating procedures that must be adhered to.

40.7.1 EECM Test Features

Several safety features will be integrated into the design of the EECM and its tests:

1. The EECM has a means of attaching a tag line while being lifted by the helicopter.
2. Cables have a rating of 3000 pounds (couch max = 400 pounds).
3. As specified by PAFB, maximum testing weight of EECM is 400 pounds. The H-3 helicopter winch is rated at 600 pounds.
4. Each configuration shall be weighed by a scale to plus or minus 1 pound.
5. All weights shall be weighed with a scale. Each weight shall be permanently marked with the correct weight.
6. A proof test will be completed before flight tests are performed.

Chapter 41.0 PRESENTATION OF TEST RESULTS

41.1 PHASE I - GROUND EVALUATION

1. Test: Verify through visual and touch inspection that EECM edges are not sharp.

   Results: All edges are smooth.

2. Test: Confirm that the length and width of the EECM are 7 x 2 feet respectively by measuring them with a tape measure.

   Results: Measurements are 7 × 2 feet.

3. Test: Verify, by moving and inverting the litters, that the weights within the EECM are securely fastened.
   a. Check Human Weight System
   b. Check Medical Weight System

   Results: Both weight systems are securely fastened.

4. Test: Measure CG and MoI variation capability of EECM

a. Measure CG locations on Medical Weight System with a tape measure
   (1) Determine location of CG at position 1
   (2) Determine location of CG at position 2
   (3) Determine location of CG at position 3
b. Determine corresponding MoI for each CG location
   (1) Calculate MoI for CG at position 1
   (2) Calculate MoI for CG at position 2
   (3) Calculate MoI for CG at position 3

Results: a. CGs are as follows (assuming human weight system at center):
   (1) CG = at center.
   (2) CG = at center.
   (3) CG = 8.125 inches from center toward head.
b. MoI are as follows:
   (1) MoI = 57.518 in^4
   (2) MoI = 57.556 in^4
   (3) MoI = 63.585 in^4

5. Test: Measure height of EECM components with a tape measure, confirm total height of 1 foot

Results: Measurements are as follows:
   a. Top litter (H_1) = 4 in
   b. Bottom litter (H_2) = 4 in
   c. Total height of wood layers (H_3 = 2 in, H_4 = 1 in, H_5 = 1 in) total ($H_3+H_4+H_5$) = 4 in
   d. Total height of EECM ($H_1+H_2+H_3+H_4+H_5$) = 1 ft

6. Test: Weigh each section of the EECM on a scale, record data and confirm the weights of EECM-A, EECM-B, EECM-C

Results: Weights are as follows:
   a. Top litter (W_1) = 55.5 lbs.
   b. Bottom litter (W_2) = 97 lbs.
   c. 2" wood layer (W_3) = 25.75 lbs.
   d. 1" wood layer-1 (W_4) = 26.5 lbs.
   e. 1" wood layer-2 (W_5) = 15.5 lbs.
   f. Harness System (W_6) = 3.75 lbs.
   g. Weights incorporated in Weight Systems (W_7)
      1. Human Weight System (variable)
         i. Empty (0 lbs)

ii. Dummy (102 lbs)
iii. Human (180 lbs)
2. Medical Weight System (variable) added weights of:
i. 3 lbs increments
ii. 10 lbs increments

h. EECM-A: W_7 = 0 lbs (Human Weight System) + 92 lbs (Medical Weight System) = 182 lbs.
$(W_1+W_2+W_4+W_6+W_7)$ = 296.5 lbs.

i. EECM-B: W_7 = 102 lbs (Human Weight System) + 40 lbs (Medical Weight System) = 142 lbs.
$(W_1+W_2+W_3+W_4+W_5+W_6+W_7)$ = 362 lbs.

j. EECM-C: W_7 = 102 lbs (Human Weight System) + 80 lbs (Medical Weight System) = 400.
$(W_1+W_2+W_3+W_4+W_5+W_6+W_7)$ = 400 lbs.

7. Test: Confirm, by bolting the layers and litters together, that the EECM varies from a simple litter to a full-sized couch (7 x 2 x 1 feet).

Results: The top litter stands alone to form a simple litter. The other layers and bottom litter can be bolted to the top litter to form a full-sized couch (7 x 2 x 1 feet).

8. Test: Ensure that the EECM sections are fastened together securely by pulling at each section.

Results: All sections of the EECM remained fastened together securely. There is no motion relative to other sections.

41.2 PHASE II - CONFIGURATION EVALUATION

41.2.1 Compatibility Tests

1. Test: Confirm, through inspection, and by pulling and/or yanking, that the EECM harness connections are secure.

Results: Harness connections are secure.

2. Test: Ensure that the EECM can be connected to the helicopter rescue cable by physically hooking the harness system to the cable hook.

   Results: Harness system attached successfully to the cable hook.

3. Test: Confirm that the harness systems allow the EECM configurations to be lifted higher than the floor of the H-3 helicopter.

   Results: A visual inspection verified that both systems are able to be lifted higher than the floor. Then each system is successfully verified by lifting the couch into the H-3.

4. Test: Verify that EECM-A, B, and C can be pulled into the helicopter by the flight engineer.

   Results: The flight engineer successfully pulled the EECM-A and B configurations into the helicopter. He reported, however, that the weight and rectangular configuration of the EECM made it difficult. Configuration C was not tested.

41.2.2 Spin Test

1. Test: Ensure that EECM does not spin excessively (in all configurations) while being raised by the helicopter with a PJ performing a spin test.

   Results: EECM-A and B were tested with the cover on. Neither configurations spun excessively. Then configuration B was tested without the cover. It was found to spin. The spin compared to the Stoke's Litter when it was lifted. During spin test on EECM-A <H-2> the harness bent at a 90 degree angle at the top crimp for cable fatigue reasons. This was unacceptable so further testing of <H-2> was ceased. EECM-C was not tested.

41.2.3 Low Hover Test

1. Test: During ascent to the helicopter record on videotape the pitch of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>

b. Repeat for EECM-B
c. Repeat for EECM-C

Results: Configuration EECM-B <2> <H-1> tended to bounce below the helicopter. EECM-B <3> <H-1> had a tendency to oscillate while in low hover. Pitch was recorded and was not found to be excessive. EECM-C was not tested.

2. Test: During ascent to the helicopter record on videotape the yaw of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

Results: Yaw was recorded for EECM-A and B and was not found to be excessive. EECM-C was not tested.

41.2.4 High Hover Test

1. Test: During ascent to the helicopter record on videotape the pitch of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

Results: Pitch was recorded for EECM-A and B and was not found to be excessive. EECM-C was not tested.

2. Test: During ascent to the helicopter record on videotape the yaw of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

Results: Yaw was recorded for EECM-A and B and was not found to be excessive. EECM-C was not tested.

41.2.5 Forward Flight Test

1. Test: While hanging from the hoist of the helicopter performing slow forward flight, record on videotape the stability of:
   a. EECM-A with configurations:
      (1) <1>,<H1>
      (2) <2>,<H2>
      (3) <3>,<H1>
   b. Repeat for EECM-B
   c. Repeat for EECM-C

Results: Stability was recorded for EECM-A and B. EECM-B <3> <H-1> had some tendency to oscillate. The rest of the EECM configurations appeared very stable. They flew feet first into the wind and spinning ceased.

41.3 PHASE III - FLOTATION EVALUATION

1. Test: Verify that the EECM can float up-right by placing it into a pool while in different configurations:

Results: With no weight in the human weight system or the medical weight system the EECM floated roughly 6 inch deep in water and righted itself up to a 95 degree tilt.

The EECM floated approximately 8 inch deep in the water and righted itself up to a 90 degree tilt with 180 pounds in the human weight system and no weight in the medical weight system.

With no weight in the human weight system and 40 pounds in the medical weight system the EECM floated approximately 7 inches deep in the water and righted itself up to a 115 degree tilt.

The EECM floated approximately 9 inches deep in the water and righted itself up to a 110 degree tilt with 180 pounds in the human weight system and 40 pounds in the medical weight system.

Each configuration rocked from side to side. The internal floats do not stay perfectly level. None of the configurations right themselves if inverted.

Chapter 42.0 OBSERVATIONS AND RECOMMENDATIONS

Based upon results from testing and input from PAFB personnel, several recommendations are made. The EECM is difficult to work with because it is bulky. The test flight engineer recommended a shorter length (6.5 ft) and a tapered width. Contouring the couch to the human form similar to the Stokes Litter, was recommended by PAFB test personnel to further enhance the handling characteristics of the EEC. Also suggested was placing medical equipment around the body in the top litter to more efficiently use volume (Figure 42.0.1).

The flight engineer pulls the litter into the helicopter head first. Having the CG forward makes it possible to pull the EEC into the helicopter with less effort. Hence, the optimum weight distribution is recommended with the CG forward. Since one flight engineer pulls the EEC into the helicopter, it is recommended the weight of the EEC be kept to a minimum.

The helicopter used during testing was an H-3. The H-3 is being phased out and the H-60 will take its place. The H-60 has a much smaller cabin and a lower ceiling than the H-3. Because of this, the flight engineer will be on his knees when attempting to retrieve the EEC. Use of a collapsible couch should be investigated as a possible method of optimizing space within the H-60 cabin. Attention should also be given to the harness height to ensure the EEC fits through the door. Special consideration must be given to the design of the EEC to fit the H-60 since the H-60 is the helicopter that will actually be used in rescue missions from Space Station Freedom.

Flotation tests revealed the EECM to be buoyant when all layers containing polystyrene were 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 are recommended. We concur with the PAFB pararescue jumpers recommendation that the EEC cover be easily detachable should it become necessary to remove it in water.

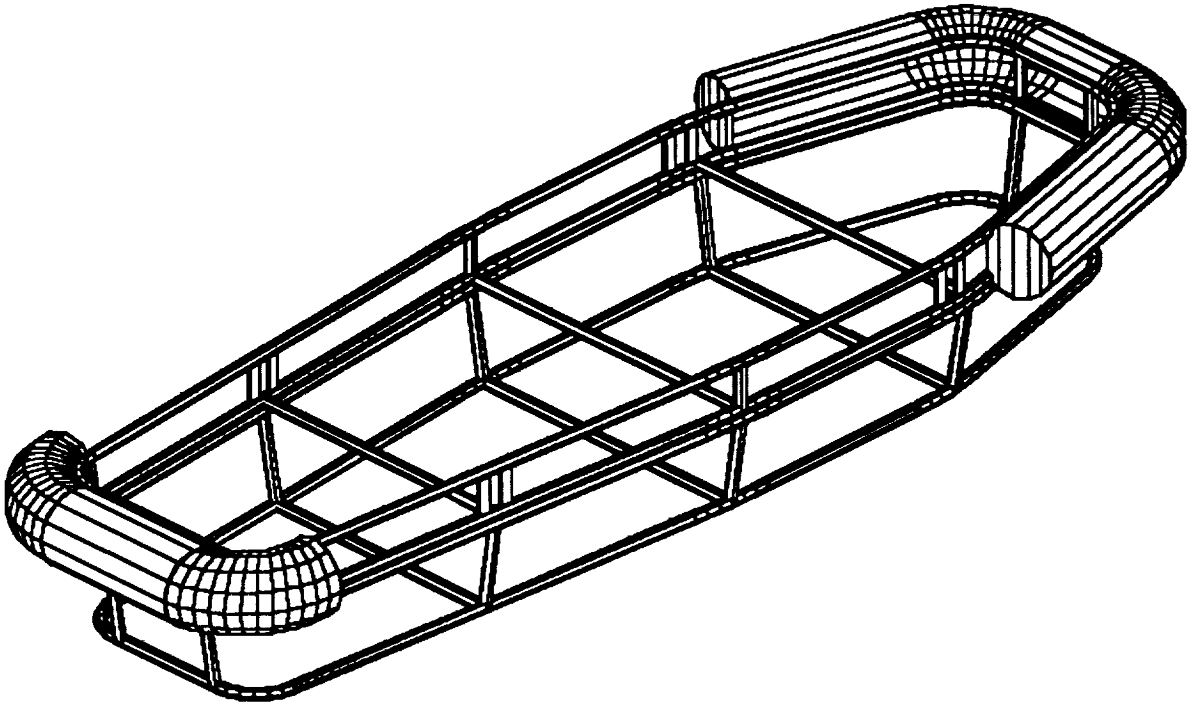


Figure 42.0.1 Recommended Configuration

SECTION V

ASSURED CREW RETURN VEHICLE POST LANDING CONFIGURATION DESIGN AND TEST

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SECTION V. 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 redesigned 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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APPENDICES

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APPENDIX A

BUCKINGHAM PI VARIABLES

Quantity	Symbol	Dimensions
length	L	L
area	A	L^2
volume	V	L^3
density	ρ	ρ
mass	M	ρL^3
moment	I	ML^2

Figure A-1 Buckingham Pi Variables

APPENDIX B

ACMD CONFIGURATION MODEL

DECISION MATRICES

SYSTEM \ DESIGN PARAMETERS	COST	DURABILITY	RIGIDITY	CONSTRUCTION TECHNIQUE	WEIGHT	SAFETY	REINFORCEMENT	WATERPROOF	REPAIR	TOTALS
WEIGHT FACTOR	10	7	7	8	9	5	4	10	7	
WOOD	18	16	12	8	12	10	16	2	5	674
FIBERGLASS	13	12	10	10	15	11	10	20	15	844
PLASTIC	6	8	5	3	18	16	8	20	4	589
ALUMINUM	2	18	15	6	7	8	18	20	15	732

Figure B-1 Materials Matrix

SYSTEM \ DESIGN PARAMETERS	INTERIOR ACCESS	INTERIOR VISIBILITY	LOCATION WRT WATER LINE	REATTACHMENT	SHELL STRENGTH	CONSTRUCTION SIMPLICITY	SAFETY	DEPENDENCE ON MATERIAL	HOW SEALABLE EASE OF FASTENING	TOTALS
WEIGHT FACTORS	10	8	10	10	8	4	5	5	6	
UPPER DECK	6	4	18	18	18	18	12	8	15	858
BACK DOOR	13	13	15	13	10	17	9	8	5	777
HORIZONTAL	18	18	12	5	18	8	14	15	18	923

Figure B-2 Sectioning Matrix

SYSTEM \ DESIGN PARAMETERS	COST	AVAILABILITY	# FASTENERS NEEDED	EFFECTIVENESS	ATTACHMENT METHOD	SAFETY	TOTALS
WEIGHT FACTOR	8	8	6	10	5	1	
O-RING	1	1	12	18	10	20	318
GASKET	18	18	12	16	19	20	615
WEATHERSTRIP	15	12	7	4	12	20	358
APPLIANCE-TYPE	10	5	7	2	12	20	242

Figure B-3 Seals Matrix

SYSTEM / DESIGN PARAMETERS	SPACE REQUIREMENT	COMPLEX TO ADJUST	MATH MODELING	COST	AVAILABILITY	CONSTRUCTION COMPLEXITY	TOTAL WEIGHT REQUIRED TO ADJUST	ACCURACY	SAFETY-SECURED	TOTALS
WEIGHT FACTORS	10	8	6	3	5	6	8	10	4	
FLAT PLATE	12	13	19	10	5	18	6	5	9	659
PERIPHERAL	15	10	10	15	15	15	18	5	12	792
RADIAL	10	17	15	6	12	12	15	13	11	806
COMBINATION	9	10	5	3	8	5	14	19	10	630

Figure B-4 Center of Gravity/Mass Moment of Inertia Matrix

SYSTEM \ DESIGN PARAMETERS	ROTATION/SWAY	SAFETY	SURFACE TENSION	EASE OF ATTACHMENT	SUBSYSTEM INTERFERANCE	TOTALS
WEIGHT FACTORS	8	10	2	5	5	
MULTI. VERTICAL	14	17	5	13	15	432
MULTI. ANGLED	17	17	12	13	15	470
SINGLE ANGLED	5	4	12	18	18	284
NET	10	15	12	3	3	284

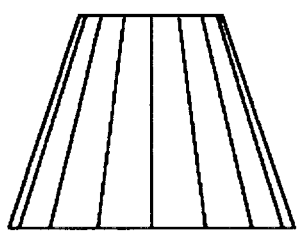
Figure B-5 Lift Attachment Point Matrix

APPENDIX C

ACMD CONFIGURATION MODEL

MATHEMATICAL MODELING

$$I_y = I_z = 1/12[m(3r^2 + h^2)]$$



$$I_y = I_z = 3/5[m(.25r^2 + h^2)]$$

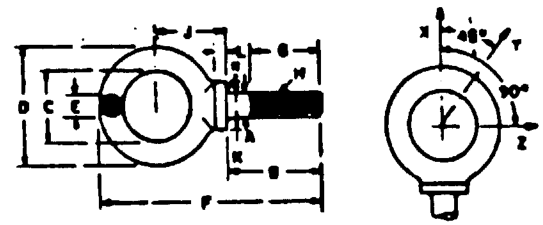
Direct Integration

Figure C-1 Math Model

APPENDIX D

ACMD CONFIGURATION MODEL

EYE BOLT CHART



Nominal Size		A Shank Dia	B Shank Length	C Eye ID	D Nominal Eye OD	E Eye Sect. Dia	F Overall Length	G Min. Length Full Thread	H Thread Size UNC-2A	J ℄ Eye To Shoulder	K Shoulder Dia	L Shoulder Height	R Radius Under Shoulder	W_x [1] Safe Working Load, lb, at 0°	W_y 45°	W_z 90°
1/4"	0.25	0.25 0.28	1.00 1.06	0.69 0.81	1.19	0.19 0.25	2.22 2.53	0.75	1/4-20 or .250-20	0.69 0.81	0.50 0.56	0.12 0.19	0.015 0.025	400	100	90
5/16"	0.31	0.31 0.34	1.12 1.19	0.81 0.94	1.44	0.25 0.31	2.66 2.97	0.81	5/16-18 or .3125-18	0.88 1.00	0.56 0.62	0.12 0.19	0.015 0.025	800	200	160
3/8"	0.38	0.38 0.41	1.25 1.38	0.94 1.06	1.69	0.31 0.38	3.09 3.47	0.88	3/8-16 or .375-16	1.06 1.19	0.62 0.69	0.12 0.19	0.015 0.025	1400	350	290
7/16	0.44	0.44 0.47	1.38 1.50	1.00 1.12	1.81	0.34 0.41	3.41 3.78	1.00	7/16-14 or .4375-14	1.19 1.31	0.75 0.81	0.19 0.25	0.015 0.025	2000	500	400
1/2"	0.50	0.50 0.53	1.50 1.62	1.12 1.25	2.12	0.44 0.50	3.81 4.19	1.12	1/2-13 or .500-13	1.31 1.44	0.88 0.94	0.19 0.25	0.015 0.025	2600	652	520
9/16	0.56	0.56 0.59	1.62 1.75	1.19 1.31	2.25	0.47 0.53	4.19 4.56	1.25	9/16-12 or .5625-12	1.50 1.62	0.94 1.00	0.22 0.28	0.020 0.045	3000	750	[illegible]
5/8"	0.62	0.62 0.66	1.75 1.88	1.31 1.44	2.56	0.56 0.62	4.56 4.94	1.38	5/8-11 or .625-11	1.59 1.72	1.00 1.06	0.25 0.31	0.020 0.045	4000	1000	800
3/4"	0.75	0.75 0.78	2.00 2.12	1.44 1.56	2.81	0.62 0.69	5.06 5.50	1.62	3/4-10 or .750-10	1.72 1.91	1.12 1.25	0.25 0.31	0.020 0.045	6000	1500	1200
7/8"	0.88	0.88 0.91	2.25 2.38	1.56 1.69	3.19	0.75 0.81	5.75 6.19	1.81	7/8-9 or .875-9	2.03 2.22	1.31 1.44	0.31 0.38	0.040 0.065	6600	1570	1330
1"	1.00	1.00 1.06	2.50 2.62	1.69 1.81	3.56	0.88 0.94	6.44 6.38	2.06	1-8 or 1.000-8	2.22 2.41	1.50 1.62	0.33 0.44	0.060 0.095	9000	2000	1600
1 1/8	1.12	1.12 1.19	2.75 2.88	1.94 2.06	4.06	1.00 1.06	7.31 7.75	2.31	1 1/8-7 or 1.125-7	2.59 2.78	1.69 1.91	0.44 0.50	0.060 0.095	10000	2500	2000
1 1/4"	1.25	1.25 1.34	3.00 3.12	2.12 2.25	4.44	1.09 1.16	8.00 8.44	2.50	1 1/4-7 or 1.250-7	2.94 3.03	1.98 2.00	0.50 0.56	0.060 0.095	15000	3750	3000
1 1/2"	1.50	1.50 1.59	3.50 3.62	2.44 2.56	5.19	1.31 1.38	9.22 9.72	3.00	1 1/2-6 or 1.500-6	3.19 3.44	2.12 2.25	0.50 0.62	0.060 0.095	18000	4500	3600
1 3/4	1.75	1.75 1.84	3.75 3.88	2.75 3.00	6.00	1.50 1.52	10.50 11.12	3.19	1 3/4-5 or 1.750-5	3.59 4.12	2.50 2.62	0.50 0.62	0.060 0.095	22000	5500	4400
2"	2.00	2.00 2.99	4.00 4.12	3.06 3.44	6.88	1.75 1.38	11.35 12.22	3.38	2-4 1/2 or 2.000-4.50	4.25 4.50	2.59 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure D-1 Eye Bolt Chart

APPENDIX E

ACMD CONFIGURATION MODEL

SPECIFICATIONS

1.0 SCOPE

1.1 Scope. This specification defines the subsystem performance requirements and operational constraints for the design, building, and testing of a one-fifth scale representation of the Assured Crew Return Vehicle (ACRV)/Model Construction subsystem (MCS). These subsystem performance requirements and operational constraints were developed in accordance with JSC-31017 "CERV (Crew Emergengy Return Vehicle) Systems Performance and Requirements Document" and other appropriate documents described in section 2.0.

1.2 Purpose. The purpose of this document is to formally establish the ACRV/Model Construction baseline performance requirements to be used during the ACRV/Model Construction design definition period and subsequent building and testing phases. This document will be revised to incorporate all approved additional or modified requirements into this baseline.

1.3 Definition. This document provides the performance requirements and operational constraints for the ACRV/Model Construction subsystem (MCS) only. The ACRV system, as a whole, encompasses all of the flotation and lift hardware and software that are required to provide a simulated water rescue of the Space Station Crew.

2.0 APPLICABLE DOCUMENTS

2.1 Specifications.

2.1.1 Federal. None

2.1.2 Military. None

2.1.3 NASA.

JSC-31017	ACRV System Performance and Requirements Document.

2.1.4 Contractor. None

2.2 Standards.

2.2.1 Federal. None

2.2.2 Military. None

2.2.3 NASA. None

2.2.4 Contractor. None

2.3 Drawings.

2.4 Bulletins. None

2.5 Other Documents.

2.5.1 Manuals. None

2.5.2 Handbooks. None

2.5.3 Textbooks.

Mechanics of Machines; Samuel Doughty; Wiley; 1988.

Vibration of Mechanical and Structural Systems; G. M. Smith, M. L. James, J. C. Wolford, P. W. Whaley; Harper and Row; 1989.

Vector Mechanics for Engineers; F. P. Beer, E. R. Johnston; McGraw-Hill; 1988.

3.0 REQUIREMENTS

3.1 Description. This section pertains to the requirements that apply to the design of the Apollo Command Module Derivative (ACMD) one-fifth scale model.

3.2 Performance Requirements.

3.2.1 General Performance Requirements.

3.2.1.1 Vehicle.

3.2.1.1.1 The MCS shall be 1/5 scale of ACMD geometrically.

3.2.1.1.2 The MCS shall be 1/5 scale of ACMD dynamically.

3.2.1.1.3 The MCS shall have a hatch that opens.

3.2.1.1.4 The MCS shall provide accessible interior space.

3.2.1.1.5 The MCS shall be rigid.

3.2.1.1.6 The MCS shall be water resistant and take on minimal water.

3.2.1.1.7 The MCS shall provide space for 1/5 scale flotation devices.

3.2.1.1.8 The MCS shall provide space for a 1/5 scale egress couch.

3.2.1.2 Lift Mechanism.

3.2.1.2.1 Lift Device.

3.2.1.2.1.1 The lift device (LD) shall be capable of lifting the MCS out of the water.

3.2.1.2.1.2 The LD shall lift vehicle with minimal rotation and sway.

3.2.1.2.2 Lift Attachment.

3.2.1.2.2.1 The lift attachment (LA) shall be located in same position as on ACMD.

3.2.1.2.2.2 The LA shall be permanently attached to vehicle.

3.2.1.2.2.3 The LA shall be accessible in water.

3.2.1.2.2.4 The LA shall be placed for minimum rotation and sway.

3.2.1.3 Hatch.

3.2.1.3.1 The hatch shall open and lock into position.

3.2.1.3.2 The hatch shall open the same way as the ACMD hatch.

3.2.1.3.3 The hatch shall lock in an open position.

3.2.1.3.4 The hatch shall be capable of supporting the weight of the egress couch.

3.2.1.3.5 The hatch shall be water resistant.

3.2.2 Specific Performance Requirements.

3.2.2.1 Vehicle.

3.2.2.1.1 The MCS dimensions are defined in figure 1.0.2

3.2.2.1.2 The dimensions for the center of gravity and mass moment of inertia for the MCS are TBD. The weight of the vehicle must be 128 plus or minus TBD pounds.

3.2.2.1.3 The MCS shall incorporate a 1/5 scale access hatch.

3.2.2.1.4 Access must be provided for the addition of weights, any required measuring devices, and the 1/5 scale egress couch to the interior of the MCS. The method of access and the volume of the interior TBD.

3.2.2.1.5 The MCS material TBD shall be rigid enough to support a TBD weight.

3.2.2.1.6 The material of the MCS shall allow no more than TBD water to enter the vehicle during testing.

3.2.2.1.7 The MCS shall incorporate the 1/5 scale model flotation devices. The placement TBD must coincide geometrically with that on the actual ACMD.

3.2.2.1.8 The MCS shall incorporate the 1/5 scale model egress couch and its extension mechanism. The mounting of the egress couch TBD.

3.2.2.2 <u>Lift Mechanism.</u>

3.2.2.2.1 <u>Lift Device.</u>

3.2.2.2.1.1 The LD TBD shall be capable of lifting the vehicle out of the water test facility.

3.2.2.2.1.2 The LD shall lift the vehicle out of the water with rotation and sway limits TBD.

3.2.2.2.2 Lift Attachment.

3.2.2.2.2.1 The LA position TBD shall be geometrically located in the same position as the LA on the ACMD.

3.2.2.2.2.2 The method of permanent attachment of the LA TBD.

3.2.2.2.2.3 The LA shall be accessible to the LD when the MCS is floating in the water test facility.

3.2.2.2.2.4 The LA placement TBD shall keep the MCS rotation and sway within TBD limits.

3.2.2.3 Hatch.

3.2.2.3.1 The MCS hatch shall simulate the movement, position, and attachment of the ACMD hatch.

3.2.2.3.2 The hatch shall open downward into a horizontal position.

3.2.2.3.3 Once the hatch is open it should lock into place so that its movement is prohibited.

3.2.2.3.4 When locked into an open position the hatch must be capable of supporting the weight of the egress couch.

3.2.2.3.5 The hatch should allow no more than TBD water into the MCS.

3.3 Operational Requirements.

3.3.1 General Operational Requirements.

3.3.1.1 Vehicle.

3.3.1.1.1 The MCS shall operate in water conditions.

3.3.1.1.2 The interior of the MCS shall be accessible for any equipment or weight changes required during testing.

3.3.1.1.3 All added weights shall be rigid and attached to the MCS to prevent vibrating or shifting during tests.

3.3.1.1.4 All MCS access openings must be water resistant.

3.3.1.1.5 The egress couch model must deploy over the opened hatch of the MCS.

3.3.1.2 <u>Lift Mechanism.</u>

3.3.1.2.1 <u>Lift Device.</u>

3.3.1.2.1.1 The LD shall attach to MCS so retrieval from water is possible.

3.3.1.2.2 <u>Lift Attachment.</u>

3.3.1.2.2.1 The LA will lift the MCS at TBD angle.

3.3.1.3 <u>Hatch.</u>

3.3.1.3.1 The hatch shall be hinged at the bottom.

3.3.1.3.2 The hatch will have a locking mechanism.

3.3.2 <u>Specific Operational Requirements.</u>

3.3.2.1 Vehicle.

3.3.2.1.1 The MCS shall operate under simulated Sea State 4 conditions.

3.3.2.1.2 The MCS shall allow test personnel access to its interior.

3.3.2.1.3 The method of securing weights and equipment to the inside of the MCS TBD.

3.3.2.1.4 The openings in the MCS shall be sealed with a TBD material to prevent TBD leakage.

3.3.2.1.5 The fully deployed egress couch and open hatch must both lock into position for testing purposes.

3.3.2.2 Lift Mechanism.

3.3.2.2.1 Lift Device.

3.3.2.2.1.1 The attachment of the LD to the LA TBD.

3.3.2.2.2 Lift Attachment.

3.3.2.2.2.1 The effects of varying lift angles on the LA TBD.

3.3.2.3 Hatch.

3.3.2.3.1 The hinge mechanism TBB for the hatch will attach the hatch to the model and allow the hatch to open.

3.3.2.3.2 The locking mechanism TBD for the hatch shall secure the hatch in its fully opened position, support the weight of the hatch, and be capable of supporting the weight of the egress couch model.

4.0 VERIFICATIONS

4.1 Definition. The following tests are intended to verify that the requirements of the ACMD one-fifth scale model have been met.

4.2 Performance Verification.

4.2.1 General Performance Verification.

4.2.1.1 Vehicle.

4.2.1.1.1 Verify that all dimensions of the MCS are geometrically 1/5 of ACMD within TBD limits.

4.2.1.1.2 Verify that the center of gravity and moment of inertia of the MCS are as specified.

4.2.1.1.3 Verify that the MCS hatch opens.

4.2.1.1.4 Verify that the interior space of the MCS is accessible.

4.2.1.1.5 Verify that the MCS is rigid.

4.2.1.1.6 Verify that the MCS takes on no more than TBD water during testing.

4.2.1.1.7 Verify that 1/5 scale flotation devices will fit into space allotted.

4.2.1.1.8 Verify that 1/5 scale egress couch will fit into interior space.

4.2.1.2 Lift Mechanism.

4.2.1.2.1 Lift Device.

4.2.1.2.1.1 Verify that lift device lifts the MCS out of the water.

4.2.1.2.1.2 Observe that lift mechanism is similar to that used with the actual ACMD.

4.2.1.2.1.3 Verify that lifting is accomplished with minimal rotation and sway of the MCS.

4.2.1.2.2 Lift Attachment.

4.2.1.2.2.1 Verify that lift attachment positions are the same on the MCS as on the ACMD.

4.2.1.2.2.2. Verify that lift attachments have been permanently attached to MCS.

4.2.1.2.2.3 Verify that attachment positions are accessible to lift device when MCS is in the water.

4.2.1.2.2.4 Verify that lift attachment positions provide no more than TBD rotation and sway of MCS.

4.2.1.3 Hatch.

4.2.1.3.1 Verify that the hatch works.

4.2.1.3.2 Verify the hatch opens the same as the ACMD hatch.

4.2.1.3.3 Verify the hatch locks into an open position.

4.2.1.3.4 Verify the weight of the egress couch can be supported by the hatch.

4.2.1.3.5 Verify the hatch is water resistant.

4.3 Operational Verifications.

4.3.1 General Operational Verifications.

4.3.1.1 Vehicle.

4.3.1.1.1 Verify that the MCS operates in water conditions.

4.3.1.1.2 Verify that the MCS interior is accessible to personnel.

4.3.1.1.3 Verify that added weights and MCS act as a rigid system.

4.3.1.1.4 Verify that MCS access openings are water resistant.

4.3.1.1.5 Verify that the egress couch can deploy over locked down hatch.

4.3.1.2 Lift Mechanism.

4.3.1.2.1 Lift Device.

4.3.1.2.1.1 Observe that LD attaches to MCS and removes it from the water.

4.3.1.2.2 Lift Attachment.

4.3.1.2.2.1 Verify that position of LA provides TBD vehicle lift angle.

4.3.1.3 Hatch.

4.3.1.3.1 Verify that the hatch is hinged at the bottom.

4.3.1.3.2 Observe that the hatch mechanism locks.

5.0 PACKAGING

6.0 NOTES

APPENDIX F

ACMD FLOTATION AND ATTITUDE MODEL

SPECIFICATIONS

1.0 SCOPE

1.1 Scope. This specification defines the subsystem performance requirements and operational constraints for the design, building, and testing of a one-fifth scale representation of the Assured Crew Return Vehicle (ACRV)/Apollo Flotation Model subsystem. These subsystem performance requirements and operational constraints were developed in accordance with JSC-31017 "CERV Systems Performances and Requirements Document" and other appropriate documents described in section 2.0.

1.2 Purpose. The purpose of this document is to formally establish the ACRV/Model flotation gear baseline performance requirements to be used during the ACRV/Apollo Flotation Model design definition period and subsequent building and testing phases. This document will be revised to incorporate all approved additional or modified requirements into this baseline.

1.3 Definition. This document provides the performance requirements and operational constraints for the ACRV/Apollo Flotation Model subsystem only. The ACRV system, as a whole, encompasses all of the flotation and lift hardware and software that are required to provide a simulated water rescue of the Space Station Crew.

2.0 APPLICABLE DOCUMENTS

2.1 Specifications.

2.1.1 Federal. None

2.1.2 Military. None

2.1.3 NASA.

JSC-31017 — ACRV System Performance and Requirements Document.

2.1.4 Contractor. None

2.2 Standards.

2.2.1 Federal. None

2.2.2 Military. None

2.2.3 NASA None

2.2.4 Contractor. None

2.3 Drawings. None

2.4 Bulletins. None

2.5 Other Documents.

2.5.1 Manuals.

Engineer-In-Training Reference Manual; Michael R. Lindebourg, P.E.; Professional Publications; 1990.

2.5.2 Handbooks. None

2.5.3 Textbooks.

Fluid Mechanics; Frank M. White; McGraw-Hill; 1986.

Fundamentals of Mechanical Component Design; Kenneth S. Edwards, Jr. and Robert B. McKee; McGraw-Hill; 1991.

Principles of Materials Science and Engineering; William F. Smith; McGraw-Hill; 1986.

Mechanics of Materials; E.P. Popov; Prentice-Hall; 1976.

Principles of Materials Science and Engineering; William S. Smith; McGraw-Hill; 1990.

Vibration of Mechanical and Structural Systems; M.L. James, G.M Smith, J.C. Wolford, and P.W. Whaley; Harper and Row; 1989.

2.5.4 Dictionaries.

The Man-In-Space Dictionary; Martin Caidin; Dutton; 1963.

3.0 REQUIREMENTS

3.1 Definition.

3.1.1 The following are requirements for the design of the one-fifth scale model of the Apollo Flotation System (FS) that will be incorporated into the one-fifth scale model of the ACRV. The requirements outlined below will be outlined as follows:

3.2.1	General Performance Requirements
3.2.2	Specific Performance Requirements
3.3.1	General Operational Requirements
3.3.2	Specific Operational Requirements

3.2 Performance Requirements.

3.2.1 General Performance Requirements.

3.2.1.1 The FS is to provide the capability to keep the one-fifth scale model of the ACRV afloat.

3.2.1.2 The FS must be designed to fit the ACRV.

3.2.1.3 The FS is to be functional under simulated adverse sea conditions.

3.2.1.4 The FS is to be redundant.

3.2.1.5 The FS and AS stored on the craft are to meet storage space requirements.

3.2.1.6 The FS is to be made from materials that can withstand adverse sea conditions.

3.2.1.7 The FS is to be designed to be reusable.

3.2.1.8 Moisture must not affect the operation of the FS or the AS.

3.2.1.9 The FS and the AS are to be designed as individual modules.

3.2.1.10 The FS and the AS are not to move independently of the ACRV.

3.2.1.11 The FS and the AS are to be designed to be easily maintained.

3.2.1.12 The FS and the AS are to be designed to have a certain operational life.

3.2.1.13 The AS is to be designed to meet buoyancy requirements.

3.2.1.14 The surface of the AS is to be large enough to function as a work platform when the Emergency Egress Couch (EEC) is extended.

3.2.1.15 The FS and the AS are to provide suitable work surfaces.

3.2.1.16 All necessary documents are to be provided.

3.2.2 Specific Performance Requirements.

3.2.2.1 The FS must provide a buoyancy force TBD.

3.2.2.2 The FS must have the correct inner radius TBD to fit the ACRV.

3.2.2.3 The FS is to be deployable and functional in sea-state 4 conditions.

3.2.2.4 There are to be back-up systems for the FS in case of primary system failure.

3.2.2.5 The FS and AS stored on the craft are to meet storage requirements TBD by Rockwell.

3.2.2.6 The FS material must withstand the conditions of sea-state 4.

3.2.2.7 The FS is to be designed to be reused with TBD refurbishment.

3.2.2.8 The FS and the AS are to be designed to operate properly while submerged in water.

3.2.2.9 The FS and the AS are to be independently implemented.

3.2.2.10 The FS and the AS must be designed to move rigidly with the ACRV.

3.2.2.11 The FS and the AS are to be designed for low maintenance and must be readily refurbishable within vehicle turn-around time TBD.

3.2.2.12 The FS and the AS are to have an operational life TBD.

3.2.2.13 The AS is to be buoyant enough to support the weight of the model EEC TBD.

3.2.2.14 The surface of the AS is to be at least 1.4 feet long by .8 feet wide.

3.2.2.15 The FS and the AS work surfaces must be firm enough and wide enough (TBD) to act as a work surface.

3.2.2.16 Operation, assembly and installation procedures, schematics and parts listings are to be provided.

3.3 Operational Requirements.

3.3.1 General Operational Requirements.

3.3.1.1 The AS shall be deployed and/or rigidly attached by a TBD method.

3.3.1.2 The AS must be in place before the EEC is extended.

3.3.1.3 The FS is to be redundant.

3.3.1.4 The ACRV must be safe after FS and AS deployment.

3.3.1.5 Maintenance personnel must maintain the FS and the AS.

3.3.2 Specific Operational Requirements.

3.3.2.1 The AS must be rigidly attached to the ACRV and can be deployed from the craft or attached TBD.

3.3.2.2 The AS must be deployed or attached and functional before the EEC is extended.

3.3.2.3 A backup mechanism is to take the place of the primary system for the FS in case of primary system failure.

3.3.2.4 There are to be no sharp surfaces as a result of FS and AS deployment.

3.3.2.5 Maintenance personnel must repair, maintain, install and remove mechanisms and material used in the FS and the AS as needed.

4.0 VERIFICATIONS

4.1 Definition.

4.1.1 The following tests and procedures are intended to verify the requirements of the RES. The verification outlined below will be divided as follows:

- 4.2.1 General Performance Verification
- 4.3.1 General Operational Verification

4.2 Performance Verifications.

4.2.1 General Performance Verifications.

4.2.1.1 Verify that the FS will provide buoyancy force to keep the ACRV afloat.

4.2.1.2 Verify that the FS has correct dimensions.

4.2.1.3 Verify that the FS is functional in sea-state 4 conditions.

4.2.1.4 Verify the FS backup system functions properly.

4.2.1.5 Verify that the FS and AS stored on the craft meet storage space requirements.

4.2.1.6 Verify that the components of the FS will withstand the conditions of sea-state 4.

4.2.1.7 Verify that the FS is reusable.

4.2.1.8 Verify the capability of the FS and the AS to operate properly after submersion into water.

4.2.1.9 Verify that the FS and the AS work independently.

4.2.1.10 Verify that the FS and the AS move rigidly with the ACRV.

4.2.1.11 Verify that the FS and the AS can be refurbished within the determined turn-around time.

4.2.1.12 Verify the operational life of each component.

4.2.1.13 Verify that the AS is buoyant enough to support the determined weight.

4.2.1.14 Verify that the AS has the specified surface area.

4.2.1.15 Verify that the FS and the AS provide suitable work surfaces.

4.2.1.16 Verify that the operation, assembly and installation procedures, schematics and parts listing are present.

4.3 Operational Verifications.

4.3.1 General Operational Verifications.

4.3.1.1 Verify that the AS is rigidly attached to the ACRV.

4.3.1.2 Verify that the EEC does not extend until the AS is functional.

4.3.1.3 Verify that upon failure the FS backup system is operable.

4.3.1.4 Verify that no sharp objects or dangerous corners are protruding from the craft after FS and AS deployment.

4.3.1.5 Verify that maintenance is performed.

5.0 PACKAGING Not applicable.

6.0 NOTES Not applicable.

APPENDIX G

ACMD FLOTATION AND ATTITUDE MODEL

DECISION MATRICES

DESIGN PARAMETERS	SAFETY	COST	FEASIBILITY	REDUNDANCY	DEPENDABILITY	SIMPLICITY	MAINTENANCE	RIGIDITY	OPERATIONAL PERFORMANCE	
WEIGHT FACTOR	8	8	10	6	9	7	2	10	9	
SINGLE-CHAMBERED CONTINUOUS RING	17	18	17	5	18	19	18	19	17	1154
SPHERES	18	16	19	17	18	16	18	12	14	1120
SEGMENTED RING	18	15	16	17	18	15	18	17	18	1161
MULTI-CHAMBERED RING	19	6	10	19	18	6	14	19	19	1007

Figure G-1 Flotation System Matrix

DESIGN PARAMETERS	SAFETY	COST	FEASIBILITY	REDUNDANCY	DEPENDABILITY	SIMPLICITY	MAINTENANCE	SIZE	WEIGHT	OPERATIONAL PERFORMANCE
WEIGHT FACTOR	8	8	10	3	9	7	2	10	9	9	
INFLATABLE MATTRESS	19	18	19	10	15	18	19	5	18	17	1266
LATTICE SUPPORT STRUCTURE	15	15	14	10	17	9	19	10	10	17	1150
TELESCOPING BEAMS	16	16	18	10	19	15	19	17	17	19	1428
ZODIAC TYPE ATTACHED VEHICLE	19	5	12	15	19	18	19	20	20	10	1232

Figure G-2 Attitude System Matrix

DESIGN PARAMETERS	STRENGTH	DURABILITY	ATTACHABILITY/ WORKABILITY	COST	REPAIRABILITY	LEAKPROOF	RIGIDITY	AVAILABILITY	WEIGHT	
WEIGHT FACTOR	7	4	9	8	5	9	8	7	2	
KEVLAR	20	20	17	3	19	19	18	15	14	940
RUBBER	10	10	18	18	20	17	14	20	17	963
COATED CANVAS	17	19	17	16	19	19	17	19	18	1047
COATED NYLON	18	18	17	15	19	19	16	16	19	1007

Figure G-3 Materials Matrix

	DESIGN PARAMETERS	FEASIBILITY	SAFETY	COST	REDUNDANCY	DEPENDABILITY	SIMPLICITY	OPERATIONAL PERFORMANCE
WEIGHT FACTOR	10	10	8	8	9	8	10	
COMPRESSOR PUMP	5	15	10	1	18	18	20	794
HAND/FOOT PUMP	19	20	20	15	19	20	18	1181
COMPRESSED AIR CARTRIDGE	10	10	15	15	15	16	17	873
PYROTECHNICS (AIR BAG TECHNOLOGY)	3	3	8	15	15	10	17	629

Figure G-4 Inflation Method Matrix

APPENDIX H

SCRAM CONFIGURATION MODEL

SPECIFICATIONS

1.0 SCOPE

1.1 Scope. This specification defines the subsystem performance requirements and operational constraints for the design, building, and testing of a one-fifth scale representation of the Assured Crew Return Vehicle/Station Crew Return Alternative Module (ACRV/SCRAM). These subsystem performance requirements and operational constraints were developed in accordance with JSC-31017 "CERV Systems Performance and Requirements Document" and other appropriate documents described in section 2.0.

1.2 Purpose. The purpose of this document is to formally establish the ACRV/SCRAM baseline performance requirements to be used during the ACRV/SCRAM design definition period and subsequent building and testing phases. This document will be revised to incorporate all approved additional or modified requirements into this baseline.

1.3 Definition. This document provides the performance requirements and operational constraints for the ACRV/SCRAM system only. The ACRV system, as a whole, encompasses all of the flotation and lift hardware and software that are required to provide a simulated water rescue of the Space Station Crew.

2.0 APPLICABLE DOCUMENTS

2.1 Specifications.

2.1.1 Federal. None

2.1.2 Military. None

2.1.3 NASA.

JSC-31017	ACRV System Performance and Requirements Document

2.1.4 Contractor. None

2.2 Standards.

2.2.1 Federal. None

2.2.2 Military. None

2.2.3 NASA. None

2.2.4 Contractor. None

2.3 Drawings. None

2.4 Contractor. None

2.5 Other Documents.

2.5.1 Manuals. None

2.5.2 Handbooks. None

2.5.3 Textbooks.

Popov, Egor P., "Engineering Mechanics of Solids," Prentice Hall, 1990.

Bureau of Naval Personnel, "Principles of Naval Engineering," U.S. Govt. Printing Office, 1987.

White, Frank M., "Fluid Mechanics," McGraw Hill, 1986.

Smith, G. M., James, M. L., Wolford, J. C., Whaley, P. W.

"Vibration of Mechanical and Structural Systems," Harper and Row, 1989.

Doughty, Samuel, "Mechanics of Machines," Wiley, 1988.

3.2.2.1.2 The SCRAM model will have a center of gravity that is 0.4 feet above the plane of the crew compartment floor along the axis of symmetry.

3.2.2.1.3 The SCRAM model will have a center of buoyancy that is __ feet above the plane of the crew compartment floor.

3.2.2.1.4 The SCRAM model will be able to fit through a space no less than 2.5 feet wide.

3.2.2.1.5 The center of gravity of the SCRAM model will be adjustable both with respect to the axis of symmetry and the vertical distance from the floor of the crew compartment.

3.2.2.2 <u>Specific Waterborne performance Requirements.</u>

3.2.2.2.1 The SCRAM model will float in static water; it will have the ability to displace more water than 100 percent of its own weight.

3.2.2.2.2 The SCRAM model will have an attachable cover from the body of the crew compartment to the edge of the heat shield. This cover will not leak more than four liquid ounces of water per hour.

3.2.2.2.3 The SCRAM model will not let more than 16 liquid ounces of water per hour into the crew compartment.

3.2.2.2.4 The SCRAM model will have attachment points for flotation devices to be determined.

3.2.2.2.5 The SCRAM model will have accelerometers attached in a position that enables the determination of the motion of the center of mass and the rotation of the body. This positioning is yet to be determined.

3.2.2.3 Specific Lift Attachment Performance Requirements.

3.2.2.3.1 The lift attachment points (LAP system) will be positioned above the center of mass of the SCRAM model.

3.2.2.3.2 The LAP system will be able to support at least 180 pounds.

3.2.2.3.3 The LAP system will have attachment points that are placed so that they do not hinder the operation of the hatches, parachutes, rocker stoppers, or other exterior devices of the full scale design concept.

3.2.2.3.4 All LAP system components will have a factor of safety of at least 1.4.

3.3 Operational Requirements.

3.3.1 General Operational Requirements.

3.3.1.1 The SCRAM model will have a system of weights so that the center of gravity can be adjusted to match the desired center.

3.3.1.2 The SCRAM model will be constructed so that it can be disassembled to facilitate transportation.

3.3.1.3 The sub-assemblies of the SCRAM model will be joined in a way to limit water leakage.

3.3.1.4 The SCRAM model and LAP system assembly will have sufficient structural strength so that it can support itself and any water that the entire SCRAM model has taken on.

3.3.1.5 The LAP system attachment points, if more than one point, will each be strong enough to support the weight of the entire

SCRAM model.

3.3.2 Specific Operational Requirements.

3.3.2.1 The SCRAM model will have a system of weights that have the ability to adjust the center of gravity by 6 inches horizontally, and 3 inches vertically.

3.3.2.2 The SCRAM model will have at least two sub-assemblies that will each weigh less than 45 pounds.

3.3.2.3 The linkages of the SCRAM model sub-assemblies will be sealed with a resealable gasket.

3.3.2.4 The SCRAM model and LAP system assembly must be able to support at least 180 pounds of static weight.

3.3.2.5 The LAP system attachment points must each be capable of supporting a load of 180 pounds.

4.0 VERIFICATIONS

4.1 Definition.

4.1.1 This section contains the tests and procedures required to verify the requirements delineated above for the SCRAM model.

4.2 Performance Verifications.

4.2.1 General Performance Verifications.

4.2.1.1 General Physical Performance Verifications.

4.2.1.1.1 Measure the dimensions of the SCRAM model and verify that they are one-fifth of the dimensions of the SCRAM/ACRV design concept.

4.2.1.1.2 Verify that the center of gravity of the SCRAM model matches the center of buoyancy of the SCRAM/ACRV design concept in a static flotation situation.

4.2.1.1.4 Verify that the unassembled SCRAM model will fit through a doorway greater than 2.5 feet wide.

4.2.1.1.5 Verify that the center of gravity of the SCRAM model is adjustable.

4.2.1.2 General Waterborne Performance Verifications.

4.2.1.2.1 Verify that the SCRAM model floats in static water.

4.2.1.2.2 Verify that the gap between the heat shield and the body of the crew compartment does not leak excess water when the heat shield shroud is installed.

4.2.1.2.3 Verify that the crew compartment does not leak an undue amount of water.

4.2.1.2.4 Verify that there are attachment points for flotation stabilization devices.

4.2.1.2.5 Verify that there are motion sensors attached to the SCRAM model.

4.2.1.3 General Lift Attachment Performance Verifications.

4.2.1.3.1 Verify that the LAP system is a stable configuration.

4.2.1.3.2 Verify that the LAP system will support the equivalent of the maximum weight of the ACRV/SCRAM design concept times 1.4.

4.2.1.3.3 Verify that the LAP system places its attachment points so that the LAP system doesn't interfere with the operation and placement of external systems in the SCRAM/ACRV design concept.

4.2.1.3.4 Verify that each of the LAP system components has the material strength to withstand its loading demand.

4.3 Operational Verifications.

4.3.1 General Operational Verifications.

4.3.1.1 Verify that the center of gravity of the SCRAM model can be adjusted to match the desired center and that the range values possible are at least those desired.

4.3.1.2 Verify that the SCRAM model can be easily disassembled.

4.3.1.3 Verify that the sub-assemblies of the SCRAM model can be sealed when together to limit water leakage.

4.3.1.4 Verify that the SCRAM model and LAP system assembly will support itself and the maximum amount of water that is allowed to be taken on.

4.3.1.5 Verify that each of the LAP attachment points can support the maximum weight of the SCRAM model and LAP assembly in a dynamic loading situation that approximates a factor of safety of 1.4.

5.0 PACKAGING

6.0 NOTES

APPENDIX I

SCRAM CONFIGURATION MODEL

DECISION MATRICES

SYSTEM / DESIGN PARAMETERS	COST	EASE OF FABRICATION	DEPENDABILITY	FEASIBILITY	TIME TO FABRICATE	DURABILITY	BUILDING METHOD	WEIGHT						WEIGHTED TOTAL
WEIGHT FACTOR	7	9	6	7	4	6	8	6						
PLYWOOD	17	17	8	15	17	8	17	11						743
SHEET METAL	8	7	18	7	8	17	6	8						506
FIBERGLASS	15	14	15	19	10	15	13	16						784 *
PLASTIC	10	15	13	12	13	11	9	18						665

WEIGHT FACTOR = 10 MAX.   SYSTEM FACTOR = 20 MAX.   * = DESIRED ALT.

Figure I-1 Model Fabrication Material Matrix

SYSTEM \ DESIGN PARAMETERS	COST	EASE OF FABRICATION	DEPENDABILITY	FEASIBILITY	DURABILITY	ADJUSTIBILITY	STABILITY	SPACE UTILIZATION				WEIGHTED TOTAL
WEIGHT FACTOR	6	7	6	6	4	8	7	9				
SUSPENDED MASS	12	8	10	9	14	17	10	8				576
MASS ON VERTICAL ROD	15	14	17	12	15	13	12	9				691
FLAT CIRCULAR PLATES	19	16	16	15	17	12	17	16				839
CONCENTRATED MASS	18	19	17	14	17	10	18	10				791
ADJUSTABLE ROTATING WEIGHT SYSTEM	12	14	18	18	15	19	15	19				874 *
PERIPHERAL WEIGHTS	14	15	16	16	17	11	16	17				802

WEIGHT FACTOR = 10 MAX. SYSTEM FACTOR = 20 MAX. * = DESIRED ALT.

Figure I-2 Inertia and Moment Systems Matrix

SYSTEM \ DESIGN PARAMETERS	COST	EASE OF FABRICATION	DEPENDABILITY	FEASIBILITY	DURABILITY	REDUNDANCY	ABILITY TO REMOVE WATER	SAFETY					WEIGHTED TOTAL
WEIGHT FACTOR	8	7	8	6	4	9	7	9					
SEA SLING	19	18	14	18	12	10	9	19					1025 *
3 LAP'S ON ROOF	12	12	18	16	18	16	9	18					1005
3 LAP'S ON SIDE	12	12	18	15	18	16	9	19					864
2 LAP'S ON ROOF & 1 ON HEAT SHIELD	10	13	16	11	17	15	17	17					840
DUAL OFFSET LAP'S	18	17	15	17	13	17	18	14					942

WEIGHT FACTOR = 10 MAX SYSTEM FACTOR = 20 MAX * = DESIRED ALT.

Figure I-3 Lift Attachment Point Matrix

SYSTEM \ DESIGN PARAMETERS	COST	EASE OF FABRICATION	DEPENDABILITY	FEASIBILITY	DURABILITY	WATER REMOVAL							WEIGHTED TOTAL
WEIGHT FACTOR	7	8	6	4	7	9							
FLAT SHROUD	15	15	13	15	17	15							617 *
INCLINED SHROUD	13	12	15	12	13	15							551
INFLATED BALLOON SHROUD	8	5	8	9	8	7							299

WEIGHT FACTOR = 10 MAX.

SYSTEM FACTOR = 20 MAX.

* = DESIRED ALT.

Figure I-4 Shroud Design Matrix

APPENDIX J

SCRAM CONFIGURATION MODEL

WORK BREAKDOWN STRUCTURE DICTIONARY

WORK BREAKDOWN STRUCTURE DICTIONARY
CONSTRUCTION PHASE

1.0 Build the SCRAM/ACRV model. (1/25/92)

1.1 Retrieve necessary information to build the SCRAM model.

1.1.1 Research requirements and specifications for the model.

1.1.2 Write class reports

1.1.3 Prepare and deliver class presentations.

1.2 Finalize design drawings. (2/10/92)

1.2.1 Create dimension drawings.

1.2.2 Create mold profile drawings.

1.2.3 Create detail drawing for ARWS subsystem.

1.2.4 Create detail drawings for lid, shroud, and crew compartment sub-assemblies.

1.3 Raw material acquisition. (3/5/92)

1.3.1 Acquire data acquisition systewm sub-components.

1.3.2 Obtain joint assembly materials.

1.3.3 Obtain LAP subsystem materials

1.3.4 Obtain materials and fabricate ARWS subsystem.

1.3.5 Obtain materials to fabricate the SCRAM model's mold.

1.4 Provide for the assembly, fabrication, and finish work of the SCRAM model. (3/12/92)

1.4.1 Construct the scale model of the SCRAM/ACRV.

1.4.2 Fabricate and assemble ARWS subsystem.

1.4.3 Fabricate LAP subsystem.

1.4.4 Fabricate fastening mechanisms.

1.4.5 Assemble subsystems to complete the SCRAM model.

2.0 Test SCRAM model and subsystems.

2.1 Write procedure for model testing.

2.1.1 Research testing requirements, needed parameters, and conditions.

2.1.2 Develop and document a logically structured test procedure.

2.1.3 Closeout: confirm the model design meets required specifications and document results. (4/2/92)

2.2 Confirm that subsystems and model match specifications. (3/30/92)

2.2.1 Confirm structural durability of model. (2/06/92)

2.2.2 Find location of CG and mass moments of inertia.

2.2.3 Confirm water tightness of model.

2.2.4 Perform static flotation test on the model.

2.2.5 Set up data acquisition system and confirm accuracy.

2.2.6 Find final weight and volume of model, and confirm they meet required specifications.

2.2.7 Test LAP subsystem under static conditions.

2.3 Perform flotation and lift tests and gather data for model in a variety of wave conditions. (4/03/92)

2.3.1 Perform tests with the heat shield shroud.

2.3.2 Perform tests without the heat shield shroud.

APPENDIX K

SCRAM CONFIGURATION MODEL

TESTING MATRIX

Run No.	Ident.	Sea State RG2 0.52 ft.	Sea State RG1 1.2 ft.	Sea State RN 0.33 ft.	Weight Mid 76 lbs.	Weight High 120 lbs.	Vertical CG High 1.2 in.	Vertical CG Low 1.2 in.	Offset CG Large 1.2 in.	Offset CG Small 1.2 in.	Shroud	Static Angle (Deg.)
1	NFHU				X			X		X	OFF	10 Bow Up
2	NFPU				X			X		X	OFF	
3	NFHM				X			X		X	OFF	
4	NFPM				X			X		X	OFF	
5	NSFM				X			X		X	OFF	
6	LS01	X			X			X		X	OFF	
7	LS02		X		X			X		X	OFF	
8	LS03			X	X			X		X	OFF	
9	HS01	X			X		X			X	OFF	13.5 Bow Up
10	HS02		X		X		X			X	OFF	
11	HS03			X	X		X			X	OFF	
12	HL01	X			X		X		X		OFF	14.5 Bow Down
13	HL02		X		X		X		X		OFF	
14	HL03			X	X		X		X		OFF	
15	LLO1				X				X		OFF	9.5 Bow Down
16	LLO2				X			X	X		OFF	
17	LLO3				X			X	X		OFF	
29	NFHNU				X			X	X		ON	5.5 Bow Down
30	NFPNU				X			X	X		ON	
31	NFHNM				X			X	X		ON	
32	NFPNM				X			X	X		ON	
33	NFSNM				X			X	X		ON	
34	LLN1	X			X			X	X		ON	
35	LLN2		X		X			X	X		ON	
36	LLN3			X	X			X	X		ON	
37	HLN1	X			X			X	X		ON	7 Bow Down
38	HLN2		X		X				X		ON	
39	HLN3			X	X					X	ON	
40	HSN1	X			X					X	ON	4.5 Bow Up
41	HSN2		X		X					X	ON	
42	HSN3			X	X					X	ON	
43	LSN1	X			X					X	ON	3.5 Bow Up
44	LSN2		X		X					X	ON	
45	LSN3			X	X						ON	
55	HLSO1	X				X			X		OFF	13.5 Bow Up
56	HLSO2		X			X			X		OFF	
57	HLSO3			X		X			X		OFF	
58	HLL01	X				X				X	OFF	17 Bow Down
59	HLL02		X			X				X	OFF	
60	HLL03			X		X				X	OFF	

Figure K-1 Flotation Testing Matrix

Run	Ident.	Sea	Weight	Vert CG	Off. CG	Shroud		Notes..
No.		State	Mid	High	Large	On	Off	
		Lg. Reg.	76 lbs	1.2 in.	1.2 in.			
18	THLO1	X	X	X	X	X		Tension
19	THLO2	X	X	X	X	X		2 in.
20	THLO4	X	X	X	X	X		4 in.
21	THLO8	X	X	X	X	X		8 in.
22	LHLO1	X	X	X	X	X		Normal
23	LHLO2	X	X	X	X	X		Lift Test
24	LHLO3	X	X	X	X	X		w/o
25	LHLO4	X	X	X	X	X		Shroud
26	AHLO1	X	X	X	X	X		Angled
27	AHLO2	X	X	X	X	X		Lift
28	AHLO3	X	X	X	X	X		w/o Shr.
46	LHLN1	X	X	X	X		X	Normal
47	LHLN2	X	X	X	X		X	Lift Test
48	LHLN3	X	X	X	X		X	w/ Shr.
49	AHLN1	X	X	X	X		X	Angled
50	AHLN2	X	X	X	X		X	Lift
51	AHLN3	X	X	X	X		X	w/o Shr.
52	CHLN1	X	X	X	X		X	Extended
53	CHLN2	X	X	X	X		X	Cable
54	CHLN3	X	X	X	X		X	Test

Figure K-2 Lifting Test Matrix

Run No.	Ident.	Sea State RG2	Weight Mid 76 lb.	Vert. CG Low	Off. CG Low	Shroud
61	YAWN	X	X			Off
62	YAWS1	X	X	X	X	Off
63	YAWS2	X	x	X	X	Off
64	YAWE	X	X	X	X	Off
65	YAWW	X	X	X	X	Off

Figure K-3 Yaw Test Matrix

APPENDIX L

SCRAM CONFIGURATION MODEL

TEST LEGEND

TEST LEGEND

Natural Frequency Test Identification (Tests 1 - 5 and 29 - 33):

NFHU - Natural Frequency, Heave, Unmoored

NFPU - Natural Frequency, Pitch, Unmoored

NFHM - Natural Frequency, Heave, Moored

NFPM - Natural Frequency, Pitch, Moored

NFSM - Natural Frequency, Surge, Moored

NFHNU - Natural Frequency, Heave, Shroud On, Unmoored

NFPNU - Natural Frequency, Pitch, Shroud On, Unmoored

NFHNM - Natural Frequency, Heave, Shroud On, Moored

NFPNM - Natural Frequency, Pitch, Shroud On, Moored

NFSNM - Natural Frequency, Surge, Shroud On, Moored

Wave Test Identification (Tests 6 - 17 and 34 - 45):

Ex:LSO1 - Low Vertical Offset, Small Horizontal Offset, Shroud Off

First Column: L = Low

H = High

Second Column: S = Small

L = Large

Third Column: N = Shroud On

O = Shroud Off

Fourth Column: Wave State Identifier

1 = Intermediate Sea State (RG2)

APPENDIX M

SCRAM CONFIGURATION MODEL

CALCULATIONS

INTRODUCTION

Within the scope of the model pre-tests, the primary sources of calculation requirements are the CG/Mass Moment tests and model scaling. The CG/Mass Moment tests can divided into two subcategories, one being the swing tests, and the other the purely theoretical predictions. The scaling refers to the dimensional adjustments made to the model and the waves generated during the dynamic water tests.

The only calculation requirement for the post dynamic water testing is the natural frequency analysis. The purpose of this analysis is to confirm the assumption that the model frequency is equal to its natural frequency.

CENTER OF GRAVITY/MASS MOMENT DETERMINATION

SWING TESTS

The basic equations for finding the model CG and mass moments from its swing period, were derived from the compound pendulum model. By development of this model, one obtains the first given equation:

$$\omega_n=\sqrt{\frac{m\cdot g\cdot L}{I_o}} \qquad (1.1)$$

This equation is then manipulated into a more useful form:

$$\tau_n^2=\frac{4\cdot\pi\cdot I_o}{m\cdot g\cdot L} \qquad (1.2)$$

Where the variables of the equations 1.1 and 1.2 are given as follows.

τ_n = *Period of the model during a swing test.*

$\omega_n = \dfrac{2\cdot\pi}{\tau_n}$ = *Angular frequency of model during swing test.*

I_o = *Mass moment of inertia about the model centroid.*

m = *Mass of the model.*

L = *Distance from the pendulum pivot to the CG.*

g = *Acceleration due to gravity.*

Equation 1.2 is again modified by breaking up the L term into one component expressing the length of the pendulum (which is constant), and another component comprised of the remaining distance from the pivot to the centroid. From this modification, the following forms are obtained:

$$(\tau_{Ntop})_1 = \frac{I_{ox}}{m\cdot g\cdot(L+L_{Bar})} \qquad (1.3)$$

$$(\tau_{Nbottom})_1 = \frac{I_{ox}}{m\cdot g\cdot(L+(L_{Bar}-h))} \qquad (1.4)$$

$$(\tau_{Nside})_1 = \frac{I_{oz}}{m\cdot g\cdot(L_{Bar}+R_1)} \qquad (1.5)$$

$$(\tau_{Nside2})_1 = \frac{I_{oz}}{m\cdot g\cdot(L_{Bar}+(D-R_1))} \qquad (1.6)$$

Equations 1.3 through 1.6 represent the final form of the equations which were solved simultaneously (using a spreadsheet) in order to determine the mass moments and the location of the center of gravity. Some numerical results are given as follows:

THEORETICAL PREDICTION

The primary goal of formulating a purely theoretical method is to predict the position of the model's center of gravity for ARWS configurations. This provides an efficient means to determine the feasible configurations for the wave tests. The input values required for the appropriate model are as follows:

1) Weight of the model shell (no weight added by the ARWS).
2) Total weight of the model (with added ARWS weight).
3) The weight added to one arm of the ARWS (this value is assumed).
4) The distance along the arm of the assumed weight (this value is also assumed).

Taking into consideration the above values, one may derive a set of equations which can be solved simultaneously. Such equations are developed and can be symbolically expressed as follows:

$$X_1=\left[\frac{(X_2\cdot\cos\ 17^\circ+2)\cdot W_2-\frac{1}{7}\cdot 53.5-X_{cg}\cdot W_T}{W_T-53.5-W_1}-2\right]\cdot\frac{1}{\cos\ 17^\circ} \qquad (1.7)$$

$$X_2=\left[\frac{\frac{1}{7}\cdot 53.5+(X_1\cos\ 17^\circ+2)\cdot W_1-W_T\cdot X_{cg}}{W_T-53.5-W_1}-2\right]\cdot\frac{1}{\cos\ 17^\circ} \qquad (1.8)$$

$$Y_2=\frac{Y_{CG}\cdot W_T-9.06\cdot 53.5}{W_T-53.5}-4.4-X_2\cdot\sin 17^\circ \qquad (1.9)$$

The parameters for each expression may be defined as the following:

The remainder of values from the equations are constants

$X_1 \equiv$ *The distance along the ARWS arm for the weights closest to the hatch.*

$X_2 \equiv$ *The distance from the center and along the ARWS arm to the weights furthest from the hatch.*

$X_{CG} \equiv$ *The location along the ARWS arm of the desired CG location.*

$Y \equiv$ *The height of both sets of weights along their riser.*

$W_T \equiv$ *The total weight of the model.*

$W_1 \equiv$ *Weight added to the arm closest to the hatch.*

$W_2 \equiv$ *Weight added to the arm furthest from the hatch.*

determined specifically for the SCRAM.

SCALING FACTORS

In order to ensure proper modeling characteristics a set of scaling factors needed to be derived. The primary scaled dimensions include length, time, mass, and volume.

LENGTH

In a mathematical sense, the scaling coefficient for the model dimensions can be easily deduced. Since the model is intended to dimensional be a 1/5th scale model of the full scale JSC model, the scaling equation may be expressed as:

$$(length)_{1/5scale} = \frac{(length)_{fullscale}}{5} \qquad (2.0)$$

TIME

The derivation required to determine the scaled time value is more indirect than the previous. Using dimensional analysis and the definition of acceleration, one may obtain a form for the scaled time of:

$$(time)_{1/5scale}=\frac{(time)_{fullscale}}{\sqrt{5}} \qquad (2.1)$$

MASS

The determination of the scaled mass value can be performed in a manner similar to the scaled time. Using dimensional analysis and the definition of density, the following expression may be found:

$$(mass)_{1/5scale}=\frac{(mass)_{fullscale}}{5^3} \qquad (2.2)$$

FORCE

Taking equations 2.0, 2.1, 2.2, Newton's second law, and performing a dimensional analysis, one may find the proper scaling coefficient for the force. In the process of simplification of this expression, the scaling factors for length and time cancel. This means the scaling coefficient for the force is equal to the same coefficient for the mass, and can be expressed as:

$$(Force)_{1/5scale}=\frac{(Force)_{fullscale}}{5^3} \qquad (2.2)$$

NATURAL FREQUENCY DETERMINATION

The natural frequency can be expressed in terms of the period as follows:

$$\omega_n = \frac{2\pi}{\tau}$$

Where:

$\omega_n \equiv$ *Natural angular frequency.*
$\tau \equiv$ *Period of wave.*

The relationship between an object's natural frequency and the frequency induced by a damped oscillation may be given as:

$$\omega_{damp.} = \omega_{nat.} \sqrt{1 - \xi^2}$$

If the condition holds that:

$$\xi < 0.2$$

Then it can be assumed:

$$\omega_{damped} \approx \omega_n$$

The amplitude of two successive damped waves may be exponentially expressed as:

Where:

$\xi \equiv$ *Damping coefficient.*
$X_{1 or 2} \equiv$ *Successive wave amplitudes.*

Taking the natural log of this equation:

$$\ln\frac{X_1}{X_2} = -\xi\omega_n\tau$$

Solving for the damping coefficient:

$$\xi = \frac{1}{\omega_n\tau} \ln\frac{X_1}{X_2}$$

The required values are obtained from the natural frequency test data. Then the damping coefficients for the model heave and pitch are derived.

APPENDIX N

EEC CONFIGURATION MODEL

SPECIFICATIONS

1.0 SCOPE

1.1 Scope. This specification defines the subsystem performance requirements and operational constraints for the design, building, and testing of a full scale model of the Emergency Egress Couch (EEC). These subsystem performance requirements and operational constraints were developed in accordance with JSC-31017 "CERV Systems Performance and Requirements Document" and other appropriate documents described in section 2.0.

1.2 Purpose. The purpose of this document is to formally establish the EEC/Rapid Egress baseline performance requirements to be used during the EEC/Rapid Egress design definition period and subsequent building and testing phases. This document will be revised to incorporate all approved additional or modified requirements into this baseline.

1.3 Definition. This document provides the performance requirements and operational constraints for the ACRV/Rapid Egress subsystem only. The ACRV system, as a whole, encompasses all of the floatation and lift hardware and software that are required to provide a simulated water rescue of the Space Station Crew.

2.0 APPLICABLE DOCUMENTS

2.1 Specifications.

2.1.1 Federal.

2.1.2 Military.

2.1.3 NASA.

JSC-31017 ACRV System Performance and Requirements Document.

2.1.4 Contractor.

2.2 Standards.

2.2.1 Federal.

2.2.2 Military.

2.2.3 NASA.

NSS/GO-1740.9 Crane and Hoist Safety Standard.

2.2.4 Contractor.

2.3 Drawings.

2.4 Bulletins.

2.5 Other Documents.

2.5.1 Manuals.

2.5.2 Handbooks.

2.5.3 Textbooks.

Space Station, The Next Logical Step; W. Froelich; Government Printing Office; 1985.

Humans in Space, 21st Century Frontiers; H.L. Shipman; Plenum Press; 1989.

Space Safety and Rescue; G.W. Heath; Science and Technology Press; 1982.

3.0 REQUIREMENTS

3.1 Definition. The Emergency Egress Couch Model (EECM) is a full scale test model which will be used to test the dynamic and geometric characteristics of the couch.

3.2 Performance Requirements.

3.2.1 General Performance Requirements.

3.2.1.1 General Performance System Requirements.

3.2.1.1.1 Buoyancy.

3.2.1.1.1.1 The EECM shall be able to float while at the maximum weight capacity.

3.2.1.1.2 The EECM shall vary from a simple litter to a complex medical couch.

3.2.1.1.3 Dynamic Characteristics.

3.2.1.1.3.1 The EECM shall have the ability to model different locations of center of gravity.

3.2.1.1.3.2 The EECM shall have the ability to model different moments of inertia.

3.2.1.1.4 Geometric Characteristics.

3.2.1.1.4.1 The length shall be specified by NASA.

3.2.1.1.4.2 The width shall be specified by NASA.

3.2.1.1.4.3 The EECM shall be capable of varying height.

3.2.1.1.4.4 The EECM shall have a top cover.

3.2.1.1.5 Helicopter Rescue Procedures.

3.2.1.1.5.1 Connections.

3.2.1.1.5.1.1 The EECM shall have varying methods of connecting to the helicopter rescue cable.

3.2.1.1.5.1.2 The EECM shall be connected to the helicopter cable within an allotted time.

3.2.1.1.5.1.3 The EECM connections shall be secure.

3.2.1.1.5.2 Lift.

3.2.1.1.5.2.1 The maximum weight of the EECM shall not exceed the rated load of the helicopter lift mechanism.

3.2.1.1.5.3 Pulling in Emergency Egress Couch Model.

3.2.1.1.5.3.1 The EECM shall be able to fit through the HC-60 helicopter door.

3.2.1.1.5.3.2 The EECM shall be able to be pulled in by the Flight Engineer.

3.2.1.1.5.3.3 The sling height shall allow the EECM to be lifted even with the door of the helicopter.

3.2.1.1.6 Attachment Points.

3.2.1.1.6.1 Attachment points shall be capable of varying along the perimeter of the EECM.

3.2.1.1.7 Sling Configuration.

3.2.1.1.7.1 The sling configuration shall be capable of varying with the attachment points.

3.2.1.1.8 Durability.

3.2.1.1.8.1 The EECM life span shall last until tests are completed.

3.2.1.1.8.2 Environmental Conditions.

3.2.1.1.8.2.1 The EECM shall be able to withstand windy conditions.

3.2.1.1.8.2.2 The EECM shall be able to withstand rainy conditions.

3.2.1.1.8.2.3 The EECM shall be able to withstand rough seas.

3.2.1.1.8.2.4 The EECM shall be able to resist salt water corrosion.

3.2.1.1.9 Transportation.

3.2.1.1.9.1 The EECM shall be able to withstand transportation.

3.2.1.1.10 Product Assurance.

3.2.1.1.10.1 Safety.

3.2.1.1.10.1.1 The EECM shall have no unsafe features.

3.2.1.1.10.1.2 The slings of the EECM shall meet safety set standards.

3.2.1.1.10.1.3 The weights within the EECM shall be fastened securely.

3.2.1.1.10.2 Operational Reliability.

3.2.1.1.10.2.1 The EECM shall be able to perform enough tests to collect the needed data.

3.2.1.1.11 Data Collection.

3.2.1.1.11.1 Data shall be collected on the pitch of the EECM during ascent.

3.2.1.1.11.2 Data shall be collected on the yaw of the EECM during ascent.

3.2.1.1.11.2 Data shall be collected on the heave of the EECM during rescue retrieval.

3.2.2 <u>Specific Performance Requirements</u>.

3.2.2.1 Specific Performance Requirements

3.2.2.1.1 Buoyancy.

3.2.2.1.1.1 The EECM shall be able to float up-right while at a maximum weight of 600 pounds.

3.2.2.1.2 The EECM shall vary from a simple backboard of minimal weight to a complex medical couch of maximum weight of 600 pounds and height TBD.

3.2.2.1.3 Dynamic Characteristics.

3.2.2.1.3.1 The EECM shall be able to model different centers of gravity over a TBD range, in TBD increments, in the vertical and longitudinal axes. The longitudinal axis is defined as running along the length of the couch.

3.2.2.1.3.2 The EECM shall be able to model different moments of inertia over a TBD range of magnitudes in the longitudinal axis.

3.2.2.1.4 Geometric Characteristics.

3.2.2.1.4.1 As specified by NASA, the length of the EECM shall be seven feet.

3.2.2.1.4.2 As specified by NASA, the width of the EECM shall be two feet.

3.2.2.1.4.3 The height of the EECM shall vary from a flat litter to a (TBD) height not to exceed one foot, not including cover.

3.2.2.1.4.4 The cover of the EECM shall lock into place along the perimeter of the couch. This shall represent the cover which protects the injured crewmember on the EEC.

3.2.2.1.5 Helicopter Rescue Procedures.

3.2.2.1.5.1 Connections.

3.2.2.1.5.1.1 The EECM shall incorporate TBD number of latches for connection with the HC-60 helicopter rescue cable.

3.2.2.1.5.1.2 The connections shall be completed in a TBD allotted time.

3.2.2.1.5.1.3 The connection of the EECM to the HC-60 helicopter cable shall have a fail-safe mechanism to prevent detachment.

3.2.2.1.5.2 Lift.

3.2.2.1.5.2.1 The EECM shall not exceed the rated load of 600 pounds of the HC-60 helicopter lift mechanism.

3.2.2.1.5.3 Pulling in Emergency Egress Couch Model.

3.2.2.1.5.3.1 The EECM shall fit into the XXX feet wide by XXX feet high door of the HC-60 helicopter.

3.2.2.1.5.3.2 The EECM shall be pulled inside of the HC-60 helicopter door by a Flight Engineer.

3.2.2.1.5.3.3 The sling height shall incorporate vertical alignment with HC-60 helicopter door.

3.2.2.1.6 Attachment Points.

3.2.2.1.6.1 Attachment points of the EECM shall be capable of varying along the perimeter in TBD number of positions.

3.2.2.1.7 Sling Configuration.

3.2.2.1.7.1 Sling configuration shall be able to vary in accordance with the TBD placement of attachment points.

3.2.2.1.8 Durability

3.2.2.1.8.1 The EECM life span shall last a TBD amount of time during which the data needed will been obtained.

3.2.2.1.8.2 Environmental Conditions.

3.2.2.1.8.2.1 The EECM shall be able to withstand up to XXX knots of wind.

3.2.2.1.8.2.2 The EECM shall be able to withstand XXX rain conditions.

3.2.2.1.8.2.3 The EECM shall be able to withstand Sea State 4 conditions.

3.2.2.1.8.2.4 The EECM shall be able to resist salt water corrosion for the duration of the testing period.

3.2.2.1.9 Transportation.

3.2.2.1.9.1 The EECM shall be able to withstand transportation from the storage facility to the test sight.

3.2.2.1.10 Product Assurance.

3.2.2.1.10.1 Safety.

3.2.2.1.10.1.1 The EECM shall have no sharp edges.

3.2.2.1.10.1.2 The slings of the EECM shall meet TBD standards as specified in NSS/GO-1740.9 safety standard document.

3.2.2.1.10.1.3 The weights within the EECM shall be securely fastened to the EECM by TBD methods.

3.2.2.1.10.2 Operational Reliability.

3.2.2.1.10.2.1 The EECM shall perform XXX amounts of tests to obtain the data needed.

3.2.2.1.11 Data Collection.

3.2.2.1.11.1 Data shall be collected on the magnitude and frequency of pitch the EECM experiences during ascent.

3.2.2.1.11.2 Data shall be collected on the magnitude and frequency of yaw the EECM experiences during ascent.

3.2.2.1.11.3 Data shall be collected on the magnitude and frequency of heave the EECM experiences during rescue retrieval.

3.3 Operational Requirements.

3.3.1 General Operational Requirements.

3.3.1.1 General System Operational Requirements.

3.3.1.1.1 The EECM shall covert from a backboard configuration to a full size medical couch configuration within an allotted time.

3.3.1.1.2 Dynamic Characteristics.

3.3.1.1.2.1 The center of gravity shall be changed by varying weight distributions.

3.3.1.1.2.2 The moment of inertia shall be changed by varying weight distribution.

3.3.1.1.3 Geometric Characteristics.

3.3.1.1.3.1 The EECM shall change height by adding sections in TBD increments.

3.3.1.1.3.2 The EECM cover shall occupy the least amount of space and be attached and removed with minimal effort.

3.3.1.1.4 Helicopter Rescue Procedures.

3.3.1.1.4.1 The sling configuration shall be connected by PJ's.

3.3.1.1.4.2 The EECM shall be captured and pulled into the helicopter by a PJ.

3.3.1.1.4.3 The EECM shall be recovered and secured by helicopter PJ's with minimal effort and in the allotted time.

3.3.1.1.4.4 The EECM shall slide on the helicopter floor with minimal effort.

3.3.1.1.5 Transportation.

3.3.1.1.5.1 The EECM shall be transported by means of a vehicle.

3.3.1.1.5.2 The EECM shall be carried by test personnel in a safe and efficient manner.

3.3.1.1.6 Product Assurance.

3.3.1.1.6.1 Safety.

3.3.1.1.6.1.1 All procedures involved with the EECM shall be performed without endangering personnel.

3.3.1.1.7 Data Collection.

3.3.1.1.7.1 Pitch shall be measured in a simple internal method.

3.3.1.1.7.2 Yaw shall be measured in a simple internal method.

3.3.1.1.7.3 Heave shall be measured in a simple internal method.

3.3.1.1.8 Documentation.

3.3.1.1.8.1 Visual data shall be collected with video equipment and personnel observations.

3.3.1.1.8.2 All data shall be collected and stored.

3.3.1.1.8.3 All documentation shall be provided for operation.

3.3.2 Specific Operational Requirements.

3.3.2.1 Specific System Operational Requirements.

3.3.2.1.1 The EECM shall convert from a backboard configuration to a full size medical couch configuration within a TBD amount of time.

3.3.2.1.2 Dynamic Characteristics.

3.3.2.1.2.1 The center of gravity shall be changed by varying the weight distributions in a quick and accurate procedure. The calculated center of gravity shall be within TBD inches from the actual center of gravity.

3.3.2.1.2.2 The moment of inertia shall be changed by varying the weight distributions in a quick and accurate procedure. The calculated moment of inertia shall be within TBD percentage of the actual moment of inertia.

3.3.2.1.3 Geometric Characteristics.

3.3.2.1.3.1 The EECM shall change height by adding sections to facilitate the changing of configuration in a minimal amount of time and effort TBD.

3.3.2.1.3.2 The EECM cover shall use the minimal amount of space and still protect the injured crewmember.

3.3.2.1.4 Helicopter Rescue Procedure.

3.3.2.1.4.1 The sling configuration shall be connected by TBD number of PJ's and in a TBD amount of time.

3.3.2.1.4.2 The EECM shall be captured and pulled into the helicopter by a PJ with XXX amount of effort and time TBD.

3.3.2.1.4.3 The EECM shall slide on the helicopter floor with a minimal amount of effort TBD.

3.3.2.1.5 Transportation.

3.3.2.1.5.1 The EECM shall be transported by means of a TBD size pickup truck or van.

3.3.2.1.5.2 The EECM shall be carried by TBD number of test personnel in a minimal TBD number of units. Each separate unit carried shall not exceed a TBD weight to provide safe handling.

3.3.2.1.6 Product Assurance.

3.3.2.1.6.1 Safety.

3.3.2.1.6.1.1 All procedures involved with the EECM shall be performed without exposing personnel to potential harm. This includes transporting, assembling, and testing.

3.3.2.1.7 Data Collection.

3.3.2.1.7.1 Pitch shall be measured by an internal method which is powered and operated independent of ground support. This system shall operate under minimal manual interaction and without interfering with other procedures.

3.3.2.1.7.2 Yaw shall be measured by an internal method which is powered and operated independent of ground support. This system shall operate under minimal manual interaction and without interfering with other procedures.

3.3.2.1.7.3 Heave shall be measured by an internal method which is powered and operated independent of ground support. This system shall operate under minimal manual interaction and without interfering with other procedures.

3.3.2.1.8 Documentation.

3.3.2.1.8.1 Visual data shall be collected with video equipment and by personal observations. Markings representing the center of gravity, dimensions, and orientation shall be used to facilitate this documentation.

3.3.2.1.8.2 All data shall be collected and stored on paper and computer disk.

3.3.2.1.8.3 All documentation shall be provided for the operation of the EECM in manuals and on a computer disk.

4.0 VERIFICATIONS.

4.1 Definition.

4.2 Performance Verification.

4.2.1 General Performance Verification.

4.2.1.1 General Performance System Verifications.

4.2.1.1.1 Buoyancy.

4.2.1.1.1.1 Verify that the EECM can float up-right while at maximum weight of 600 pounds.

4.2.1.1.2 Confirm that the EECM is capable of varying from a simple litter to a complex medical couch.

4.2.1.1.3 Dynamic Characteristics.

4.2.1.1.3.1 Verify that the EECM is capable of varying the location of the center of gravity in the vertical and longitudinal axes.

4.2.1.1.3.2 Verify that the EECM is capable varying the moment of inertia in the longitudinal axis.

4.2.1.1.4 Geometric Characteristics.

4.2.1.1.4.1 Verify that the length of the EECM is seven feet.

4.2.1.1.4.2 Verify that the width of the EECM is two feet.

4.2.1.1.4.3 Confirm that the EECM can vary in height up to one foot.

4.2.1.1.4.4 Confirm that the EECM cover locks on and off.

4.2.1.1.5 Helicopter Rescue Procedures.

4.2.1.1.5.1 Connections.

4.2.1.1.5.1.1 Verify that the EECM can connect to the helicopter rescue cable in a TBD number of methods.

4.2.1.1.5.1.2 Verify that the EECM can be connected to the helicopter cable within an allotted time.

4.2.1.1.5.1.3 Verify that the EECM connections are secure.

4.2.1.1.5.2 Lift.

4.2.1.1.5.2.1 Confirm that the maximum weight of the EECM does not exceed the rated load of the lift mechanism.

4.2.1.1.5.3 Pulling in EECM.

4.2.1.1.5.3.1 Verify that the EECM can fit through the helicopter door.

4.2.1.1.5.3.2 Verify that the EECM can be pulled into the helicopter by a PJ.

4.2.1.1.5.3.3 Confirm that the sling height allows the EECM to be lifted even with the helicopter door.

4.2.1.1.6 Attachment Points.

4.2.1.1.6.1 Confirm that the attachment points can vary along the perimeter of the EECM.

4.2.1.1.7 Sling Configuration.

4.2.1.1.7.1 Confirm that the sling configuration is capable of varying with the attachment points.

4.2.1.1.8 Durability.

4.2.1.1.8.1 Verify that the EECM lifespan is capable of lasting until the tests are completed.

4.2.1.1.8.2 Environmental Conditions.

4.2.1.1.8.2.1 Test the integrity of the EECM in windy conditions.

4.2.1.1.8.2.2 Test the integrity of the EECM in rainy conditions.

4.2.1.1.8.2.3 Test the integrity of the EECM in rough seas.

4.2.1.1.8.2.4 Verify that the EECM can resist salt water corrosion.

4.2.1.1.9 Transportation.

4.2.1.1.9.1 Confirm that the EECM can withstand transportation.

4.2.1.1.10 Product Assurance.

4.2.1.1.10.1 Safety.

4.2.1.1.10.1.1 Confirm that the EECM has no sharp edges.

4.2.1.1.10.1.2 Confirm that the slings of the EECM meet specified safety standards.

4.2.1.1.10.1.3 Verify that the weights within the EECM can be fastened securely.

4.2.1.1.10.2 Operational Reliability.

4.2.1.1.10.2.1 Confirm that the EECM can perform enough tests to obtain the data needed.

4.2.1.1.11 Data Collection.

4.2.1.1.11.1 Verify that data can be collected on the pitch of the EECM during ascent.

4.2.1.1.11.2 Verify that data can be collected on the yaw of the EECM during ascent.

4.2.1.1.11.3 Verify that data can be collected on the heave of the EECM during rescue retrieval.

4.3 Operational Verifications.

4.3.1 General Operational Verifications.

4.3.1.1 General System Operational Verifications.

4.3.1.1.1 Verify that the EECM converts from a backboard configuration to a full size medical couch configuration within an allotted time.

4.3.1.1.2 Dynamic Characteristics.

4.3.1.1.2.1 Verify that the center of gravity changes by varying weight distributions.

4.3.1.1.2.2 Verify that the moment of inertia changes by varying weight distributions.

4.3.1.1.3 Geometric Characteristics.

4.3.1.1.3.1 Confirm that the EECM can change height by adding sections.

4.3.1.1.3.2 Confirm that the EECM cover can be secured and removed with minimal effort.

4.3.1.1.4 Helicopter Rescue Procedures.

4.3.1.1.4.1 Verify that the sling configuration can be connected by PJ's.

4.3.1.1.4.2 Verify that the EECM can be captured and pulled into the helicopter by a PJ.

4.3.1.1.4.3 Verify that the EECM can slide along the helicopter floor with minimal effort.

4.3.1.1.5 Transportation.

4.3.1.1.5.1 Verify that the EECM can be transported by means of a vehicle.

4.3.1.1.5.2 Verify that the EECM can be carried by test personnel in an efficient and safe manner.

4.3.1.1.6 Product Assurance.

4.3.1.1.6.1 Safety.

4.3.1.1.6.1.1 Verify that all procedures involved with the EECM can be performed without endangering personnel.

4.3.1.1.7 Data Collection.

4.3.1.1.7.1 Confirm that pitch can be measured by a simple, internal method.

4.3.1.1.7.2 Confirm that yaw can be measured by a simple, internal method.

4.3.1.1.7.3 Confirm that heave can be measured by a simple, internal method.

4.3.1.1.8 Documentation.

4.3.1.1.8.1 Verify that data can be taken visually using video equipment and personal observations.

4.3.1.1.8.2 Verify data storage capability.

4.3.1.1.8.3 Verify documentation is provided for operation.

5.0 PACKAGING

6.0 NOTES

APPENDIX O

EEC CONFIGURATION MODEL

DECISION MATRICES

SYSTEM	DESIGN PARAMETERS	INITIAL COST	OPERATIONAL COST	SAFETY OPERATIONAL PERFORMANCE	RELIABILITY	MAINTENANCE	DURABILITY	SIMPLICITY	FLEXIBILITY	CONSTRUCTION	STRENGTH	TOTAL
	7	5	10	9	8	4	8	9	9	8	7	
DUMMY	8	19	18	17	19	15	16	7	4	6	15	1076
* WEIGHT SYSTEM	14	19	16	18	17	10	18	16	18	16	18	1395
DO NOTHING	20	20	20	0	0	20	20	20	0	20	0	1020

* OPTIMAL SOLUTION

Figure O-1 Human Weight Distribution System Matrix

SYSTEM \ DESIGN PARAMETERS	INITIAL COST	OPERATIONAL COST	SAFETY	OPERATIONAL PERFORMANCE	RELIABILITY	MAINTENANCE	DURABILITY	SIMPLICITY	FLEXIBILITY	CONSTRUCTION	STRENGTH	TOTAL
	7	5	10	9	8	4	8	9	8	8	9	
* RAIL SYSTEM	17	16	17	17	17	16	17	18	16	15	18	1430
WORM SYSTEM	15	17	18	18	14	13	14	15	17	13	15	1318
RAIL AND WORM	10	15	19	18	15	13	12	10	18	7	16	1127
WEIGHT BLOCKS	5	16	11	5	8	10	10	8	18	10	10	840
PEG SYSTEM	15	16	17	10	13	15	12	16	10	17	12	1173

* OPTIMAL SOLUTION

Figure O-2 Medical Weight Distribution System Matrix

SYSTEM / DESIGN PARAMETERS	INITIAL COST	OPERATIONAL COST	SAFETY	OPERATIONAL PERFORMANCE	RELIABILITY	MAINTENANCE	DURABILITY	SIMPLICITY	FLEXIBILITY	CONSTRUCTION	STRENGTH	TOTAL
	7	5	10	9	7	4	8	8	6	9	9	
* LAYERS	16	18	17	17	18	17	16	17	10	15	18	1340
ATTACHABLE BLOCKS	7	10	12	12	6	12	10	5	18	8	7	780
INFLATEABLE SIDES	5	12	13	16	10	13	9	18	4	6	8	857

* OPTIMAL SOLUTION

Figure O-3 Adjustable Height System Matrix

SYSTEM \ DESIGN PARAMETERS	INITIAL COST	OPERATIONAL COST	SAFETY	OPERATIONAL PERFORMANCE	RELIABILITY	MAINTENANCE	DURABILITY	SIMPLICITY	FLEXIBILITY	CONSTRUCTION	STRENGTH	TOTAL
	7	5	10	9	7	4	8	8	8	9	9	
PERIMETER			17	17	16	10	18	10	19	5	16	1040
* SPECIFIC AREA			17	19	18	18	18	17	16	12	16	1199
* SLIDING COMPRESSION COLLAR	17	19	17	15	18	17	16	15	19	15	17	1401
FIXED RING	17	19	16	14	18	16	16	17	12	12	18	1320
SWING-WAY HOOK	17	15	18	15	15	16	15	11	10	16	12	1218

* OPTIMAL SOLUTION

Figure O-4 Sling and Attachment Point Matrix

SYSTEM \ DESIGN PARAMETERS	INITIAL COST	OPERATIONAL COST	SAFETY	OPERATIONAL PERFORMANCE	RELIABILITY	MAINTENANCE	DURABILITY	SIMPLICITY	FLEXIBILITY	CONSTRUCTION	STRENGTH	TOTAL
	7	5	8	9	8	4	7	7	9	8	8	
EXTERNAL FLOAT	16	18	17	14	18	17	15	13	13	13	14	1205
MATTRESS FLOAT	17	18	8	19	18	17	16	18	12	18	13	1250
INTERNAL INFLATEABLE FLOAT	9	10	15	17	10	14	13	16	6	12	18	1019
* INTERNAL SOLID FLOAT	16	16	19	17	19	18	18	13	15	17	17	1345

* OPTIMAL SOLUTION

Figure O-5 Flotation System Matrix

	SYSTEM	INITIAL COST	OPERATIONAL COST	SAFETY	OPERATIONAL PERFORMANCE	RELIABILITY	MAINTENANCE	DURABILITY	SIMPLICITY	WEIGHT	CONSTRUCTION	STRENGTH	TOTAL
	DESIGN PARAMETERS	9	2	10	9	8	3	7	9	8	7	8	
*	STEEL	14	15	14	17	16	4	18	12	12	16	18	1175
	ALUMINUM	15	16	14	17	16	15	12	11	15	11	11	1101
*	WOOD	18	14	16	10	15	17	16	15	18	19	11	1223
*	STYROFOAM	20	16	18	15	12	12	12	18	18	16	18	1305
	FIBERGLASS	12	18	17	16	17	16	17	7	13	3	12	1045
	PVC	19	14	18	15	15	18	12	16	16	12	6	1176
	CANVAS	15	16	14	11	12	16	11	11	16	7	8	994

* OPTIMAL SOLUTION

Figure O-6 Materials Matrix

APPENDIX P

EEC CONFIGURATION MODEL

WORK BREAKDOWN STRUCTURE DICTIONARY

WORK BREAKDOWN STRUCTURE DICTIONARY

1.0 DEVELOPMENT

1.1 FINAL DESIGN DRAWINGS

1.1.1 Rough Sketches: The rough sketches include a preliminary drawing of the couch and its components without any specific dimensions. These drawings are not drawn to scale but include every parameter of variances to be modified.

1.1.2 Detailed Drawings: After completing the rough sketches, the designs are drawn to detail with dimensions and to scale.

1.1.3 Final Working Plans: These plans include the detailed drawings with addition to the modifications of the parameters. These parameters consist of height of the couch, weight, material specifications, and overall size.

1.2 PURCHASING

1.2.1 Construction Materials: Materials to be purchased for the product include the premade basic litter, wood and styrofoam, and aluminum.

1.2.2 Construction Tools: Hand-held tools will be purchased for basic construction and welding operations. This includes all safety devices for application.

1.2.3 Fasteners: Fasteners include the compression collars for the lift attachment points, nuts and bolts, nails, and epoxy.

1.3 MANUFACTURING

1.3.1 Make Layers: Three layers will be assembled to vary the height of the EECM. Two 1 inch layers and one 2 inch layer will be made of wood frames and styrofoam.

1.3.2 Pretest: Individual components of the model will be checked for construction defects and compatibility with other connecting components.

1.3.3 Assemble: All components will be attached together to form the form the entire EECM. Any construction or compatibility problems will be corrected in 1.3.4.

1.3.4 Rework: The EECM will be disassembled for rework. Individual components will be modified if problems arose in the preliminary assembly phase.

1.3.5 Assemble: All components, including revised parts, will again be assembled into the entire EECM. Pretesting of the couch may begin once the manufacturing phase is completed.

1.4 FINISHING

1.4.1 Final Working Model: The finishing phase will be carried out simultaneously with the pretesting phase. All alterations to the EECM during the pretesting will contribute to the final working model. The final working model will be completed once the pretesting phase is concluded.

1.5 GOVERNING EQUATIONS

1.5.1 Center of Gravity: Equations will be determined for finding centers of gravity from varying weights on a rail system.

1.5.2 Moment of Inertia: Equations will be determined for finding moments of inertia from varying weights on a rail system.

1.6 REPORTS

1.6.1 Scheduling Report: This report is the preliminary report for the manufacturing and testing for the EECM. This includes the basic outline for the semester in the form of WBS, CPM, and milestone charts.

1.6.2 Midterm Report: This report is the construction and test planning report. It includes the performance of the testing procedure in detail.

1.6.3 Final Report: After all testing and modifications are completed, a test report or final report is written. This includes all observations and recommendations, including all positive and negative results of tests.

2.0 TESTING

2.1 PRETESTING

2.1.1 TEST REQUIREMENTS AND PROCEDURES

2.1.1.1 Objective: Is to design a full scale test model of the Emergency Egress Couch (EEC). This test model will have variable dynamic and geometric characteristics to aid in determining the optimal constraints and configuration of the actual EEC.

2.1.1.2 Requirements: The Emergency Egress Couch Model (EECM) will need to model a human from a 20% female to a 95% male. Medical equipment must also be modeled within the EECM using varying weights on a rail system.

2.1.1.3 Procedures: Pretesting the EECM consists of providing a wide variation of options for each of the following dynamic and geometric characteristics. Testing of the EECM by PAFB will determine the optimal setting for each characteristic.

2.1.1.4 Closeout: Closeout reviews and verifies the testing procedure for each of the dynamic and geometric characteristics.

2.1.2 ADJUSTABLE DYNAMIC CHARACTERISTICS

2.1.2.1 Weights: The EECM will vary from a simple backboard of minimal weight (175 lbs.) to a complex medical couch of maximum weight (600 lbs.). The weights should fasten securely and without difficulty.

2.1.2.2 Center of Gravity: Using a weighted rail system, several weight distributions will be created to shift the center of gravity. The center of gravity will be varied along the length of the couch up to 2 feet from the centerline.

2.1.2.3 Moment of Inertia: Varying moments of inertia will be tested using the weighted rail system.

2.1.2.4 Lift Attachment Points: Pretesting of the lift attachment points will consist of varying the connections about the perimeter of the couch. Four lift attachment points, chosen by PAFB in 2.2.1.4, will be employed in the final EECM.

2.1.3 ADJUSTABLE GEOMETRIC CHARACTERISTICS

2.1.3.1 Height: Incremental sections made of wood and styrofoam will be added to the EECM to change the height. The total height of the model will be varied from a flat liter of 4 inches to a maximum height of one foot, not including cover. Sections should be added and removed with a minimal amount of time and effort.

2.1.3.2 Cover: Three different EECM covers that will be tested are the triangular, trapezoidal, and curved configurations. Covers should fasten securely to the perimeter of the couch.

2.2 TESTING (PAFB)

2.2.1 OPTIMAL DYNAMIC CHARACTERISTICS

2.2.1.1 Placement of Medical Equipment: Optimal settings for the weight system will be chosen by PAFB to the model placement of medical equipment.

2.2.1.2 Location of Center of Gravity: Optimal settings for placement of weights on the rail system will be chosen by PAFB to match the center of gravity of actual medical equipment.

2.2.1.3 Placement of Moment of Inertia: Optimal settings for the placement of weights on the rail system will be chosen by PAFB to duplicate the moment of inertia of actual medical equipment.

2.2.1.4 Location for Lift Attachment Points: Four optimal lift attachment points will be chosen by PAFB.

2.2.2 OPTIMAL GEOMETRIC CHARACTERISTICS

2.2.2.1 Couch Height: PAFB will choose an optimal couch height to suitably fit medical equipment.

2.2.2.2 Shape of Cover: An optimal cover will be chosen by PAFB for the couch model.

APPENDIX Q

EEC CONFIGURATION MODEL

MODEL CONFIGURATION RATING FORMS

Example Questionnaire

(1 = POOR, 2 = FAIR, 3 = GOOD, 4 = VERY GOOD, 5 = BEST)

TEST: ____________________

DATE: ____________________

TEST PERFORMED BY: ____________________

EECM CONFIGURATION: ____________________

1. <u>HEIGHT:</u> *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ____ YES ____ NO
   (b) pull the couch into the helicopter?
   ____ YES ____ NO
   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. <u>WEIGHT:</u> *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ____ YES ____ NO
   (b) pull the couch into the helicopter?
   ____ YES ____ NO
   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. <u>SPIN TEST:</u> *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ____ YES ____ NO
   (b) did the EECM spin uncontrollably?
   ____ YES ____ NO
   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. <u>HARNESS:</u> *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ____ YES ____ NO
   Rate the handling qualities of this EECM configuration:
   1 2 3 4 5

5. <u>OVERALL:</u> *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. <u>COMMENTS:</u> ____________________
____
____
____
____
____

D-3 No
H-1 Cove

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: HIGH HOVER
DATE: 3/26/92
TEST PERFORMED BY:
EECM CONFIGURATION: B, 3, H-1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS:

B-3 No
H-1 Cover

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: Low Hover & Spin
DATE: 3/26/92
TEST PERFORMED BY: ____
EECM CONFIGURATION: B-3, H-1 ~~[illegible]~~ ~~B-1, H-1~~

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO
   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO
   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓ NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓ NO
   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓ NO
   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: Had tendency to oscilate while in Hover

63 – H1

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: HIGH HOVER
DATE: 3/26/92
TEST PERFORMED BY:
EECM CONFIGURATION:

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓ NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓ NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓ NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: Had some tendency to want to oscillate in fwd flt

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: LOW HOVER & SPIN
DATE: 3/26/92
TEST PERFORMED BY:
EECM CONFIGURATION: ~~B2~~ B-1

~~B2~~ B3-H1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS:

B-3

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: COMPATIBILITY
DATE: 3/26/92
TEST PERFORMED BY:
EECM CONFIGURATION: ~~B, 1, H-1~~ B3, H-1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

N/A ~~3.~~ SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS:

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: SLOW FORWARD FLIGHT

DATE: 3/26/92

TEST PERFORMED BY: ______

EECM CONFIGURATION: B, 2, H1

1. <u>HEIGHT:</u> *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO
   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. <u>WEIGHT:</u> *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO
   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. <u>SPIN TEST:</u> *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO
   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. <u>HARNESS:</u> *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO
   Rate the handling qualities of the harness:
   1 2 3 4 5

5. <u>OVERALL:</u> *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. <u>COMMENTS:</u> ______

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: HIGH HOVER
DATE: 3/26/92
TEST PERFORMED BY:
EECM CONFIGURATION: ~~B, 2, H2~~ B-1, H-1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ✓YES Bounced ___NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS:

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: LOW HOVER & SPIN
DATE: 3/26/92
TEST PERFORMED BY: ____________
EECM CONFIGURATION: B, 2, ~~H-8~~ H-1

1. **HEIGHT:** *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. **WEIGHT:** *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. **SPIN TEST:** *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓ NO
   (b) did the EECM spin uncontrollably?
   ✓ YES Bounced ___NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. **HARNESS:** *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓ NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. **OVERALL:** *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. **COMMENTS:** Couch Tended to Bounce Below the [illegible]

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: SLOW FORWARD FLIGHT
DATE: 3/26/92
TEST PERFORMED BY: ______
EECM CONFIGURATION: A, 3, H-1

1. <u>HEIGHT:</u> *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. <u>WEIGHT:</u> *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. <u>SPIN TEST:</u> *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓ NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓ NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. <u>HARNESS:</u> *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓ NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. <u>OVERALL:</u> *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. <u>COMMENTS:</u> BEST YET

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: HIGH HOVER

DATE: 3/26/92

TEST PERFORMED BY: ______

EECM CONFIGURATION: A, 3, H-1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO
   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO
   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO
   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO
   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: BEST TO DATE

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: LOW HOVER ~~& SPIN~~
DATE: 3/26/92
TEST PERFORMED BY:
EECM CONFIGURATION: A, 3, H-1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓ NO
   (b) pull the couch into the helicopter?
   ___YES ✓ NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓ NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓ NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓ NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: BEST YET

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: SLOW FORWARD FLIGHT
DATE: 3/26/92
TEST PERFORMED BY: ______
EECM CONFIGURATION: A, 2, H-2

1. <u>HEIGHT:</u> *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. <u>WEIGHT:</u> *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. <u>SPIN TEST:</u> *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. <u>HARNESS:</u> *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. <u>OVERALL:</u> *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. <u>COMMENTS:</u> ______

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: HIGH HOVER
DATE: 3/21/92
TEST PERFORMED BY: ______
EECM CONFIGURATION: A, 2, H-2

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ✓YES ___NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: ______

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: LOW HOVER & SPIN
DATE: 3/26/92
TEST PERFORMED BY: ________
EECM CONFIGURATION: A, Z, H-2

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO
   Rate the handling qualities of the EECM at this height:
   1 2 ~~3~~ 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ✓YES ___NO
   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

3. SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO
   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO
   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: The LONG CABLE ON THE HARNESS WAS BENT AT A 90° ANGLE AT THE TOP CRIMP WHICH IS UNACCEPTABLE.

QUESTIONNAIRE

(1=POOR, 2=FAIR, 3=GOOD, 4=VERY GOOD, 5=BEST)

TEST: COMPATIBILITY TEST

DATE: 3/24/92

TEST PERFORMED BY:

EECM CONFIGURATION: A, 1, H-1

1. HEIGHT: *Did the height of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ___YES ✓NO

   Rate the handling qualities of the EECM at this height:
   1 2 3 4 5

2. WEIGHT: *Did the weight of the EECM interfere with your ability to:*
   (a) hook up the couch to the harness and helicopter cable?
   ___YES ✓NO
   (b) pull the couch into the helicopter?
   ✓YES some ___NO

   Rate the handling qualities of the EECM at this weight:
   1 2 3 4 5

NA ~~3.~~ SPIN TEST: *Did the EECM SPIN interfere with your ability to:*
   (a) pull the couch into the helicopter?
   ___YES ✓NO
   (b) did the EECM spin uncontrollably?
   ___YES ✓NO

   Rate the spin characteristics of this EECM configuration:
   1 2 3 4 5

4. HARNESS: *Did the harness interfere with your ability to pull the EECM into the helicopter?*
   ___YES ✓NO

   Rate the handling qualities of the harness:
   1 2 3 4 5

5. OVERALL: *Rate the overall handling qualities of this EECM configuration:*
   1 2 3 4 5

6. COMMENTS: