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Medical Evaluations on the KC-135 1991 Flight Report Summary

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ACRONYMS/ABBREVIATIONS

ABG	Arterial Blood Gas
ACLS	Advanced Cardiac Life Support
ACRV	Assured Crew Return Vehicle
AHA	American Heart Association
ALS	Advanced Life Support
AMAK	Airway Medical Accessory Kit
BCPs	Birth Control Pills
BP	Blood Pressure
BVM	Bag Valve Mask
CAD	Computer Aided Drafting
CCAD	Cardiac Compression Assist Device
CHeCS	Crew Health Care System
CMO	Crew Medical Officer
CMRS	CHeCS Medical Restraint System
CPR	Cardiopulmonary Resuscitation
CVP	Central Venous Pressure
DMCF	Definitive Medical Care Facility
DSO	Detailed Supplementary Objective
ECG	Electrocardiogram
EDO	Extended Duration Orbiter
EHS	Environmental Health System
EMK	EDO Medical Kit
EMT	Emergency Medical Technician
EMT-B	Emergency Medical Technician - Basic
ET	Endotracheal Tube
HAL	Hyperbaric Airlock
HMF	Health Maintenance Facility
HPLC	High-Pressure Liquid Chromatography
IB	Inboard
IV	Intravenous
KED	Kendrick Extraction Device
LFD	Laminar Flow Device
MBK	Medications and Bandage Kit
MDSSC	McDonnell Douglas Space Systems Company
MRS	Medical Restraint System
MTC	Man-Tended Capability
NPA	Nasopharyngeal Airway
OB	Outboard
OPA	Oropharyngeal Airway

PDR	Preliminary Design Review
PMC	Permanent Manned Configuration
prn	As needed
P2	Pocket 2
SOC	Surgical Overhead Canopy
SOMS	Shuttle Orbiter Medical System
SSF	Space Station Freedom
TBD	To Be Determined
TPN	Total Parenteral Nutrition
VI	Ventolin® Inhaler
Vfib	Ventricular fibrillation
Vtach	Ventricular tachycardia

PREFACE

This document is a product of the efforts expended by the Medical Operations Branch at the Johnson Space Center to support medical evaluations in a microgravity environment. It is a collection of 25 flight reports from work performed on the KC-135. The reports, appearing in chronological order, include investigations of various areas of the medical sciences. The report format follows general guidelines and may vary slightly from one report to the next to accommodate differences in experiment design and procedures.

This document is intended to serve as a record of the continued development, planning, and evolution of the Health Maintenance Facility and Medical Operations for Space Station Freedom.

Funding for this document was provided by the Research and Technology Objectives and Plan (199-02-31-40).

ABSTRACT

This document represents the medical investigations completed on the KC-135 during Fiscal Year 1991 in support of the development of the Health Maintenance Facility and Medical Operations. The experiments, consisting of medical and engineering evaluations of medical hardware and medical procedures, were conducted by both medical and engineering personnel. The hardware evaluated during this time period included prototypes of a crew medical restraint system and advanced life support pack, shuttle Orbiter medical system, airway medical accessory kit, supplementary Extended Duration Orbiter medical kit, and a surgical overhead canopy. The results of these engineering evaluations will be used to design flight hardware and to identify hardware-specific training requirements. In addition, the following procedures were evaluated: transport of an ill or injured crewmember at Man-Tended Capability, surgical technique in microgravity, transfer of liquids in microgravity, Advanced Cardiac Life Support using Man-Tended Capability Health Maintenance Facility hardware, medical transport using a model of the Assured Crew Return Vehicle, and evaluation of delivery mechanisms for aerosolized medications in microgravity. The results of these medical procedure evaluation flights allow for a better understanding of the types of procedures that can be performed in a microgravity environment. These efforts estimate the time required to complete specific medical tasks, identify microgravity-specific problems which will need to be resolved, identify medical operational problems with instrument configuration, and provide a better understanding of what will need to be included in the training programs.

Second Prototype Medical Restraint System for Space Station Freedom

Flight Date:	January 15, 1991
Principal Investigators:	Roger Billica, M.D. (NASA-JSC) Tom Taylor (KRUG Life Sciences)
Co-investigators:	Terry Guess (KRUG Life Sciences) Victor Kizzee (KRUG Life Sciences) Ed Cordes (MDSSC) Debbie Orsak (MDSSC)

GOAL

The purpose of this flight investigation was to test and evaluate the second generation prototype medical restraint system (MRS) for the Space Station Freedom (SSF) Health Maintenance Facility (HMF).

OBJECTIVES

1. Demonstrate the safety of the new design in zero-gravity (zero-g) and 2g flight, including weight-bearing of human subjects.

2. Evaluate the functionality of the new design and determine any modifications needed for its usefulness as the MRS in later project work.

3. Investigate some of the new design concepts that have evolved from the first prototype and are being proposed for the flight unit.

4. Consider associated restraint issues such as operator foot and waist restraint, patient restraint, equipment restraint, cardiopulmonary resuscitation (CPR) performance, and spine stabilization.

5. Assist the McDonnell Douglas Space Systems Company (MDSSC) engineers in using the new MRS to perform a human factors analysis and reach envelope study (see separate flight report).

INTRODUCTION

A KC-135 flight test was performed to evaluate the second generation MRS for the Space Station HMF. The standard 40-parabola flight profile was followed affording approximately 30 seconds of near-zero-g with each parabola. Three investigators from the HMF project were present during the flight and were accompanied by two investigators from MDSSC, who performed a parallel and simultaneous study (see Crew Medical Restraint System). The new MRS underwent extensive preflight evaluation, including safety and stress analysis. Additionally, MDSSC design engineers responsible for the flight MRS incorporated proposed concepts into the prototype.

The design of the second generation MRS evolved from a concept originally developed by Dr. Bruce Houtchens which had been used and evaluated extensively for several years. For this study, the flight activities focused primarily on

the basic function and efficacy of the new design to ensure that it would fulfill a useful role in the ongoing project development and would serve as a foundation for further medical studies and simulations (both in the ground lab and in KC-135 flight). The flight sequence was as follows:

Parabolas 1-10

- Evaluate basic mechanical function
  - *position headboard up/down*
  - *position footboard down/up*
  - *remove/install headboard*

- Evaluate load deflection
  - *supine, midsection*
  - *sitting, end of headboard*
  - *sitting, midsection*

Parabolas 11-30

- Evaluate foot and waist restraints
- Evaluate equipment restraints
- Evaluate Cardiac Compression Assist Device (CCAD)
- Perform reach envelope study

Parabolas 31-40

- Evaluate spine stabilization
- Evaluate transport function of headboard

From the earliest phases of the SSF HMF project, it was realized that a multifunctional medical restraint system was required to provide a stable foundation for the many required medical tasks. This knowledge was based on spaceflight data and on medical simulations in KC-135 zero-g. As a result, most activity protocols for the HMF now begin with the phrase "deploy MRS." Its multifunctional role encompasses providing restraint and stability for the 1) patient, 2) crew medical officer(s) (CMO), and 3) equipment. Its utility incorporates a wide variety of scenarios including that of patient bed, operating table, examination table, dental chair, stretcher for transport, work surface, and spinal stabilization backboard. The first prototype was designed primarily for use with surgical procedures and provided many good features, especially regarding a wide variety of attachment points and flexible positioning and configurations. As experience accumulated, it was realized that a much simpler and more basic design was needed to suit a broader range of uses.

The new design went from a single-center support column to a four-leg concept to provide greater stability for CMO restraint and a more solid platform for vigorous procedures (such as CPR.) A detachable headboard was incorporated for emergency and transport functions, and a variety of handholds and restraint locations were provided as well as a built-in foot restraint bar. The primary use for the MRS on SSF will be in a one-g orientation with the patient supine and the CMO restrained with hands free. Astronauts have emphasized that if the patient does not require supine positioning, the preference would be for minimal or no restraint (such as for simple examinations). As a result, the new MRS eliminated the spectrum of available position configurations and provided the capability for only simple adjustments for height, head-up and foot-down positions (no pitch, roll or yaw.) This simplification afforded the flexibility to incorporate other desired features.

As part of the process, it was well understood that the second prototype MRS was merely a step along the way toward the final flight article. Many issues remained unresolved at the time of its design, with hopes that its use would assist in resolving those issues. It was also known that many aspects of the second design would have to be adapted to qualify it for human use on the KC-135 (requiring 8g crash load capability).

METHODS, MATERIALS AND PERSONNEL

Second generation MRS prototype
HMF miniracks
Patient manikin
Patient restraints
CMO restraints (various types)
Advanced Life Support (ALS) pack
Instrument tray
C-spine collar and head brace with tape
CCAD prototype
Measuring ruler (for load deflection)
Misc. tape, straps, carabiners, bungee cords
Video recorder

Personnel consisted of one test engineer (non-flyer), one project physician, two technicians including an Emergency Medical Technician (EMT), and two MDSSC engineers.

Test results were recorded using written notes, dedicated project video, and nondedicated NASA still photography.

Preflight: Prior to flight, the test program was fine-tuned and the ground safety analysis was accomplished. Concepts for restraint mechanisms were incorporated into the flight test.

Parabolas 1-10: It was decided that no height adjustments would be performed during flight because it is difficult to perform this maneuver secondary to KC-135 design requirements and future users could determine preferred height prior to flight. The evaluation of basic mechanical function was performed by the two technicians familiar with the mechanisms of the MRS. They were loosely restrained during this activity, with one technician located on each side of the MRS to coordinate the tasks as a team.

The load deflection evaluation was accomplished by having one of the technicians (weighing approximately 200 lbs) restrained using the patient restraint straps of the MRS. Any positioning or adjustments were accomplished during the zero-g portion of the flight, and deflection measurements were taken during the 2g portion of the parabolas. The first measurement was taken from the midportion of the MRS frame (external railing) with the subject supine and load distributed. Next the patient was placed in a head-up, semireclining position with the headboard raised to approximately 45 degrees. The load measurement was taken at the far end of the elevated headboard in reference to the frame. The final measurement was taken again at the midportion of the frame with the patient sitting and full weight load on the center section of the MRS.

Parabolas 11-30: While the MDSSC engineers performed the reach envelope study, one investigator subjectively evaluated the utility of the new foot restraint bar and some simple concepts for waist restraint (for future KC-135 use rather than for SSF). As the reach study progressed, various items of HMF equipment were deployed with the MRS and again subjectively evaluated for function in future project activities. At the conclusion of the reach study, an attempt was made to use the CCAD prototype with the manikin restrained to the MRS, but the new MRS design was not compatible with the old CCAD.

Parabolas 31-40: One of the MDSSC engineers (representing the smaller body size range of 5% female) was restrained only to the headboard section of the MRS. Additional head and neck restraints were employed (leaving hands and arms free for safety) and stability during zero-g was subjective evaluated. The headboard was then detached (with patient) and used as a short spine immobilization board. During zero-g the patient and board were manipulated free of the MRS and an assessment made. The head and neck restraint portions

were removed and the patient was then transported using the headboard and torso straps.

RESULTS

Basic Mechanical Function

For the most part, the MRS functioned as planned. Some of the locking pins were awkward or difficult to insert due either to tightness of fit or shortness of the tether cord. The tether cords were useful in maintaining control of the pins, although more pins were needed to avoid having to relocate those provided during flight. During the manipulation of the footboard, the handle for the adjustment knob became detached due to rapid and vigorous adjustment; it was recommended that a detent be added to prevent future malfunctions. Raising and lowering the headboard was a two-person job that required coordination and the full parabola for each step. The footboard could be manipulated by one person. The headboard detachment and reattachment procedures functioned smoothly and easily.

It became clear during the flight that the footboard benefited from the extra reinforcing strap to prevent its fall in 2g, and that the headboard benefited from a similar retaining strap to keep it from floating up and then crashing down during negative-G. It was recommended that these straps be continued or functionally replaced in the KC MRS design.

Load Deflection

	Zero-g	2g	Difference
Supine, midportion	$30\ ^{1}/_{16}$"	$30\ ^{1}/_{16}$"	0
Semirecline, headboard	$19\ ^{3}/_{16}$"	$18\ ^{15}/_{16}$"	$^{1}/_{16}$"
Sitting, midportion	$30\ ^{1}/_{16}$"	30"	$^{1}/_{16}$"

These load deflections during 2g were minimal and well within the range of safe operation.

Foot and Waist Restraints

The new circumferential foot restraint bar was used and liked by all investigators. It was easy to step into and stay with, and simple to move along using feet only. The tendency to dorsiflex the feet under the bar to provide more secure restraint could prove fatiguing in prolonged activities. The bar was used exclusively during brief activities and precluded the need for waist restraint.

The simple cord loop ties with carabiners attached to the MRS rail proved effective and could serve as a waist restraint attachment until a more specific flight design concept is available. In some instances, the cords were so snug the investigators struggled to attach or release the carabiner.

In previous flights, it was noted that, for waist restraints to be really useful, the CMO must be able to snug the restraint tight against the MRS frame. If the waist restraint is loose, it only keeps the CMO in the general proximity of the MRS, and the foot restraint must be relied on for actual stability.

Two types of waist restraint were used during the flight: a mountain climbing seat harness and a wraparound belt. The seat harness provided more security and stability, especially regarding rotation. The wraparound belt provided more movement and freedom, especially with respect to rotation. More thorough evaluation of the restraints on this flight can be found in the report of the reach envelope study.

It was also noted that the simple patient restraint straps were effective and comfortable. However, the width of the MRS made it difficult

for one individual to deploy them in flight, and if the straps were unbuckled they tended to fall through the slots during 2g.

Equipment Restraints

The bracket and pin setup for attaching the instrument tray, CCAD and ALS pack were functional and effective. They required minimal time, especially if the subassembly of pieces was accomplished prior to deployment. There was some laxity noted in the interfacing of parts that was fine for zero-g but could become a problem with further loading during 2g.

CCAD Prototype

The new MRS and the CCAD were incompatible. The new MRS is significantly wider and the CCAD would not reach the desired area. Further evaluation was therefore postponed.

Reach Envelope Study

See Functional Reach, Restraint, and Deployment Study.

Spine Stabilization

The subject reported that head stabilization was good using the torso straps and cardboard head stabilizer with the MRS headboard in supine position. The addition of C-spine stabilization appeared to be quite effective. Both subjects noted a preference for torso and head padding and insulation for the MRS with prolonged supine restraint (even during zero-g.) The current design of slots in the headboard actually interfered with the placement of the head restraint due to lack of continuous surface area for attachment. This emphasized the need for an integrated design that allows the headboard to incorporate and interface with whatever head and neck immobilizer is selected for SSF use.

Transport Function

When the headboard and patient were detached from the MRS, it was easy for one or two operators to manipulate and move the assembly using the handholds in the headboard. The patient retained positioning on the headboard during zero-g without difficulty although a more secure method of strapping may provide less chance of slippage. Based on previous KC-135 transport studies, the headboard may be improved by incorporating more Kendrick Extraction Device (KED)-like features.

CONCLUSIONS

In general, the MRS proved to be safe, functional and effective for KC-135 use. Additional knowledge was gained concerning restraints and human factors interfaces that will contribute to further developmental progress. It is recommended that the few fine-tuning adjustments detailed in the Results Section of this report be incorporated into the second prototype.

Most of the knowledge and experience gained from this and previous studies continues to point toward a simple MRS with flexible function and one that is easy to deploy. Many of the original design features seem less desirable at this stage of the project. The transport and emergency functions seem paramount, and for each utilization scenario, the factors of restraint, stability, and mobility must be considered for patient, CMO, and equipment.

It is recommended that the second generation prototype be employed in support of a series of KC-135 flight tests and ground simulations, and that careful commentary be recorded as to its features and function. Using these data and the results of the SLS-1 Shuttle Flight MRS DSO, the next generation prototype should be available within the next year.

PHOTOGRAPHS

S91-26644: Investigators set up the MRS. One investigator attached to the MRS with CMO restraints passes a medical kit to the other.

S91-26645: Two investigators restrain medical hardware to the MRS. The waist straps used by the investigators are the prototype CMO restraints.

S91-26646: The investigator floats, restrained above the MRS. He is removing a medical kit for use.

S91-26649: A prototype CCAD is used on a test manikin.

S91-26650: Using the MRS, investigators simulate transport of a patient in microgravity.

S91-26651: The retaining pins are removed from the backboard of the MRS in preparing for patient transport.

S91-26653, S91-26656, and S91-26657: A restrained patient is moved about the cabin simulating transport of a patient in microgravity. Patient is attached to the head board of the MRS with restraint straps, and head is immobilized with a head strap.

S91-26656: *A restrained patient is moved about the cabin simulating transport of a patient in microgravity.*

Functional Reach, Restraint, and Deployment Study

Flight date:	January 15, 1991
Principal Investigator:	Roger Billica, M.D. (NASA-JSC)
Co-investigators:	Ed Cordes (MDSSC) Debbie Orsak (MDSSC) Terry Guess (KRUG Life Sciences) Victor Kizzee (KRUG Life Sciences)

GOAL

The purpose of this flight investigation was to determine and map accurately the maximum reach and deployment envelope for CMOs using the SSF HMF. This system is presently composed of SSF rack-mounted medical equipment, deployed life support systems, and the CHeCS Medical Restraint System (CMRS).

OBJECTIVES

1. Verify the HMF rack-mounted equipment's front panel accessibility for 5th and 95th percentile test subjects while restrained to a prototype CMRS using proposed foot and waist restraints.

2. Evaluate the proposed HMF CMRS waist and foot restraint systems as they relate to HMF accessibility.

3. Evaluate use volumes and methods for proposed HMF deployable equipment such as the defibrillator, ALS pack, and powered infusion pumps.

INTRODUCTION

A KC-135 flight test was performed in conjunction with a related CMRS prototype evaluation conducted by members of the HMF project team. The standard 40-parabola flight profile was followed affording approximately 30 seconds of near-zero-g with each parabola. Five test subjects were involved in the investigation. During the parabolas in which reach mapping was conducted, one test subject served as the 95% male profile (actual height 6' 2"), another as the 5% female (actual height 4' 9"), and one assisted in equipment preparation for subsequent parabolas. The flight also included dedicated video tape coverage.

Preflight evaluation and rehearsals identified the most promising CMRS restraint mechanisms, as well as procedures to allow the most effective use of available microgravity time. It was decided to use three types of waist restraint. The most basic waist restraints was a simple double waist loop attached at a single point to the CMRS outer rail. Other restraints included a 3-point mountain climbing harness and a hybrid harness developed by KRUG Softgoods. Foot restraint was accomplished using the foot restraint bar provided by the CMRS prototype. Although stated objectives of this

test did not include waist or foot restraint evaluation, preliminary design evaluations are provided in this report.

Reach/deployment mapping was not conducted during the initial and final 10 parabolas since a concurrent CMRS prototype evaluation was being conducted (see Second Prototype Medical Restraint System for Space Station Freedom report). The flight sequence was as follows:

Parabolas 1-10

- Assist in deployment of CMRS and determination of effective CMO/restraint attachment method. Assist dedicated video tape recording.
- Assist in CMRS deflection measurements.

Parabolas 11-20

- Map reach limits for 5% and 95% CMOs onto a simulated rack front panel from a midboard CMRS position.
- Map reach limits for 5% and 95% CMOs onto a simulated rack front panel from a headboard CMRS position.

Parabolas 21-30

- Evaluate and map deployed equipment use volumes for various sized test subjects.
- Evaluate various CMO and equipment restraint mechanisms

Parabolas 31-40

- Evaluate transport function of headboard and spine stabilization. Assist dedicated video tape recording.

As the rack installation design fidelity of the HMF and CHeCS in general has increased, it has become apparent that layouts sensitive to ergonomic and anthropometric issues are necessary to ensure the effective use of installed equipment. Earlier layouts have been sensitive to reach boundaries based on subjective one-g evaluations. The addition of a "free-standing" medical restraint system which provides definitive restraint of both patient and CMO further complicates the entire reach volume issue. Finally, the possibility of increasing reach boundaries in zero-g using certain types of waist restraint mechanisms made it apparent that a simulated zero-g environment study was needed. The results of this study, which involve representative examples of a CMRS, waist restraints, and rack front panel surfaces, will be the empirical data used to determine future equipment and interface panel locations. The rack face-to-CMRS relationship is representative of current habitation module or node layouts and has been favored by CMOs in various ground-based and KC-135 medical simulations. This configuration reflects a one-g orientation with the patient supine and parallel to the rack faces. The distance between the CMRS and the rack faces is 28.5 inches (see figures 1 and 2) which closely approximates the distance in the HMF habitation module configuration. All reach measurements were taken with the test subjects using some form of a waist restraint. Current CMO opinion is that the majority of CMRS medical procedures will require at least a waist restraint. Test subject reach measurements were taken using the integral foot bar and using only the waist restraint.

Measurements were taken at two discrete positions on the CMRS. Test subjects were restrained using the CMRS top rail at both the midboard and the top of the headboard. Only single position measurements were recorded.

If later waist restraint designs allow for 360-degree mobility around the CMRS top rail, the effective reach volume will increase correspondingly. Measurements taken in flight were transferred to a Compression Assist Device (CAD) model to be superimposed later on various rack layouts for configuration evaluations.

METHODS, MATERIALS AND PERSONNEL

Second generation CMRS prototype
HMF miniracks with gridded panel attached to the front
Various CMO waist restraint devices
ALS pack
Measuring tape and recording devices
Box volumes representing various pieces of portable HMF equipment
Video recorder

Personnel consisted of one test conductor (MDSSC design engineer), two test subjects (representing both the 95th and 5th percentile CMO size range), one co-investigator (project physician), and a dedicated video recorder.

Test results were recorded using written notes, dedicated video, reach boundary marking, and nondedicated NASA still photography.

Preflight: Prior to the flight, parabola sequencing was completed and rehearsed. KC-135 safety personnel performed a ground safety analysis, and restraint hardware was fitted and adjusted for the various test subjects.

Parabolas 1-10: Initial evaluation of the second generation CMRS was conducted (see Second Prototype Medical Restraint System for Space Station Freedom report). Deflection measurements were taken using the 95th percentile test subject during the 2g pullout. The utility of various restraint pieces (such as the backboard section) was evaluated. Preparations for the reach study were completed.

Parabolas 11-15: The 5th and 95th percentile test subjects marked their reach boundaries on the rack face from the CMRS midboard position. The test subjects alternated marking reach boundaries while using foot/waist restraints and waist restraint only techniques. Reach envelopes and observations were recorded real time on the gridded front panel surfaces. Waist restraints were the simple double loop design.

Parabolas 16-20: The 5th and 95th percentile test subjects marked their reach boundaries on the rack face from the CMRS headboard position. The test subjects alternated marking reach boundaries while using foot/waist restraints and waist restraint only techniques. While reach boundaries were being recorded, an informal evaluation of the mountain-climbing-type harness was conducted. The KRUG Softgoods harness could not be evaluated because a number of restraint loops failed before the zero-g portion of the flight.

Parabolas 21-30: A number of deployed equipment reach volumes were recorded. Reach boundaries were recorded from a number of positions using various pieces of equipment. A volume representing the HMF powered infusion pump was "deployed" from the rack face and mounted to the CMRS. Visual and reach access to controls on the box were recorded from a number of positions around the CMRS. A prototype ALS pack was also deployed. Various subpacks were attached to the CMRS and access to them was recorded. Subjective analysis of the CMRS foot rail was also conducted.

Parabolas 31-40: Spine immobilization techniques were conducted using the detached headboard section of the CMRS. The 5th percentile test subject was restrained to the backboard and zero-g transport was practiced (see Second Prototype Medical Restraint System report).

RESULTS

Rack Front Panel Mapping

Results of the flight mapping exercises have been plotted and mapped to standard SSF rack front panels. Results can be found in Figures 3 through 8. The worst case scenario of a 5th percentile female restrained at both the waist and feet still allows access to approximately 1/3 of the usable rack front panel surface. As seen in picture S91-26635, the double loop waist restraint allows the 5th percentile test subject to float up from the table edge slightly. The ability to float up while still effectively restrained to the table top rail allows the smaller CMOs to increase their access by approximately 20%.

Mapping of the 95th percentile test subject reach boundaries shows that the test subject can access approximately 2/3 of the usable rack front surface while restrained at both the waist and feet. With only a waist restraint, the subject can access almost the entire usable rack face surface, especially when able to float slightly away from the table edge.

Mapping is reflective of measurements taken at two discrete points along the CMRS top rail. If actual flight restraints allow for 360-degree translation around the CMRS as suggested, the actual reach boundaries can be increased significantly. Figure 9 maps a horizontal interpretation of these boundaries. Future rack layouts will include an analysis of equipment locations based on these mappings. CMO preferences for working from the midboard section of the CMRS will further help determine the placement of rack-mounted equipment controls and stowed items.

Deployed Item Reach Boundaries

A number of foam-core boxes representing pieces of HMF hardware were used in a subjective analysis of deployed equipment usage. The 5th percentile test subject could easily access the representative infusion pump volume from a number of locations on the rack front panel while tethered to the CMRS with a waist restraint. When the pump was mounted to the footboard of the CMRS, the test subject could also physically and visually access the pump control surface from anywhere around the circumference of the top rail. Portions of the ALS pack were also deployed. Again, the 5th percentile test subject had little difficulty accessing the packs restrained to a work tray from any position around the CMRS. By releasing her feet from the foot bar, the test subject was able to float horizontally over the top of the table with only her waist tethered. Access boundaries for the 95th percentile test subject were significantly better. It appears that the current size and general form of the CMRS accommodates the full range of CMO movements. A flight design which incorporates 360 degrees of waist restraint and an integral/quick release foot restraint also offers reach limits sufficient for most medical procedures.

Waist Restraints

Initially, three different waist restraints were to be flown and subjectively evaluated (see figure 10). The failure of the KRUG Softgoods restraint prior to the zero-g portion of the flight removed it from the evaluation process. It is, however, anticipated that this restraint will perform well in situations when a more firm waist-to-CMRS attachment is required. Its design evolved as a cross between the double loop and the mountain climbing harness. The full climbing harness provided a much more secure waist-to-table edge attachment but did not allow the

CMO to rotate away from the table effectively. This type of restraint would be preferable when medical procedures involve delicate tasks such as suturing. As a general purpose restraint, the double loop system performed well. This design allows the CMO to rotate completely around while still attached to the CMRS top rail. To remove slack from the belt and give a more stable waist attachment, the CMO must apply pressure upward from the legs. For this reason, the double loop restraint may prove fatiguing during long or delicate procedures. A complete MRS should offer both types of restraints, especially if there is to be more than one CMO involved in a specific procedure.

CMRS Integral Foot Restraint Bar

A new design feature of the second generation CMRS prototype is an integral foot restraint bar around the circumference of the base. The bar is reflective of the top rail profile and is set approximately 2 inches off the floor surface. All the test subjects felt this type of foot restraint provided adequate foot positioning. It was also demonstrated that with this system, a CMO could effectively translate the full length of the table without any other form of restraint. Concerns include the height and profile of the bar. Test subjects wore military boots which were large enough to simply wedge between the bar and floor. If crewmembers intend to work in stocking feet or light shoes, the rail profile should be contoured or padded for comfort. A lowering or reshaping of the rail would also prevent the CMOs from dorsiflexing their feet to remain in place. Overall, the basic foot rail design seems to be an effective method of lower body restraint and should be incorporated in subsequent flight prototypes.

CONCLUSIONS

Empirical reach information gathered regarding the HMF/CMRS system will be applied to all future rack integration and front panel layouts and will aid in designing for human factors/anthropometric considerations. This information will also provide a basis for evaluating the effectiveness of a particular rack layout prior to further KC-135 test flights. Data gathered regarding rack front panel reach envelopes is also adaptable to other CMRS/HMF rack relationships and should prove useful if other locations, such as the resource nodes, are selected as installation locations for the HMF system.

Subjective deployed reach analysis showed that it is possible to access almost any area of the current CMRS prototype while restrained to the table top rail. Equipment volumes, such as the powered infusion pump and ALS pack, when mounted at the foot of the CMRS, could be physically and visually accessed by the 5th percentile test subject located at the headboard section.

Waist restraint evaluations concluded that both prototypes proved effective in basic CMO-to-CMRS restraint. The double loop system allowed the test subject to rotate away from the table, increasing the possible reach volume. The mountain climbing harness provided a much more stable and secure waist-to-table connection but prevented the CMO from easily rotating. The final flight hardware list should include both forms of restraints or a hybrid design which accommodates the features of both systems. A restraint which would allow the CMO to move around the circumference of the table without unclipping from the waist restraint would also be preferable. The two prototypes flown should provide adequate restraint for further KC-135 medical simulation and equipment flights.

The CMRS integral foot restraint system functioned well and was favored by all the test subjects. The simplicity and adaptability of its design suggest that it should be further refined and continued in future CMRS prototypes.

PHOTOGRAPHS

S91-26635: 5th percentile test subject marks upper reach boundaries while using only the double loop waist restraint.

S91-26633: 5th and 95th percentile test subjects mark reach boundaries while using proposed waist and foot restraints.

S91-26646: 95th percentile test subject performs deployed item (ALS pack) reach analysis.

S91-26633: *Using proposed waist and foot restraints, 5th and 95th percentile test subjects mark reach boundaries.*

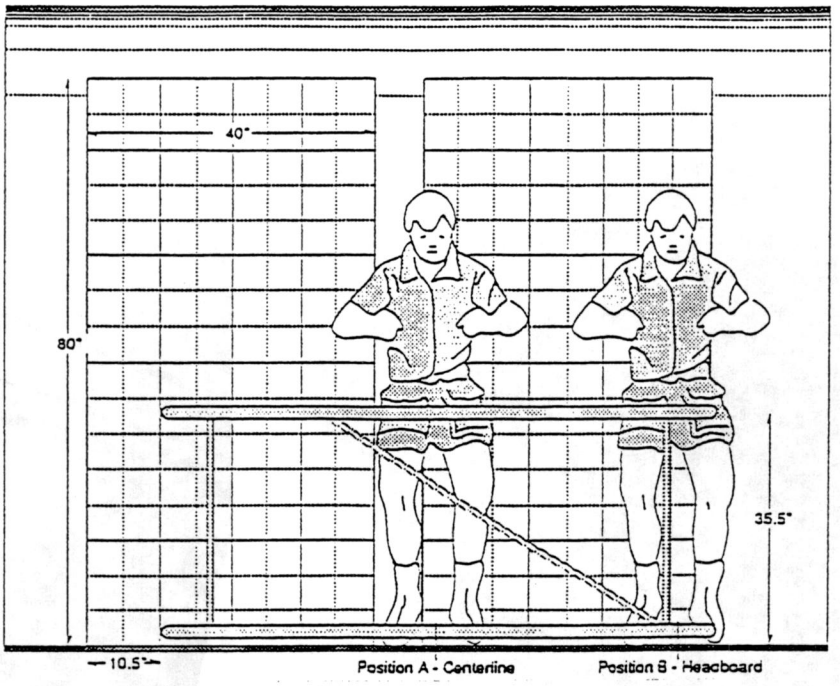


Figure 1. Front view of KC-135 test installation showing two measurement positions.

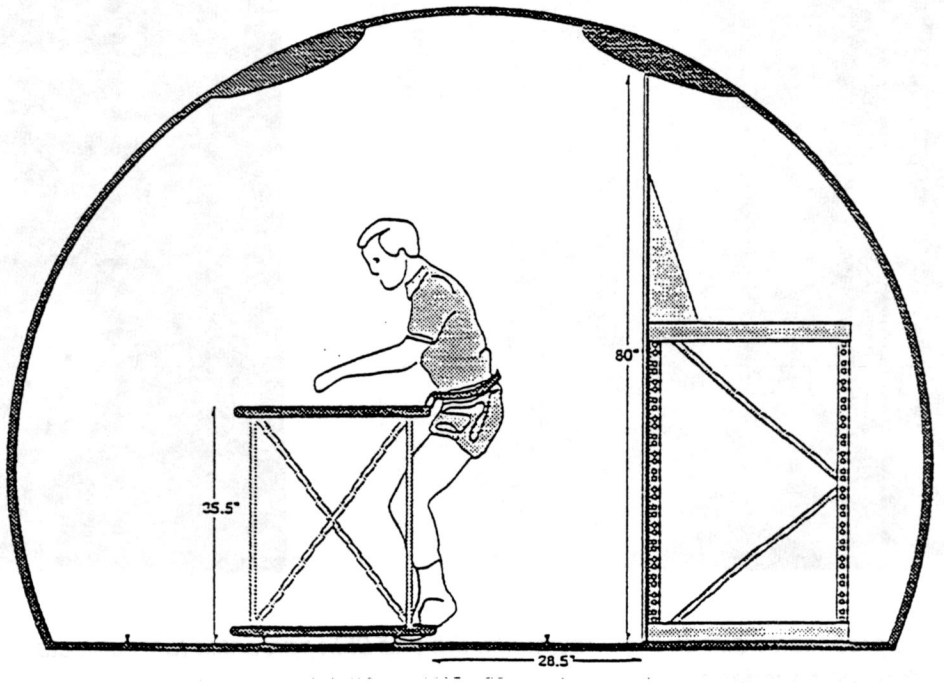


Figure 2. Side view of KC-135 test installation.

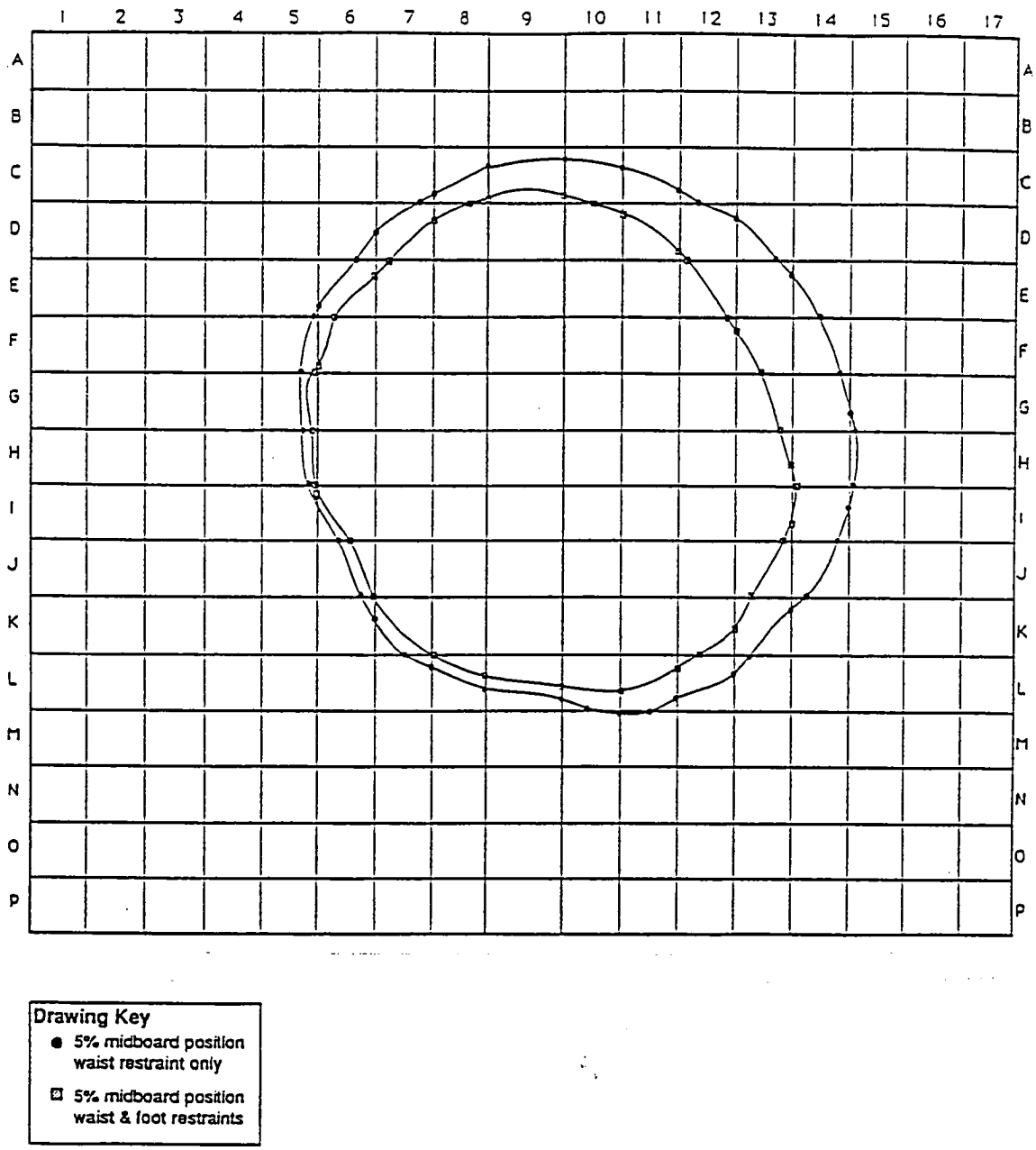


Figure 3. 5th percentile at midboard position, rack front reach boundaries.

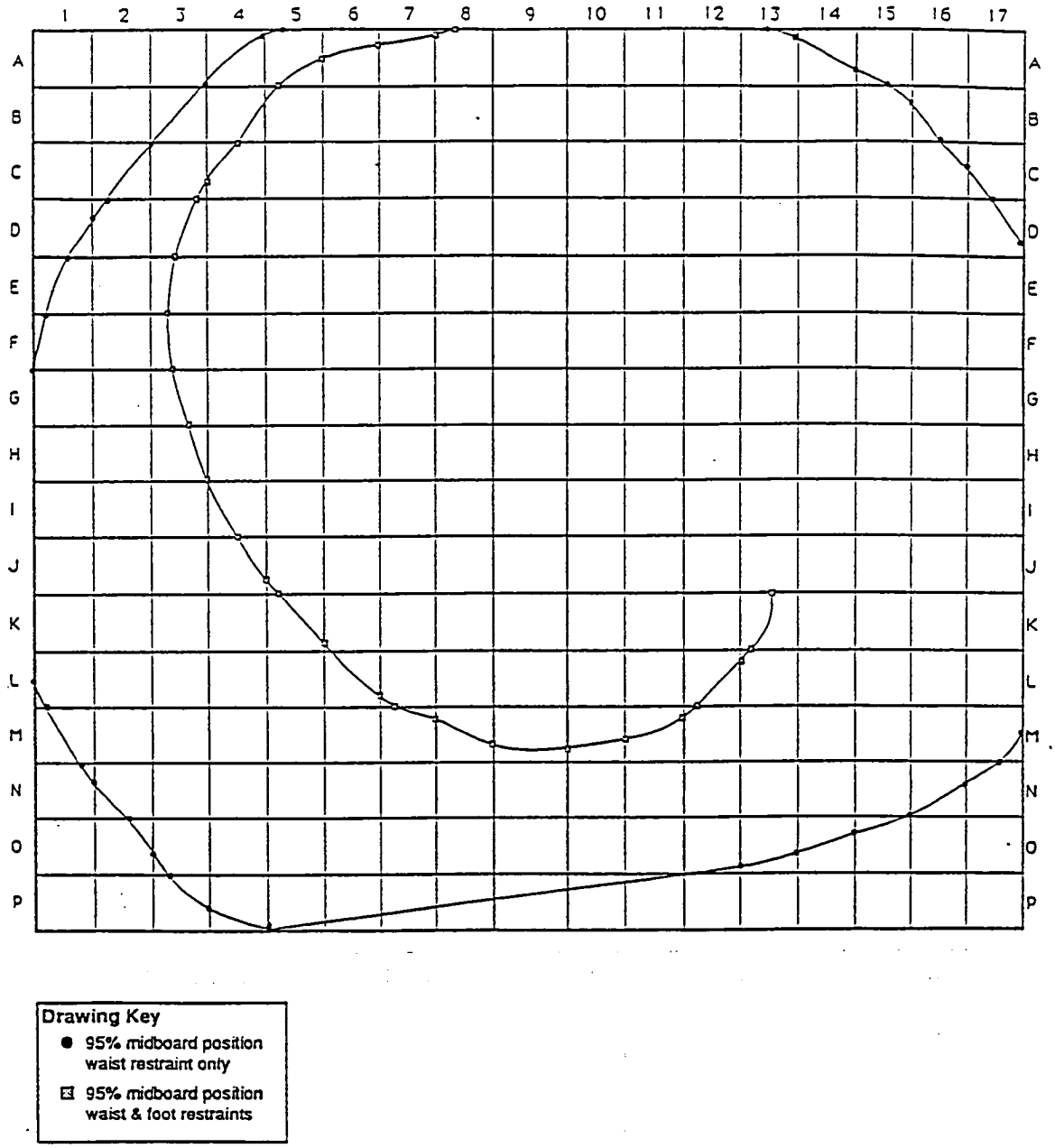


Figure 4. 95th percentile at midboard position, rack front reach boundaries.

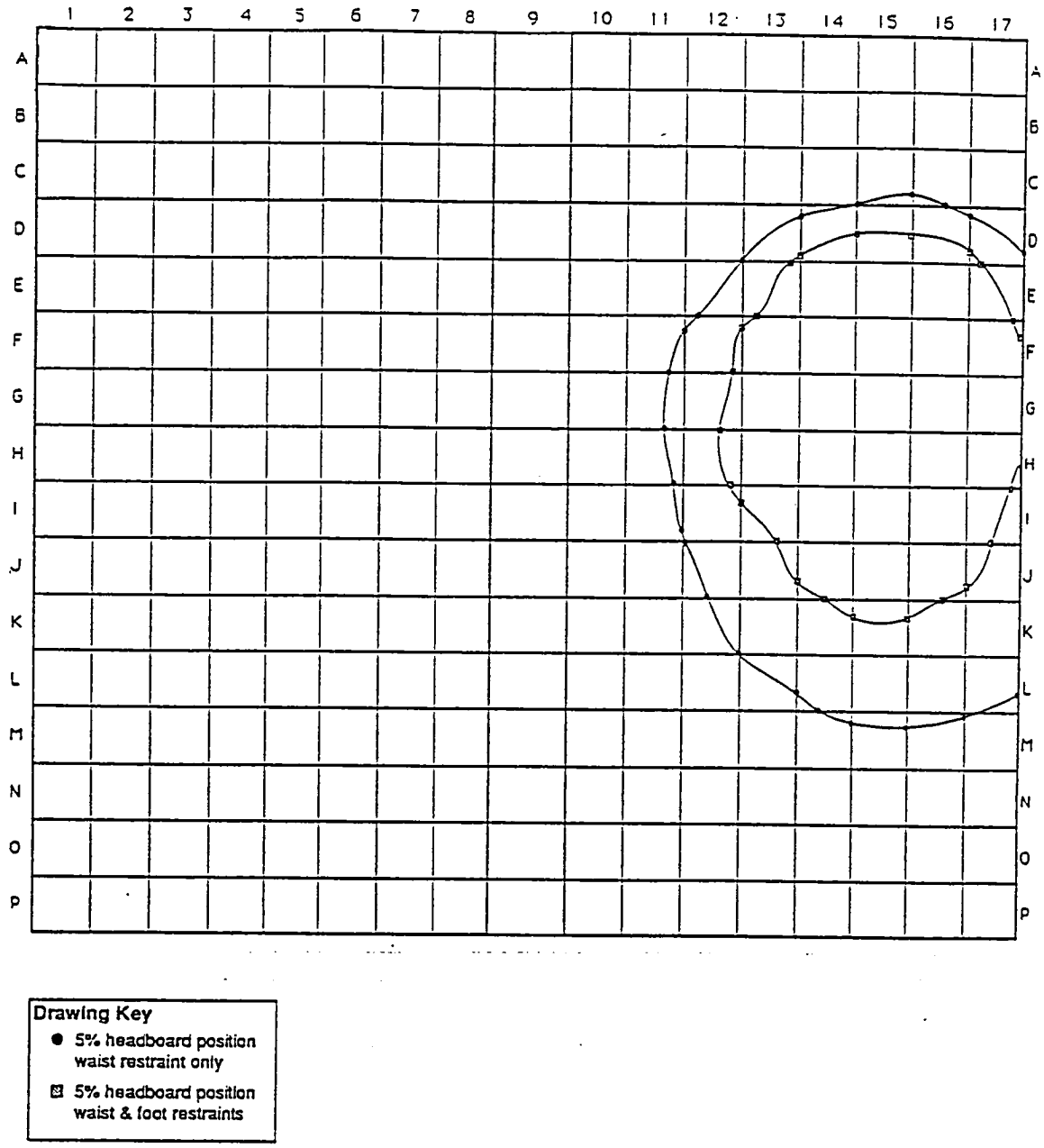


Figure 5. 5th percentile at headboard position, rack front reach boundaries.

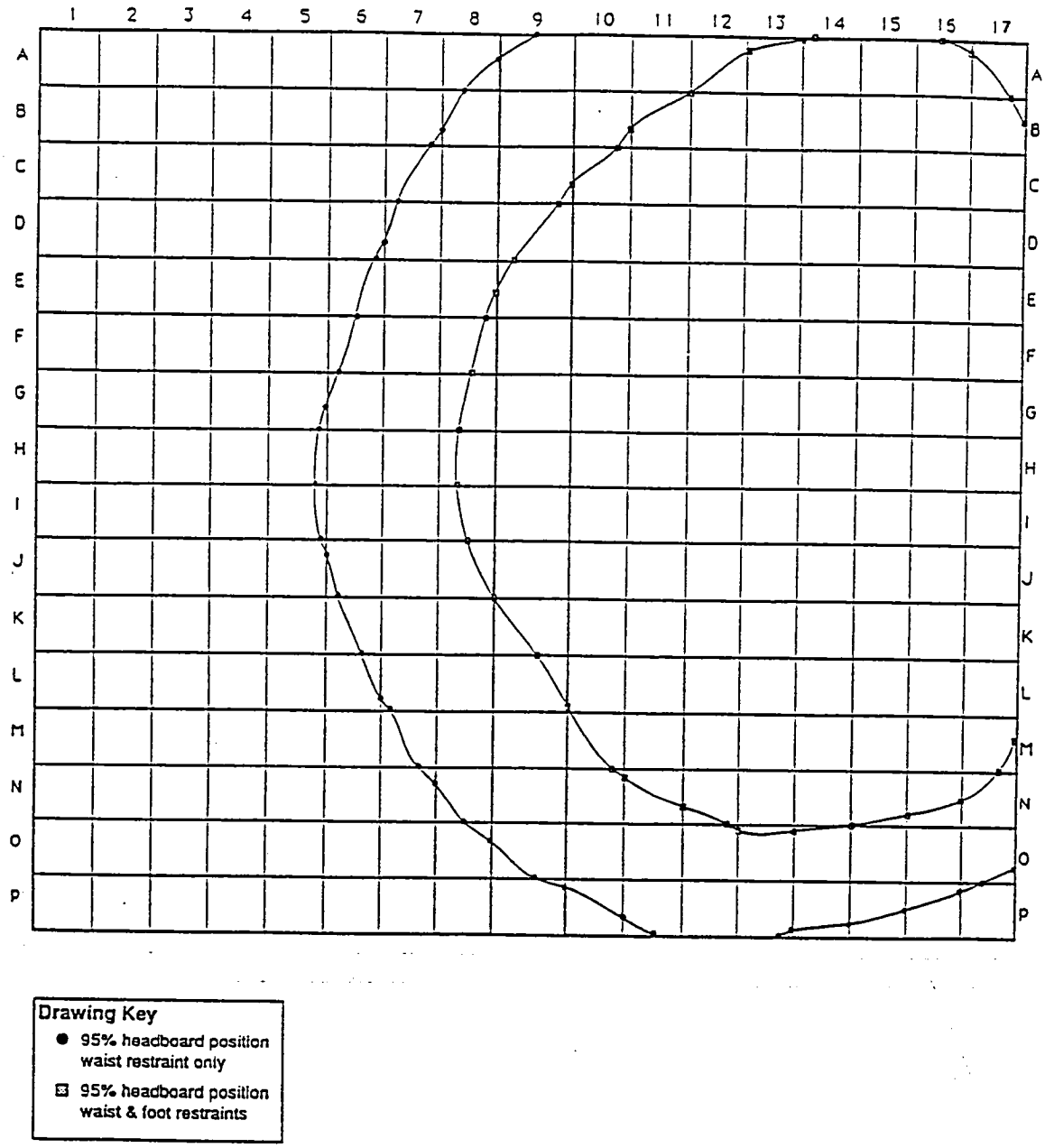


Figure 6. 95th percentile at headboard position, rack front reach boundaries.

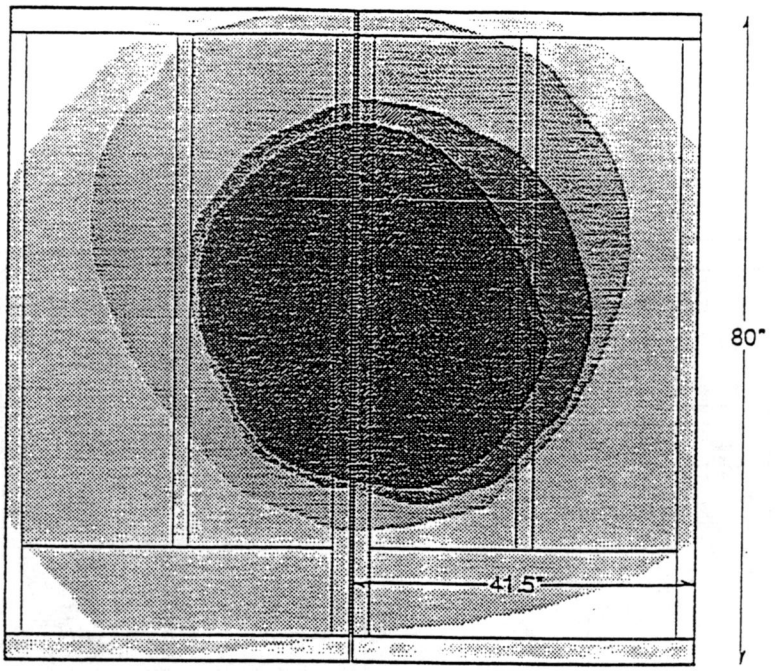


Figure 7. Midboard reach boundaries mapped to standard SSF rack faces.

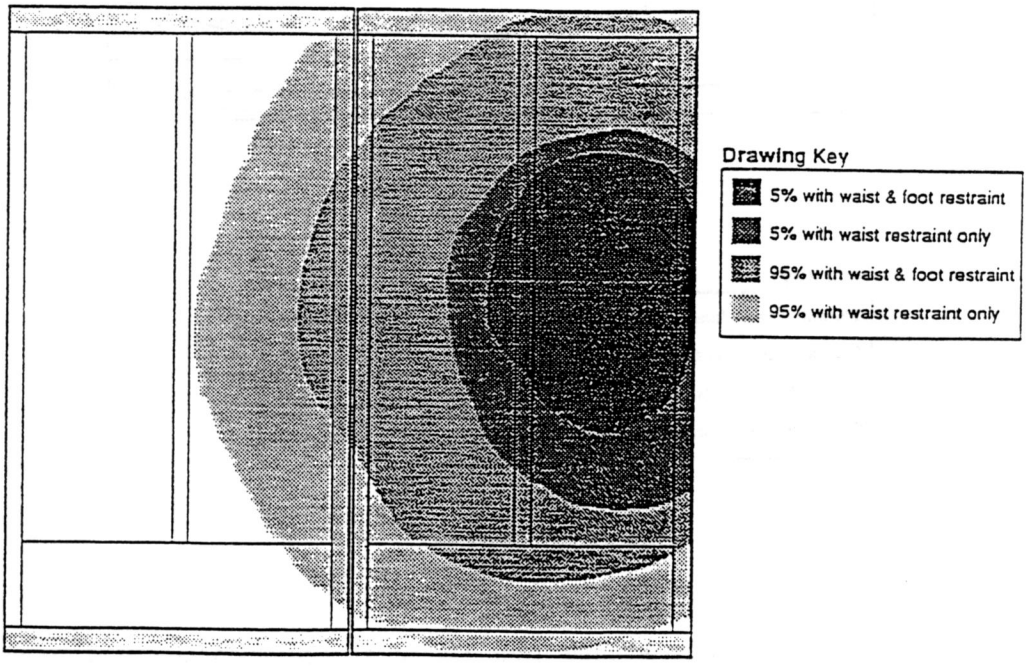


Figure 8. Headboard reach boundaries mapped to standard SSF rack faces.

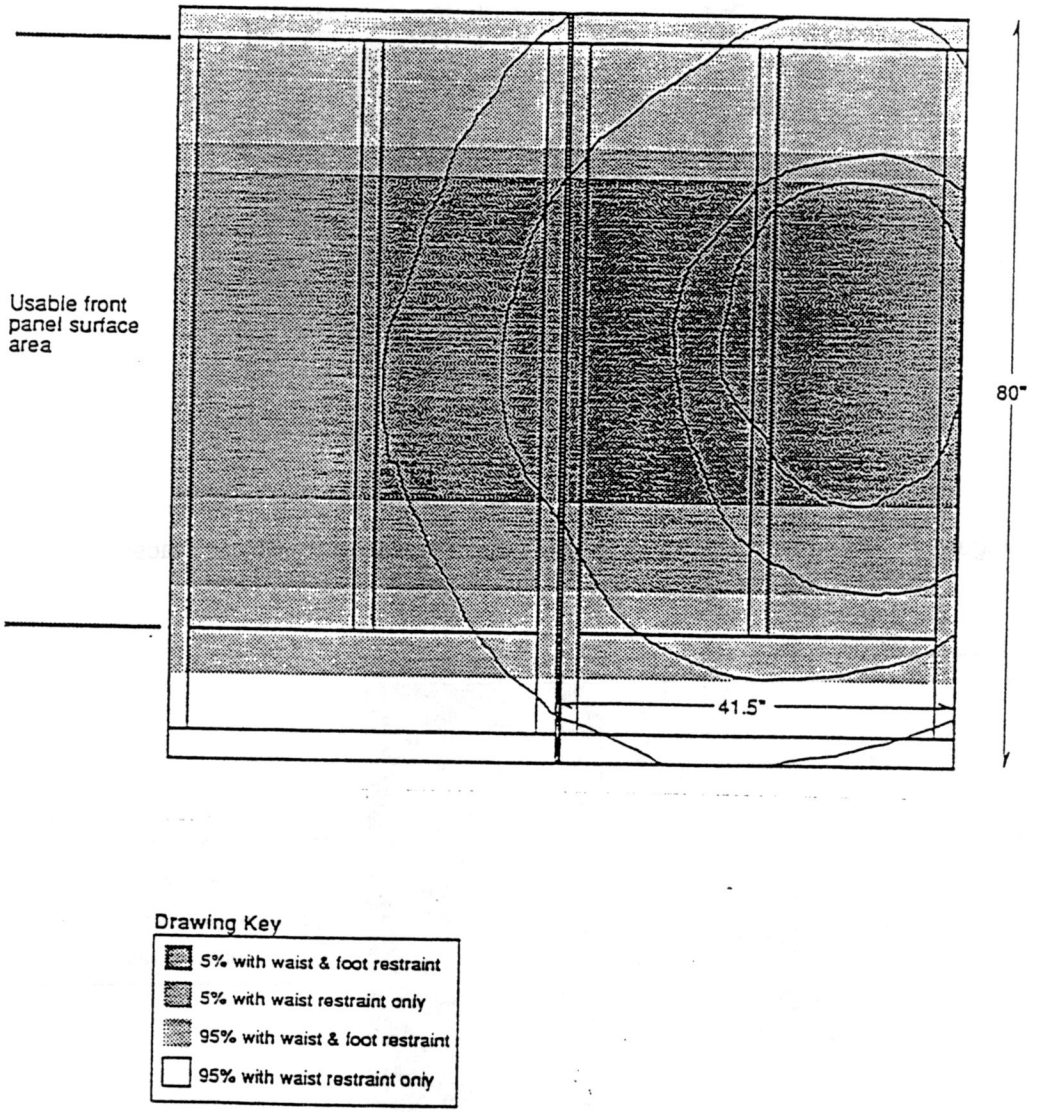
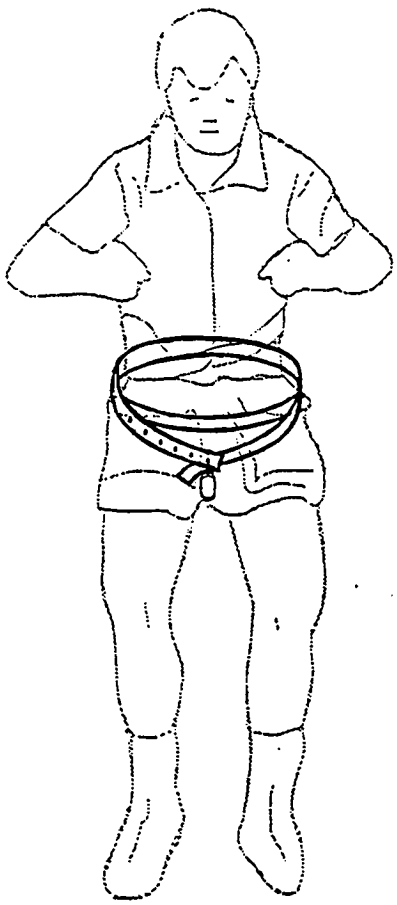
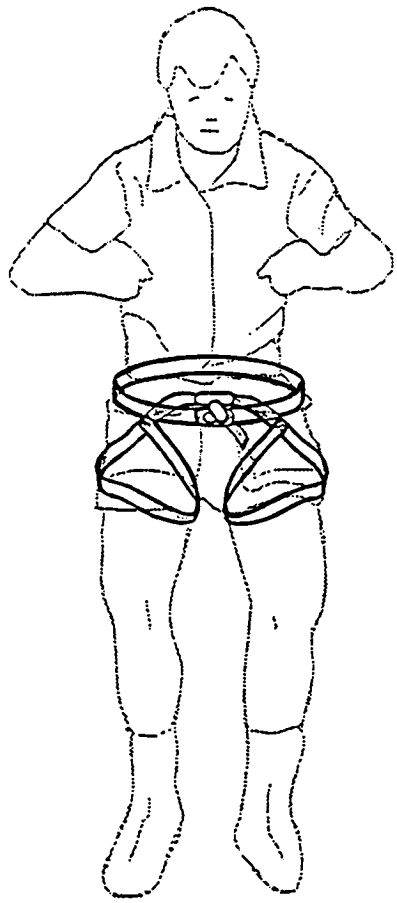


Figure 9. Projected mapping of reach volumes using a waist restraint which translates around the CMRS top rail.



Adjustable double loop restraint



Mountain climbing harness restraint

Figure 10. Waist restraint prototypes used.

KC-135 Shuttle Orbiter Medical System Equipment/Supplies Evaluation

Flight Date:	January 16, 1991
Principal Investigators:	Denise Baisden, M.D. (NASA-JSC) Kristen M. Maidlow (KRUG Life Sciences)
Co-investigator:	William Pierce (KRUG Life Sciences)

GOAL

The purpose of this flight was to analyze flow through an IV administration set to be included in the Shuttle Orbiter Medical System (SOMS) medical kits. Different pill containment systems were also evaluated for the SOMS medical kits.

OBJECTIVES

1. Measuring IV Flow Rate

One-g Testing: The one-g test was designed to obtain control flow rates for the Baxter Travenol® set. Testing was completed prior to the flight, such that modifications (if necessary) could be made to the design prior to zero-g testing.

Microgravity Testing: The effectiveness of the Baxter Travenol® IV administering was evaluated based on the following criteria.

- *flow rate*
  - — Can the set deliver a large quantity of fluid quickly?
- *flow quality*
  - — Does the air/fluid separator remove the bubbles consistently and continuously?
- *components*
  - — Are all components necessary?
  - — Do all components function as expected? specifically:

    air/fluid separator:
    - — effectiveness evaluated by observing flow immediately before and after the component
    - — maximal flow rate through this component

    one-way flow valve:
    - — low immediately before and after the valve

Each set will be tested for three parabolas.

The comparability of the Baxter Travenol® set was evaluated with the procedures listed in the Medical Checklist, JSC 48031 (included in appendix A).

2. Alternative Pill Containment Systems

Sodium Chloride Tablets and Birth Control Pills (BCPs): Alternative pill containment systems for both medications were evaluated based on the following criteria.

- *single tablet administration*
  - — Does the design allow single tablet removal?

- *reusability/reliability*
  - Is the design appropriate for multiple uses? This is a concern because the plastic material used to construct bags tends to stretch and tear if stressed continuously.

- *volume*
  - Due to limited volume in the SOMS medical kits, the alternative pill containment systems cannot occupy more volume than the current bags.

INTRODUCTION

Measuring IV Flow Rate

IV fluid administration is unique in zero-g because air bubbles contained in the IV bag become evenly distributed in the solution. To prevent air bubble administration to the patient, a reliable air/fluid separation device is needed.

The SOMS currently includes an off-the-shelf IV administration set produced by Cutter Pharmaceuticals. The set has been tested extensively, and flow quality (the absence of air bubbles in the fluid following the air/fluid separator) has proven consistently excellent. Although the set provides reliable air/fluid separation, the resultant flow rates are less than desired. Flow rates obtained in micro-gravity range from 0.5021 cc/sec to 0.8766 cc/sec. The Cutter® set also contains components unnecessary for zero-g operation. For detailed analysis of the Cutter® set, see NASA Technical Memorandum 104740, "KC-135 Shuttle Orbiter Medical System Equipment/Supplies Evaluation Executive Summary," flight dates May 3, 1990 and May 25,1990.

To obtain higher flow rates and delete extraneous components, an alternative IV set was designed by Medical Operations and produced by Baxter Travenol®. The set includes the following components:

- IV bag spike
- air/fluid separator
- one-way flow valve
- roller clamp valve
- medicinal entry with swab pad injection site
- Luer® adapter
- 36" of tubing

See appendix B for a schematic.

If the IV administration set produces the desired flow rate and quality in microgravity, it will replace the current IV administration set in the SOMS kits. Further certification for flight is not necessary per memorandum SD2/87-T36 "Deviation Request-JSCI 8080.2G JSC Criteria and Standards."

To take advantage of the benefits of both brands of IV administration sets, a "makeshift" IV administration set was constructed. The set consisted of the Baxter Travenol® set with the air/fluid separator replaced with the Cutter® component. Data obtained from the flight will be used to compare the Cutter® set data with the Baxter Travenol® set data.

Alternative Pill Containment Systems

Sodium chloride tablets and the Norgestral/Ethinyl Estradiol (BCPs) located in the Medications and Bandage Kit (MBK) in Pocket 2 (P2) are currently contained in zip lock plastic bags for flight.

On STS-38, flight crewmembers had difficulty removing single sodium chloride tablets for fluid loading. When the bag was opened, several tablets floated out. The BCPs, which have not been used on orbit, are smaller tablets which will amplify the problem. An alternative containment method is necessary for both types of tablets.

METHODS AND MATERIALS

Baxter Travenol® IV administration set
"Makeshift" IV administration sets
Blood pressure (BP) cuff, EMK C1-1
250 cc saline pouches (dyed for video purposes), EMK D1-8
Receiving bags
Towels
Duct tape
Dermicel® tape, MBK F1-4, EMK B1-8
Stop watch
2x3 foot table
Scissors
Pill containment systems - five different types
Sodium chloride tablets
BCPs

Preflight Procedures

Measuring IV Flow

One-g Testing: This portion of the experiment was designed to obtain control flow rates. Control valves were used postflight to compare the Baxter Travenol® set with the Cutter® set. To evaluate the Baxter Travenol® IV administration set, six different sets were analyzed each consisting of:

- IV administration set
- saline bag (five 250 cc bags and one 500 cc bag), injected with blue dye for observation purposes
- BP cuff
- receiving bag attached to the terminal end of the IV line

To obtain control flow rates, the following protocol was used with each setup.

1. Labeled saline bag and IV administration set for data recording.
2. Recorded mass of saline bag in data table.
3. Closed roller clamp valve and clamped IV line above the air/fluid separator to keep the unit dry before flow initiation.
4. Inserted the IV spike into saline bag and the terminal end into the receiving bag.
5. Placed setup on testing surface with the following air/fluid separator orientations:
   - horizontal
   - vertical with excessive agitation
   - alternated vertical/horizontal position
   - horizontal with IV line looped
   - horizontal
   - horizontal
6. Initiated flow and continued for 3 minutes, recorded exact flow time (Dt) and flow quality in data table.
7. Measured and recorded postflow mass.

Zero-g Testing: In-flight test procedures were practiced by all flyers prior to flight. Flight assignments were clearly delineated, time requirements were estimated, and in-flight progress goals were established.

In-flight Test Procedures

Measuring IV Flow Rate

Eight IV sets were analyzed during the flight. The test protocol was identical for all sets. Each set was analyzed separately. The setup is described in the preflight write-up (see appendix A). IV administration procedures listed in the Medical Checklist were evaluated by inflating a BP cuff wrapped around each 250 cc saline bag to 300 mmHg prior to the initiation of flow.

Two types of IV administration sets were used:

- ***Baxter Travenol®:*** Custom-produced for Medical Operations, this flight signifies the first microgravity test of the set.

- ***"Makeshift" IV set:*** Cutter® brand air/fluid separator inserted in the Baxter Travenol® set.

Spike insertion was attempted both before and after inflation of the BP cuff with both IV configurations. The roller clamp valve was closed on all eight sets prior to flow initiation. Flow was controlled using the roller clamp valve.

Time recording started when the roller clamp valve was opened.

Alternative Pill Containment Systems

All five designs were evaluated by all flyers. Oral observations were made, and the investigators agreed on the best design (see appendix C for designs).

RESULTS

Measuring Flow Rate

One-g Testing

A. Data (see table below)

B. Graphs

See appendix D for one-g flow rates for Baxter Travenol® IV administration set as a function of BP cuff pressure.

C. Observations

Baxter Travenol® set
SETUP 1

- Numerous air bubbles were in the IV line throughout the flow period.
- Bubbles were highly concentrated around the air/fluid separator and one-way flow valve.
- Air was mixed in the fluid up to the air/fluid separator, only fluid after.
- Agitating the system dislodged air bubbles which passed through the tube into the receiving bag.
- Microbubbles flowed from the IV bag past the air/fluid separator throughout the flow period.
- Three minutes of flow in one-g produced significantly more flow than in zero-g.
- Higher flow rates were achieved with less pressure compared to zero-g.

SET UP	PREFLOW MASS (gms)	POSTFLOW MASS (gms)	TOTAL FLOW VOLUME (cm^3)	FLOW TIME (sec)	FLOW RATE (cm^3/ sec)	BP CUFF PRESSURE (mmHg)
1	294.10	53.30	240.80	155.41	1.55	300
2	293.84	205.41	88.43	180.30	0.49	150
3	290.90	115.74	175.16	180.13	0.97	200
4	295.40	83.79	211.61	179.42	1.18	200
5	291.90	70.61	221.29	179.89	1.23	250
6	551.90	414.20	137.70	350.80	0.39	150

SETUP 2

- We air-blocked the system, and the only way to clear it was to place it in a one-g orientation.
- The system was agitated extensively.
- At 151 seconds the BP cuff defaulted and stopped flow. The pressure degraded almost down to 0.00 mmHg. The bladder of the BP cuff overinflated forcing us to switch to an alternative unit.

SETUP 3

- Air bubbles flowed through the line for the first 14 seconds.
- Air bubbles concentrated around the one-way flow valve; agitation dislodged bubbles from the component.
- Bubbles continued to flow past air/fluid separator the entire duration of flow.

SETUP 4

- The IV line was looped around several times.
- Air passed the injection port.
- Air bubbles were continual throughout the flow period.

SETUP 5

- Kept BP cuff pressure below 300 mmHg.
- Nonagitated.
- Minimal air passed air/fluid separator.

SETUP 6

- No air bubbles flowed into the air/fluid separator.
- We attempted to air-block the system
- BP cuff pressure reduced to as low as 108-200 mmHg.
- At 123 seconds, we achieved total air-block of the system during which flow was reduced to zero.
- We primed the line and reinitiated flow, but the air/fluid separator did not refill.
- The second air-block couldn't be fixed with the line in the horizontal position.
- Raised the bag up to one-g orientation, flow started again.

In-flight Testing

A. Data (see table below)

SET UP	PREFLIGHT MASS (gms)	POSTFLIGHT MASS (gms)	TOTAL FLOW VOLUME (cm^3)	FLOW TIME (sec)	FLOW RATE (cm^3/ sec)	BP CUFF PRESSURE (mmHg)
1	294.20	192.53	101.67	78.59	1.290	300
2	292.67	212.52	80.15	67.55	1.187	280-300
3	295.10	213.48	82.12	65.98	1.245	180-300
4	295.10	215.50	79.60	70.83	1.123	300
5	293.20	176.18	117.02	69.34	1.688	300
6	295.10	179.88	119.52	71.15	1.679	300
7	578.20	498.20	80.00	65.90	1.214	300
8	566.10	441.10	125.00	68.64	1.820	300

B. Graphs

See appendix E for microgravity flow rates for the Baxter Travenol® IV set and the "Makeshift" IV set.

C. Observations

Baxter Travenol® set

SETUP 1. Parabola 1
- IV line filled immediately following spike insertion into the saline bag. Line filled almost to the end of the IV line, approximately 7" of line not filled.
- Air bubbles mixed with fluid flowing through the line.

Parabola 2
- Air bubbles appeared past the air/fluid separator.
- Flow rate appeared consistent.

Parabola 3
- Microbubbles flowed past the air/fluid separator.
- Pressure in the cuff was consistent at 300 mmHg.

SETUP 2. Parabolas 4-6
- Waited until zero-g to insert the IV spike into the saline bag. Line filled immediately following insertion.
- Flow quality was not as good as with the first set.
- Air/fluid separator was held in a one-g vertical position.
- Pressure in the cuff ranged from 280-300 mmHg.

SETUP 3. Parabola 7
- IV tubing was looped around several times.
- BP cuff was faulty, had difficulty maintaining pressure which averaged between 180-200 mmHg.
- Flow rate appeared very slow.

Parabola 8
- BP cuff 200 mmHg.
- Air bubbles were in line consistently even after the line was primed.

Parabola 9
- BP cuff 300 mmHg.
- Air bubbles were apparent throughout the flow period.

SETUP 4. Parabola 10
- Air/fluid separator was in one-g horizontal position.
- BP cuff at 300 mmHg.

Parabola 11
- Data recording error occurred; lost approximately 2 seconds in the time measurement.

Parabolas 12-15
- Attempted to air-block the system, but could not. Agitation dislodged air bubbles from the one-way flow valve and the injection site.

SETUP 5. Parabolas 16-18
- Filter was wet before flow initiation.
- Filled up to the air/fluid separator.
- Flow quality appeared better; after priming the set, air bubbles were not seen in the IV line.
- Flow in the receiving bag was significantly less than with the Baxter Travenol® set "Makeshift" IV set.

SETUP 6. Parabolas 19-21
- IV spike inserted in microgravity, line filled immediately following insertion.
- Air/fluid separator was dry prior to initiation of flow.
- IV spike inserted in microgravity.
- Following priming of the set, no bubbles were seen following the air/fluid separator.

SETUP 7.

- IV spike inserted in microgravity.
- Air/fluid separator filled immediately following insertion of IV spike.
- After the air/fluid separator filled and the line was primed, no more bubbles were in the line.
- BP cuff pressure steady at 300 mmHg.

SETUP 8.

- IV spike inserted in microgravity.
- After the air/fluid separator filled, bubbles were not seen in the IV line.

CONCLUSIONS

Measuring IV Flow Rate

The Baxter Travenol® IV administration set provided higher flow rates but lower flow quality when compared to the Cutter® set. The set was found to operate best when the air/fluid separator was orientate in a one-g horizontal position. Further, air bubbles were not as prevalent when the set was held steady. Agitation of the system caused a greater number of air bubbles to be seen in the IV line. When comparing the flow achieved with the Baxter Travenol® IV set to that with the Cutter® set, it is apparent that a trade-off must be made to obtain greater fluid infusion capabilities. The Cutter® set produces an extremely high flow quality with a low flow rate whereas the Baxter® set produces a high flow rate with a lower flow quality.

A linear relationship between BP cuff pressure and flow rate was seen in one-g testing of the Baxter Travenol® set. In microgravity, this correlation could not be extracted from the data. To further analyze this relationship, more data is necessary.

Combining the Cutter® air/fluid separator with the Baxter® IV set seems to provide "the best of both worlds" in that high flow quality is coupled with higher flow rate. Prior to the flight, it was thought that the air/fluid separator was the cause of the low rates seen with the entire Cutter® set. The flight disproved this theory. The solution to the IV problem in the SOMS appears to be the combination of the two sets. Both pharmaceutical companies have been approached to manufacture this combination, however, neither was able to do so.

Unless an alternative construction method can be found, Medical Operations must either select the Baxter® set or stay with the Cutter® set. Before this decision is made, further data is necessary. On the next flight, more "Makeshift" sets will be analyzed to determine if the increased cost associated with combining the two corporations components is justifiable. Also, more data points will be gathered for the Baxter Travenol® set.

Alternative Pill Containment Systems

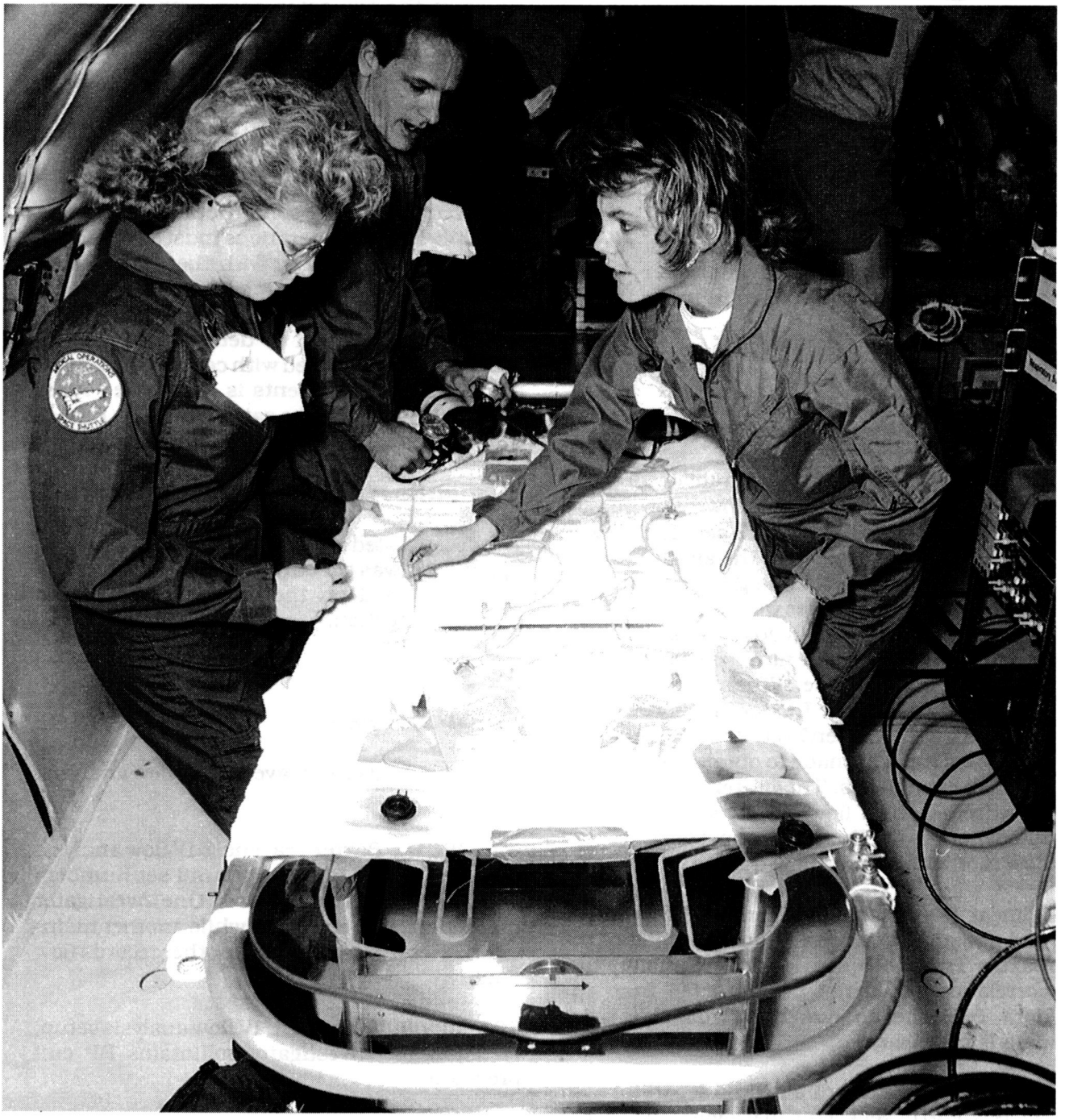
The design listed as the "optimal design" seen in appendix C was concurred upon by all flyers as the best based on the criteria listed in the Objectives section.

PHOTOGRAPHS

S91-26611: Baxter Travenol® IV flow analysis, IV setup 4.

S91-26612: Baxter Travenol® IV flow analysis set up. BP cuff inflated around set numbers 3&4, flow just started in set 4. One investigator holds medicinal entry site while another maintains BP cuff pressure and another records flow time.

S91-26608: "Makeshift" IV flow analysis setup, IV setup 6. Investigator maintains BP cuff pressure.



S91-26612: *IV flow analysis set up on the workstation.*

APPENDIX A

In-Flight Test Procedures

Analysis of IV Flow Using the Baxter Travenol® IV Administration Set
Eight IV sets will be analyzed during the flight. The test protocol will be the same for all. Each set will be analyzed separately; however, all sets will be laid out on the testing surface prior to the beginning of the experiment. The standard setup is:

1. 250 cc saline bag
2. IV administration set
3. receiving bag

IV administration procedures listed in the Medical Checklist will be evaluated by inflating BP cuff wrapped around each 250 cc saline bag to 300 mmHg prior to the initiation of flow.

Before the zero-g portion of each parabola, the IV tubing will be clamped to avoid premature flow caused by the inflated BP cuff. The roller clamp valve will also be closed.

During each parabola:

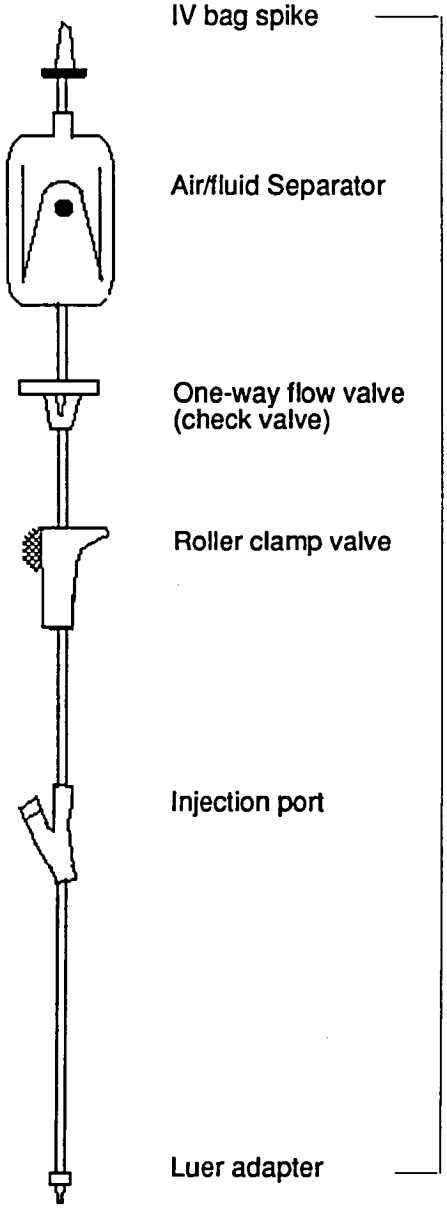
1. "Go" to initiate flow will be given by the time recorder.
2. Flow administrator will initiate flow upon the "go" and stop flow the time recorder's request.
3. Time recorder records the exact flow time to three significant figures.
4. Flow will be initiated for 3 parabolas for each set for a total of 15 parabolas allocated to the IV portion of the experiment.

Data will be placed in the following table postflight.

FLIGHT ONE

SET UP #	TOTAL FLOW VOLUME (ml)	TOTAL FLOW TIME (sec)	FLOW RATE (cm3/sec)
1			
2			
3			
4			
5			
6			
7			
8			

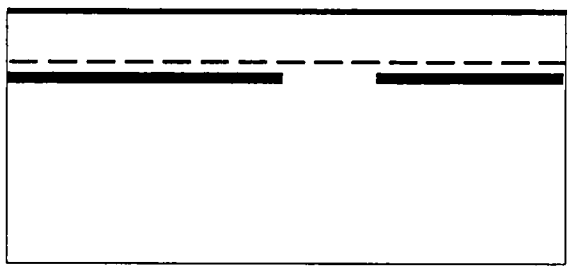
APPENDIX B



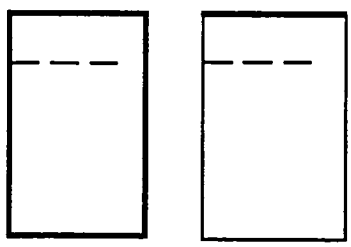
Design Proposition for the IV Administration Set of the SOMS medical kits

APPENDIX C

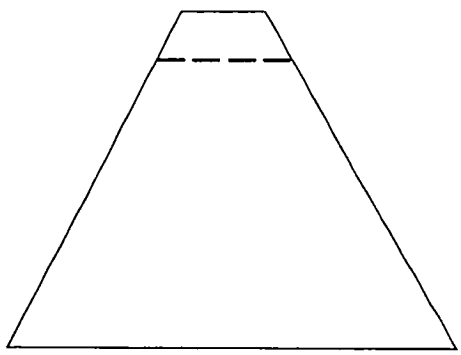
Alternative Pill Containtment Systems



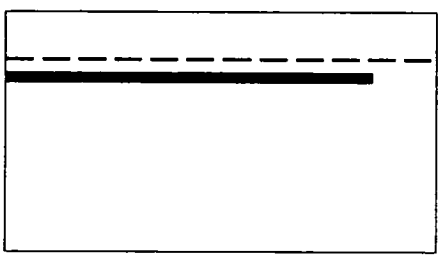
Optimal Design



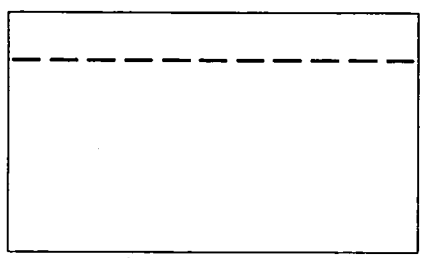
Individual Sodium Chloride Tablet Containers



Pyramid Design



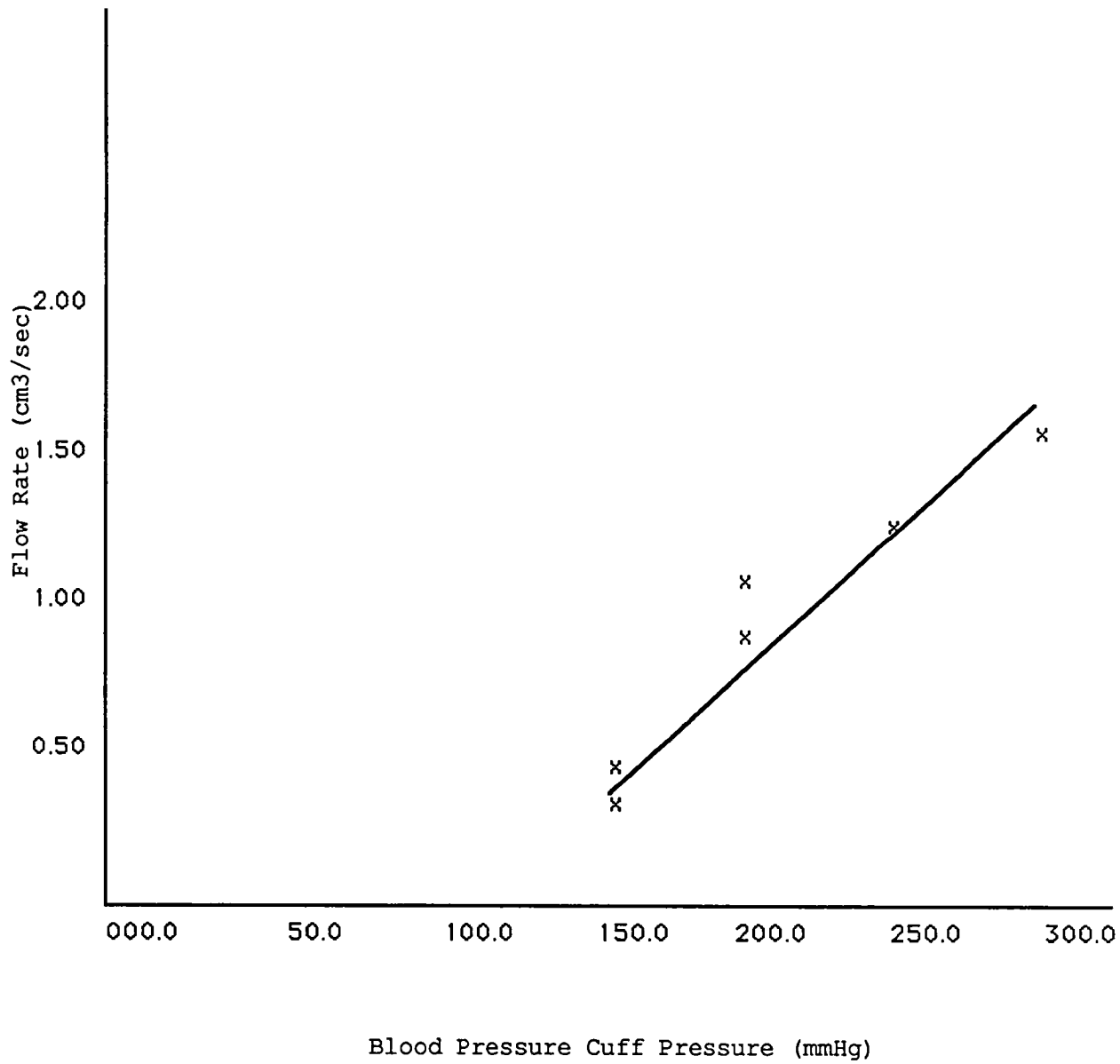
Single Tablet Side Dispension Design



Current Design

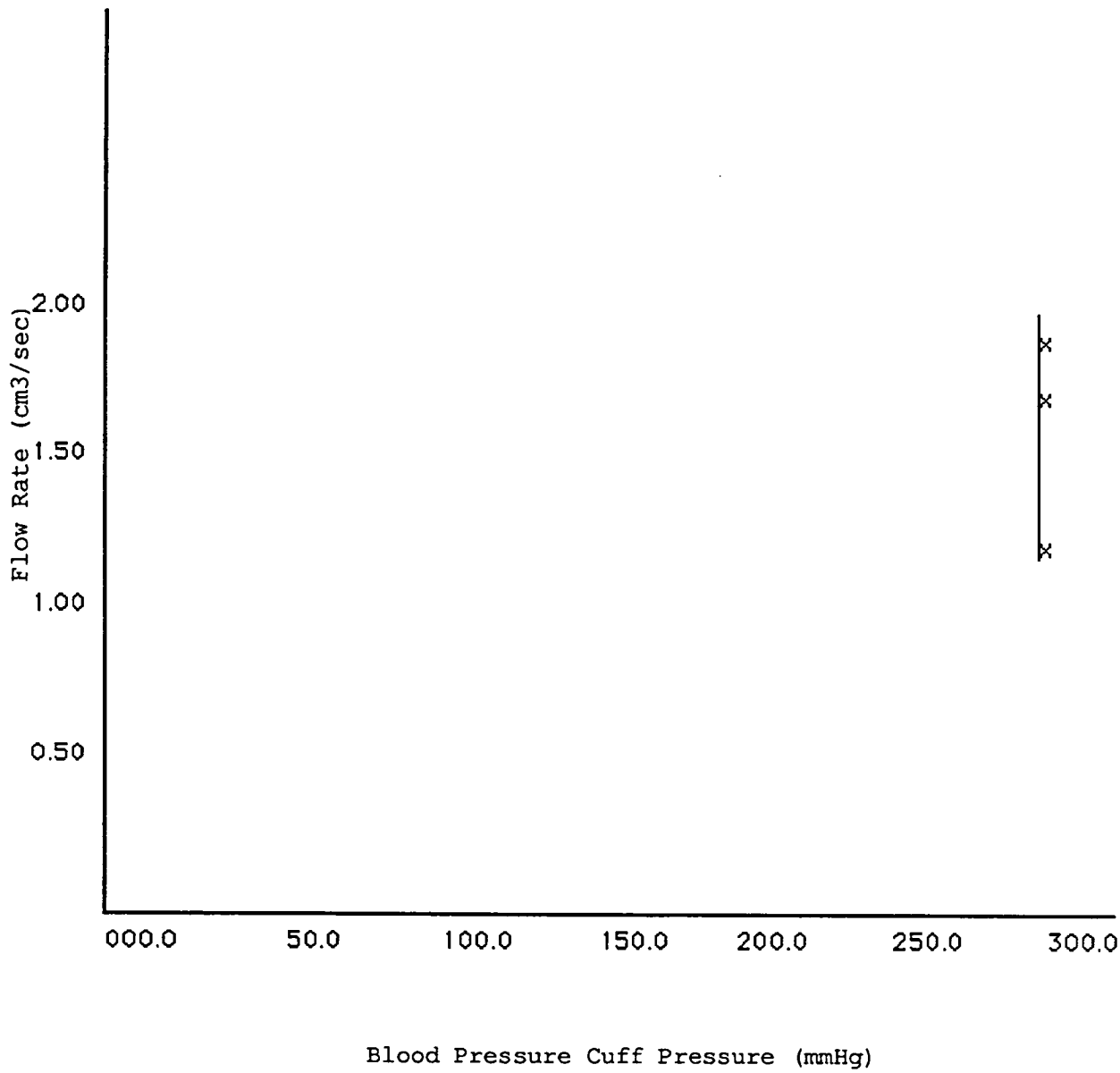
APPENDIX D

One-g Flow Rates for Baxter Travenol®
IV Administration Set



APPENDIX E

Microgravity Flow Rates for "Makeshift" IV Administration Set



Needle and Tube Thoracostomy Placement in Microgravity

Flight Date:	January 17, 1991
Principal Investigator:	Roger Billica, M.D. (NASA-JSC)
Co-investigators:	Robert Pinter, M.D. (KRUG Life Sciences) Debra Krupa, R.N. (KRUG Life Sciences) Kris Moore, R.N. (KRUG Life Sciences)

GOAL

The purpose of this flight was to investigate and evaluate needle and tube thoracostomy placement techniques in microgravity.

OBJECTIVES

1. Evaluate the restraint requirements needed for both patient and operator to perform thoracostomy techniques in microgravity with emphasis on operator leverage.
2. Determine the number of operators needed to perform the procedures effectively especially with regard to sterile technique and material flow.
3. Evaluate safe handling of sharps in a microgravity environment and test one possible new sharps container.
4. Evaluate interference from free-floating lines and tubes with regard to keeping sterility.
5. Evaluate dressing application and securing the chest tube to the patient.
6. Evaluate time required to perform the procedures in microgravity.
7. Aid in establishing operational protocols for thoracostomy placement in microgravity.
8. Evaluate the "specialty kit concept" with the thoracostomy kit as an example.

INTRODUCTION

A KC-135 parabolic flight test was performed to evaluate thoracostomy placement techniques in microgravity. The standard 40-parabola flight profile was followed affording approximately 30 seconds of near-zero-g. Two physicians and two nurses were chosen for the study. All have had extensive critical care background, and three of the four have placed a needle thoracostomy. Both physicians have placed multiple chest tubes on Earth.

The evaluation was carried out with the aid of a new MRS (which resembles a gurney) that was bolted to the floor of the KC-135. A standard, soft-bodied, average-sized male manikin simulated the patient. To facilitate tube placement, a hole was drilled in the manikin at the right anterior axillary line in the fifth intercostal space. This hole was closed over inside and out with duct tape. Chest wall puncturing was performed in the laboratory in one-g prior to the flight, and was felt by investigators to closely simulate the actual forces involved in puncturing the chest wall with a Kelly clamp in an actual patient.

Needle thoracostomy was also tried on the manikin prior to the flight. The forces needed in placing the needle were greater than those normally encountered in an actual patient. Also, due to very poor compliance of the "skin" of the manikin, the angiocath sheath had to be removed from the needle prior to placement, otherwise the catheter would bunch up on itself.

To aid in performing the above procedures, manikin and operator restraints consisted of the standard bungee cords and the new prototype carabiner waist restraints, respectively. These restraints had been used previously on the MRS experiment, January 15, 1991. In addition, MRS interface was accomplished by placing the operator's feet "under" the lower rails of the MRS, either with or without waist restraints.

The materials involved in thoracostomy placement were the standard "off-the-shelf" materials available in the current inventory for SSF, with the exception of a straight needle suture, which was added for evaluation purposes. When using the Minor Procedures Kit–which as yet has not been fully designed–all standard instruments were left off in order to have more room to place chest tube items (see Minor Procedures Kit list in appendix). The kit contained only a rubber band (low fidelity) instrument restraint board and a magnetic pad (Magmat) (Photo S91-26556).

The study sequence was as follows:

- Patient evaluation, prep and needle thoracostomy placement.
- Patient evaluation, prep, tray set up, and tube thoracostomy placement simulating a simple pneumothorax.
- Redo of patient prep and tube placement with tube clamped distally simulating a hemothorax thoracostomy. Also in this redo, the operator acted alone without the aid of a sterile co-operator.

Spontaneous pneumothorax is an infrequently occurring problem on Earth (incidence of idiopathic spontaneous pneumothorax 4.3/100,000 patient years[1]), but if it occurred in space with no way to treat the condition, consequences would be devastating. Risk factors associated with spontaneous pneumothorax are young age, thin body habitus, and being male.[1] These factors reflect generally the composition of the astronaut corps. Pneumothorax and/or hemothorax can occur with several types of major trauma. As more work is performed in the space environment, the greater is the likelihood of these occurrences. Since treatment is simple and definitive, the techniques involved should be evaluated and an operational procedure should be devised to facilitate performance of the procedure in the microgravity environment. Currently, there is no capability of tube thoracostomy in the Space Shuttle Program.

The possibility of a tension pneumothorax is more remote than a simple pneumothorax and this is easily dealt with by current Shuttle capabilities, but only to the point of *emergent care*. Like the tube thoracostomy, a needle thoracostomy has also not been evaluated in microgravity. However, unlike a tube thoracostomy which usually can be placed in a semi-emergent time frame, a needle thoracostomy needs to be placed immediately–within a few minutes – before full respiratory embarrassment occurs.

METHODS, MATERIALS AND PERSONNEL

Average-sized adult male manikin with soft shell body and anatomical landmarks
Minor Procedures Kit, consisting of magnetic pad (Magmat), rubber band restraint board, and a surgical tray
Surgical instruments: knife and blade (one unit), two Kelly clamps, and straight suture needle
Chest tubes, #28 and #36 French
Suction tubing (2) with Heimlich® valves (2)

4x4 gauze pads: two large packs and Vaseline® gauze (2)
Syringe 5 cc and #23 needle preloaded with 1% Lidocaine® 5 cc's (Lidocaine® simulated)
Incise drapes (2)
Betadine® swab sticks-two packs of three
Angiocath #14, 4" long
MRS
Belt/carabiner restraints
Videocamera
Bungee restraints
Paper tape and duct tape
Cloth bag to contain materials
Trash container
Sharps container, new prototype
Deployable instrument tray (Mayo stand)
Wall suction faceplate mockup
Standard miniracks

Personnel consisted of three investigators involved in the procedure, one investigator on videocamera, and a nondedicated NASA photographer for still photography.

All procedures were first performed in the HMF ground laboratory for familiarization.

Needle thoracostomy placement

Trash is deployed prior to the procedure. The diagnosis: tension pneumothorax. The patient is restrained supinely on the MRS. Betadine® swabs with angiocath and needle are destowed from the minirack by free-floating lone operator. The patient is prepped in the left midclavicular second intercostal space, and the needle is placed in the proper area. The angiocath is removed from the needle prior to placement. Patient is reevaluated (Photos S91-26554 and S91-26553).

Tube thoracostomy placement

The diagnosis: simple pneumothorax. The patient is supine on the MRS. An x-ray would probably be obtained for aid in diagnosis, depending on patient appearance. The Minor Procedures Kit is destowed and attached to the MRS on the side opposite the operator. A "chest tube kit," consisting of a #28 chest tube, two Kelly clamps, and a 3-0 straight needle suture, is removed from the rack and placed under bungees on the patient's lap. The rest of the materials needed for the procedure are in the miniracks. In an actual situation, these materials may be removed individually and placed in a bag and then secured to the side of the MRS. On the KC-135, this bag was prepacked, removed from the rack, and kept by a second operator (CMO 2).

The Minor Procedures Kit is opened and the towel flaps covering it are restrained beneath the tray with tape (Photo S91-26556). The patient's right arm is taped superior to the head and out of the way by the primary operator (CMO 1) (Photo S91-26558). CMO 2 destows Betadine® swab sticks and passes them to CMO 1. CMO 1 opens the pack and preps the patient. CMO 2 assists CMO 1 in gloving sterilely. Next, the incise drape is placed with CMO 2 assistance. CMO 2 opens the chest tube kit and gives the contents to CMO 1, who places them on the surgical tray. The preloaded Lidocaine® syringe is destowed, given to the CMO 1 who administers the local anesthesia, and then placed on the tray. The CMO 1 then places the rest of the materials on the tray with CMO 2 assisting.

CMO 1 removes the scalpel, makes an incision, replaces the scalpel, and constrains fluids by using 4x4 gauze pads in the nondominant hand. A Kelly clamp is used to puncture the intercostal muscles and subcutaneous tissues (Photo S91-26561). Counterforce is applied by CMO 2. The chest tube with Kelly attached is then placed into the thoracic cavity (Photo S91-26562). CMO 2 maintains the placement of the tube to assure sterility. CMO 1 removes the straight needle suture pack from the tray and opens the pack. Sutures are placed in the skin, and the chest tube is attached to the chest wall by hand-tying it to those sutures. CMO 2 cuts

the suture and replaces the scalpel and needle onto the Magmat. A Heimlich® valve is placed on the end of the chest tube by CMO 1, while CMO 2 maintains the tube's position. Vaseline gauze is given to CMO 1; he places this and then 4x4 gauze pads around the tube, removes his gloves, removes the incise drape, and tapes the tube in place. CMO 2 sets up suction, checks for good negative pressure, and attaches the suction to the tube. **Note:** In the actual flight, the incise drape was not removed until after the tube was taped down.

Repeat tube thoracostomy placement

The patient is prepped and Lidocaine® local given as before. This time the chest tube is clamped distally to simulate hemothorax thoracostomy placement. CMO 1 simulates doing the procedure by himself.

Sharps disposal in a new prototype device

- Angiocath needle placed in the box.
- Suture placed in the box.

These procedures are performed at the appropriate times.

RESULTS

Needle thoracostomy placement

As expected, the procedure was easily performed in microgravity. Restraint with feet under the MRS lower rail was sufficient to place the needle. Patient prep with Betadine® also was easily accomplished.

Tube thoracostomy for simple pneumothorax (Objective 1)

Restraint evaluation

Patient: Restraint of the patient was easily obtained with previously used belt restraints (Photo S91-26558). The right arm which was raised superior to the head was also easily restrained with paper tape, although the paper tape frequently broke or doubled over on itself, and was in general difficult to handle. The other issues not addressed were need of sedation for the extremely anxious patient and need of airway control in an unconscious patient. The latter is an extremely important issue considering the likelihood of multiple injuries in a major trauma scenario.

Operator: Operators were easily restrained. CMO 1 was restrained with a waist belt harness on a carabiner (Photo S91-26555). This restraint allowed good movement along the rail of the MRS–approximately one meter in each horizontal direction. In addition, the belt was easy to turn around in to maneuver behind one's self. The belt provided excellent restraint hands off the MRS, which is needed to counter the force of puncturing the chest wall. CMO 2, however, needed to apply an opposing force to keep the patient stable while CMO 1 punctured the chest wall with a Kelly clamp. CMO 2's restraint was accomplished with ease by placing feet beneath the bottom rail of the MRS above the floor to which it was bolted. Free floating to obtain supplies worked very well.

Material flow, sterile technique, and number of operators needed to perform the techniques effectively (Objective 2)

Material flow was accomplished very well by placing CMO 1 opposite CMO 2 and the instrument tray table (Mayo stand) (Photo S91-26556). There were no problems with either placing the instruments taken directly from the minirack in a bag or later dispensing the instruments one by one to the operator from the bag. The rubber band/Magmat system worked well to restrain

all instruments, and was easy for both operators to use even with keeping sterility a high priority (Photo S91-26559). CMO 2 kept the distribution bag shut by pressing her waist against the top of the bag in contact with the MRS. (See NASA video master S-VHS/905218 minutes 31-42 and in-house video of the flight.)

The tray needs to be set up, with a minimum of two operators because supplies are stored non-sterilely. Since instruments and supplies have to be restrained, the luxury of placing sterile materials onto the tray by one non-sterile operator is not practically feasible.

Once the tray is set up, the procedure can be done well with only one operator. However, one operator has difficulty keeping the chest tube sterile on both ends and tamponing with 4x4 gauze pads in one hand. This difficulty was especially true in the hemothorax scenario, which adds a second Kelly clamp distally on the tube. The tube moved around in all directions, and the distal end was easily contaminated. Although this contamination may not be very significant since the distal Kelly need not be removed until after the tube is sutured in and dressed, suturing the tube in place will be difficult without an assistant to keep the tube stable. For this reason, an assistant may be needed by the operator to perform this part of the procedure acceptably. The assistant preferably should be sterile; however, with caution a non-sterile assistant would also be acceptable once the chest tube is inside the thoracic cavity.

One further comment regarding contamination. Trash generated after tray set up need not be disposed of until after the procedure, with the exception of blood-drenched 4x4 gauze pads. These contaminated pads probably could be placed on the surgical tray away from other instruments. This would have to be done by either a sterile operator or an assistant.

The flow of materials went very well, overall, but a few problems were encountered. A problem occurred with use of the straight needle suture– an item not yet on the central supply inventory for SSF HMF. Hand-tying with two hands was difficult for the operator, primarily because the end of the suture with the needle floated around in the field. A one-handed tying technique would not be effective due to the needle being located on the proximal end of the suture. Also the needle was free to float aimlessly, causing "a dangerous proposition" as CMO 2 stated, when it is necessary to dispose of it. Note that the actual full technique of suturing the tube in place was not done, due to the difficulty in suturing the manikin skin. The needle was not placed through the manikin skin. This technique omission may have changed the experimental outcome.

A problem was also encountered with the 4x4 gauze pads sticking in their package container after momentum was applied to it. The operator could contaminate himself by reaching into the package to pick out the remaining gauze pads (Photo S91-26560).

Another problem which may be encountered, but which was not seen on the KC-135 flight since the experimental design was altered, is that there may not be enough room on the Minor Procedures Kit surgical tray if all the instruments are prepackaged on the tray. An instrumentless surgical tray was used on the KC-135 flight exclusively (Photo S91-26556), so the tray had adequate room for all the instruments needed during the procedure.

Lastly, incise drape removal was not evaluated. This removal should be performed prior to taping the dressing down. It does not need to be removed sterilely, therefore it should cause no problem if the operator removes his gloves, which are laden with Vaseline from the Vaseline gauze, before taking off the drape.

Safe handling of sharps and test of a new disposal device (Objective 3).

Sharps disposal in general caused no problems during the flight, but several potential problem areas were identified. The new small sharps container could have caused problems because items disposed of previously could float to the top when the flap is opened. It was also difficult to put sharps inside because of the floating of them caused by microgravity. The straight needle kept floating to the top. The preloaded syringe and needle did not fit inside the container. Since the box is so small, it could easily be filled quickly with sharps, causing inconvenience with frequent changes of disposal containers. (See NASA video master S-VHS/905218 approximately min. 40 for picture of prototype sharps container.)

Sharps, including the straight needle and scalpel were well restrained on the Magmat/rubber band board.

Evaluation of floating of lines and tubes with sterility considered (Objective 4).

Most of the previous discussion has addressed this point. In addition, the suction tubing was no problem to hook up and did not interfere with sterility since the insertion site is sterilely dressed before hook up. The Heimlich® valve was no problem to connect to the thoracostomy tube and did not cause any problems after hook up. In an actual case, the valve may need to be taped to the chest tube and suction tubing as an added precaution against dislodgment.

Dressing application and chest tube restraint to patient (Objective 5).

The chest tube was well secured to the patient by using a standard one-g dressing protocol. However, the Vaseline from the Vaseline gauze tended to stick to other surfaces touched by the operator after placing the Vaseline dressing, making subsequent procedures (like removing the incise drape) more difficult. This problem was more of a minor inconvenience than a true difficulty that needs to be addressed.

Evaluation of time required to perform the procedure in microgravity (Objective 6).

The time to perform the procedure was slightly increased, as compared with one-g, primarily because more attention needed to be given to sterility and sharps disposal.

DISCUSSION

Few problems were encountered with placing a chest tube in microgravity. However, the need for oxygen, the need for sedation/pain medications in the anxious or traumatized patient, and the need for airway control in an unconscious patient were not addressed. These real and potential necessities offer possibilities for future KC-135 flights.

Another KC-135 flight could possibly address setting up a sterile field by only one operator. This operator could remove supplies from non-sterile wrappers and propel the objects onto the tray to evaluate the effectiveness of solo sterile field set up.

In regard to sterility, a non-sterile assistant is acceptable to assist in setting up the tray, stabilizing the chest tube, and dressing the wound. After the tube is intrathoracic, no internal contamination should occur by holding the distal tube end. Sterile gowning is not needed since only the chest tube is at high risk of being contaminated, and this contamination risk should be easily controlled by the operator's technique. The distal tube end with or without a Kelly clamp is easily contaminated since it floats freely in microgravity, but this is

not important if internal tube sterility is maintained. It is unlikely the operator will contaminate the proximal tube with the contaminated distal tube end.

Prior to the flight, a plastic pack containing the chest tube, Kelly clamps, and straight needle was designed (Photo S91-26556, package under bungee in left central area). This kit is a prototype which was tested to evaluate grouping specific procedural items together. The idea worked well.

The straight needle did not work well, and in fact instrument tying may be preferable for those less skilled at suturing in microgravity. Also, since the "skin" of the manikin was not actually sutured, either previously flown suturing techniques need to be closely reviewed or a KC-135 flight addressing instrument versus hand-tying needs to be considered.

The Minor Procedures Kit, as previously stated, was instrumentless. The kit contained instruments not needed in the scenario. A further KC-135 flight could address whether there is room enough for extra instruments on the surgical tray with instruments, or if only the empty kit tray itself is adequate.

Another area not addressed in the flight was removal of the incise drape. This may need to be looked at in a future flight to assure ease of removal of the drape and to evaluate any possible problems.

The incise drape helps control bio-waste such as blood, but a second operator is needed to hold gauze over the operative area to contain fluids. The procedures of containing fluids and operating simultaneously are too difficult to perform solo.

CONCLUSIONS

1. Two operators are necessary to perform the tube thoracostomy procedure in microgravity.

2. Separate procedure kits should be designed for "specific rare occurrences" which call for specialized instruments. One example is a chest tube kit.

3. A separate surgical procedures tray without instruments and consisting of a rubber band/magnetic pad restraint system works well and should be manifested for the HMF.

4. A straight needle should not be used for suturing.

5. The small sharps container prototype is probably inadequate for microgravity and should not be used in the future.

6. The current patient/operator restraint system works well for thoracostomy procedures and should be continued.

7. Address at some point sedative and anxiolytic therapy in an uncooperative patient needing this procedure.

8. Use cloth tape instead of paper tape if possible.

9. Use the incise drape; it works well in microgravity and will probably help contain biowaste.

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6. Billica, R, MD, KC-135 Flight Test Report-Evaluation of Cardiopulmonary Resuscitation Techniques in Microgravity, May 4, 1990; NASA document, unpublished.

PHOTOGRAPHS

S91-26553: The manikin is auscultated to ensure reinflation of the lung after needle thoracostomy procedure.

S91-26554: The chest area is prepared for insertion of the thoracostomy needle. The investigator looking on is restrained to the MRS.

S91-26555: One investigator is restrained to the MRS while another is looking at the patient and another looks on.

S91-26556: One investigator opens packaging as another attends to the patient and a third shoots standard video. A prototype instrument tray is in the foreground to the right of the manikin's legs.

S91-26557: Two investigators prepare to perform a procedure on the manikin while the activities are recorded on video.

S91-26558: A sterile package is opened as the procedure begins.

S91-26559: An instrument is removed from the sterile instrument tray. The tray uses the Magmat system with rubber bands.

S91-26560: 4x4 gauze pads are provided to the CMO. The instrument tray is in the lower left-hand corner.

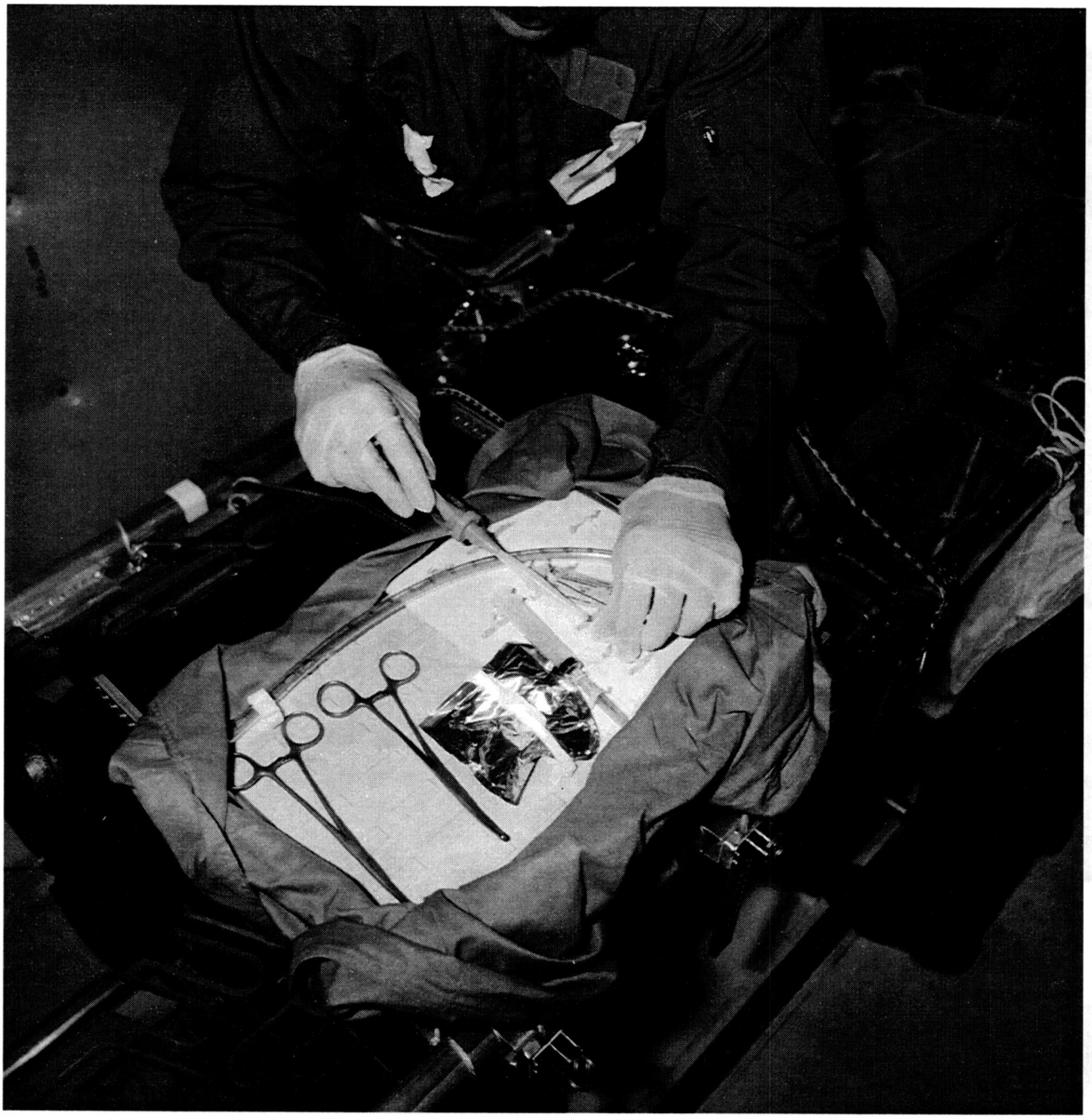
S91-26561: The chest wall is penetrated with a Kelly clamp, and gauze is applied to the area. The activities are recorded on video.

S91-26562: The chest tube with Kelly attached is inserted into the thoracic cavity while activities are recorded on video.

NASA Master Video #905218

KRUG Video

S91-28562: *The chest tube with Kelly attached is placed into the thoracic cavity. Activity is recorded on video.*



S91-26559: *An instrument is removed from the sterile instrument tray. The tray uses the Magmat system with rubber bands.*

APPENDIX

Minor Procedures Kit

Knife Handle	#3
Knife Blades	#10, #11, #15
Forceps Adson	4.75 in.
Clamps Kelly (curved)	5.5 in. (2)
Halsted Mosquito (curved)	5.5 in. (2)
Scissors Metz	7 in. (curved)
Needle Holder Mayo-Hegar	7 in. 2500 Jaw

Airway Management/Cricothyrotomy	
Flight Date:	January 18, 1991
Principal Investigator:	Joey Boyce, M.D. (NASA-JSC)
Co-investigators:	Maureen Smith (KRUG Life Sciences) William Norfleet, M.D. (KRUG Life Sciences) Debbie Orsak (MDSSC)

GOAL

The purpose of this flight was to determine the best technique for establishing a patent airway in microgravity under various circumstances.

OBJECTIVES

1. Determine the effectiveness of terrestrial airway management procedures in zero-g.

2. Evaluate the difficulty of performing an emergency cricothyrotomy in zero-g.

Various methods of opening the patient's airway and administering oxygen will be tested. An emergency cricothyrotomy will also be assessed in the event that a patent airway cannot be established using other means. The equipment for the procedures will be deployed out of the ALS pack, though the cricothyrotomy procedure may require supplies from the miniracks.

METHODS AND MATERIALS

- Two miniracks racks were used to hold medical supplies for the experiment. Rack evaluation was not part of the experiment.
- HMF second prototype MRS
- Airway management manikin
- Manikin for cricothyrotomy simulation
- In-flight written questionnaires
- Video documentation - Reference Master: 455459
- Self-report postflight

RESULTS

Initial position of participants (looking from the head of the MRS)

- The CMO was at the head of the MRS.
- The assistant CMO was on the right side of the patient and MRS.
- The participant performing documentation was on the left side of the MRS.
- The participant providing video support was at the foot of the MRS.

The CMO used a waist restraint as well as the foot restraint on the MRS. The other participants used only the foot restraint.

Using the intubation manikin, perform the various methods of opening a patient's airway including the head-tilt, chin-lift, jaw-thrust and triple airway maneuver.

A problem with locating equipment on the MRS was immediately noted when the Bag Valve Mask (BVM) was deployed for testing the patency of the airway. Items such as the BVM or a tray like the Nu-Trake kit need to be collocated with the patient and work area. The most convenient position for the BVM and airway trays would be next to the patient's head on the MRS headboard and on both sides of the patient's feet. Perhaps a pad of Velcro® should be placed on both sides of the headboard and footboard with a corresponding piece of Velcro® being used on any equipment necessary.

Ventilate the patient using the BVM (which is the current Shuttle resuscitator) to determine if an airtight seal can be achieved around the patient's mouth for one-handed operation.

The Shuttle resuscitator includes a head restraint mounted to the BVM via a four-point connector over the mouthpiece. Problems with the Shuttle resuscitator head restraint include strap effectiveness and strap placement. The straps on the restraint are elastic which do not provide enough pressure to ensure a proper seal on the patient's face. Although the patient could still be ventilated using one hand, the ventilations were inadequate for extended use. Also, the upper straps extend directly over the patient's eyes. If the mask is used improperly, pressure on an eye may cause corneal abrasion or blindness. Finally, the straps simply get in the way of other operations. The CMO stated that two hands would be the first choice for using a BVM.

Deploy the endotracheal intubation roll to the CMO's torso.

The CMO used the airway "apron" during the flight. Some problems noted immediately included difficulty in securing it to the waist. The attachment point at the end of the straps does not allow the CMO to see where the straps are connected, and the length of the straps do not take various sized people into account. An alternative would be to cross the straps in the back and connect them in front with a buckle to allow for adjustment to size. Another problem stemmed from the CMO's unfamiliarity with the pack and the location of the contents in it. A more logical layout or CMO training may alleviate the problem. Also, the endotracheal tube (ET) tube, pocket would not accommodate a "hockey stick" tube possibly requiring modification or a curved pocket for that item. The pack did not interfere with any operations and could be deployed from a higher pack assembly or kit.

C-spine stabilization and patient positioning during various techniques for opening airway.

Without any restraint, the patient's head moved uncontrollably, making intubation difficult and c-spine stabilization impossible.

C-spine immobilization is necessary in any injury in which trauma to the spinal column, head, or neck is suspected. Four methods were employed for c-spine stabilization during BVM use and intubation. The first method involved a second crewmember standing on the side of the patient and holding c-spine across the patient. Although this method works, proper stabilization may be more difficult than with other methods. The second method called for a crewmember to straddle the patient and hold c-spine from above. This method follows the

terrestrial means for stabilization for a patient in the supine position. The third method was tested in the event that only one person was present and involved securing the patient with 2" tape across the forehead. Finally, the CMO, if skilled, could control the patient's head with one hand holding the mask while using the BVM and with one forearm while intubating.

The CMO stabilization while attempting intubation was the least desirable because it tended to allow for hyperextension of the neck and did little to actually immobilize the c-spine. The chief concern of the CMO was achieving a successful intubation, not maintaining c-spine. Because of the lack of proper c-spine immobilization and therefore patient positioning (the sniffing position is optimal for proper technique), some other means of stabilizing the patient apart from the CMO is necessary for intubation.

Taping the forehead was not helpful either because it also allowed hyperextension of the neck, which is improper positioning for intubation and can aggravate spinal column injuries. Perhaps more effective taping across the forehead and chin of a patient in a cervical collar would be adequate, though the proper "sniffing" position may not then be attainable without some support under the patient's head.

Stabilization while standing to the side of the patient worked adequately, but was not as effective as straddling the patient and immobilizing from above.

Before attempting to stabilize the patient's c-spine, the crewmember must be restrained/positioned, otherwise the crewmember's mobility in zero-g causes the patient's head to move as well.

The CMO could maintain adequate control of the patient's head while using the BVM as long as both hands were involved. If operation is one-handed, some means of stabilizing the c-spine is necessary so the CMO can use the other hand.

Intubation of the airway manikin by people of various levels of training, with and without some type of c-spine stabilization.

The person with the least experience intubating (trained just prior to flight) could not intubate the manikin unless it was stabilized in the proper position by a second crewmember. For inexperienced personnel or difficult intubation, cricothyroid pressure may be necessary to achieve a successful intubation. If cricothyroid pressure is required as well as effective c-spine immobilization, a third crewmember is required to apply the cricothyroid pressure.

The more experienced persons did not have much difficulty intubating, but each commented on the fact that, without stabilization, the procedure was more difficult and proper position for intubation and c-spine immobilization could not be maintained efficiently. The assistant CMO felt he applied more downward pressure during intubation than he would have needed terrestrially. Also, the intubations took longer than usual due to ineffective patient position.

Deploy the cricothyrotomy equipment and perform an emergency cricothyrotomy.

The CMO's comments: "The Per-Trake has an advantage over the Nu-Trake in that it includes a cuffed tube. Unfortunately (actually, fortunately), I have not used either of these devices in clinical practice, so I'm speculating here. My reluctant recommendation is to use the Nu-Trake rather than the Per-Trake because the latter is more difficult to place and the procedure is far less intuitively obvious. Placement

of either device will only be performed under extreme duress, and I'm afraid that failure to establish an airway is much more likely with the Per-Trake in inexperienced hands. Although aspiration and a leak of oxygen-enriched gas around a Nu-Trake into the cabin is more likely because of the lack of a sealing cuff, I suspect that the likelihood of rapid tracheal cannulation and ultimate patient survival is higher with the Nu-Trake than with the Per-Trake, given the level of expertise of the CMO as currently anticipated."

Restraint required for performance of the procedures.

The foot rail on the MRS provided a quick, convenient method for restraining all crewmembers so that the procedures could be easily performed without need for additional restraining measures. Utilization of the foot rail as an effective means of restraint while deploying equipment and supplies from the rack requires further testing.

CONCLUSIONS

To perform any medical procedure, the CMO must be restrained as well as the patient.

Establishing a patent airway in microgravity can be accomplished using terrestrial methods (head-tilt, chin-lift, jaw-thrust, etc.) but needs constant support to be maintained. To perform effective ventilations, two hands are required to operate the BVM although some ventilation occurs when the straps are employed for one-handed operation of the BVM.

Ease of intubation depends on the level of training of the CMO and the amount of stabilization/immobilization of the patient. To hold c-spine stabilization, a second restrained crewmember or adequate taping/head restraint needs to be employed.

The foot rail on the second prototype MRS is adequate for restraint of all the crewmembers involved in rendering aid to the CMO and/or patient. Further microgravity testing on the MRS needs to address the ease of deploying/stowing equipment or supplies with only the foot rail for restraint.

PHOTOGRAPHS

S91-26576 The Nu-Trake is inserted through the simulated cricothyroid membrane on the manikin. The technique is observed and videotaped. The foot rail at the base of the MRS is being used for restraint.

S91-26575 The manikin's stomach is removed following the cricothyrotomy using Nu-Trake.

S91-26594 The possibility of one-handed BVM operation is tested using the Shuttle resuscitator head strap. One investigator checks the seal between the BVM and face for leakage while another records comments.

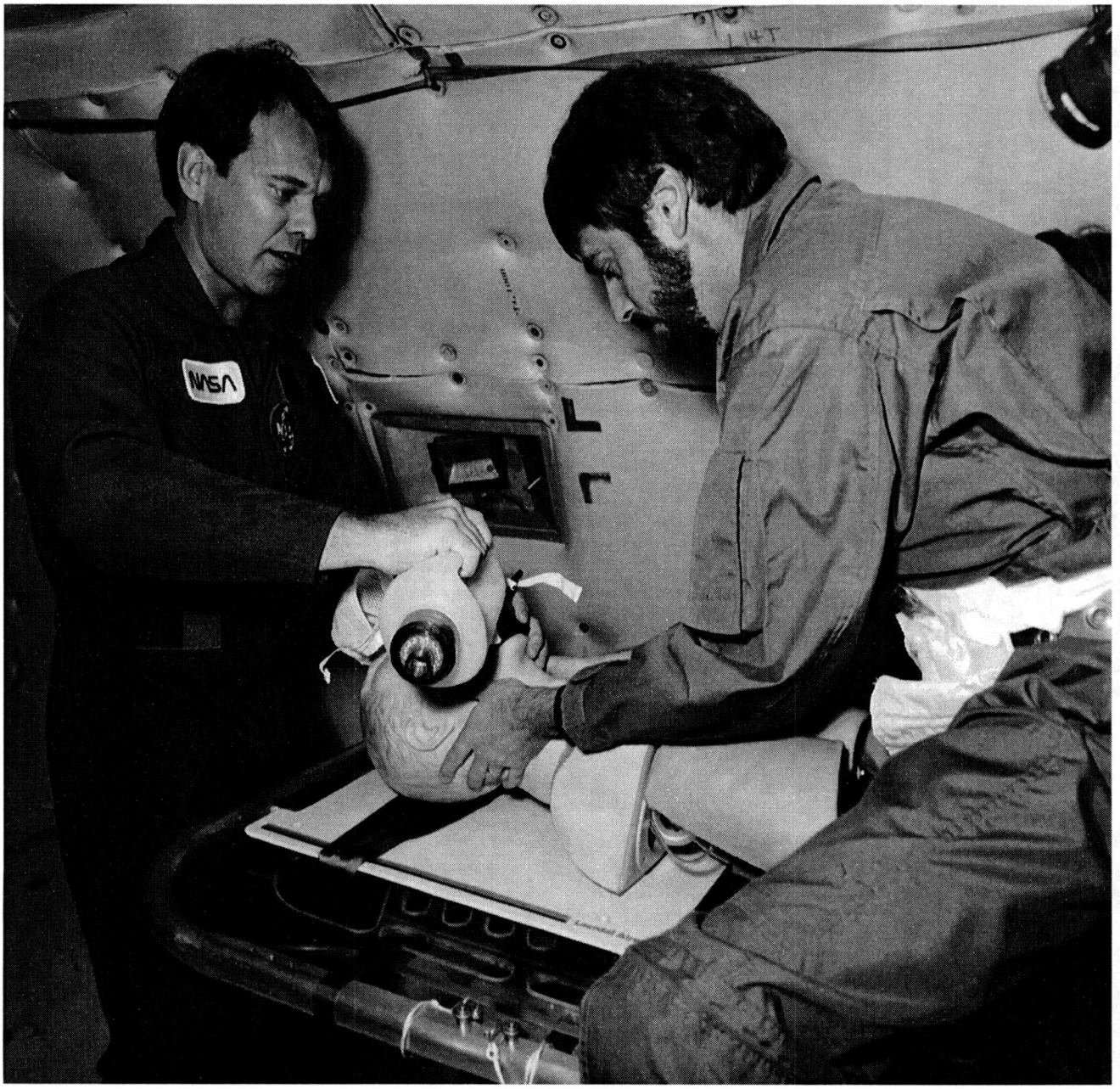
S91-26593 One investigator attaches head restraint for BVM while another stabilizes the patient's c-spine. A third investigator observes and records comments.

S91-26592 One investigator stabilizes the patient's c-spine and another ventilates patient's head using a BVM.

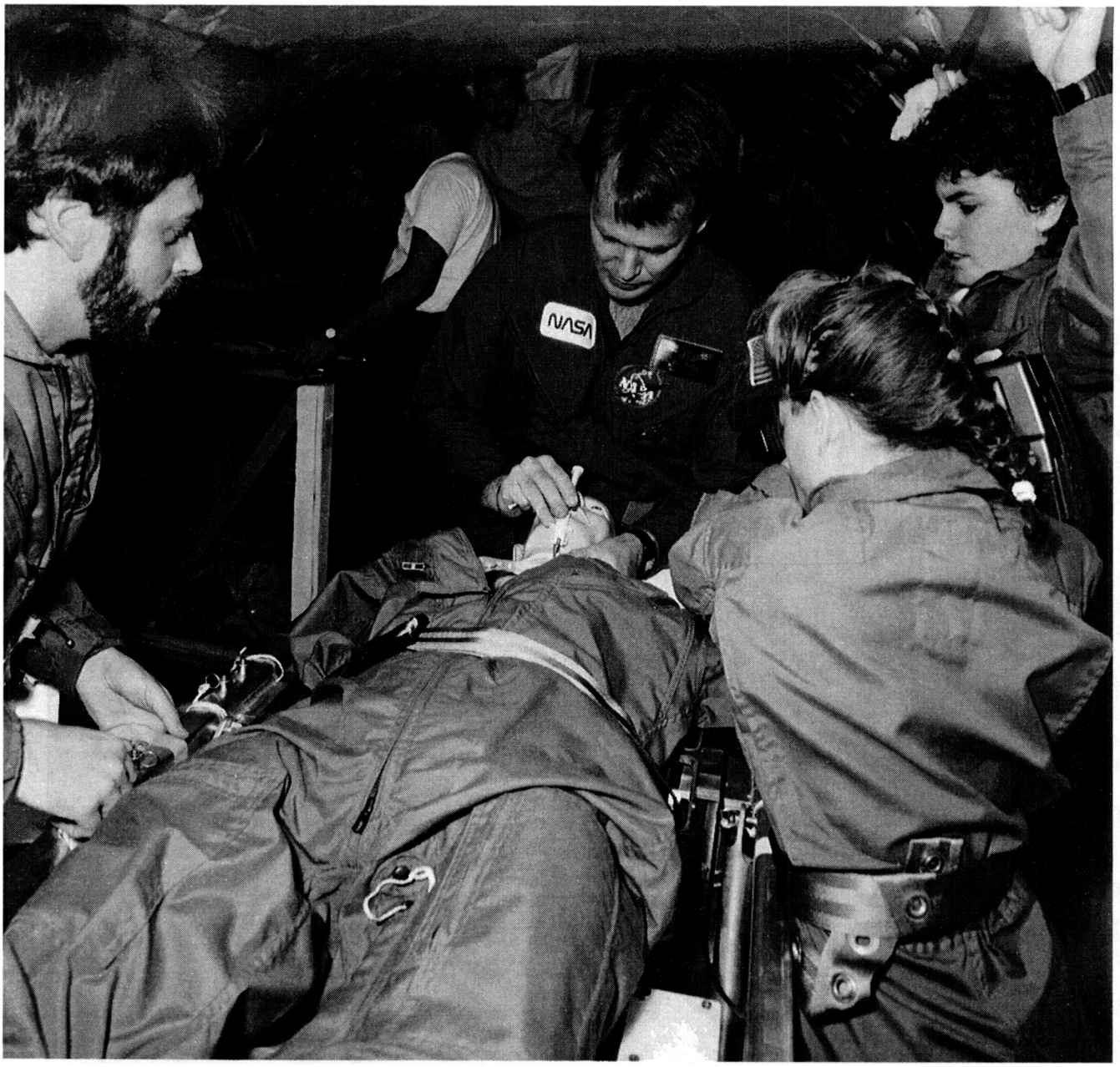
S91-26577 Wearing the airway "apron," one investigator performs an emergency cricothyrotomy using the Per-Trake system. Another investigator assists while activities are videotaped.

NASA Master Video #905218

KRUG Video



S91-26592: *Patient (manikin) c-spine is stabilized while head is ventilated with the BVM.*



S91-26576: *The Nu-Trake is inserted through the simulated cricothyroid membrane on the manikin.*

KC-135 Microgravity Investigation of Assured Crew Return Vehicle Medical Transport

Flight Date:	March 19 and 20, 1991
Principal Investigators:	Roger Billica, M.D. (NASA-JSC) John Gosbee, M.D. (KRUG Life Sciences)
Co-investigators:	Joe Kerwin, M.D. (Lockheed) Nathan Moore (NASA-JSC)

GOAL

The purpose of this flight was to gain experience and knowledge concerning Assured Crew Return Vehicle (ACRV) medical transport issues to assist in requirements definition.

OBJECTIVES

1. Evaluate issues of ingress into the ACRV for a medical transport mission, including patient handling, positioning of patient and attendant, and level of effort and time needed.

2. Evaluate types of transport support equipment under consideration, including types of transport devices and deployment of equipment within the ACRV.

INTRODUCTION

Two KC-135 flight tests were performed to investigate issues related to performing medical missions using the SSF ACRV. A standard sequence of parabolic flight yielded forty 25-second periods of zero-g on each day. Several investigators with medical background and previous KC-135 experience (including one Skylab astronaut) were recruited to perform the study.

Three different transport devices were used to move a medical manikin from outside the ACRV mockup into a couch restraint within. Each device was used once without medical transport equipment attached and once with such equipment attached. Once inside the mockup, various configurations of patient, attendant, and equipment were evaluated.

During the flight test, human factors issues regarding ACRV ingress in general were evaluated concurrently and are reported separately.

Overall, the testing went smoothly with good information obtained. Each of the transport devices was successful in assisting a safe translation of the patient into the ACRV, and it was evident that an appropriate level of medical monitoring and patient care could be provided with proper positioning of the attendant, equipment, and patient.

METHODS AND MATERIALS

Parabola Sequence

A set of 10 parabolas was used for each transport device and equipment configuration.

Day 1, Series 1:	Short spine board without equipment
Day 1, Series 2:	Short spine board with equipment
Day 1, Series 3:	Kendrick extraction device (KED) without equipment
Day 2, Series 1:	KED with equipment
Day 2, Series 2:	Evac-U-Splint without equipment
Day 2, Series 3:	Evac-U-Splint with equipment

Each series of 10 parabolas followed a standard pattern.

Parabola 1: Two attendants translate the manikin restrained to the transport device over the top of the ACRV mockup.

Parabola 2: CMO ingresses ACRV, two assistants move manikin toward ACRV hatch.

Parabola 3: Assistants pass manikin through hatch to CMO; CMO restrains manikin and transport device to ACRV patient couch.

Parabola 4: Assistant ingresses ACRV and assists in deploying medical equipment.

Parabola 5: CMO and assistant complete equipment deployment.

Parabolas 6-10: CMO evaluates the access to patient and equipment and the ability to perform basic monitoring and patient care.

Equipment

Short spine board (from the second generation prototype HMF MRS)
KED
Evac-U-Splint
Medical manikin
C-collar
ET and attachments
Nasogastric tube
Mechanical suction device (V-Vac)
IV bag and tubing
ALS pack and contents (stethoscope, BP cuff, penlight)
Ambu BVM
Mockups of O2 tank
Ventilator
Monitor
Transport aspirator
Defibrillator
IV pump
Various tubes-straps-wires-tape-connections.

RESULTS

Comparison of Transport Devices

All three devices were functional and were rated on the positive scale by the investigators.

The short spine board was bulkier and appeared as if it would be less comfortable, but provided better handholds and equipment attachment options.

The KED provided easier and more secure spinal restraint, closely conformed to the torso and was easy to manipulate. It appeared that it would readily interface with an ACRV couch or rescue stretcher and allowed for hip and knee flexion (which made for easier ingress and positioning but provided no leg stabilization.)

The KED provides minimal opportunity for equipment interface as commercially available.

The Evac-U-Splint was the sole full-length transport device. It appeared to be most conforming and stable, was easy to manipulate and could accommodate some of the transport equipment placed around and between the legs. It required ongoing adjustment in pressure with changing altitude and, since it was full length, was a little more difficult to ingress while requiring a flat couch interface.

Medical Ingress

Medical ingress was accomplished readily (within 10-15 seconds on the average) with two attendants. Restraint of the patient and deployment of the equipment was variable depending on the configuration. It was obvious that a variety of carefully placed handholds were needed to assist in translation. Care was required to avoid bumping the patient's head or some of the equipment while passing through the hatch. It was possible to move the patient with attached equipment through both size hatches provided, although the smaller hatch required more practice. The patient's ingress required additional space beyond the couch area to angle the lower body through the hatch. The full length restraint naturally required the greatest amount of room to achieve the angles necessary to move through the hatch.

It was possible to accomplish the ingress with two attendants. This became more challenging if manual patient ventilation (using ambu bag and mask) was required during movement, although it was feasible provided all equipment and tubes were securely attached.

The patient couch in a sitting configuration worked well with the first two short transport devices, but a fully flat couch was necessary for the full length restraint. In all cases, it appeared that the patient would benefit from at least a three-point restraint for security. The CMO kept himself loosely restrained during activities.

Equipment Deployment

The high priority medical transport equipment appeared to be the IV bag(s) and pump, the monitor, and the O_2 source with ventilator (or manual BVM.) With some ingenuity, these items were easily secured to and moved with the transport devices. Other items (such as the ALS pack and the defibrillator) were moved separately.

The equipment was evaluated in positions above the patient, beside the patient, at the patient's head, and randomly about the cabin. Without exception, the favorite choice was above the patient and CMO within reach of the CMO. All other areas were awkward to see and reach. The issue of control of the tubing and connections from equipment to patient was an obvious one, as they tended to interfere with movement and become entangled.

Patient/CMO Positioning

It did not appear to matter where the patient couch was located. There seemed to be plenty of options to allow non-interference with the pilot and command/control areas. It was evident that the medical attendant (if required) should be immediately next to the patient. With proper placement of equipment and loose restraint, the CMO was able to perform a variety of medical activities including equipment control and monitoring and patient examination.

CONCLUSIONS

The transport device should be a subset of the HMF provided MRS. It should be a simple, lightweight yet sturdy device that is clinically proven. Its main function should be to stabilize the patient's head, neck and spine and provide support for patient translation. Full-length immobilization should be TBD for the near-term until a clearer definition of need is established. The flexibility of providing only head to pelvis support should be considered, with additional splints provided for lower extremity stabilization if needed. The transport device should interface easily with the ACRV patient couch *and* the standard litter or stretchers to be used by the rescue forces without requiring patient removal from the device until arrival at the DMCF. Patient security and comfort, as well as attendant handholds and equipment interfaces should be considered.

Medical ingress would be better evaluated using a higher fidelity mockup of the approach, hatch, and interior of the ACRV. The medical patient couch should be part of the upper tier of seats to avoid having to translate the patient past seats, people, and other equipment. A maximum time of 15 minutes should be more than adequate to get the patient and medical equipment into place and secured. Additional space will be needed beyond the patient couch to manipulate the patient ensemble (how much space will depend on the design and whether a full-length restraint is used). The patient's arms and legs should be restrained during transport for safety. It appears that medical ingress can be accomplished with two attendants.

The medical equipment should have preplanned designed interfaces and attachments for both the transport device and deployment within the ACRV. The preferred deployment is above the CMO and patient within the CMO's visibility range and manual reach. Once the specific transport equipment is selected, methods for rapid and secure attachment should be achievable. Design for power and O_2 interfaces should be included, and plans for management of the tubing and wires from equipment to patient should be made.

The medical attendant should be immediately adjacent to the patient to have visible and manual access to vital areas (head, neck, arm, thorax). Patient position should be driven by ease of ingress and egress.

Helpful information regarding requirements and possible solutions for medical transport issues for the ACRV program was obtained from this 2-day KC-135 microgravity flight test. As usual, further questions were raised and the need for higher fidelity evaluation was evident. Overall, it appeared that use of the ACRV for a medical transport mission is feasible and could be readily accomplished with careful design and planning.

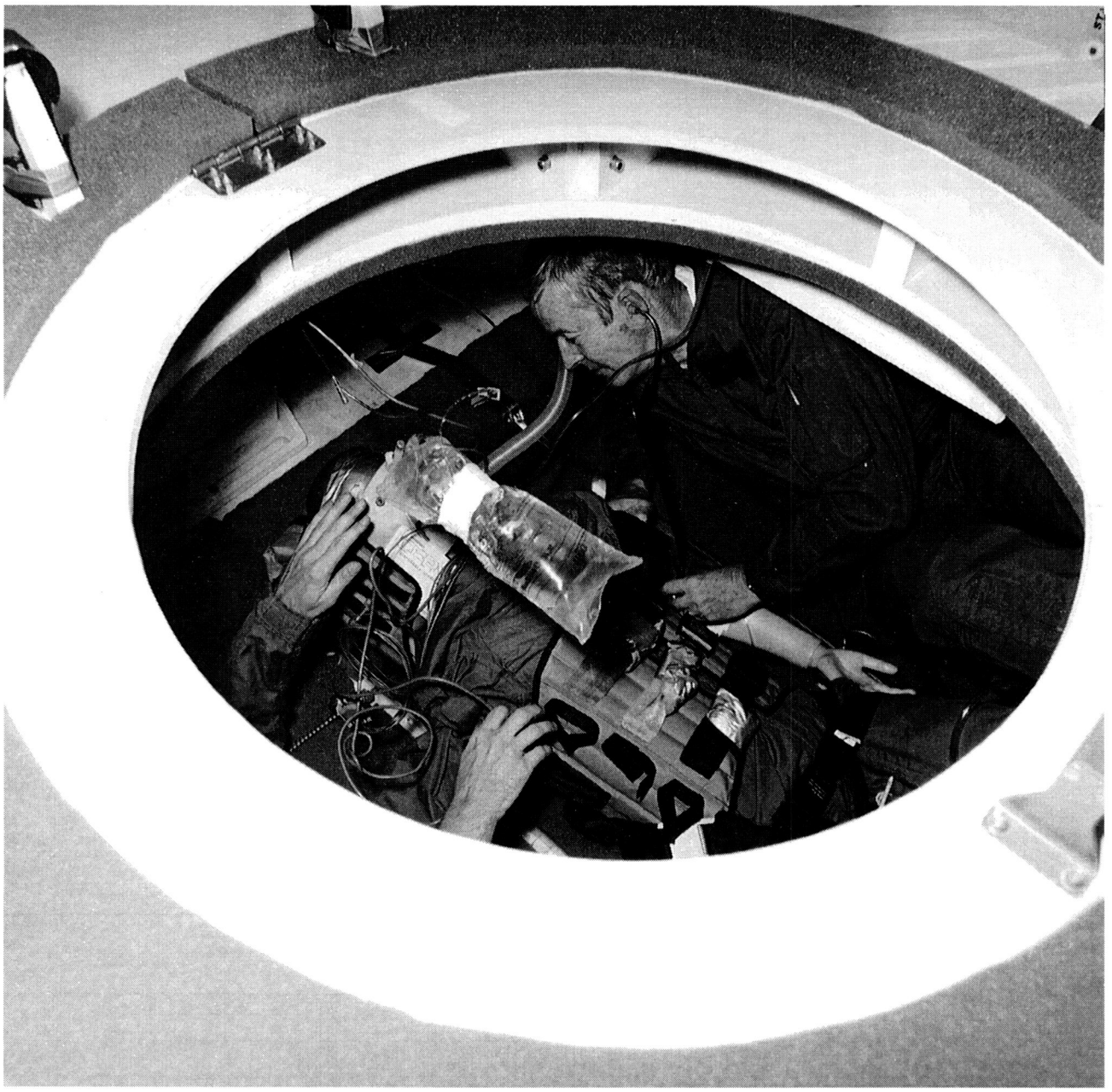
PHOTOGRAPHS

S91-31554: Simulated medical patient is transported into the ACRV mockup during KC-135 microgravity.

S91-31556: Medical personnel evaluate optimal placement of monitoring hardware inside the ACRV.

S91-31554: *Simulated medical patient is transported into the ACRV mockup during KC-135 microgravity.*

S91-31556: *Medical personnel evaluate optimal placement of monitoring hardware inside the ACRV.*



S91-31564: *Patient assessment for ACRV transport is simulated in microgravity.*

Microgravity Analysis of the Airway Medical Accessory Kit in the Shuttle Orbiter Medical System

Flight Date:	March 20, 1991
Principal Investigators:	Brad Beck (NASA-JSC) Robert Janney (KRUG Life Sciences)
Co-investigator:	Kristen M. Maidlow (KRUG Life Sciences)

GOAL

The purpose of this flight was to perform configuration analysis of equipment in the Airway Medical Accessory Kit (AMAK). Flow rates and flow quality through the Baxter Travenol® IV administration set were also analyzed.

OBJECTIVES

1. Evaluate the AMAK design to assure the configuration provided the most expedient equipment access possible. This is of primary concern due to the emergent nature of treatment required with the airway equipment in the kit.

2. Evaluate treatment procedures proposed for Medical Checklist, JSC 48031, to assure compatibility with the Shuttle environment.

3. Gather further data points on the Baxter Travenol® IV administration set to evaluate flow rate and quality. On January 16, 1991, a KC-135 flight was dedicated to this objective. Postflight analysis determined more data was needed before a recommendation could be made to replace the set that is currently flown.

INTRODUCTION

AMAK Evaluation

External medical consultants recommended that the emergency airway management capabilities of the SOMS be expanded to include endotracheal intubation capabilities and improved tracheotomy capabilities. It was also suggested that the existing airway equipment be extracted from the SOMS and isolated in a separate kit for rapid access. For this reason, the AMAK was designed using a preexistent stowage container (Boeing's medium-sized stowage assembly). The cricothyrotomy set was removed from the SOMS and a laryngoscope, an ET, and an end tidal CO_2 detector were added.

Measuring IV Flow Rate

See KC-135 SOMS Equipment/Supplies Evaluation Executive Summary dated January 16, 1991, for background information.

METHODS AND MATERIALS

AMAK Stowage Assembly including
Medium-sized stowage assembly
- Pertrach® kit
- End tidal CO_2
- ET with stylet
- Laryngoscope
- 10 cc syringe
- Dermacil® tape
- Alcohol wipes
- Gauze pads, 4x4 in.
- Water soluble lubricant

Intubation dummy
Patient restraints to restrain the intubation dummy
Simulated middeck locker rack for AMAK destow and attachment
Velcro® mounts required to attach the AMAK in microgravity

For measuring IV flow rate, a complete list of materials is in the KC-135 SOMS Equipment/Supplies Evaluation Executive Summary dated January 16, 1991.

Preflight Procedures

AMAK Evaluation

A one-g configuration analysis was conducted with a NASA Flight Surgeon. The test was designed to evaluate the AMAK relative to the design/function criteria established in the preflight report. Preflight test results deemed the AMAK configuration suitable for further evaluation in microgravity.

Measuring IV Flow Rate

One-g testing was not necessary for the IV administration set as it was thoroughly analyzed in one-g in preparation for previous flights. See the KC-135 SOMS Equipment/Supplies Evaluation Executive Summary dated January 16, 1991, for information.

In-Flight Test Procedures

AMAK Evaluation

Configuration Analysis

- Destow equipment and make oral observations on the ease of removing equipment from the kit.
- Formulate recommendations as to how the configuration should be altered.

Treatment Protocol Analysis

- Simulate airway management treatment using proposed medical checklist procedures (see Preflight Report Appendix) including intubation and tracheotomy using the Pertrach kit.
- Are the procedures compatible with the configuration of the AMAK?

Measuring IV Flow Rate

Three sets will be analyzed, one Cutter® brand set (the type that currently flies in the SOMS) and two Baxter Travenol® sets (projected to replace the Cutter® brand set). See the section on In-flight Test Procedures, in the SOMS KC-135 Flight Report dated January 16, 1991, for procedures used during the flight.

** All sets were analyzed in the horizontal position.

RESULTS

AMAK Evaluation

Configuration Analysis: Internal configuration of the AMAK appeared excellent with one exception: The tension of the elastic straps on two of the internal pockets should be slightly increased. It was also suggested that Velcro® "dots" be placed on each component to facilitate rapid equipment access after it has been deployed from the AMAK. A note of caution: The Pertrach emergency tracheotomy kit must be opened gently in zero-g to maintain contents within the kit. (The kit is opened by peeling back a metallic lid from a plastic tray in which all components are contained in depressions. If the metallic lid is removed quickly, the components are shaken out of their depressions.)

Treatment Protocol Analysis

Intubation: The procedures established in the preflight report were performed several times during the flight.

On the first attempt, it took two parabolas to properly complete the procedure which includes

administering the ET
inflating the balloon on the ET
attaching the end-tidal CO_2 detector
attaching the resuscitator

Upon further testing, the procedures were completed in one parabola (25-30 seconds).

Tracheotomy: The procedures established in the preflight report were adhered to and deemed appropriate in zero-g. The Pertrach kit is highly preferable to the set that currently flies in the SOMS.

It was established that in order to effectively perform both procedures, two individuals are required: one to assist in restraint and equipment transfer and one to perform the procedure.

It was determined that the configuration of the AMAK was optimal for destowage and for use with the proposed medical checklist procedures established preflight.

Measuring IV Flow Rate

Data (see table below)

Observations

Setup 1

- The BP cuff was inflated to 300 mmHg prior to IV spike insertion into the bag.
- The spike was inserted in one-g and initial flow stopped at the drip chamber.

SET UP #	PREFLOW MASS (gms)	POSTFLOW MASS (gms)	TOTAL FLOW VOLUME (cm^3)	FLOW TIME (sec)	FLOW RATE (cm^3/sec)	BP CUFF PRESSURE (mmHg)
1	291.82	192.92	98.90	45*	2.19	300
2	293.80	213.59	80.21	66	1.22	300
3	294.69	251.32	43.37	64	0.67	300

* *No time was recorded for the first parabola (timer error)*

- When microgravity was obtained, the roller clamp valve was opened.
- With the air vent pointed upward, flow ceased at the air/fluid separator.
- *No time was recorded for the first parabola (timer error).*
- Drip chamber filled approximately 80% on the first parabola.
- After the line was primed, it appeared that air and fluid was flowing into the air/fluid separator and only fluid was flowing out.
- Flow quality was excellent.

Setup 2
- On the first parabola, air bubbles were flowing past the air/fluid separator.
- The air/fluid separator filled up almost completely.
- Air was seen in the air/fluid separator throughout the test.
- When the set was held stable, bubbles remained in the air/fluid separator.
- Agitation of the set caused micro air bubbles to travel through the line.

Setup 3
- The IV line was full; however, it appeared as though there was little or no flow.
- In the second parabola, a kink was found in the IV line causing reduced flow.
- Flow quality was similar to that seen on the second set.

CONCLUSIONS

AMAK Evaluation

Analysis of the components, configuration, and proposed procedures yielded excellent results in a microgravity environment. Two suggestions were proposed to improve the overall effectiveness of the AMAK:

- Increase the tension of the internal straps.
- Add Velcro® attachments to each component of the kit.

Both suggestions have been incorporated in the flight unit fabrication. Medical Operations recommends the addition of the AMAK to the Orbiter's medical kit locker as a standard piece of medical equipment.

Measuring IV Flow Rate

Flow rate data obtained from this flight was inconclusive because there was a time recorder error on the first setup and a flow stoppage in the third set. Flow quality analysis was completed, however, and data gathered for the Baxter Travenol® IV administration set supported that obtained on previous flights. Although the flow quality of the Baxter Travenol® set is lower than the set that currently flies in the SOMS, the flow rates (calculated from previous flights) are approximately three times greater. Because the IV administration set is required for rapid fluid infusion, it appears as though the Baxter Travenol® IV set will replace the set that currently flies.

PHOTOGRAPHS

NASA Master Video 905406: Video recording of the entire AMAK evaluation including equipment destow, intubation procedure walk-through, and Pertrach kit evaluation.

S91-31633: Investigator opens the AMAK attached to the face of a rack.

S91-31634, S91-31635, S91-31636, S91-31637: Investigator removes supplies from the AMAK.

S91-31639, S91-31640: The larynx is visualized in preparation for intubation.

S91-31641, S91-31642: The manikin head is intubated with the ET. Stylet has been removed.

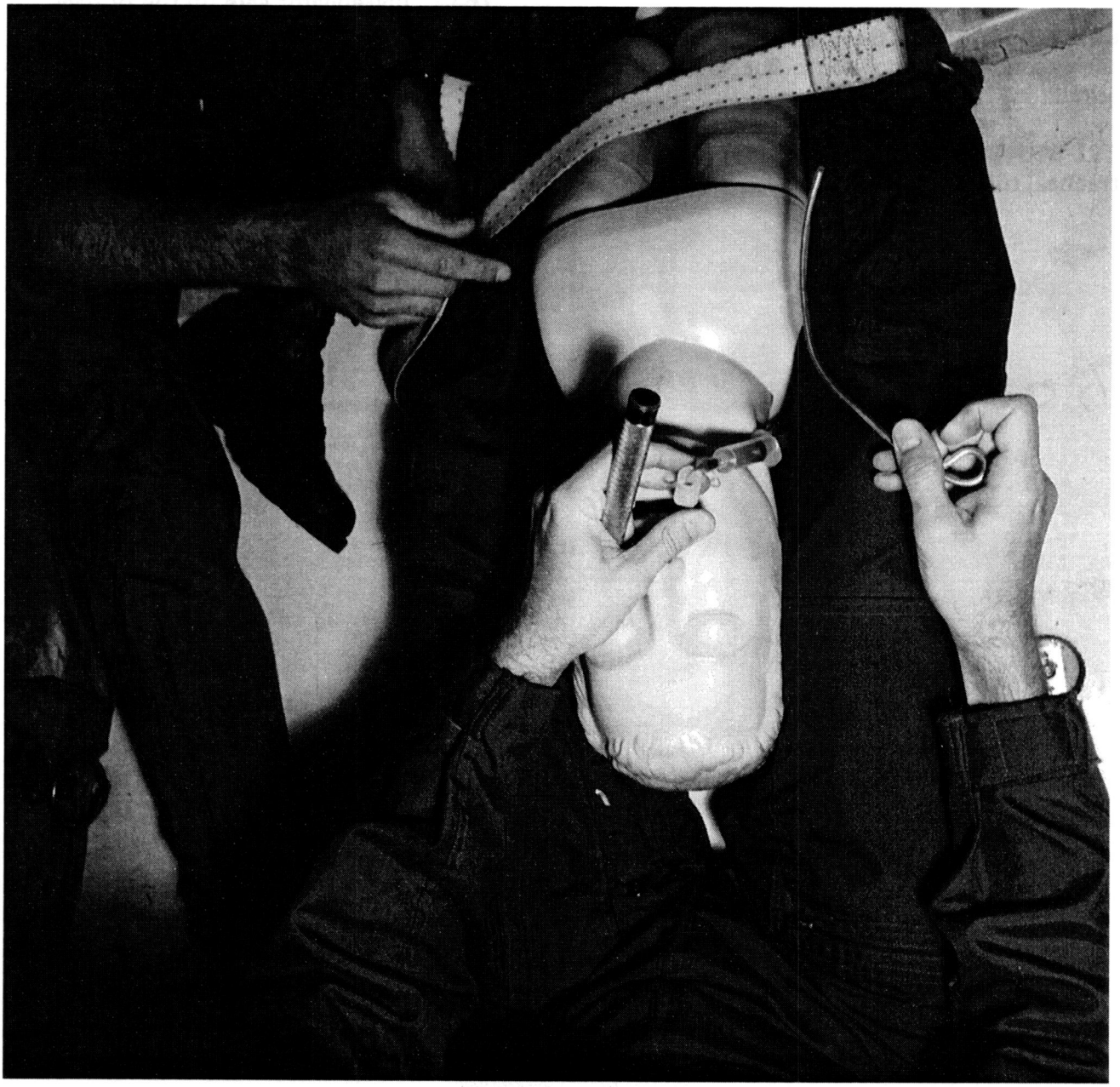
S91-31643, S91-31644: Investigator places the end tidal CO_2 monitor in line with the O_2 regulator.

S91-31646: Investigator performs mouth-to-tracheal tube intubation.

S91-31647: Investigator holds O_2 demand regulator and end tidal CO_2 monitor in hand.

S91-31648: Investigator sets up the IV bags and BP cuff on the MRS.

S91-31655: The IV bags are secured.



S91-31542: *The manikin head is intubated with the ET. Stylet has been removed.*

S91-31655: *The IV bags are secured.*

Transport Simulation for Man-Tended Capability

Flight Date:	March 21, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigators:	Maureen S. Smith (KRUG) Smith Johnston (KRUG Life Sciences) Victor Kizzee (KRUG Life Sciences) Frank Eichstadt (MDSSC) Chris Lucas (U. of Florida)

GOAL

Determine effectiveness of the Man-Tended Capability (MTC) ALS pack and MRS prototypes.

OBJECTIVES

1. Determine the effectiveness of the Evac-U-Splint mattress as the MRS for MTC.

2. Evaluate the second generation ALS pack. Also, the restraints needed by the CMO, MRS, and ALS pack will be considered. The equipment for the procedures will be deployed out of the ALS pack and the miniracks.

MATERIALS, METHODS AND PERSONNEL

One minirack (21"x31"x54") was used to hold medical equipment for the experiment but was not tested for configuration effectiveness in that drawer position was not considered prior to flight. Placement of the defibrillator and ventilator in the rack was not considered since the ALS pack would be deployed off the rack face before or simultaneously with the defibrillator allowing easy access to the ventilator. Also, the MRS was stowed in the bottom of the rack because it did not fit into the drawers. Rack evaluation was not part of the experiment although deployment of equipment was included.

HMF prototype MRS: Evac-U-Splint Mattress

ALS pack: The old Bushwalker prototype from 1989 was used because the second generation pack was not complete.

Data acquisition included in-flight written questionnaires, video documentation, and self-report post-test.

Participant responsibility for parabolas 1-20:

Maureen Smith	CMO 1
Smith Johnston	CMO 2
Victor Kizzee	Crewmember
Chris Lucas	Patient
Chuck Lloyd	Comments/Spotter
Frank Eichstadt	Director/Spotter
Lynette Bryan	Video

IN-FLIGHT TEST PROCEDURES PER PARABOLA WITH COMMENTS

Parabolas 1-2: CMO 1 attempted to stabilize patient's c-spine while CMO 2 deployed the c-collar from the ALS pack and the defibrillator pads from the defibrillator. Crewmember deployed the Evac-U-Splint mattress from the bottom of the minirack and secured it to the floor of the plane.

To stabilize the patient's c-spine, CMO 1 needed at least one foot restrained to allow both hands to be used; having both feet restrained was more stable. Securing a foot under the bungee cord took more time than expected; but, once achieved, provided the CMO with enough stability for patient c-spine immobilization. The method used for c-spine immobilization was similar to that used terrestrially for water rescue and proved as effective in microgravity. On board SSF in a pulseless, apneic patient, CPR would need to be initiated immediately, regardless of c-spine trauma; and, therefore, some means of rapid restraint/stabilization of the CMO is required.

Parabolas 3-4: While CMO 1 continues to stabilize the patient's c-spine, CMO 2 removes patient's shirt and applies c-collar and defibrillator pad. Meanwhile, crewmember deploys the ALS pack from the rack.

Parabola 5: CMO 2 applies remaining defibrillator pad. Crewmember secures ALS pack in position. Once CMO 2 arrived with the medical supplies, stabilization of the patient became more difficult due to lack of proper restraint by CMO 2 prior to applying c-collar and defibrillator pads. Without foot restraint, CMO 2 had a tendency to use the patient to stabilize himself which led to ineffective c-spine immobilization.

Parabola 6: CMO 1 moves patient into the MRS and crewmember prepares the MRS restraints. CMO 2 deploys the defibrillator and secures into position.

Moving the patient to the floor/MRS was difficult since the CMO 2's hands were both used for c-spine immobilization and could not be used for translation while the feet were unrestrained. Because the CMO's feet were unrestrained for movement, both the CMO and patient were unstable in the attempt to move. Placing the patient in the MRS then moving to the "HMF work area" may be a better strategy, or having another crewmember assist in translation of the patient and CMO.

Parabolas 7-8: CMO 2 accesses the BVM in the ALS pack and uses it on the patient. CMO 1 continues restraining the patient in the MRS while the crewmember begins evacuating the air from the mattress (to stiffen it).

Packaging the patient in the Evac-U-Splint was difficult due to the single restraining strap that had to be locked in place at each point prior to tightening it to properly restrain the patient. Meanwhile, the crewmember was evacuating the air to provide rigidity without anyone packaging the patient; therefore, the full effect of the mattress was not achieved.

Parabolas 9-10: Crewmember begins CPR restrained at the patient's side: CMO 2 tapes the head to the MRS for c-spine stabilization and continues bagging. CMO 1 attaches leads to defibrillator pads and opens the ALS pack for accessing.

Parabolas 11-12: CMO 2 and crewmember perform CPR, "clear" for defibrillation, and return to CPR. Crewmember performs chest compressions while straddling the patient. The

crewmember had some problems unhooking his feet from the bungee cords in order to clear the patient. Because he was straddling the patient, he had to clear completely while he may have been able to leave his legs restrained when positioned at the patient's side. Both methods worked well though the straddle method was more comfortable. Once the patient is restrained in the MRS, kneeling at the side may be the best alternative during defibrillation attempts.

Parabola 13: CMO 1 deploys the airway management kit from the ALS pack. The crewmember deploys the portable oxygen supply from the rack. The Director/Spotter performs chest compressions by placing his feet against the ceiling of the aircraft so that his body is perpendicular to the patient's chest. The option of vertical CPR is viable only if the crewmember is tall enough to reach from the floor to the ceiling and still achieve proper compressions. Also, this method may not allow the crewmember to easily determine if the compressions are adequate.

Parabola 14: The crewmember uses the vertical method of chest compression (feet at ceiling). CMO 2 connects the portable oxygen to administer 100% oxygen via the BVM and hyperventilate the patient in preparation for intubation. CMO 1 opens the airway management kit and accesses/prepares the equipment and supplies necessary for intubation.

Once the airway kit was deployed, it had to be held while supplies were accessed because there was no place to restrain it. Also, as supplies were deployed, they too had to be held before handing them to CMO 2 as a group since he was bagging the patient and did not have any free hands.

Parabolas 15-16: Intubation begins. When CMO 2 is ready, the crewmember removes the front of the c-collar and stabilizes the c-spine. CMO 1 applies cricothyroid pressure and CMO 2 performs intubation. C-collar is repositioned.

Parabola 17: While CMO 2 bags with the BVM, the crewmember listens for breath sounds to ensure proper placement of the ET. CMO 1 accesses the drug kit to obtain epinephrine 1:10,000. The drugs need to be rapidly accessed especially since the preceding steps (intubation, etc.) may take longer than normal in microgravity. Because the ALS pack flown on this flight was the original prototype, it did not have the updated inner-roll assemblies and, therefore, could not be evaluated effectively. Also, the supplies were not packaged correctly which further hampered evaluation.

Parabola 18: CPR continues with the crewmember straddling the patient for chest compressions, BVM administration of 100% oxygen, and epinephrine injected into the ET. Possible problems associated with administering drugs through the ET in microgravity were not tested.

Parabola 19: CPR is interrupted for defibrillation attempt; CMO 2 and the crewmember must "clear" patient. Normal sinus rhythm present. CMO 1 deploys assessment equipment. The crewmember had less trouble clearing patient since he was not restrained (doing CPR with his feet on the ceiling). Caution must be taken to prevent inadvertent patient contact during defibrillation by free-floating crewmembers.

Parabola 20: The crewmember takes complete set of vitals. CMO 2 simulates hooking patient to ventilator.

During turnaround, Smith takes over as CMO 1, Victor becomes CMO 2 (airway management), and Chuck Lloyd assumes crewmember position.

Parabola 21: CMO 2 suctions patient's oropharynx using V-vac. CMO 1 accesses the IV supplies from the ALS pack. The crewmember monitors patient by taking a set of vitals. The suctioning procedure was no problem though the functionality of the V-vac was not tested.

Parabolas 22-23: CMO 1 continues to prepare the IV supplies while the crewmember secures the equipment (to MRS and atop patient) for transport. CMO 2 continues airway management. Although restraining medical equipment atop the patient works for transport to the rescue vehicle, once the patient is secured in the vehicle, the equipment would need to be removed since the g-forces present during reentry could cause further trauma to the patient.

Parabola 24: While the crewmember prepares equipment for transport, CMO 1 uses a saline-filled syringe to wet a container of gauze to use to dress a simulated burn on the patient's arm. The wetting procedure involved drawing saline from the IV bag into a syringe then injecting it into the packaged gauze. No difficulties were encountered.

Parabola 25: CMO 1 applies saline-soaked gauze dressing and bandages the burn. The test proved that the procedure works; however, when creating a saline-soaked dressing, a larger syringe would avoid the need for repeated injections.

Parabola 26: CMO 1 and the crewmember clean up waste, etc. by restowing it in the ALS pack in preparation for transporting patient. Techniques of waste management were not properly evaluated since the ALS pack was an older model which did not contain any trash containers. Throughout the flight, the generated trash was stuffed wherever was convenient at the time.

Parabola 27: Final preparation was made for moving the patient by releasing restraints between MRS and floor. Because some of the bungees were still attached to the MRS, the hooks tended to catch on the D-rings making transport difficult.

Parabola 28: Patient moved off floor to waist height by crewmember and CMO 1 (one on each side) while CMO 2 stands at the patient's head and assists ventilations with BVM. CMO 2 experienced some difficulties in self-stabilization which caused inefficient bagging. Also, the possibilities of extubation are high in this configuration.

Parabolas 29-30: Performing the same patient movement, CMO 2 stabilizes himself by gripping the head of the MRS between his knees. The Director/Spotter attempts to evacuate more air from the mattress to provide more stiffness. CMO 2 is more stable in using this method of self-restraint though extubation is still a concern. While performing airway management, the ET should be held in one hand while bagging with the other to ensure that the tube does not extubate.

Parabolas 31-40: Patient transported around the interior of the plane by CMO 1 and Director/Spotter while CMO 2 manages the airway by straddling the patient, grasping the MRS between his legs for self-stabilization, and bagging. This configuration for airway management was easiest on CMO 2 for stabilizing himself while the patient was being moved.

RESULTS

CMO and other crewmembers must be adequately restrained before attempting any treatment of the patient, especially if there is a possible spinal injury. Patient should not be used as a mechanism of restraint or stabilization for the CMOs.

ABCs of primary survey should be of utmost importance; therefore, free-floating CPR should begin as soon as pulseless and apneic patient is discovered, even at the expense of c-spine stabilization. The purpose of this flight was to determine the effectiveness of the c-spine stabilization technique as well as the difficulty associated with applying the c-collar.

Equipment, especially the MRS, needs to be restrained tightly to the floor (or wall or any hard, flat surface). Loose restraint mechanisms made it difficult to perform procedures and access equipment.

The Evac-U-Splint mattress was never very rigid possibly due to constant altitude changes. Also, packaging the patient into the mattress was difficult due to the single restraint lacing up the body. Instead, several straps are needed which would each hold the patient firmly to the MRS. Because of the single strap, packaging the patient effectively (to the capability of the Evac-U-Splint) while evacuating the splint was not accomplished.

Some means of restraining equipment/supplies near or on the MRS is necessary for easy access, use, and restow so that two crewmembers can perform medical procedures simultaneously and rapidly.

Producing saline-soaked dressing by injecting saline into gauze package worked well. Performing with a larger syringe should be tested.

CONCLUSIONS

It was concluded that the MRS design (Evac-U-Splint mattress) will need several modifications to ensure that it can be being rapidly deployed and secured to the floor so that once it is in place it will not float off the surface. The MRS had a tendency to float up at all points along the device during the zero-g portion of the parabola which caused the CMO to have difficulty performing the medical evaluation or procedure on the patient (Photos S91-31495, S91-31496, S91-31500, S91-31509, S91-31510, S91-31513).

The CMOs had difficulty stabilizing the c-spine of the patient at the site of the accident. The problem appeared to be with getting the CMOs feet stabilized to allow for hands-free functions (Photos S91-31497, S91-31498). When the patient was being moved from the site of the accident to the deployed MRS, the CMOs appeared to have poor control of the patient's C-Spine. They appeared to be having difficulty getting the patient onto the MRS and strapped into position. One problem encountered was that the CMOs needed to lower the patient onto the MRS when they themselves were not restrained in any way. During this transfer process, the CMOs had to perform multiple functions simultaneously. Straps had to be undone at the same time the CMO had to push the patient to the MRS resulting in the CMO struggling with undoing the straps and maintaining the patient's position on the MRS until properly secured.

Another problem was the lack of enough restraint for the CMO to work at the MRS. There was a problem with having efficient access to the equipment and supplies in the ALS pack while the CMOs were secured near the MRS. Another problem was with having rapid release capability from the restraints so the CMOs

could clear the area prior to performing defibrillation. While this procedure was being performed with the bungee cord restraints, both the CMOs expressed concern about not being able to clear the area rapidly because their legs were getting tangled up in the restraints (Photos S91-31521, S91-31525).

A problem was noted with being able to rapidly and efficiently gain access to the drugs and to prepare the medication prior to administration to the patient. Proper disposal of trash appeared to be difficult, and paper products and needle covers were lost to the cabin environment. There should be rapid access to trash holders at the MRS and in the ALS pack.

During attempts to simulate moving the patient from the site on the floor to the transport vehicle, the CMOs had difficulty properly restraining equipment to the MRS as well as maintaining the MRS in a stiff flat position (Photos S91-31534, S91-31535, S91-31536, S91-31537, S91-31538). These photographs demonstrate the problem with the bungee cord restraints getting caught on the D-rings on the floor, arching of the MRS, and proper positioning of a CMO performing manual pulmonary resuscitation. For this simulation, the equipment can be seen simply stacked up on the patient and secured to the restraint with bungee cords.

During the first 10 parabolas, two major activities were occurring. Near the back of the plane (where the accident occurred) the CMOs were attempting to stabilize the patient and access the problem. At the same time, other crewmembers were deploying the MRS from the rack face and deploying it to the floor. While CMO 1 stabilized the patient, CMO 2 moved to the racks to obtain necessary medical equipment to stabilize the patient at the site of the injury (Photo S91-31494). By the end of this set of parabolas, the following tasks had been completed.

- Patient's problems had been assessed.
- C-collar and electrode patches were in place.
- The MRS had been deployed.
- The patient had been moved and secured to the MRS.
- The patient's airway had been established
- CPR had been started.
- Defibrillator was set up and prepared for operation.

During this set of parabolas, the crew experienced significant negative g's which presented them with the problem of maintaining position, and stabilizing personnel and supplies (Photos S91-31497, S91-31498). CMO 2 was able to obtain the medical supplies from the rack by the completion of the second parabola (S91-31494). The MRS was deployed within three parabolas (Photos S91-31495, S91-31496). Negative g's during parabola 4 caused the crew not to complete any activities. The c-collar was placed during parabolas 2 and 3. The placement of the c-collar on the patient appeared to be difficult since the CMOs had difficulty getting good foot restraint while attempting to maintain stability of the patient's c-spine. An attempt was made to move the patient during Parabolas 5 and 6. The CMOs had significant difficulty maintaining control of the patient's c-spine during the transport to the MRS because it was hard to maintain good foot and hand restraint . The MRS continued to float upward since it was not tightly secured at all points to the floor, and there were problems with lowering the patient onto the MRS while attempting to maintain body control, and with clearing the area of straps intended to hold the patient once placed on the MRS (S91-31500). During parabolas 7 and 8, the patient's airway was established and bagging started. The patient needed to be secured more tightly during parabola 9, CPR

was started during parabola 10, and the defibrillator was set up to prepare for shocking the patient.

PHOTOGRAPHS

S91-31494: CMO 2 deploys defibrillator pads from the defibrillator drawer. Comments/Spotter looks on as CMO 1 attempts to stabilize the patient.

S91-31495: Crewmember deploys the prototype MRS Evac-U-Splint mattress from the rack to begin securing it to the floor. The Director/Spotter and Comments/Spotter observe, ready to assist if necessary. Meanwhile, CMO 1 attempts to stabilize the patient using the technique used terrestrially in water .

S91-31496: Crewmember secures the MRS to the aircraft floor. CMO 2 moves toward the patient with the first response supplies (c-collar and defibrillator pads). Camera operator moves to a better location for videotaping. Comments/Spotter observes patient spinal immobilization.

S91-31497: CMO 1 secures herself before attempting patient immobilization while patient stands by to be immobilized. CMO 2 restrains a foot before placing the c-collar on the patient.

S91-31498: While CMO 1 attempts to prevent further injury to the patient, CMO 2 attaches defibrillation pads, just in case. Comments/Spotter supervises the procedure. Director/Spotter calls out the next item for crewmember (off-camera) to deploy from the rack.

S91-31500: Crewmember and CMO 1 begin packaging the patient in the Evac-U-Splint while CMO 2 attaches the defibrillator leads to the pads. Director/Spotter and Comments/Spotter compare notebook restraint mechanisms.

S91-31504: Comments/Spotter and CMO 2 begin moving patient in a simulated transport while crewmember continues bagging by securing himself over the patient. A basic EMT-B supervises the procedure.

S91-31508: After patient is packaged in the MRS including head restraint, CMO 1 begins accessing supplies from the ALS pack while CMO 2 continues using the BVM for airway support. The patient has not been intubated yet nor is 100% oxygen being delivered.

S91-31509: As CMO 1 restrains herself prior to accessing supplies from the ALS pack, crewmember deploys the portable oxygen supply so that CMO 2 can begin administering 100% oxygen.

S91-31510: In an effort to test various methods of chest compression, Director/Spotter attempts a vertical method (feet on the ceiling for stability). An extra hand helps to achieve initial stabilization as Comments/Spotter is seen doing for Director/Spotter. Crewmember and CMO 2 continue to hook up the portable oxygen supply to the BVM for 100% oxygen administration. CMO 1 deploys the airway management kit from the ALS pack in preparation for intubation of the patient.

S91-31513: As CMO 2 prepares to intubate the patient, crewmember maintains c-spine stabilization on patient while Comments/Spotter assists crewmember in keeping himself fixed. While intubation takes place, CMO 1 deploys the assessment supplies for the stethoscope to check for breath sounds post-intubation attempt.

S91-31520: Now that the patient's heart is returned to a normal rhythm, crewmember takes a set of vitals including BP as CMO 2 continues to bag with 100% oxygen via the ET. CMO 1 continues accessing necessary supplies from the ALS pack.

S91-31521: Crewmember continues to take a BP reading and CMO 2 continues bagging while reaching for something off camera, possibly a bolus drug to administer via the ET. Crewmember's restraints seem a bit awkward.

S91-31522: CMO 1 prepares the IV equipment while CMO 2 assembles the V-vac suction unit to perform oral suction.

S91-31524: As CMO 1 finishes establishing an IV line, CMO 2 ventilates patient while crewmember prepares the (simulated) ventilator for connection. Camera operator moves in to record the huddle on film and EMT-B observes the procedures.

S91-31525: As CMO 2 ventilates the patient with the BVM, he keeps the manual suction unit on hand in case the airway needs clearing. Meanwhile, crewmember takes a BP reading and CMO 1 inflates the manual infusion device to begin IV fluid resuscitation.

S91-31534: Now that the patient is properly packaged for transport, including the equipment and supplies, crewmember and CMO 1 begin moving the patient. The crewmember stabilizes himself between the ceiling and floor while the CMO 1 uses floor restraints only which make him less mobile. During transport, the patient must still be ventilated and his airway protected/monitored; therefore, CMO 2 tries securing himself to the MRS using only his free hand. This method does not seem adequate since his feet are floating freely.

S91-31535: As the end of the parabola draws near, the patient is lowered to the ground by the CMO 1 and the crewmember while the CMO 2 continues airway management. The patient's arm is left free so that a BP reading could be acquired during the transport every 5 minutes or when necessary.

S91-31536: Patient transport is again tested. This time the CMO 1 and crewmember both secure themselves between the ceiling and floor for better movement possibilities as well as more patient stability. Also, CMO 2 fixes himself at the head of the MRS with his knees which leaves his hands free to work the BVM.

S91-31537: Patient transport continues in the same configuration - one crewmember on each side of the MRS and CMO 2 at the head of the patient/MRS. Although the MRS is bending, the portion covering the head to hips seems straight thereby immobilizing the spine.

S91-31538: As the Director/Spotter attempts to stiffen the MRS, transportation techniques continue. While CMO 1 unhooks himself from a foot restraint, crewmember prepares for patient transport. CMO 2 finds that straddling the patient and holding the MRS with his knees provides the most stability for the person managing the patient's airway.

S91-31510: *Chest compression is attempted using the ceiling for stability.*

S91-31513: *One investigator maintains c-spine stabilization as another prepares for intubation.*

S91-31535: *As parabola comes to an end, the CMOs lower the patient to the floor.*

Central Supply/Pharmacy Stowage and Deployment Mechanisms

Flight Date:	April 16, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigators:	Debra Orsak (MDSSC) Ed Cordes (MDSSC) Dr. Bob Pinter (KRUG Life Sciences) Susan Shimamoto (KRUG Life Sciences) Dr. Mark Campbell (Consultant)

GOAL

The purpose of this flight was to evaluate the "card" stowage concept for various central supply and pharmacy items. In general, evaluations of this stowage mechanism were made concerning destowage, deployment, unpacking, preparation for use, and restowage.

OBJECTIVES

1. Qualitative evaluation of the ease of use for the stowage card design.
2. Qualitative evaluation of the card stowage mechanism when deployed to a seat track.
3. Qualitative evaluation of the layout or ordering of supplies on the cards.

INTRODUCTION

The KC-135 test flight was performed in conjunction with a medical simulation of an arterial line placement conducted by members of the HMF simulations team. The simulation involved the placement of both a single line central venous pressure (CVP) catheter and a triple lumen catheter. Drawing of arterial blood gases (ABGs) and suturing were demonstrated in microgravity. All consumables used to perform these procedures were stowed using the prototype stowage mechanism to be evaluated. A standard flight profile of 40 parabolas was followed. All stowage mechanisms tested were developed by Ed Cordes of MDSSC Modular Outfitting and Design.

On April 20, 1990, prototype pharmacy/central supply stowage cards developed by Darren Binz of MDSSC Modular Outfitting Design were flown on NASA's KC-135. At this time, the conclusion was reached to use the standard man systems stowage trays of 5.25 and 10.5 inch height with a system of stowage cards for stowage of CHeCS consumables. This flight revealed the importance of using the stowage mechanism as the work surface from which items are deployed and used.

Recommendations from the flight included the need to develop interfaces between the card and the CMRS or other areas within the CMO's work space. Future, higher fidelity flights were anticipated to refine the card stowage mechanism in the areas of interface, packaging efficiency, and item retention. Results from this flight were presented by Binz at the June 1990 Preliminary Design Review (PDR).

Restructure forced the April 1991 flight to center on MTC consumables and a simplified MTC CMRS. For this reason, ancillary supplies for the ventilator and defibrillator were stowed along with prepackaged IV fluids. Cards were interfaced with seat tracks developed for the flight and mounted to the HMF miniracks. The cards were made from an aluminum alloy, instead of a more pliable material as would be expected for the flight unit.

MATERIALS, METHODS AND PERSONNEL

CVP kit (at least 2)
Preparation kit (at least 2)
Fluid IV kit (at least 1)
Assorted general stowage cards
Drawer of prepackaged IV fluids
Standard miniracks

No special requirements existed for intervals and spacing between parabolas. The permanent manned configuration (PMC) CMRS was set up by the simulation team personnel prior to the first parabola. The tasks performed in these parabolas coincided with those of the CVP flight.

Parabolas 1-10

Evaluated retention/removal mechanisms, destowage and deployment for the preparation kit (Photo S91-35743) and the CVP Kit (Photo S91-35746). Evaluated unpacking the items and preparing them for use, restowage of the items (when appropriate), and the cards.

Parabolas 11-40

Evaluated retention/removal mechanisms, destowage and deployment for assorted supplies from general stowage cards (for the performance of arterial puncture and complete placement of the CVP line). Evaluated placement of these items on trays, problems associated with destowage from various areas in the minirack, evaluated unpacking the items, preparing them for use, restowage of the items (when appropriate), and the cards.

This flight was a "piggyback" onto an existing simulation flight. One observer was dedicated to recording the activities on this flight. Three others performed the various activities of destowage, deployment, item usage, and restowage. Still photography was provided by a nondedicated NASA photographer.

RESULTS

Stowage Card Deployment

The stowage cards were deployed to two different surfaces: a series of seat tracks mounted to the miniracks and a flat metal tray attached to the PMC CMRS. The tracks were mounted in a vertical configuration to simulate those proposed for the standard SSF rack design. Two keys were cut into the bottom of the card to grip the track section it interfaced with. Cards were deployed, bowed slightly, and hooked into the track (Photo S91-35730). The operator had to use both hands to attach the card to the track. This seemed to be an easy operation even for an unrestrained crewmember. The fifth percentile operator found it difficult to attach and disengage the cards, but this was attributed to the fidelity of the card construction not the mechanism itself. Cards placed on metal trays were deployed and attached (by means of Velcro®) using one hand (Photo S91-35740). All operators performed this task and subsequently deployed items from the card with relative ease.

The seat track method of attachment had several advantages over the flat tray method. With the seat track, the card could be quickly and easily adjusted for use by crewmembers of

varying stature. Also, items could be placed on both sides of the card for access and visualization. Only one-sided cards could be secured on the metal tray. In many cases, the crewmember would need to deploy several cards at one time. The track method of deployment would allow for multiple cards to become a "staging area," within the crewmember's reach, but unhindering to patient care. The best solution would include a variety of interface sites including both seat track, CMRS, and tray compatibility.

Stowage Card Layout

Some stowage cards were developed so that all items required to perform specific procedures were included on one card (Photo S91-35744). Other general stowage cards containing a mixture of items commonly used in medical procedures were also developed. The specific kit cards, general stowage cards, and all drawings were developed for the flight by Ed Cordes. The representative layout drawings are included at the end of this report.

A number of cards were developed specific to CHeCS MTC supplies. These cards were not used by the medical simulations team and included ancillary supplies for the ventilator and defibrillator (Photo S91-35745). The Environmental Health System (EHS) consumables were not available for evaluation. They should be addressed on future flights. Initial evaluation of these ancillary supplies suggested that functional grouping would be preferred. Due to the size and shape of these items, a rigid card (as used in this flight) did not appear to be the best solution. Soft cards or rolls (as those within the ALS Pack) might prove to be better suited for stowage of these items. Another possibility may be stowing these items with the component itself (as in some type of case).

CONCLUSIONS

It was concluded that operators preferred specific "kit" cards with all items required to perform a procedure organized on one card in the order used. This took less time than deploying multiple cards for various supplies. This method, however, tended to generate more waste and cause redundancy in the items to be stowed. A combination of specific "kit" cards and general stowage cards seemed to be the optimum solution. The kit cards would contain only those items used each time a procedure was performed. Items such as 4x4's would probably be better located separately on general stowage cards which would be deployed as needed for most medical procedures.

This test showed the need for deployment of multiple cards to support medical procedures. As stated before, this would require several staging areas which cards could be deployed to and items removed from. To support access to a number of cards, various attachment sites would be required in the vicinity of the CMRS. These attachment sites could include the seat tracks along the racks and interfaces to the CMRS.

This flight demonstrated the card stowage concept to be valid when used in conjunction with attachments to the CMRS and surrounding areas. It also made obvious the need for several types of stowage mechanisms including different types of cards and soft cards or rolls. This flight did not evaluate packaging efficiency using the card mechanism. Future flights should test cards constructed of a more realistic material with EHS supplies included. At that time, a more detailed and systematic analysis of a complete CHeCS stowage would be possible.

Higher fidelity cards are necessary to adequately demonstrate attachment to the seat track and

to simulate card usage as deployment areas and work sites on future KC-135 flights.

Mechanisms for retention of items to cards, which was not addressed in this flight, must be addressed in future flights. This would be better accommodated with high fidelity cards and actual CHeCS MTC supplies.

Non-card stowage was not addressed well on this flight. Future flights should include simulation of tray stowage, especially for the EHS supplies.

PHOTOGRAPHS

S91-35730: CVP trays are placed on the seat track of a standard rack.

S91-35740: Betadine® swabs are passed to the investigator who is preparing the chest for CVP placement. Standard video is being taken.

S91-35743: CVP prep kit.

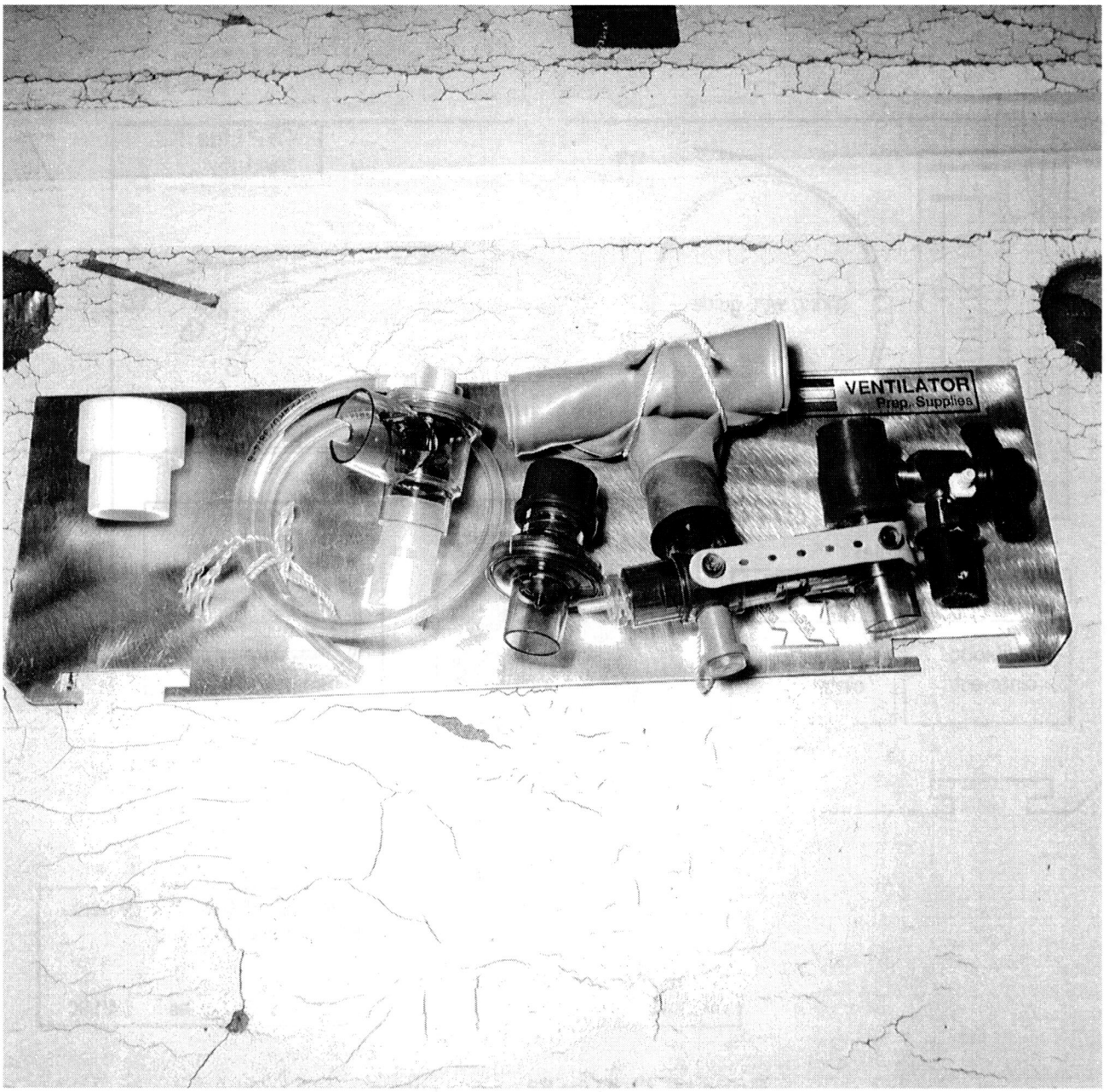
S91-35744: CVP instrument tray

S91-35745: Ventilator supply tray

S91-35746: CVP kit

S91-35748: CVP kit on seat track

KRUG Video: CVP Line Placement Simulation/ Evaluation of Central Supply/Pharmacy Stowage and Deployment Mechanisms.



S91-35745: *Ventilator supply tray.*

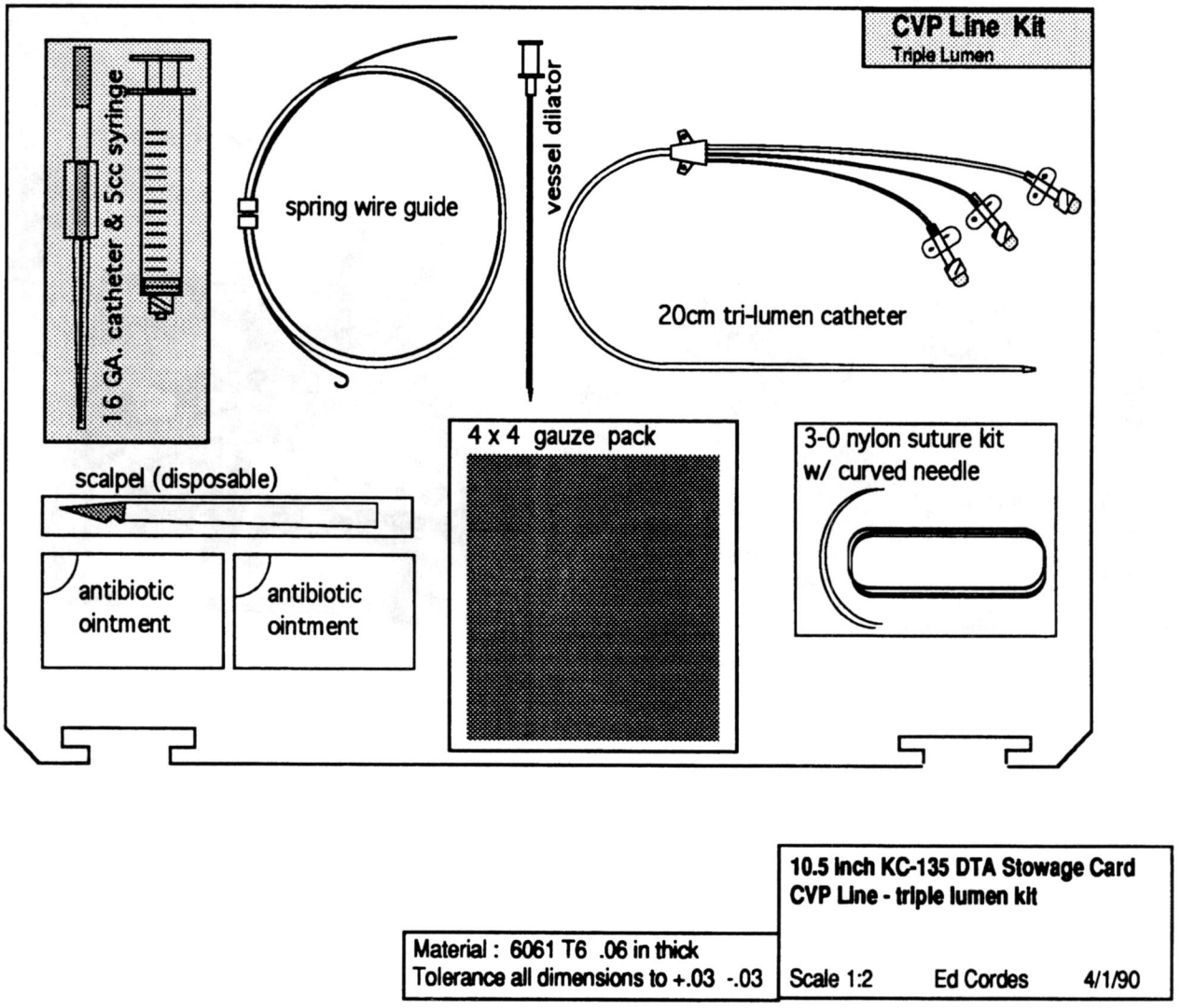


Figure 11. CVP Line Kit—Triple Lumen.

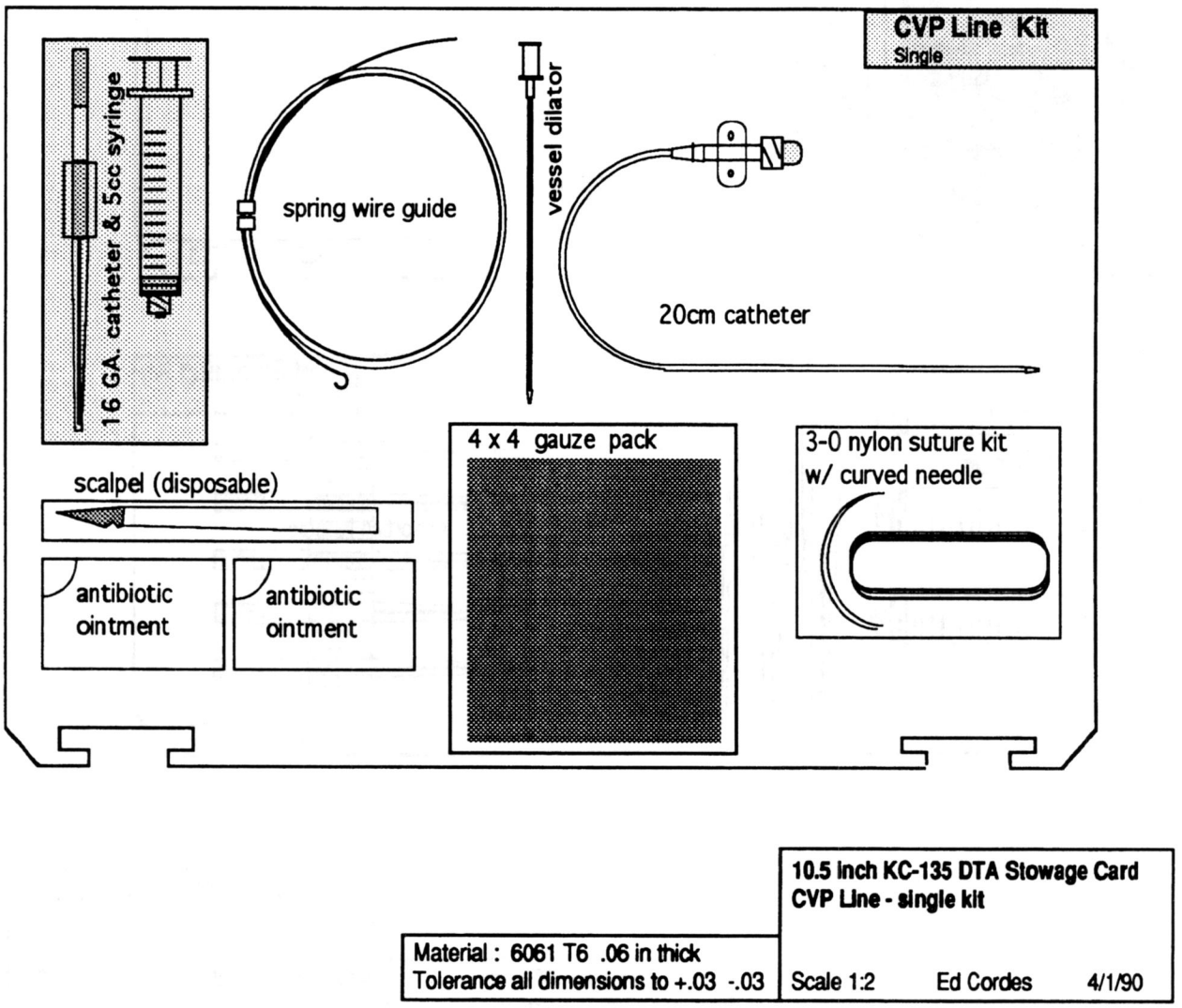


Figure 12. CVP Line Kit—Single.

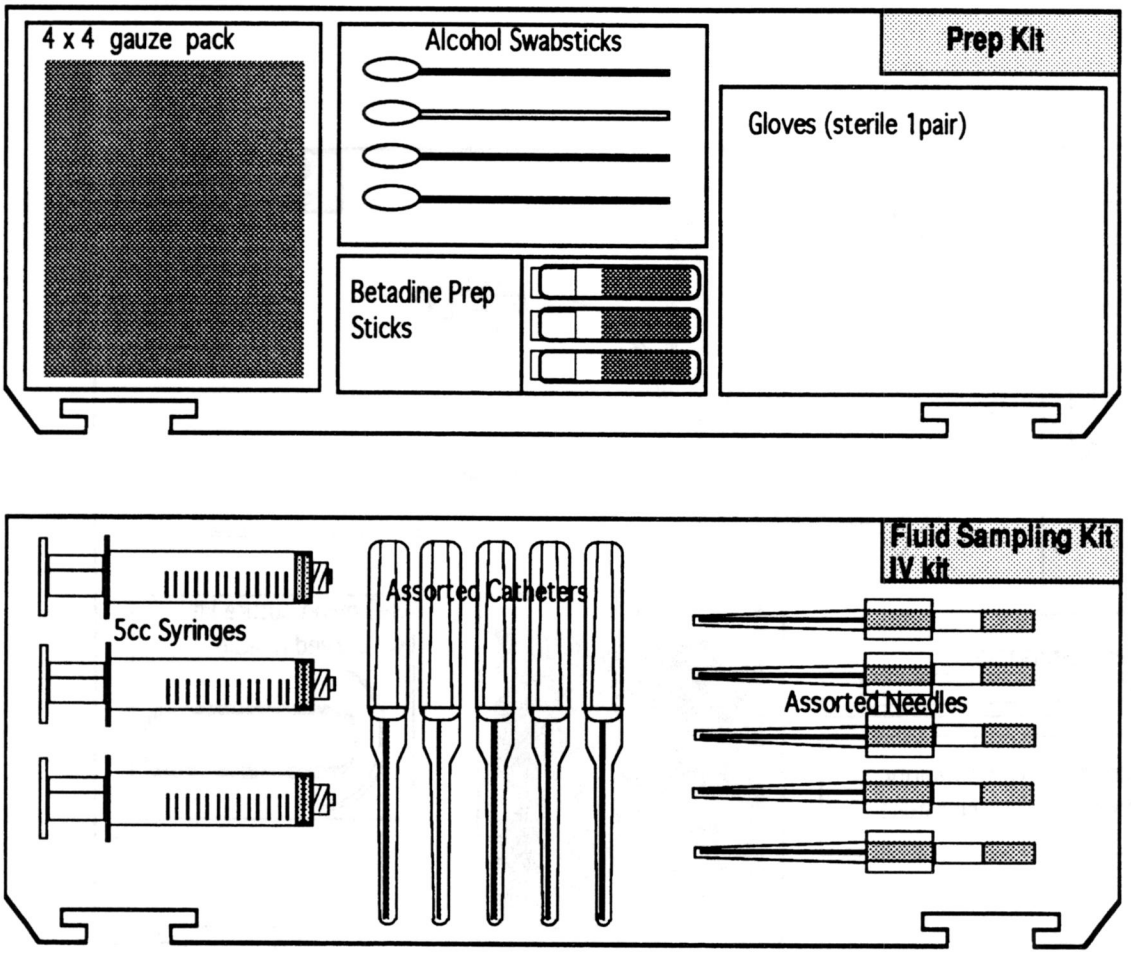


Figure 13. Prep Kit.

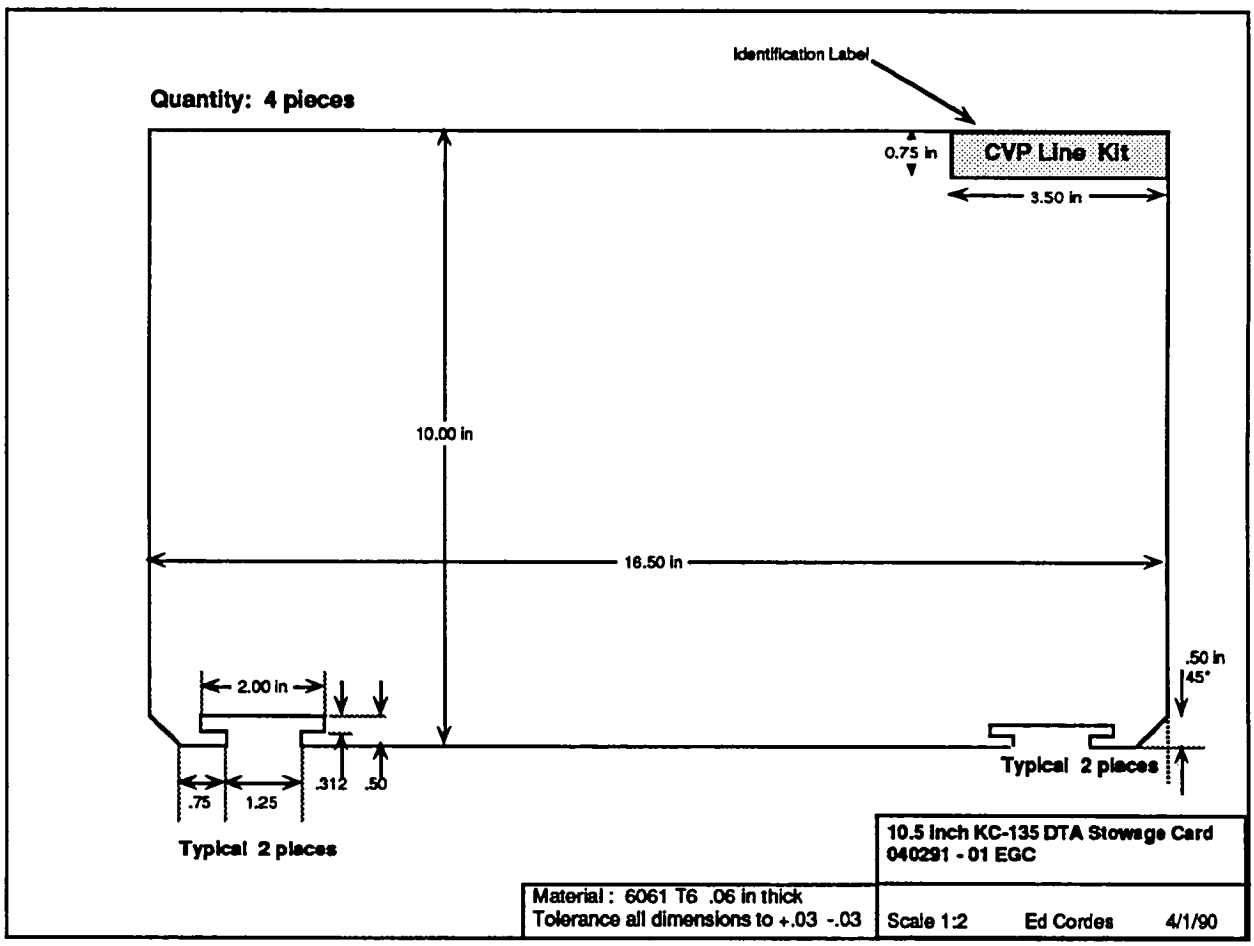


Figure 14. CVP Line Kit—Dimensions.

Central Venous Pressure Placement Technique and Arterial Blood Gas Drawing in Microgravity

Flight Date:	April 16, 1991
Principal Investigators:	Roger Billica, M.D. (NASA-JSC)
Co-investigators:	Robert Pinter, M.D. (KRUG Life Sciences) Susan Shimamoto (KRUG Life Sciences) Mark Campbell, M.D. (Consultant) Edward Cordes (MDSSC)

GOAL

To demonstrate and evaluate placement of a CVP line and drawing of ABGs in microgravity. In addition, microsurgical techniques and packaging and distribution of supplies were investigated.

OBJECTIVES

1. Demonstrate placement of a single and a triple lumen CVP line during microgravity.
2. Determine operator restraint needed to perform the procedures in Objective 1.
3. Determine the number of operators needed to perform the techniques effectively with regard to sterile technique and material flow.
4. Demonstrate arterial puncture for blood gases in microgravity.
5. Aid in establishing operational protocols for CVP placement and arterial puncture in microgravity.
6. Compare and contrast the feasibility of placing a single versus a triple lumen CVP.
7. Evaluate the level of skill needed to perform CVP placement, especially considering potential complications.
8. Evaluate stowage techniques, different kit configurations, and deployment of materials from the miniracks.
9. Evaluate microsurgical techniques in microgravity.

INTRODUCTION

The KC-135 parabolic flight test followed the standard protocol of 40 parabolas with 20-25 seconds of microgravity at each apex. The five experimenters chosen for the study included three physicians, a biomedical engineer involved in SSF crew training, and a stowage consumables system designer for the HMF of SSF.

The CVP lines were placed to illustrate an emergency situation where vascular access is needed. A triple lumen CVP was placed to simulate an emergency situation where

multiple deep lines are needed. One such situation occurs when fluids and multiple nonmixable medications need to be given (e.g., TPN and a dopamine drip). The CVP lines were not placed to simulate the measurement of the CVP from which the line derives its name.

The first line placement, the triple lumen version, was placed by a skilled physician who had performed central line placement more than a hundred times. The second line, a single lumen CVP, was placed by the biomedical engineer. She had only a few weeks experience in placing the line, learning in the laboratory on a manikin. She had become quite skilled in placing the line before the flight and was able to achieve vascular access at will.

Vascular access was simulated quite well with two special manikins – one, an upper torso and the other, an arm only. The manikins have latex conduits under the artificial skin which were filled with a red blood substitute. The CVP torso manikin has only a passive reservoir while the arm has a bulb pump which simulates arterial pulsation. Arterial puncture for ABGs was simulated quite well with this arterial pulsating arm.

In addition to the above vascular procedures, microsurgery techniques were performed by Dr. Mark Campbell, to familiarize him with needed techniques for a forthcoming animal operation experiment on the KC-135 (Evaluation of Animal Surgery in Microgravity).

Materials involved in placement of the lines and in performance of the ABG draw were standard off-the-shelf materials available in the current inventory for SSF.

Designers from MDSSC created several kits which consisted of materials grouped according to procedural area. One kit had the triple lumen CVP materials, another the single lumen CVP materials, a third the dressing materials, and a fourth the additional syringes, ABG syringes, and needles.

Velcro® was used extensively to keep materials restrained on the kit trays. Since the trays were low-fidelity prototypes, no attempt was made to simulate sterility by placing an overwrap on them nor was sterility simulated during the flight.

The study sequence was as follows:

- ABG syringe obtained from minirack, arterial puncture performed, ABGs analyzed.
- Materials (triple lumen CVP tray, dressing tray) obtained from miniracks and placed on Mayo stand, prep of patient, triple lumen CVP introduction, suturing and dressing the site, IV fluids begun.
- Materials (single lumen CVP tray) obtained from miniracks and placed on Mayo stand, prep of patient, CVP introduction.
- Simultaneously with the above procedures, at the other end of the MRS, (i.e., the operating table) a physician practices microsurgical techniques.

In most trauma scenarios, fluid resuscitation is the most important life-saving action. Currently, the American College of Surgeons[1] strongly encourages the use of peripheral IV access when fluid resuscitation is mandated. The next recommended form of IV access is through performance of a venous cutdown. If these two forms of access fail, the third mode of access is through the central venous circulation. The three most common sites of central venous access are through the femoral, the subclavian, and the internal jugular veins. All the central venous circulation points require a high level of skill to access, and the different

entry points make the risks of serious side effects variable.

In general, the greatest risk of placing a subclavian line is inadvertent puncture of the lung tissue, leading to pneumothorax. This complication is readily remedied by placing a chest tube on the affected side. The other major complication is in piercing the subclavian artery. When the artery is punctured in this area, it is impossible to tamponade the blood flow, which could lead to exsanguination.

The major complication with the internal jugular vein site is inadvertent piercing of the carotid artery. The artery may be pierced either in an easily accessible area for tamponage or in an inaccessible area. Other important structures in the neck, such as the trachea, esophagus, and various nerves, are all subject to serious injury by puncture. Pneumothorax is also a possible complication here. The level of skill needed to perform this procedure is probably beyond the abilities of a non-physician operator, given the risks.

The femoral artery has no complications of pneumothorax nor with piercing an artery inaccessible for tamponading, but it is difficult to place in most trauma situations, has higher infection rates when left indwelling for long duration, is easy to dislodge, and may be more difficult to initiate in a microgravity situation due to decreased venous return from the lower extremities.

For the above reasons, it was decided that central venous access is probably best obtained from the subclavian vein. The subclavian vein most likely would be at least as much if not more engorged with blood in microgravity than it would be in one-g because of cephalic fluid shifts.

Placement of a triple lumen catheter using the subclavian approach, with all of its attendant steps is demonstrated for the nonmedical audience. This placement is compared with the placement of a single lumen subclavian angiocath to demonstrate a simplified placement procedure. An unskilled operator was chosen for this assignment since most likely the CMO will have a background similar to this person. This unskilled operator was well trained in the placement of the CVP, but had never placed one during a "pressure" situation, such as in a real emergency or during a stress-producing KC-135 flight.

An arterial puncture was performed to identify possible problems with drawing ABGs in microgravity.

MATERIALS AND PERSONNEL

Average-sized adult male torso with full landmarks present was used for placing both subclavian and internal jugular CVP's. This manikin has a venous conduit system with simulated blood in the exact locations of the major veins of the upper torso (Photo S91-35729).

Average-sized adult upper extremity with vascular conduit containing artificial blood with a hand pump system was used to simulate arterial pulsations. The upper extremity is anatomically correct (Photo S91-35747).

A triple lumen CVP kit consisting of a flat tray (aluminum), a triple lumen CVP, a 16-gauge 10 cm long angiocath cath over the needle type, one 5 cc syringe, a j-wire, a dilator catheter, 4x4 gauze pads, #11 scalpel, 3-0 silk (in actuality nylon) suture on a curved needle, and two packs of antibiotic ointment.

A single lumen CVP kit consisting of the same materials as in a triple lumen CVP kit, including

the j-wire, the dilator catheter, and the single lumen CVP line, although these latter items were not to be, and were not, used during single lumen CVP placement.

A dressing kit (on an aluminum tray) with a package of 4x4 gauze pads, Betadine® swabsticks in a package of three, alcohol swab sticks prepackaged, and a pair of sterile gloves (Photo S91-35743).

A fluid sampling kit and IV kit on an aluminum tray with three 5 cc syringes, and five assorted syringes with 5 assorted needles (Photo S91-35744).

Two incise drapes (Photo S91-35728, covering manikin)

IV set-up with D5W 500 cc bag and IV tubing

Belt/carabiner restraints

Video camera

Strap restraints for the manikin

Paper and duct tape

MRS

Trash container, fish trap metal wire mesh

Two sharp-Trap Bio-Disposable Container

Deployable instrument tray (Mayo stand)

ABG analysis faceplate mockup.

Standard miniracks (Photo S91-35748)

Sterile surgical gloves (4 pair)

Two 3 cc pre-Heparinized (simulated) ABG syringes with #23 needles attached

Two 5 cc syringes preloaded with 1% Lidocaine®

Two needle holders

Five investigators participated: three were involved in the procedure, one operated the video camera, and one performed microsurgical techniques. Still photographs were by a nondedicated NASA photographer.

METHODS

All procedures were first performed in the HMF ground laboratory for familiarization.

Arterial Puncture and ABG Measurement Simulation

Trash containers were deployed once before all procedures. The manikin arm is duct-taped to the MRS. Sterile gloves are applied prior to the parabolas. A Betadine® swab and a pre-Heparinized syringe are removed from the miniracks, and the lone operator preps the wrist of the upper extremity manikin over the radial artery site. The arterial puncture is performed, and the lone operator applies pressure over the site of the stick. After hemostasis is achieved, the operator floats to the miniracks and injects the blood from the syringe into the ABG analyzer faceplate. The ABG syringe is disposed of in the sharps container (Photo S91-35747).

Triple Lumen CVP Placement

Two operators are involved in the procedure. The assistant operator floats over to the miniracks, destows the sterile gloves, and assists the operator with placing them on (in reality this step was skipped since the operator already had gloves on from the prior procedure). Betadine® prep swabs are destowed by the CMO 2 and sterilely passed to CMO 1. CMO 1 preps the site in the right subclavian area. CMO 2 then hands off sterilely the incise drape to CMO 1. The operators place the drape in the

appropriate location, and trash is disposed of as needed.

Next, the triple lumen CVP kit is destowed from the miniracks by CMO 2 and placed on the Mayo stand. There was no attempt to simulate sterility with this procedure, but once the kit was in place, it was assumed to be sterile.

From this time forward, CMO 1 will perform the entire procedure without assistance except for hemostasis control by ballottement of the site with 4x4s by CMO 2 (4x4s are removed from the kit by CMO 2).

CMO 1 anesthetizes the site with prefilled syringe of Lidocaine®. The 16-gauge angiocath is removed from the kit, a 10 cc syringe is placed on it, and the needle insertion is made in the appropriate site. A blood rush from the vessel ensues, and to ensure placement, blood is pushed in and out of the syringe. The syringe is removed from the needle with immediate occlusion of the open needle with the thumb to prevent air embolus. The syringe is placed back onto the kit tray and the j-wire is removed from the tray. The j-wire is placed into the vein and the needle is removed and disposed of in the sharps container. An incision is made in the skin at the insertion site with the scalpel taken from the tray, and the scalpel replaced onto the tray. The dilator catheter is removed from the tray and placed over the wire and inserted into the skin and removed. It is then replaced onto the CVP tray. The triple lumen catheter is removed from the tray and unwrapped, with trash disposed. The catheter is threaded over the wire until its full length is under the skin up to the hub of the catheter. The wire is removed from the catheter and disposed. CMO 2 destows the IV fluids from the miniracks and plugs in the fluid. A small opening is made in the incise drape around the site of the CVP insertion, and the suture is removed from the tray. CMO 2 hands the needle holder to CMO 1 while holding the CVP line in place. CMO 1 sutures the line in place, cuts the suture with the scalpel, and disposes of the scalpel and the curved needle in the sharps. Gauze pads are placed on the CVP insertion site after antibiotic ointment is applied to the opening. The gauze cloth is taped into place and the incise drape is removed.

Single Lumen CVP Placement

The same steps are performed for the single lumen CVP placement, but the CMO 1 now performs the procedures of CMO 2 and vice versa. The procedure differs from the other in that the steps after the syringe is removed from the #16-gauge angiocath are eliminated up to the point of connecting the IV line. All steps after this point remain the same (Photo S91-35726).

Microsurgical Techniques

Throughout the entire time the above procedures were performed, Dr. Mark Campbell performed microsurgical suturing techniques at the other end of the MRS (Photos S91-35732, S91-35741, S91-35742).

RESULTS

Arterial Puncture in Microgravity

The procedure was performed without problems. Pulsation of the blood column was clearly seen in the syringe. There appeared to be no mixing of air bubbles with the blood in the syringe. Air was easily expelled from the remainder of the syringe, although intentional shaking or disruption of the air/blood column was not done. Transfer of the fluid to the analyzer was easily accomplished, and also appeared to proceed without mixing of the air and fluid. One caveat, however: The fluid solution used, for technical reasons, was not

actually blood. Blood may have significantly different adhesive qualities that could cause visible mixing with air and probably should be the trial solution used in the future. To be optimal, the blood solution should be whole uncitrified blood to enable evaluation of the heparinization ability of the ABG syringe. It would be helpful to have a second operator holding the post-draw puncture site to enable more expedient measurement of the ABGs.

Demonstration and Comparison of Triple Lumen versus Single Lumen CVP Placement in Microgravity

The placement of the triple lumen CVP was well demonstrated, except for a few steps that were skipped to expedite the procedure. The steps skipped were local anesthetization of the skin and surrounding tissues, removal of the incise drape after dressing the wound, and actual dressing of the wound with antibiotic ointment and cloth tape.

During the procedure, few microgravity-related problems were seen except for the difficulty with controlling the ends of the j-wire and the triple lumen CVP while inserting them. The ends of the objects tended to wield freely in space, making sterility maintenance a major concern. The operator needs to be much more cognizant of this fact, and needs to exercise greater awareness to possible contamination.

The set-up of the CVP kit and dressing kit went very well and was easy to accomplish. The kits were very easy to use. Grouping of needed items together was helpful for the procedural flow.

The placement of the single lumen CVP was not as well demonstrated. The step of local anesthetization was also skipped. The actual insertion of the CVP did not occur because the operator failed to achieve vascular access after several attempts. During the nonmicrogravity time between parabolas, vascular access was easily achieved by another physician present, so the first operator's failure was not caused by equipment problems. In actuality, the only steps left after vascular access is achieved are to remove the needle, connect the IV line, and suture and dress the area. From this viewpoint, the goal of demonstrating the procedure *was* achieved.

Operator Restraint

Operator restraint needed to perform the procedures was adequate with both belt restraint to the MRS and with no restraint to the MRS other than wedging of the feet between the floor and the closest rail of the MRS.

Amount of Operators Necessary to Perform the Procedures

It would be extremely difficult for a lone operator to insert a CVP. The difficulties occur with containment of fluids (especially blood) and hooking up of IV lines. Without the aid of gravity to hold gauze pads to the skin of the patient, fluids would be unrestricted when the operator is engaged in performing an action that requires two hands. There is no necessity for the needed assistant to be sterile to be an effective helper.

Microsurgical Techniques in Microgravity

This section was written in its entirety by Mark Campbell, M.D., except for the comment in the final paragraph.

The purpose of this project was to simulate surgical techniques requiring the meticulous use of fine motor muscles and more extensive coordination as compared to standard surgical technique to better delineate the effects of microgravity on performing a surgical procedure.

Microsurgical techniques were simulated using a headlight, 2.5X mag surgical loops, microsurgical instruments, 9-0 nylon suture, and a plastic microsurgical practice card (16 incisions at four different angles). The project redemonstrated the importance of rigid restraint of the patient, surgeon, instruments, supplies, and discarded consumables for the successful performance of a surgical procedure. A fine trembling of the hand motor muscles was encountered for the first set of 10 parabolas, but acclimation was quickly achieved. In general, the procedure appeared no more difficult and no different than the ground simulation performed the previous day using the same hardware and techniques.

One further observation, not addressed by Dr. Campbell, was that he noted motion sickness symptoms when using the magnifying loops. These symptoms of motion sickness resolved with removal of the loops, even though he continued suturing as before.

DISCUSSION

The placement of a CVP in any situation is a highly skilled procedure, with many potential and life-threatening complications. In microgravity, placement is only slightly more difficult than on Earth, due mainly to greater fluid dispersion and a greater chance of contamination of sterile instruments. With practice, these problems are easily overcome by an experienced operator.

During the KC-135 flight, the skilled operating physician had no problem placing the triple lumen CVP. The complexity of the placement was well demonstrated. Although some steps were skipped, the procedure still took many parabolas to perform. If an operator has time to perform this procedure, a triple lumen CVP could be effectively used in a microgravity environment. If the main reason for placing the CVP is for fluid resuscitation or vascular access, then this time-consuming procedure, even in the best of hands, is very inadequate.

A triple lumen CVP may be inadequate to place when urgent need for vascular access exists. Perhaps a single lumen CVP would be more adequate. On Earth it has been used extensively in emergency situations for vascular access. It is fairly simple to insert, being only slightly more difficult than putting in a peripheral IV. However, the complication rate is much greater than with a peripheral IV. Given the different milieu of microgravity and a unique contingency situation, even the best of operators would have a difficult time with placement and theoretically a much higher complication rate.

If even in the best of hands this is a difficult procedure, what then if there is only a semi-skilled CMO performing the procedure? The level of skill required is probably beyond the CMO to perform, unless the CMO is able to practice it in *real life situations* multiple times. In our flight, the biomedical engineer was well skilled at placing the CVP in the laboratory, but when the real time situation came, she failed. In a real contingency situation, this anxiety increase and failure rate will likely be magnified many times.

How best then to achieve vascular access? Efforts would likely be better spent on learning peripheral IV access techniques, as is recommended by the American College of Surgeons in their Advanced Trauma Life Support course.[1] The complication rates for these techniques are much lower, and practice opportunities markedly greater. The issue of venous cutdown is a somewhat separate entity that also requires a somewhat high skill level, but due to its comparatively low complication rate may be a viable alternative to CVP line placement.

CONCLUSIONS

Two operators are necessary to perform CVP placement in microgravity.

Separate procedure kits worked well and need to be investigated further.

The skill level needed to perform a CVP line placement in microgravity is too great for a nonmedical person to perform and should not be used for vascular access.

A skilled medically trained operator should be able to place a CVP without difficulty, but should pursue other areas of vascular access first due to complication rates associated with the procedure.

CMO training should be directed toward obtaining peripheral access when vascular access is needed.

At some point, real uncitrified blood should be used to perform an arterial puncture to evaluate air/fluid interface potential problems.

Sterile gowning by the main operator to prevent contamination of the triple lumen catheter and guidewire on clothing will need to be considered if the triple lumen CVP procedure is to be performed.

REFERENCES

1. Advanced Trauma Life Support Student Manual, American College of Surgeons, Chicago, IL, 1989; 75-80

2. Current Emergency Diagnosis and Treatment, ed. Ho MT and Saunders CE, third edition; Appleton and Lange, Norwalk, CT, 1990; sections dealing with CVP placement.

3. Procedures and Techniques in Emergency Medicine, Simon RR and Brenner BE; Williams and Wilkins, Baltimore, MD, 1982; sections dealing with CVP placement.

PHOTOGRAPHS

S91-35724, S91-35732, S91-35741, S91-35742: Microsurgery suturing technique is performed on a suture board.

S91-35726: CVP needle is placed through the chest wall.

S91-35727: CVP catheter is tested prior to placement.

S91-35728, S91-35729: Investigators don sterile gloves.

S91-35740: Betadine® swabs are passed to investigator who is preparing the chest for CVP placement. Standard video is being filmed.

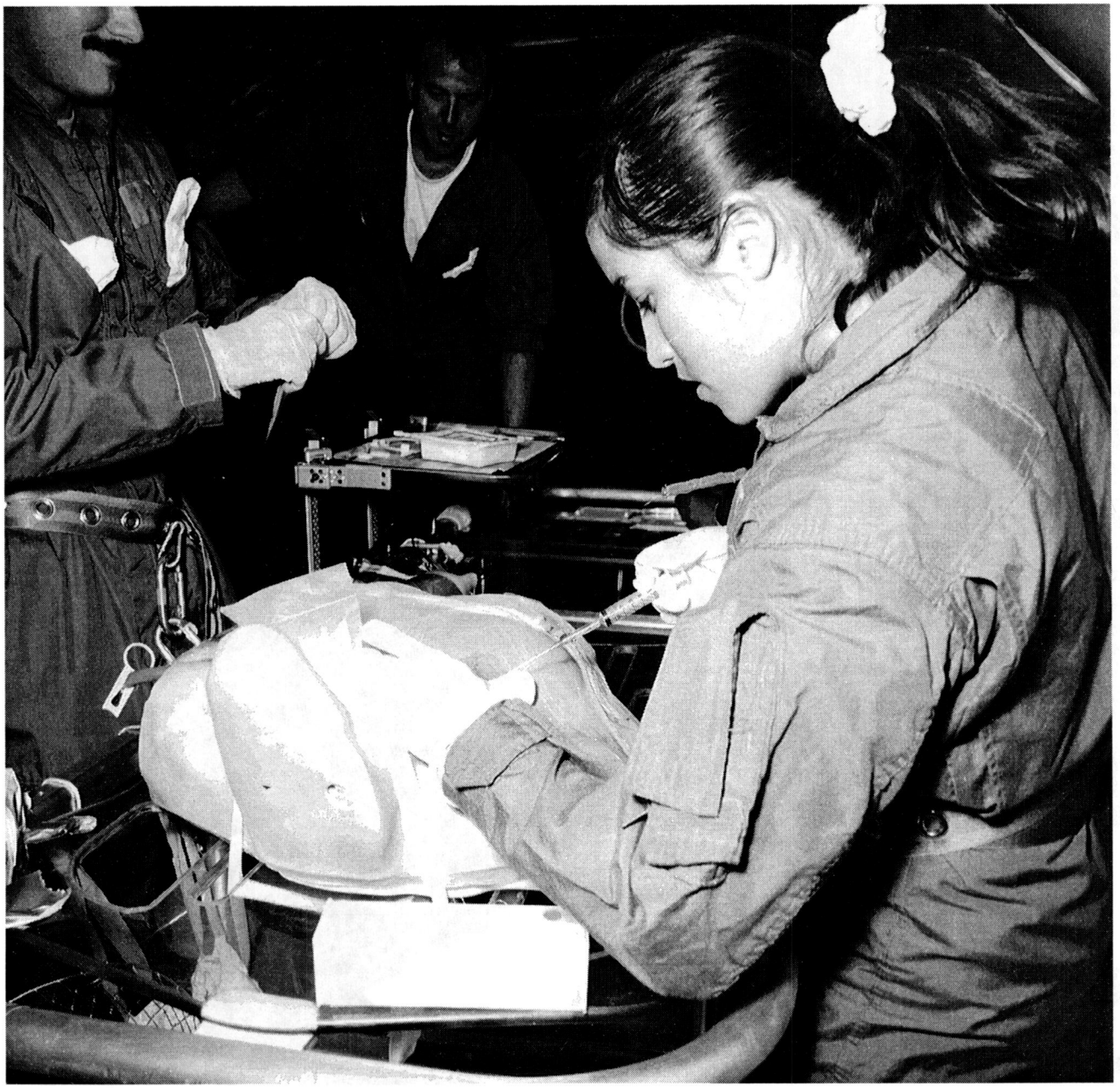
S91-35743: A dressing kit on an aluminum tray.

S91-35744: A fluid sampling kit and IV kit on an aluminum tray.

S91-35747: Investigator draws ABG from manikin arm.

S91-35748: CVP kit on seat track.

NASA Video 905702.



S91-35726: *CVP needle is placed through the chest wall.*

S91-35741: *Microsurgery suturing technique is performed on a suture board.*

Prototype Man-Tended Capability Advanced Life Support Pack

Flight Date:	June 11, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigators:	Maureen Smith (KRUG Life Sciences) Ed Cordes (MDSSC) Chuck Doarn (KRUG Life Sciences)

GOAL

Determine effectiveness of the MTC ALS pack prototype including deployment and stowage of medical equipment and supplies for use during emergent care.

OBJECTIVES

1. Evaluate the prototype Bushwalker ALS pack in an MTC configuration for engineering/design concerns.
2. Evaluate deployment from the rack, attachment configurations, and restraint mechanisms for the pack.
3. Test internal rolls for layout, accessibility of supplies, and interface to the pack.

MATERIALS, METHODS AND PERSONNEL

Node Pallet

A mockup of the node area where medical procedures would be performed on space station was built by MDSSC to be used on the KC-135 aircraft. The pallet is constructed of wood with 30-inch walls that fold up during the flight to form a volume envelope. Because the pallet is representative of the node area available to the crew during a medical contingency, crew choreography, equipment placement, patient position, and other related issues can be assessed.

One Minirack (21"x31"x54")

The rack was used to hold equipment for takeoff and landing as well as to provide a deployment surface during flight. Sections of c-track were mounted to the face of the rack to emulate space station conditions, and the ALS pack had connectors that interfaced to the c-track so that it could be deployed in various configurations on the rack. C-track was also mounted to the floor of the aircraft to allow deployment of the ALS pack to the floor.

ALS Pack

The latest prototype of the ALS pack, built by Bushwalker, is designed for PMC. The prototype pack contains supplies which are not included in the MTC ALS and does not accommodate items baselined for MTC. The flight was not affected by the fact that the pack does not meet MTC requirements because the pack size and weight does not change from MTC to PMC and the mechanisms for restraining items within the pack do not necessarily change. Also, overall layout was considered which will not change too much from MTC to PMC.

Participant Responsibility During Parabolas

Ed Cordes	Design Engineer
Maureen Smith	Assistant
Chuck Lloyd	Video
Chuck Doarn	Comments/Script

Data acquisition included video documentation: NASA 905925 and self-report post-test.

Parabolas 1-2: ALS pack was deployed from the rack and mounted on the rack-face, opening upward. The c-track attachments on the ALS pack D-rings caused some problems during deployment; they tended to hang up on the rack. Securing the pack to the rack-face was not too difficult although activating the c-track interface can be troublesome due to its size.

Parabolas 3-4: ALS pack was unhooked from the rack-mounted position and slid to the floor. Pack was attached to floor, opening onto the bottom of the rack. Detaching the pack and moving it to the floor was simple to accomplish especially since the play in the D-ring allows for easy adjustments of the interface up or down the c-track.

Parabolas 5-6: ALS pack was unhooked from the floor position and remounted to the rack-face, remaining closed. The second ALS pack was then deployed from the base of the rack. Because the D-rings had to be cut in order to attach the c-track interfaces, a D-ring failed during the 2g portion so the extra ALS pack was stowed in the bottom of the rack.

Parabolas 7-8: ALS pack was attached to the floor via c-track, opened, and the BVM was accessed. The same problems were encountered with the c-track mounted to the aircraft floor as to the tracks on the rack in that the interfaces were sometimes difficult to engage quickly. Also, when the BVM was pulled out of the pack, the IV fluid deployed spontaneously since nothing was restraining it and the lateral force supplied by the BVM was no longer present.

Parabolas 9-10: The airway, suction, drug, and assessment rolls were deployed from the pack, secured together, and checked for transport features along with the already deployed BVM. The Velcro® around the outside of the inner rolls enabled them to be stuck together quickly for carrying or passing them around the cabin easily without the bulk of the main pack. This situation would arise in the hyperbaric scenario where certain supplies would be needed but not the entire pack. During the turnaround, all rolls and supplies are restowed in the ALS pack.

Parabola 11: The airway, suction, and IV rolls were deployed and restowed. Internal pack design allowed adequate space for grasping the roll firmly and the Velcro® bond holding the individual rolls in place was easily broken for deployment. Replacing the rolls in the pack was also without problems; although, if after using the roll, supplies are jammed back into it haphazardly, stowing the roll in its original location may be more difficult.

Parabola 12: The airway kit was deployed and snapped down on the inside of the open top of the ALS pack. Snaps were difficult to engage because they need force applied by the operator's fingers on both sides of the snap which required dexterous hand manipulation in some cases.

Parabola 13: The laryngoscope handle and blade, nasopharyngeal airway (NPA), and oropharyngeal airway (OPA) were accessed from the deployed airway management roll. The double width of the airway roll caused it to be loose in the middle even though all four corners were secured. The play in the roll did not hinder the removal of the laryngoscope, NPA, or OPA though a firmly attached roll was not tested for comparison.

Parabolas 14-15: The ET and stylet were accessed by the assistant while the IV and drug rolls were deployed over the main pack using two snaps each; snaps on diagonal corners were used. The play caused by the size of the

airway roll may have caused minor delays in accessing the ET tube and stylet, but the restraint mechanism was satisfactory. Stowing the ET tubes so that they slide out the side allowed for easy access and deployment for the person positioned at the patient's head.

Parabolas 16-17: Drugs were accessed from the drug roll. The needle was placed into the sharps container which was accessed by releasing one of the two snaps restraining the drug roll. The tubex was returned to its position in the drug roll. The airway management supplies were returned to the airway kit. Drug access was accomplished without incident. The sharps container was difficult to employ not only because it was under the deployed rolls but also because the mechanism for opening the container to place a sharp inside required too many steps. Also, since the tubex and bristo-jet plungers are used for more than one drug round, they need to be restowed on the roll. When this two-handed procedure was attempted, the covers for three needles in the roll released into the aircraft cabin leaving exposed sharps on the roll.

Parabolas 18-19: Supplies to initiate an IV line were deployed from the IV roll including the administration set, tourniquet, alcohol wipe, catheter, and tape. No problems with deployment of IV supplies. The catheters were easily accessed without deploying any others. The clear pockets for the rest of the supplies allowed for rapid identification and access.

Parabola 20: The ET, Miller blade, and NPA were accessed by another crewmember. Again, no problems were encountered in accessing supplies from the airway kit for passing to the crewmember at the patient's head, even from the other side of the pack from which the ET tubes are stowed. During turnaround, nothing was changed on the pack.

Parabola 21: Grumman c-track interface was tested for one-handed operation. These attachments were duplicates of flight hardware.

Parabola 22: The mechanical aspirator was accessed from its pocket and restowed. The mechanical aspirator required some manipulation to pull it from the pocket, but generally could be removed by simply pulling hard enough. Restowing the aspirator was a problem because of the slack in the pocket which prevented it from sliding completely back into its holder.

Parabolas 23-24: The hyperbaric kit was deployed and hyperbaric, IV, airway, and drug rolls were returned to the main pack. Returning the rolls to their initial position was unremarkable; especially if supplies had been removed from the roll causing it to be smaller/flatter.

Parabola 25: Kerlix was accessed from the bandage container in the main pack. Only once did an extra roll of Kerlix deploy as the rolls were removed one at a time; therefore, the bag did an adequate job of restraining the bandages.

Parabolas 26-28: To test the pack under contingency operations, the various rolls and supplies (including the BVM, airway kit, c-collar, assessment roll, IV roll, drug kit, and suction roll) were accessed from the pack in order of use and attached to the pack. Rapid deployment of many rolls was possible but only four rolls at a time could be opened and secured to the pack for access. And if the airway management kit is one of the rolls deployed, one of the smaller rolls has to be secured beneath it. The assessment roll was handed to the second crewmember while the other four were secured to the pack. For rapid, easy access the airway and suction rolls should have been deployed together toward the head of the patient (with the suction roll deployed underneath the airway) while the drug and IV rolls should have been secured together on the main pack by the patient's arm area. Instead the airway was deployed to the main pack with the IV roll underneath and the suction and drug rolls were toward the head.

Parabolas 29-30: Supplies necessary for treatment of a critical patient were accessed from the

various packs to determine effectiveness of internal roll configuration as well as deployed position. Even though the rolls were not secured to the pack properly, accessing the supplies was satisfactory. Even the roll beneath the airway kit could be used quickly by unsnapping a corner of the top roll. Snapping both snaps on one side of a roll did cause some problems in that some pieces would dislodge from the roll when an item was deployed (e.g. the tops of some sharps came off when a bristo-jet was deployed) because of the flapping. During turnaround nothing was changed on the pack.

Parabolas 31-32: Access of the main pack beneath the deployed rolls was attempted including bandaging supplies from the top of the pack. There were some problems with rapid access to the supplies (such as the sharps container and the IV fluids) stored in the main pack. The play in the large pack allowed it to be lifted enough to slide a hand under for retrieval of the IV fluids, but pulling them out caused the snaps to release and dislodged the supplies on the roll. Access to the sharps container required one or more rolls to be released prior to opening the container which required dexterous hand movement inside the main pack.

Parabola 33: Rolls were unsnapped and restowed in preparation for transport. Snaps were extremely difficult to release — sometimes requiring two hands. This may have been exacerbated by the fact that the pack was brand new and unused before the flight.

Parabolas 34-40: The transport function of the pack was evaluated including external handholds and backpack restraints. Crew moved about the aircraft cabin with the pack, and the pack was passed between crewmembers. The pack was easy to maneuver via the handholds on the side as well as the backpack straps. Having handholds on all sides may provide better stabilization. No matter how the CMO would have to grab the pack he would have a hold. The backpack straps worked well; even with the waist restraint, the smaller crewmember could have removed the pack over her head without releasing the restraints. This problem could be alleviated by having strap adjustments down to smaller sizes. No difficulties were encountered during movement about the aircraft cabin with the pack on the crewmembers' backs.

RESULTS

Internal, replaceable pack dividers allowed rolls to be restowed easily after use. These dividers also helped maintain pack rigidity once a number of rolls were deployed. The zippered pouch containing the Kerlix rolls functioned effectively in allowing only a limited quantity to be removed at one time. Bandaging supplies located on the pack lid were easy to identify and remove, although access became somewhat more difficult once procedure rolls were deployed to the lid as a work surface. Access to the handheld suction device (V-Vac), located in an exterior pack pocket, was possible even with the pack fully deployed. This pocket also served well as a holster for temporarily restraining this device between uses though restowing it was more difficult than deploying it due to the flap of the zippered opening.

The pack transport configurations also functioned effectively. Exterior Velcro® patches allowed a number of deployed rolls to be assembled as a single unit for ease in transport or insertion in the airlock equipment "pass-through" lock. Hands-free transport of the entire pack was accomplished using the backpack straps and waist restraint. A number of test subjects noted that further sizing of these straps was required to better accommodate the sizes of crewmembers. The handles on the side of the pack was also useful for pack manipulation.

The overall layout of supplies within each roll was adequate for identification and deployment. Grouping the supplies by function within the rolls aided in quickly gathering the supplies

needed for a procedure without extensive searching. On the other hand, packaging items in order of use within each roll is unnecessary because the CMO should be highly familiar with the equipment so that ease of identification and deployment are the issues, not which items to deploy.

If the pack is to be used as the primary deployment/work surface, the position of the deployed rolls on the pack should be chosen according to use. For instance, the airway kit should be deployed toward the patient's head while the IV roll should be placed near the patient's arm.

The snap interface on the pack was difficult to engage because it requires pressure from each side of the snap. Also, disengaging took quite a bit of force which caused items on some rolls to work loose. Other methods of securing the rolls to the pack or other work surface will be evaluated by MDSSC.

The methods for restraining items within the rolls were satisfactory, allowing rapid identification and easy deployment. Some of the elastic bands were not tight enough to hold the supplies while other items were accessed; therefore, restraint mechanisms need to be fitted to the supplies they are intended to hold.

CONCLUSIONS

Elastic straps did not provide adequate restraint for a number of smaller items. Individual bristo-jets and syringes in the emergency drug roll need to be placed in pockets to prevent caps and needle covers from becoming disengaged and also to permit rapid restowage. Drug identifiers need to be placed more prominently on these pockets to prevent confusion.

Roll restraint devices must allow for one-handed attachment. The current design uses snaps which require both a visual alignment and often two hands. One suggested alternative, a small turnbuckle fastener, would permit one-handed, blind attachment of the roll corners to either the ALS pack or CMRS perimeter.

Bulky, non-roll items (such as the non-rebreather bag and mask, IV fluid bags, and the c-collar) require additional restraint straps to prevent them from floating loose of the pack when other rolls are deployed.

Both the sharps and waste containers should either be designed to be accessible from the pack exterior or easily relocated from the pack interior. It was often difficult to reach these items if pack rolls were deployed on top of them. These devices must be capable of being accessed with only one hand.

The overall conceptual organization of the ALS pack contents into various procedure rolls appears to be an effective grouping strategy. Use of the deployed pack as a roll restraint work surface also appears to be a viable solution. The current pack geometry divides the contents into two distinct sections. The upper thin section contains primarily bandaging and wound preparation supplies. The lower section contains the various procedure rolls configured according to standard ACLS protocol and more bulky items such as waste containers and Kerlix rolls. The overall dimensions and internal geometry of the pack will continue to evolve as HMF operational locations and configurations are further defined. Individual roll layouts will also be modified based on the effectiveness of the current use-ordering schemes. Key conceptual design drivers developed in this initial MDSSC prototype pack will continue to be evaluated and incorporated in future prototypes.

Further design evolution will also concentrate on developing the various CMRS and ALS pack interfaces. Since both items form the basis for MTC medical operations and patient transport, the development of a unified system will further enhance the effectiveness of both items. ALS pack and roll interface issues still need to be resolved for a variety of alternative locations

including the Shuttle middeck, airlock, and ACRV.

PHOTOGRAPHS

S91-39453 and S91-39452: The ALS pack stowed in the rack prior to take-off. This is one of the locations for pack storage during MTC. The second pack is secured in the bottom of the rack along with a bag for accessory items. Also, the video camera is secured to the side of the rack in its case. The tape on the floor depicts the node parameters as well as the MRS location.

S91-39450: One of the pack deployment locations to be evaluated is shown here. The main pack is secured to the bottom of the rack face, opening upward since bandaging supplies are stored in the top of the pack.

S91-39439: An alternate location for pack deployment (other than the rack face) is demonstrated in this photograph. The pack is secured to the floor beside the CMRS which is simulated with tape. As an investigator looks on, two others deploy an administration set from the IV roll and access a prefilled syringe from the drug roll. Procedure is recorded from the back of the aircraft.

S91-39438: The ALS pack in its deployed position with the airway kit secured to the top while the IV and drug rolls are deployed onto the main pack.

S91-39433: While one investigator secures the airway kit to the ALS pack to test rapid deployment methods, one investigator removes the BVM and another writes comments. Supplies are accessed in order of need for patient stabilization - BVM, airway, assessment, IV, drug, and suction.

S91-39432: Continuing with rapid deployment of supplies necessary for patient stabilization, the investigator flips the airway kit out of the way to attach the IV roll to the pack underneath the airway kit. The assessment roll is deployed to another investigator because only four rolls can be attached to the pack at one time; therefore, the supplies needed from the assessment kit must be deployed and the roll returned to the pack.

S91-39431: Now that the first two rolls have been deployed onto the main portion of the pack, accessing the other rolls proves more difficult than necessary. Loose supplies (BVM and c-collar) are secured beneath a bungee.

S91-39430: The suction roll is secured to the top of the pack while an investigator tries to secure the extra assessment kit by means other than the pack.

S91-39429: After removing the necessary assessment supplies, the investigator dictates the next series of supplies needed from the various rolls.

S91-39427: After deploying the IV supplies and fluid, the investigator repositions himself for accessing the suction.

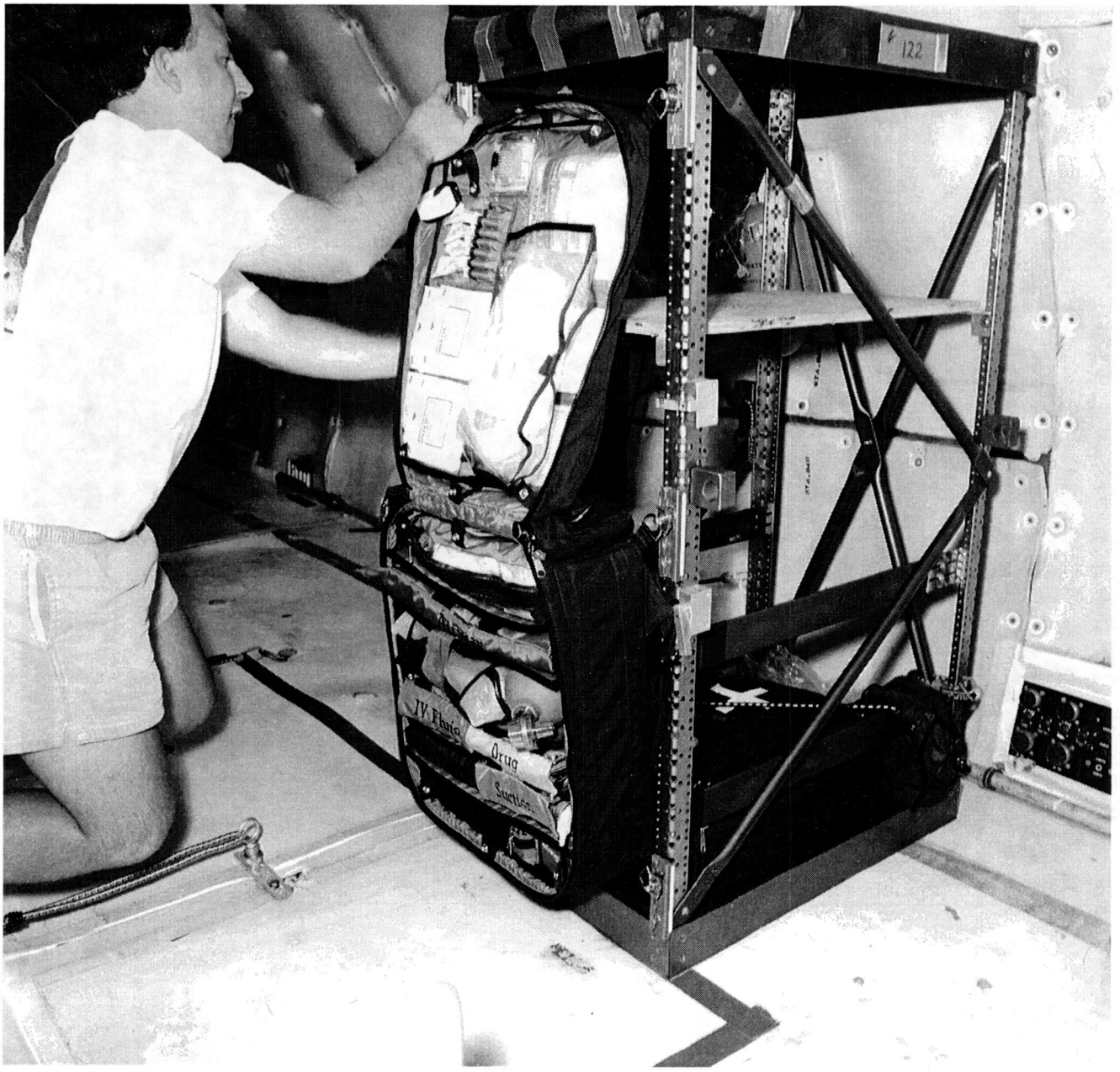
S91-39425: Investigators remove the rolls from their snap interfaces to stow the kits back into the pack. Pertinent information is recorded.

S91-39424, S91-39423, S91-39422, and S91-39421: An investigator evaluates the transport function of the pack by strapping it to his back and moving about the aircraft. The evaluation is captured on video.

S91-39420: Investigator tries free-floating with assistance. The scene is videotaped.

S91-39419: Investigator keeps the camera steady during negative-g's to film two investigators demonstrating the transport and handling capabilities of the ALS pack.

S91-39418: Investigator demonstrates that the ALS pack does not rely on classic, terrestrial orientation to maintain effectiveness during transport scenarios.



S91-39450: *The ALS pack is deployed on the face of the rack.*

S91-39433: *Investigators remove items from the pack.*

Foley Bag Evaluation

Flight Date:	June 13, 1991
Principal Investigators:	C. W. Lloyd (NASA-JSC)
Co-investigators:	James Breeding (MDSSC) D. Orsak (MDSSC)

GOAL

This experiment was devised to evaluate the ability of several test subjects to independently and visually determine, in microgravity, the volume of fluid contained in an unmodified terrestrial Foley urine collection bag within ± 25 ml. Current requirements for monitoring urine output from an incapacitated crewmember on SSF (during the MTC phase) indicate the desire to use the commercially available Foley bag without modifications, yet specify an accuracy level believed unattainable with that bag.

MATERIALS AND METHODS

The materials used for this test included four commercially available urine collection bags. The 2-liter capacity bags are manufactured by Kendall Company. An exercise bag was used to transport the four bags and towel (in case of spills) on and off the plane. The bags were loaded preflight with water that had been colored reddish-yellow (to resemble urine) with food coloring.

The volumetric analysis was performed by three subjects on four commercial Foley bags prefilled with a measured amount of the colored water. The subjects were not allowed to examine any prefilled bags before the beginning of the zero-g portion of a parabola, but were allowed to view an empty bag to familiarize themselves with the bag layout and measurement graduations. The test subjects were informed that the bags would contain between 1 and 2000 mls (inclusive) of colored water.

The evaluation was a controlled blind test in that the test subjects were not informed of the fluid volume contained in any Foley bag, but were to determine the container volume visually during the flight. Test subjects were to perform the volumetric estimations by any means available, such as squeezing or swinging the bag to force the fluid to one end. The subjects were aware that, since this was a blind test, results of evaluations were not to be discussed before, during, or after an evaluation. Following the test, each subject was supposed to record the estimated volume on sheets provided to them before the test.

RESULTS

This test was originally scheduled to be performed by three test subjects. One subject was not able to participate because of motion

sickness during several parabolas and unexpected difficulties encountered during another experiment.

The test was initiated by the two subjects on parabola 24. Each subject evaluated two bags on two successive parabolas. The volume of each bag and the results of the in-flight determinations are included in the table below. Two points of interest should be noted.

- Both subjects discussed the results of their findings after the second determination, rendering invalid any further analysis. The subjects realized the error and discontinued the test.

- During the evaluations, the subjects were able to obtain excellent visual evidence of the behavior of the Foley bags in microgravity. The time used for photography reduced the available time for microgravity evaluation of the bags and may have contributed to the observed error.

During the performance of the tests, the subjects recorded several observations concerning the present Foley bag design and bag manipulation for volume determination. While attempting to squeeze the fluid to the bottom of the bag, one subject noticed leakage from the outlet port of bag 3. This port, which is used to drain the fluid in a terrestrial setting, consists of a 1/4" ID rubber tube with a plastic clamp. During postflight analysis, additional leakage was noticed from a hydrophobic filter in the top right-hand corner of the bag. This indicates the potential for two design modifications: replacing the clamp with a more reliable design, and either blocking or "doubling" the hydrophobic filter (doubling refers to using two filters).

Bag 1, which contained 150 ml, was difficult to read because of surface tension in the corners (or "edges") of the bag, where the surface area to volume ratio is highest. This effect is demonstrated in Photo S91-39749 in which the majority of the fluid is seen to be localized, with the remaining volume held at the bag edges. The subject attempted to shake the bag and force the volume to one corner where the low-volume graduations are located, but could not free the fluid from the bag perimeter. The subject has stated, however, that it is possible that the task may be accomplished given adequate time.

Bags 2, 3 and 4 contained considerably more volume and were difficult to evaluate for reasons other than those of bag 1, in that surface tension at the edges did not have a significant effect on the fluid, but more so on the trapped air. In the case of higher fluid volumes, air bubbles tended to remain in the corners. Photos S91-39750 (Bag 2) and S91-39753 (Bag 3) show that, although there is a difference in volumes of 350 ml, it is difficult to visually detect a significant volume difference without manipulating the bag. Large pockets of air may

BAG #	SUBJECT	MEASURED VOLUME (PREFLIGHT)	ESTIMATED VOLUME (IN FLIGHT)	MEASURED VOLUME (POSTFLIGHT)
1	Orsak	150 ml	500 ml	145 ml
2	Lloyd	750 ml	1000 ml	748 ml
3	Orsak	1100 ml	1600 ml	867 ml
4	Lloyd	1750 ml	1800 ml	1648 ml

be seen on the perimeter of the bags, with smaller bubbles dispersed throughout. The primary difficulty in determining volume is not simply localizing the fluid, but separating air bubbles from the fluid. As shown in Photos S91-39750, 39751 and 39752, all the bags were difficult to fold to isolate the fluid. This is largely due to the test environment, in that the subject could use only one hand to perform the test while the other was used to maintain body position. Using both hands to perform the test might enhance the ability of the subject to isolate the fluid and separate out most of the bubbles (if adequate time is provided during the parabola).

The "swing" maneuver (in which centrifugal force is used to isolate fluid to one end of the bag) was not attempted. The subject analyzing bag 2 stated that the volume estimation was a "wild guess," estimating the bag to be half full (1000 ml). Bag 3 exhibited leakage during the analysis; the subject apparently squeezed the bag rather vigorously and possibly opened the clamp.

Analysis of bag 4 is not to be taken into account in this study. During the test, the subject observed the bag to be "very full, with limited air." The subject admittedly biased the results by guessing that the Principal Investigator would not fill the bag 100%; the estimation was based more on intuition than objective observation of the bag.

CONCLUSIONS

Of the three bags analyzed, the most accurate microgravity assessment was in error by 250 ml (or 33%) of true volume. The limited results show that a crewmember will *not* be able to determine the volume within the specified accuracy limit, using the commercially available terrestrial Foley bag.

If unmodified terrestrial Foley bags are to be used, a more realistic accuracy level for urine monitoring must be determined; for example, an accuracy level specified by percent error instead of by tolerance. This accuracy level, which will require further testing, should be based on medical need and statistical determination of a feasible accuracy level.

Modify the terrestrial Foley bag for easier analysis. Potential modifications include changing the bag shape or using some form of mechanical clamp and roller system to separate out large bubbles and squeeze fluid to one end (without creating a back-pressure into the bladder). Many different design modifications can be derived and analyzed, yet the exercise would be time-intensive and not cost-effective if the accuracy level is relaxed.

PHOTOGRAPHS

S91-39749: Display of bag 1.

S91-39750: Display of bag 2.

S91-39751: With bag 2, investigator attempts to isolate fluid in bag with one hand.

S91-39752: With bag 2, investigator folds bag and performs volumetric analysis.

S91-39753: Displays of bag 3.

S91-39749: *Display of bag 1.*

Crew Medical Restraint System

Flight Date:	June 13, 1991
Principal Investigators:	C. W. Lloyd (NASA-JSC)
Co-investigator:	D. Orsak (MDSSC)

GOAL

This test is a continuation of a series of evaluations of a prototype CMRS intended for use during the initial MTC phase of SSF.

OBJECTIVES

1. Evaluate reach envelopes between the ALS pack and MRS using a 5% female and 95% male.
2. Evaluate ability to deploy ALS pack items and secure them to the MRS.
3. Evaluate unsecure items for restowage within the ALS pack.

MATERIALS AND METHODS

The materials used for this test include a prototype CMRS and the ALS pack.

This was a subjective evaluation of the MTC CMRS and ALS pack. The areas under scrutiny for the MTC CMRS included foot restraints, supply deployment restraints, restraint and positioning of a patient, and CMO mobility around the CMRS. The areas under scrutiny for the MTC ALS pack included deployment of the various kits (and their use with the CMRS), deployment of supplies from the kits and the pack, and use of the pack as a deployment area. All evaluation was generated by two test subjects: one in the 95th percentile range and the other in the 5th percentile range.

The MTC CMRS was placed on the floor of the KC-135 close to the side of the plane. Adequate room was left along the perimeter of the device to test operator mobility. The ALS pack was restrained nearer to the wall of the plane at the head of the CMRS. In most medical simulations, one operator is positioned at the head of the CMRS (near the ALS pack) and the other at the patient's side. During this flight, no specific medical protocol was attempted, and the operators positioned themselves at several areas on the CMRS.

Prior to flight, the test subjects familiarized themselves with the features of the CMRS and the ALS pack. Anticipated activities were not rehearsed. Activities were not scheduled by parabola for this portion of the flight. The discussion centers around activities that occurred during the set of 10 parabolas dedicated to this evaluation.

RESULTS

A true evaluation of the ALS pack was not possible on the day of the flight because we were unable to secure the top flap of the ALS pack to the floor of the plane. Consequently, the ALS pack could not be kept open during the microgravity portions of the flight. This prohibited evaluation of the ALS pack as a work surface or deployment area, as well as reach/restraint interface between the pack and the CMRS.

To partially evaluate the pack, several kits were deployed to the CMRS and the pack was subsequently closed. The kits could be restrained to the CMRS with minor difficulty. The trouble associated with this deployment was seen as a CMRS issue and will be discussed later. It should be noted that attachment mechanisms on the kits and rolls must match those found on the CMRS for a working interface to occur.

All kits and rolls were easy to open for the removal of supplies. Some of the loops used to restrain supplies within the kits were loose, and consequently several items floated out of their restraints. This phenomenon was especially apparent within the Drug Kit, where different size injectables were stored. Neither subject had a difficult time removing items from the kits, indicating that the restraint mechanisms could be used by all operators independent of size.

Although not addressed specifically, layout of items within the kits seemed adequate.

The following observations were made concerning the MTC CMRS.

- Both male and female snaps were located around the edge of the CMRS. The combination of two different attachment types made it difficult to quickly deploy the kits from the ALS Pack. Different size bungees or loops were also placed along the CMRS for deployment of supplies. Although this method of deployment was feasible, the loops were too loose to adequately restrain deployed items.

- A bungee cord encircling the perimeter of the CMRS was used to restrain the operators. This proved to be a sound method of restraint, although modifications would optimize the design. Both operators attempted to restrain themselves by placing the bungee cord over their calves while in the kneeling position. Several operations, such as deploying kits, removing and attaching items from kits, restraining a patient, etc. were performed in this restrained configuration. Both operators had difficulty establishing themselves in the restrained position during microgravity. This was attributed to the boots worn on the KC-135 and not to the restraint mechanism itself. Once restrained, both operators felt that they lacked the stability to perform two-handed procedures. This was attributed to the looseness, or play, in the bungee cord. The difficulty associated with some two-handed operations was due to a combination of the slack in the bungee cord and the negative-g's that occurred during this portion of the flight.

- Handholds were used to travel up and down the length of the CMRS. These handles worked very well, allowing the operator to advance anywhere on the device quickly and with one hand.

- It was decided in flight to demonstrate patient positioning and restraint by having the 5th percentile operator (1) position and restrain the 95th percentile operator (2). To position the patient, he was placed on the

CMRS between a series of straps designed to attach over his chest, torso, and legs. A similar strap was placed over his forehead for head and neck stabilization. It was extremely difficult for operator 1 to restrain operator 2, who was acting as an uncooperative patient. Part of the difficulty was attributed to the negative-g's incurred during the flight, part to the lack of stabilization of operator 1, and part to the size difference between operators. It was difficult to determine where to position the patient horizontally along the CMRS to properly align his head with the forehead strap. Once operator 2 was positioned and restrained with the lower body straps, it was hard to move him up or down as necessary to adequately restrain his head. Although not observed, this phenomenon was anticipated to be similar for restraining operator 1.

- The straps used to restrain the patient were configured so that the strap originated on one side of the CMRS and interfaced with a buckle across the patient on the other side of the device. The original design concept was to allow the strap to be secured initially on one side of a patient, so that when the patient first lies on the device the straps are not underneath him. This was an excellent avenue for patient restraint, with one hand used to unbuckle the strap and one hand used to secure the patient. Once unbuckled, the strap was placed across the patient and reconnected on the other side. Loops were available on the top side of the strap for deployment of medical supplies to be used during treatment. The current design was confusing, however, in that the strap could be unbuckled (for placement over the patient) from both sides. If unbuckled incorrectly, the loops for medical supply deployment were on the underside of the strap and could not be used.

CONCLUSIONS

A fine line exists between firmly restraining an item and rendering it difficult to deploy. Mechanisms for retaining supplies within the ALS pack must provide secure restraint without hindering immediate access to the item.

The idea of using snaps to attach items to the CMRS is valid. The snaps must be uniform in type and spaced so that the operator does not have to search for snaps of a suitable distance when deploying a kit or roll. The distance between snaps must directly match those found on the ALS pack kits. It might also be good to increase the layer of snaps on the CMRS perimeter to increase the possibility of attachment sites.

The loops on the CMRS need to be tighter to accommodate the deployment and restraint of medical supplies.

Some MTC supplies will not be stored in the ALS pack. If any of these items are to be deployed to the CMRS, they must be able to interface with the CMRS surface. This is even more important for transition between the MTC and PMC CMRS, since at PMC the majority of supplies to be attached to the CMRS will be contained on stowage cards. It has been proven in previous flights that the CMRS must serve as a deployment area, or work surface at PMC in regard to medical supplies, kits, and trays. (See reports *Pharmacy and Central Supply Stowage Mechanisms, April 1990* and *Evaluation of Central Supply/Pharmacy Stowage and Deployment Mechanisms, April 1991.*)

The bungee cord mechanism proved sound for restraint of the operator as well as for allowing the operator to move about the device unhindered. A cord with adjustable tension could be used to allow for ease in establishing the re-

strained configuration, as well as capability to attain stabilization and provide mobilization. A double track or layer of bungee cords would also allow for proper restraint of the operator.

Patient positioning in regard to the distance between the straps requires further anthropometric evaluation. The method of tightening/releasing these straps must also be modified to allow for single-handed operation.

The straps used to restrain the patient should be modified so that they are always placed across the patient with the deployment loops in the correct position in spite of operator error. Also, these straps must be capable of being adjusted, buckled, and unbuckled single-handedly. This is necessary during adjustment of the patient position for employment of the head strap.

PHOTOGRAPHS

S91-39740: The two investigators are restrained to the CMRS. Kits from the ALS pack are attached along the side of the CMRS. One investigator holds the Foley bag in place.

S91-39741: The two investigators hold onto the CMRS during the zero-g portion of the parabola. Kits from the ALS pack are attached at different points along the sides of the CMRS. The Foley bag floats freely above the CMRS.

S91-39742: The two investigators attach various kits from the ALS pack to the CMRS.

S91-39742: *The two investigators attach various kits from the ALS pack to the CMRS.*

Liquid Transfer to Sample Bottles in Zero-Gravity

Flight Date:	June 13, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigator:	James Breeding (MDSSC) Elizabeth Richard (KRUG Life Sciences)

GOAL

The purpose of this experiment was twofold:

1. Evaluate the ability of a test subject to perform in microgravity all manipulations associated with filling various typical laboratory containers from a flexible fluid bag, and then sealing the container with a cap.

2. Evaluate the effect of the different container configurations on the fluid during liquid transfer.

METHODS AND MATERIALS

A Foley bag sealed at one end, clamped at the outlet orifice. The flexible bag, which simulates a proposed water sampling device for SSF, was filled prior to the test with approximately two liters of red-colored water.

Six standard 50 ml RX prescription bottles with snap-on caps; three bottles marked with a line at 40 ml.

Two 50 ml glass Erlenmyer flasks with screw-caps.

Two 100 ml urine collection cups with screw-caps.

Two 50-ml Falcon centrifuge tubes with screw-caps.

Two Falcon polystyrene test tubes with screw-caps.

A 2" thick strip of styrofoam to contain each sampling container before and after use.

A large towel to mop up spills.

A large exercise bag to transport the experiment.

The test subject conducted the experiment in a seated position using a bungee cord stretched across her thighs as a restraint. A cord was attached to the flexible fluid bag so that it could be hung from the subject's neck, and the bag was positioned so that during periods of one-g it rested in her lap. The various containers were placed in a styrofoam holder as described above and secured to the floor with Velcro® on the right side of the subject. An assistant handed the empty container (uncapped) and its lid to the subject prior to the microgravity phase of the parabola. Once microgravity was achieved, the subject attempted to fill the container as full as possible and seal it with the cap, then return it to the assistant who was standing by with a towel to mop up spills. One container per

parabola was filled. In addition, three prescription bottles were marked with a line. For these bottles, the procedure was to attempt to fill them as close to the line as possible.

To extract the fluid from the bag, the subject had to release the clamp at the outlet orifice located at the end of a piece of tubing, and squeeze the bag to force the fluid through the hose and into the container. For the first set of parabolas, this was attempted using a typical one-g configuration with the tube extended downward from the bag and the container held right-side up below the tube. For the second set of parabolas, the bag was held upside down, and the tube was allowed to float up. The container was held, filled, and capped upside down. This configuration successfully eliminated constrictions in the tubing and required less pressure to squeeze the water out.

RESULTS

Set 3, Parabolas 1-4: The first four parabolas were used to travel across the cabin and set up the experiment.

Set 3, Parabolas 5-10: The first attempts at filling the containers failed. As described above, the fluid bag and containers (unmarked prescription bottles) were held in a one-g configuration. When microgravity was achieved, the bag and hose floated up, which resulted in the test subject constricting the tube and/or the bag/tube interface while attempting to transfer fluid to the container. Other difficulties arose because of the seated position of the test subject. Because the bungee cord was stretched across the top of her legs near the hips, her legs floated up, rocking her backwards. This was corrected after the first few parabolas by having the assistant hold her legs down. Little fluid transfer was achieved despite numerous attempts.

Turnaround time: During the turnaround time, the subject practiced filling one of the 50 ml glass Erlenmyer flasks (S7), and it was decided that the containers should be filled upside down to prevent constriction of the tubing.

Set 4

Parabola #/Sample Container #—Containers

1/S1—Polystyrene Test Tubes
The test tube was filled as planned. Some difficulty was experienced getting the caps back on without making contact with the liquid, resulting in spillage.

2/S2—Polystyrene Test Tubes
The test subject initially tried to fill the second test tube without releasing the clamp at the end of the tube. After recognizing the mistake, she was able to partially fill the tube at the very end of the microgravity phase. Again, difficulty was encountered when the subject tried to recap the test tube.

3/S3—50 ml Falcon Centrifuge Tubes
For this container, the subject tried holding the stream farther from the edge of the container. This technique helped avoid contact with the liquid which prevented spills. The only difficulty encountered was trying to recap the container.

4/S4—50 ml Falcon Centrifuge Tubes
When the test subject attempted to fill the second centrifuge tube, the tubing floated up, interfering with the process. When the subject tried to move it out of the way, she inadvertently touched the globule of fluid, resulting in spillage. Again, recapping the container was a problem.

5.6/S5, S6—Urine Collection Cups
The wide mouths of these containers made them difficult to fill. The subject had to be very careful not to touch the fluid and cause it to spill out. Some liquid escaped even when no contact was made. In all cases, the screw caps were difficult to put on, and if any contact was made with the liquid it floated out in all directions.

7/S8—Erlenmyer Flask
The small-mouth bottle was easier to fill, and the smaller caps resulted in less spillage while sealing.

8/S10—Prescription Bottle/No Line
The smaller mouth and relatively small capacity of this container allowed it to be filled without problem. The snap-top lids were much easier to handle than any of the screw-caps used previously.

9,10/S11,S12—Prescription Bottle/With Line
These two bottles were intended to be filled only to the line marked at 4/5 of capacity rather than to the full capacity as with all previously used containers. This was by far the most easily achieved procedure. The small volume (40 ml) of liquid transferred was one advantage. Second, filling the container only partially full prevented the problems of accidentally contacting the liquid (a problem encountered when trying to fill a container as full as possible). And it was easier to cap the partially filled bottle with the snap-top lids than it was to cap the same bottles filled to the brim for the same reason.

CONCLUSIONS

Several conclusions can be deduced from this experiment. First, the smaller the mouth of the container, the easier it is to fill. This seemed to be the case regardless of the material or the container. Second, the smaller the volume to be transferred, the easier the task is to accomplish. This phenomenon may have resulted for various reasons, including the fact that the test subject was inexperienced in microgravity manipulations and she felt a sense of urgency in that a limited period of microgravity was available to achieve the task. Third, the type of cap used affected the amount of liquid spilled in trying to carry out the recapping procedure. Snap-top lids, while far from an optimal configuration for SSF, were far easier to use. The screw-caps required too many manipulations and resulted in spills at every attempt. Even more important was the difference between filling a bottle to a marked line versus filling it to the top. It was much easier to both fill and cap a bottle that was only required to be partially full. Regardless of the container shape or its cap, filling "upside down" was easier than filling "right-side up."

The Foley bag itself caused some of the difficulties initially encountered. The test subject had to squeeze the bag against her body to extract the fluid. This proved to be very awkward when trying to fill a container at the same time. Also, the tubing attached to the bag sometimes interfered with the process.

The position of the test subject caused problems. Despite the fact that a bungee cord was used as a restraint, the assistant had to hold her legs down to prevent her from rocking back so that she could properly conduct the experiment.

Negative g's could have caused another effect - when containers were turned "upside down" (with respect to the users), the fluid moved "upward" and tended to stay there. This may change current thoughts on the effectiveness of the container configuration on retaining fluids. In fact, negative g's were evident, as evidenced by the assistant having to chase loose globules up to the roof of the plane.

And lastly, negative g's may have affected the experiment by causing problems in maintaining body position during the test, resulting in further difficulties filling the containers. Because this is a test environment-induced problem, it would not be expected to occur on SSF.

Do not use screw-caps. Snap-on caps are easier to use, yet still require a high degree of manual dexterity and coordination for use. A container that can interface directly with a sample bag (or any desired fluid source) would be preferred, even with the problem of pressure equalization during filling.

A prototype design of the Water Sampler/ Archiver intended for use on SSF will become available in September 1991. This design should be used if this test is repeated.

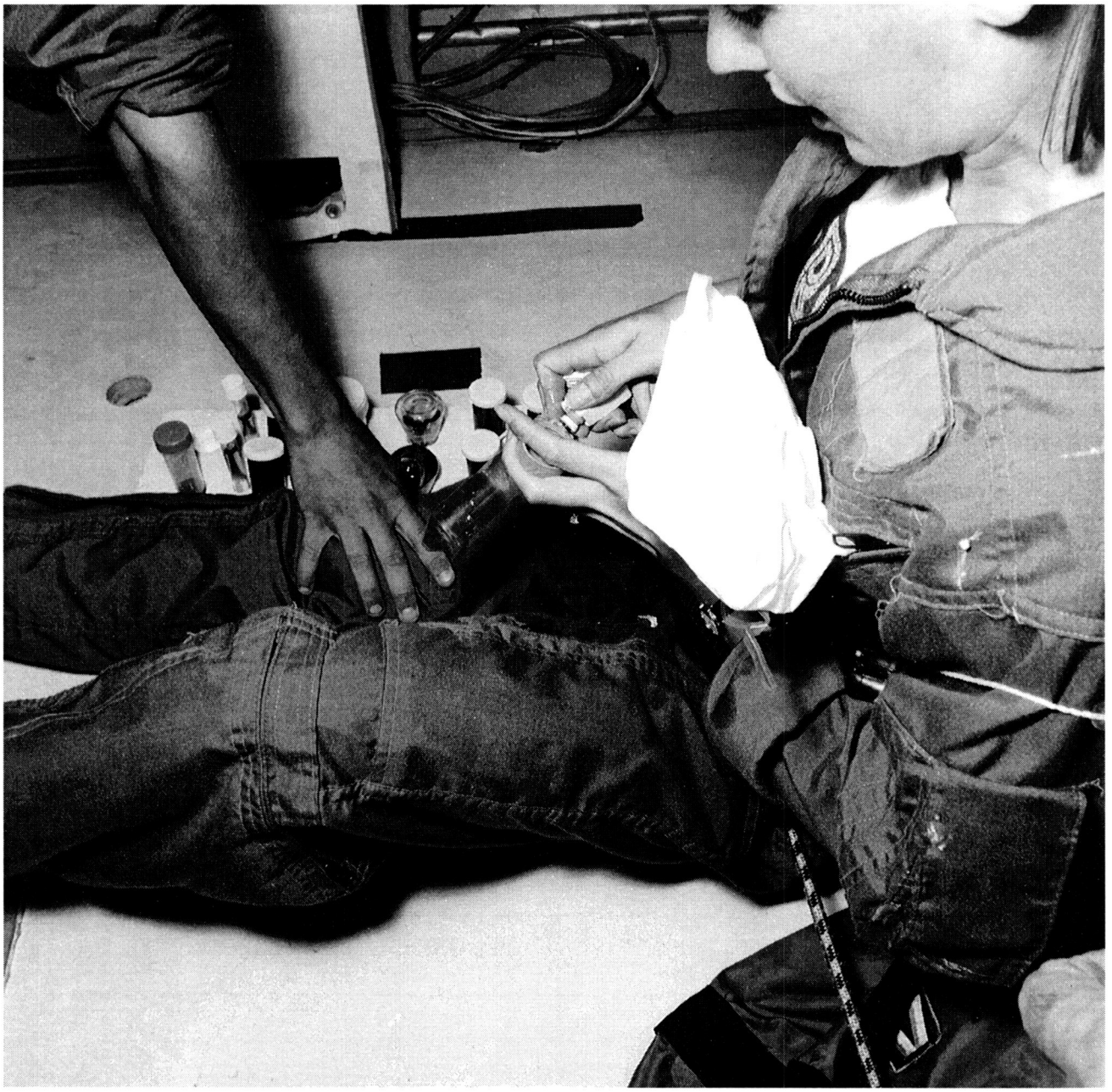
Very few containers of each type were tested. To obtain a better understanding of fluid behavior on each configuration, a minimum of five units of each should be tested to obtain repeatable results. This test was prepared to fill in several open parabolas for two individuals, but further experimentation should be considered due to the applicability of the fluid sampling problem.

The test should be conducted with the test subject in a position more closely simulating that planned for the crewmembers who will perform similar tasks on SSF, and using restraints like those planned for SSF.

PHOTOGRAPHS

S91-39745: Investigator is filling 50 ml Falcon Centrifuge Tube (S3, 4)

S91-39748: Investigator is filling polystyrene test tubes (S1, 2)



S91-39745: *Investigator fills a 50 ml Falcon Centrifuge Tube.*

Supplementary Extended Duration Orbiter Medical Kit Prototype

Flight Date	June 13, 1991
Principal Investigator:	C. W. Lloyd, Pharm. D. (NASA-JSC)
Co-Investigators:	Phong D. Hoang (KRUG Life Sciences) Kristen M. Maidlow (KRUG Life Sciences)

GOAL

The purpose of this KC-135 flight was to test, observe, and analyze the configuration of the medical kit prototype to be flown on Extended Duration Orbiter (EDO) missions (missions of 11 to 16 days) as a supplement to the existing SOMS kits.

INTRODUCTION

In addition to the EDO Medical Kit, the Emergency Medical Kit (EMK) and the Medications and Bandages Kit (MBK) are to be flown during EDO missions.

With missions of 11 to 16 days, medical operations is allocated one-and-a-half lockers on the middeck of the Orbiter. The SOMS kits and other medical accessories are stowed in one locker. The EDO medical kit will occupy one-half of the other locker.

The EDO medical kit flight units will be fabricated with blue-nomex material which has fire retardant capabilities. However, because of the high cost of this material, the prototype is fabricated from Trigger-cotton material which has been used in the development of prototypes that have flown on previous KC-135 flights. The kit is 14 inches long, 8 inches wide, and 8 inches deep and will consist of three two-sided pallets (labeled H, I, and J) and one one-sided pallet (labeled K). The contents of each pallet are listed in the appendix.

The code given to each item in the kit facilitates locating the medication/accessory in the kit and is similar to the coding method used for the SOMS kits. For example, the code H2-1 means that adaptic bandages can be located in Pallet H, side 2 (back side of pallet), pocket 1.

MATERIALS AND PERSONNEL

Materials flown with the prototype to support the analysis of it included:

Bungee cords
Towels
Duct tape
Water-spray bottle
Tape recorder

Two main investigators analyzed the kit by handling the medical equipment/accessories. One observer gave inputs/suggestions while the two investigators manipulated the accessories. Observations were tape recorded.

RESULTS

In preparation for the zero-g testing, we fabricated foot restraints by taping duct tape to the floor of the plane, allowing a loop to form for an investigator to insert a foot and remain standing on the floor during periods of zero-g. Tape was also attached to the side of the airplane to simulate middeck locker Velcro® so that pallets could be attached while the investigators were taking items out of the pockets. Bungee cords attached to rings that were screwed into the floor were used to keep the investigators on the floor of the plane while analyzing the various pallets. The kit was strapped to the floor with a bungee cord and opened during the first two parabolas. Each pallet was removed from the kit to verify that they were easily accessible and that loose or improperly secured items would not become dislodged from their location.

Starting with parabola 2, the cotton swabs were removed from packaging without any problems. All the flaps on the pockets that contain the syringes were manipulated to test for accessibility of the syringes and possible inadvertent loss of needle covers or packaging. Be cautious when removing the rubber needle covers from the needles themselves. Once the cover is removed, it does not firmly cover the needle again. During one parabola, a syringe was pulled from its pocket and the cover removed from the needle; the cover was put back on the needle and the syringe placed back into its pocket. When the syringe was pulled out again, the rubber needle cover remained inside the pocket.

During parabolas 9-11, the Mycelex® (vaginal tablets) and applicator were analyzed (photo S91-39369). There was one minor problem with stowing the applicator (which is in the shape of a thin pen). It became dislodged from its assigned slot on Pallet I2 when in zero-g. Two Velcro® straps, one at each end of applicator's pocket, should be used to hold it in place instead of just one strap at the midsection.

During parabolas 12-17, the urinary bacteria analysis kit, Bacturcult, was tested. On the ground, the direction for use of the Bacturcult states that a small amount of urine should be placed in the vial, the vial should be capped and shaken, and the excess urine should be emptied. This was rather difficult in zero-g. Water from a spray bottle was used to simulate a stream of urine. We tried to spray a stream into the vial, but once the water left the spray bottle, it immediately started to float (Photo S91-39364). The best method of wetting the inside of the vial was to use a sterile cotton swab which was wetted with water (to simulate urine). Since the analyzing agent of the Bacturcult is on the inside wall of the tube, the tip of the swab was brushed along the inside lining (Photo S91-39366). One beneficial point–this procedure can be done by one person. However, we do not know if using the Bacturcult in this manner will affect the results. This will be researched.

The sterile gloves were tested during parabola 18 to see if they can be donned by one individual or if an aid is needed in order to keep sterility. The gloves could be donned by one person, but he/she would need to secure the wrapper in which the gloves are packaged. In the zero-g environment, the large wrapper tended to float around and got in the way of the person trying to don the gloves.

During parabolas 19-20, the sterile drape was placed at a simulated wound area. This drape serves to keep the area of surgery/suturing sterile while the wound is being treated. From the analysis, more securing mechanisms (i.e., clips) are needed to keep the drape secured to the area to which it is applied. Due to the large size of the drape, excess draping floats in the

zero-g environment and gets in the way of surgical procedures.

The skin stapler and staple remover were analyzed and did not show any apparent problems. The sterile packaging did not present any difficulties. Procedures to use the two mentioned tools were not affected by the zero-g environment.

The pressurized spray bottle of Proventil Inhaler operated nominally during its testing period. However, we do not know how well the active ingredients of this type of medication mix in a zero-g environment. Additional research is planned.

CONCLUSIONS

Due to the inclement weather during the flight, the amount of parabolas flown was reduced to approximately one-half. This did not prevent us from analyzing most of the medication/accessories. We did not analyze many of the items that are already being flown in the SOMS kits.

Most of the suggestions/results from the testing of the EDO medical kit prototype can be obtained from the previous section, *In-Flight Test Procedure*. Other comments include the reconstruction of the slots containing the medication labels that appear on each of the pockets. Due to the normal "wear and tear" of testing, the clear plastic strips sewn on the blue material became separated quite easily. This caused the medication labels to fall out. Another type of material that is not as rigid as the clear plastic strips used to construct these label pockets.

Incorporating the use of an EDO medical kit pallet, while using a SOMS kit pallet, will be difficult unless they are attached to an area with an abundance of Velcro®. This would allow for easy access when obtaining any medications/accessories and not having to worry about items floating around and getting in the way of contingency procedures.

We should think of some credible scenarios requiring the use of both the EDO medical kit and the SOMS kits and simulate them on the ground (preferably in the middeck of the Orbiter mockup to simulate the lack of space to work in) and on the KC-135. We should discuss these simulations with the flight surgeons to confirm their credibility so that we do not waste time simulating a medical contingency that rarely happens. This manner of simulation will optimally test the various kits to see how well they can be used as just one big kit.

PHOTOGRAPHS / VIDEO

S91-39364: The investigators sprayed water into a Bacturcult vial using the spray bottle (to simulate a stream of urine), and then observe the liquid inside the tube.

S91-39366: One investigator applies a saturated sterile swab to the inside of a Bacturcult vial. Another investigator is capping a vial that has already been used.

S91-39367: Tubes of ointment are removed from Pallet I2.

S91-39368: Investigators observe a water spray bottle and a thick yellow liquid in a small bottle.

S91-39369: Pallet I2 has been removed from the kit. One investigator removes the Mycelex tablet applicator from its packaging while the other holds the rest of the kit in place.

NASA video #904798.

APPENDIX

Contents of the EDO Medical Kit (as of 7/5/91)

Medication/Accessories	*Location*
Adaptic Bandages (3; 4.0" x 3.0")	H2 - 1
Afrin Nasal Spray (15ml; 3.5" x 1.5")	I2 - 1
Afrin Nasal Spray (15ml; 3.5" x 1.5")	I2 - 2
Afrin Nasal Spray (15ml; 3.5" x 1.5")	I2 - 3
Ambulatory "Leg Bag"* (250-500 cc)	
Amikin (amikacin sulfate), 500 mg/2 ml-Tubex syringe	I1 - 10
Amoxil (1.75" bottle; 500 mg amoxicillin)	K1 - 21
Amoxil (3.0" bottle; 500 mg amoxicillin)	K1 - 6
Ascriptin (1.75" bottle; 325 mg Aspirin w/Maalox)	K1 - 1
Ayr Saline Nasal Mist* (3.5" x 1.5")	I2 - 4
Bactrim DS (3.0" bottle; 100 mg trimethoprim/ 800 mg sulfamethoxasole)	K1 - 12
Bacturcult* (3; 2.5" x 1.0" vial)	
Band-Aids (10; 3.0" x 1.0")	I2 - 13
Benadryl (Diphenhydramine Hydrochloride), 50mg/1ml-Tubex syringe	I1 - 1
Benzoin Swabs (3; 2.5" x 1.0")	I2 - 14
Carafate* (3.0" bottle; 1 gm sucralfate)	K1 - 10
Cotton Balls (5)	H2 - 9
Cotton Swabs (5)	H2 - 10
Cough Lozenges (3.0" bottle)	K1 - 16

APPENDIX *continued*

Contents of the EDO Medical Kit (as of 7/5/91)

Medication/Accessories	***Location***
2 ml-Tubex syringe (22G x 1.25" needle):	
Demerol (meperidine HCl), 50 mg/ml	I1-12
Demerol (meperidine HCl), 50 mg/ml	I1-1
2 ml-Prefilled Syringes (22G x 1.25" needle):	
Dilantin* (phenytoin sodium), 50 mg/ml	H1-8
Dilantin* (phenytoin sodium), 50 mg/ml	H1-9
Dilantin* (phenytoin sodium), 50 mg/ml	H1-10
Dilantin* (phenytoin sodium), 50 mg/ml	H1-11
Dilantin* (phenytoin sodium), 50 mg/ml	H1-12
Dilantin* (phenytoin sodium), 50 mg/ml	H1-13
Dilantin* (phenytoin sodium), 50 mg/ml	H1-14
Dilantin* (phenytoin sodium), 50 mg/ml	H1-15
Dilantin* (phenytoin sodium), 50 mg/ml	H1-16
Dilantin* (phenytoin sodium), 50 mg/ml	H1-17
Dulcolax (1.75" bottle; 5 mg bisacodyl)	K1-3
Duricef (3.0" bottle; 500 mg cefadroxil)	K1-7
Erythromycin (3.0" bottle; 250 mg)	K1-13
Foley Catheter*	
Forceps (1 pair)	H1-19
Garamycin (gentamicin sulfate) Ophthalmic Solution, 5 ml-bottle	I2-12
1 ml-Tubex syringe (22G x 1.25" needle):	
Heparin (heparin sodium), 100 units/ml	I1-7
Heparin (heparin sodium), 100 units/ml	I1-8
Heparin (heparin sodium), 100 units/ml	I1-9
Heparin (heparin sodium), 100 units/ml	I1-20
Heparin (heparin sodium), 100 units/ml	I1-21
Heparin (heparin sodium), 100 units/ml	I1-22
Heparin (heparin sodium), 100 units/ml	I1-23
Heparin lock (3; 3.0" x 2.0")	H2 - 7
Imodium (1.75" bottle; 2 mg loperamide)	K1-4

APPENDIX *continued*

Contents of the EDO Medical Kit (as of 7/5/91)

Medication/Accessories	***Location***
IV Saline Bag (250 cc) IV Saline Bag (500 cc; 9.0" x 4.5")	J1-1
Kenalog (triamcinolone acetonide) Cream 15 g-tube	I2 - 9
2 ml-Prefilled Syringes (22G x 1.25" needle):	
Lasix* (furosemide), 10 mg/ml	H1 - 1
Lasix* (furosemide), 10 mg/ml	H1 - 2
Lasix* (furosemide), 10 mg/ml	H1 - 3
Lasix* (furosemide), 10 mg/ml	H1 - 4
Lasix* (furosemide), 10 mg/ml	H1 - 5
Lotrimin (clotrimazole) Cream, 15 g-tube	I2 - 6
2ml-Tubex syringe (22G x 1.25" needle):	
Morphine Sulfate, 10 mg/ml	I1 - 14
Morphine Sulfate, 10 mg/ml	I1 - 15
Morphine Sulfate, 10 mg/ml	I1 - 16
Motrin (3.0" bottle; 400mg ibuprofen)	K1 - 8
Mycelex* (clotrimazole) - G; 7 Nystatin vaginal tablets w/applicator; (3.5" x 1.5" bottle; 100 mg)	I2 - 5
Mylanta II Tablets	
Needle, 14G (2; 2.5")	H2 - 6
Needle, 18G (2; 2.5")	H2 - 5
Needle, 22G (2; 2.5")	H2 - 4
Op-Site Occlusive Dressing (5; 2.5" x 2.75")	H2 - 1
Pepto-Bismol Tablets (24)	I1 - 18
1 ml-Tubex syringe (22G x 1.25" needle):	
Phenergan (promethazine HCl), 50 mg/ml	I1 - 2
Phenergan (promethazine HCl), 50 mg/ml	I1 - 3

APPENDIX *continued*

Contents of the EDO Medical Kit (as of 7/5/91)

Medication/Accessories	***Location***
Phenergan (promethazine HCl), 50 mg/ml	I1 - 4
Phenergan (promethazine HCl), 50 mg/ml	I1 - 5
Phenergan (promethazine HCl), 50 mg/ml	I1 - 6
Plunger	H1 - 6
Plunger	H1 - 7
Polysporin (Polymyxin B Sulfate) Ointment, 1 oz-tube	I2 - 7
Prednisone* (3.0" bottle; 10 mg)	K1 - 15
Proventil Inhaler* (3.0" bottle; 17g albuterol)	K1 - 17
Restoril (3.0" bottle; 15 mg temazepam)	K1 - 14
SAM Splint* (36.0" x 4.5")	I2 - 15
Scalpel, #10	H2 - 8
Scalpel, #11	H2 - 8
Scissors (1 pair)	H1 - 18
Seldane (1.75" bottle; 60 mg terfenadine)	K1 - 5
Silvadene (silver sulfadiazine) Cream, 20 g-tube	I2 - 8
Skin Staple Remover* (6.0" x 2.5")	J1 - 3
Skin Stapler* (7.0" x 4.0")	J1 - 3
Steri-Strip Skin Closure (4.5" x 2.0")	I1 - 19
Sterile Drape (6.5" x 3.0")	H2 - 1
Sterile Gloves (1 pair; 7.5" x 2.0")	H2 - 3
Strep Culture Tester* (3; 7.0"-tube)	J1 - 2

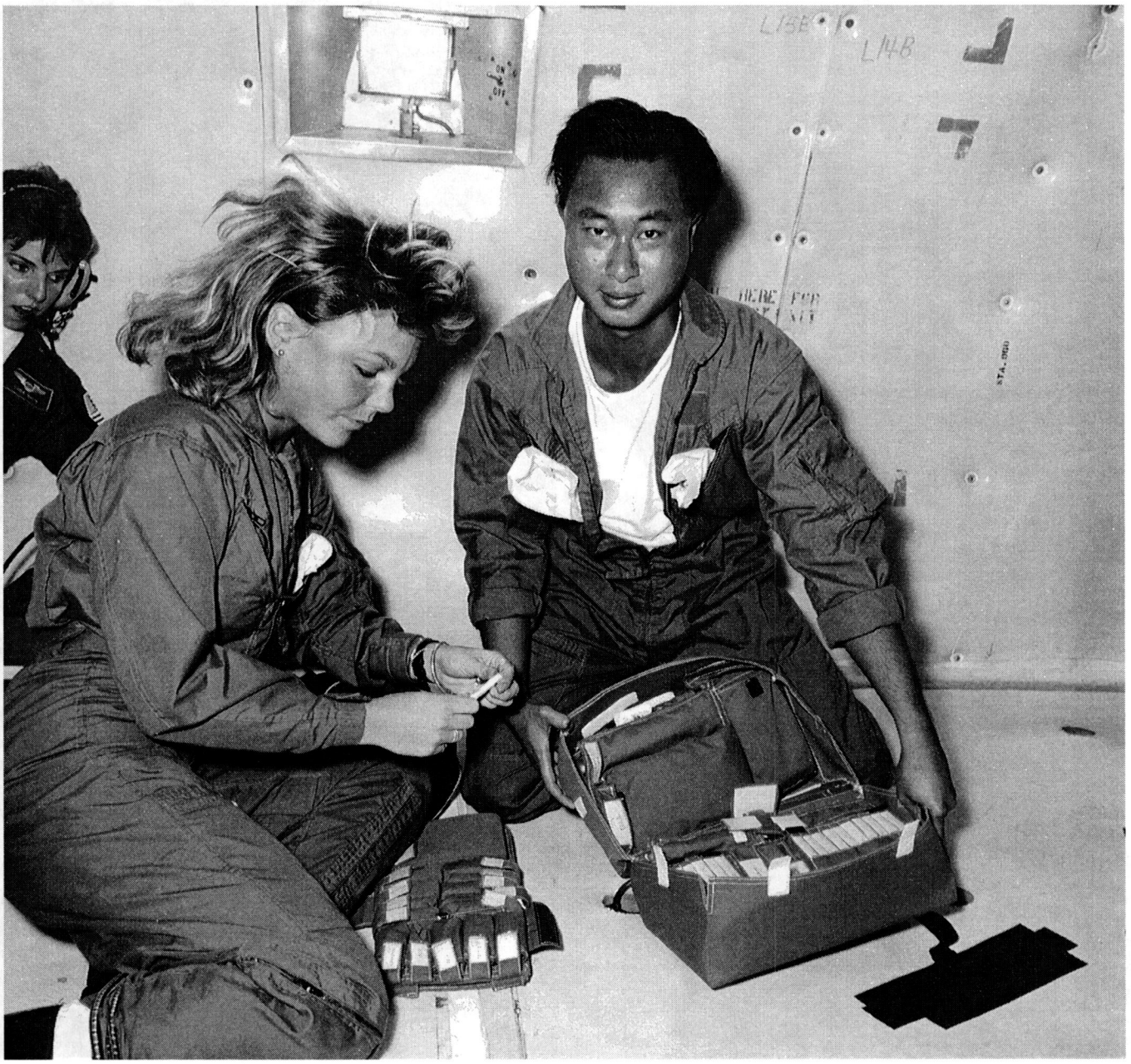
APPENDIX *concluded*

Contents of the EDO Medical Kit (as of 7/5/91)

Medication/Accessories	*Location*
Sudafed (3.0" bottle; 30 mg pseudoephedrine)	K1 - 9
Symmetrel* (3.0" bottle; 100 mg amantadine)	K1 - 11
Tearisol Eye Drops (artificial tears), 15 ml-bottle	I2 - 11
Telfa Sterile Pad (3; 4.5" x 3.5")	H2 - 1
Tongue Depressor (5; 6.5" x 1.0")	H2 - 11
Tonopen (7.0" tube)	H2 - 2
Tylenol® (1.75" bottle; 325 mg acetaminophen)	K1 - 18
Tylenol® #2 (1.75" bottle; 15 mg Codeine w/300 mg acetaminophen)	K1 - 2
Valium® (1.75" bottle; 5 mg diazepam)	K1 - 19
Vancocin®* (1.75" bottle; 250 mg vacomycin)	K1 - 20
Xylocaine® (Lidocaine® HCl) w/o Epinephrine, 2%-2 ml-Tubex syringe	I1 - 11
Zovirax®* (acyclovir) Ointment, 15 g-tube	I2 - 10
Empty syringe location	I1 - 17
Empty pill bottle location	K1 - 22

To be added: Milk of Magnesia tabs*

* This medication/accessory is NOT presently flown in the EMK or the MBK.



S91-39369: *Mycelex tablet applicator is removed from its package.*

S91-39366: *A saturated sterile swab is applied to the inside of a Bacturcult vial.*

Transport Simulation for Man-Tended Capability

Flight Date:	June 18, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigators:	Maureen Smith (KRUG Life Sciences) Dave Simmons (MDSSC) Frank Eichstadt (MDSSC) Ed Cordes (MDSSC)

GOAL

The purpose of this flight was to determine effectiveness of the MTC ALS pack and CMRS prototypes.

OBJECTIVES

1. Determine the effectiveness of the latest CMRS prototype for MTC.
2. Evaluate the Bushwalker ALS pack interface with the CMRS for emergent care.
3. Consider the restraints needed for the CMO, CMRS, and ALS pack.

MATERIALS

Node pallet

A mockup of the node area where medical procedures would be performed on the space station was built by MDSSC to be used on the KC-135 aircraft. The pallet is constructed of wood with 30-inch walls that fold up during the flight to form a volume envelope. Because the pallet is representative of the node area available to the crew during a medical contingency, crew choreography, equipment placement, patient position, and other related issues can be assessed.

The node fixture adequately represented the constraints of the typical node aisle. However, lack of a radial port well at the outboard end of the aisle did affect the fidelity of the simulation and the performance of the CMRS. Also, no restraint or mobility aids (handrails, primarily) were present in the fixture. This caused some difficulty in deploying and stowing the CMRS. Future evaluations would benefit greatly from inclusion of these features.

Prototype seat track anchors on loan from (Work Package 01 (WP01) R&MA subcontractor) were used to enhance the node fixture. These devices performed adequately as anchor points for bungee cords and as impromptu handholds.

Two Miniracks (21"x31"x54")

Racks were used to hold equipment for take-off and landing. Also, the equipment was stowed in the racks as close to MTC configuration as is currently known in order to evaluate placement and deployment.

CMRS

The latest prototype CMRS was designed by MDSSC following evaluation of the Evac-U-Splint mattress in March. It is constructed of fabric-enclosed eighth-inch pallets. Fully opened, the CMRS covers a double-rack face and provides a work surface with CMO and supply restraint as well as patient restraint.

Initially, the MRS is stowed with the KED on the OB surface of the node fixture.

ALS pack

The latest prototype of the ALS pack, built by Bushwalker, is designed for PMC of the space station. The prototype pack contains supplies which are not included in the MTC ALS pack and does not accommodate items baselined for MTC. The flight was not affected by the fact that the pack does not meet MTC requirements because the pack size and weight does not change from MTC to PMC and the mechanisms for restraining items within the pack will not necessarily change. Also, overall layout was considered which will not change too much from MTC to PMC.

Resusci-Annie

Annie was not the best manikin to use for this evaluation because it is too small, soft, and unstructured to behave as a human patient would behave. In future testing, a manikin of human size and weight should be used to better evaluate the engineering characteristics of the CMRS.

Data was acquired by videotaping activities and self-report post-test.

METHODS

Participant Responsibility During Parabolas

Frank Eichstadt	Design Engineer
Maureen Smith	Assistant
Ed Cordes	Video
Dave Simmons	Comments/Script

Comments from the design engineer and the medical personnel are included below.

Parabola 1: The design engineer deploys KED from the CMRS OB surface for patient application while the assistant detaches the manikin from the rack and begins applying KED to Annie.

KED deployment was easy by releasing the Velcro® straps which attach the KED to the CMRS. Assuming this as the CMRS stow location (per the current baseline), KED access was rapid. One feature which will probably enhance the installation is a stow cover for the CMRS which would serve as a "carry bag" and keep the CMRS clean until it is used.

Patient's c-spine is not maintained. It is also difficult to position the patient properly until the KED is partially attached, i.e. the KED straps are hooked however possible, then it is positioned on the patient properly, then the straps are tightened. The movement involved during KED application by a single crewmember may defeat the purpose of the spinal immobilization unit.

Parabolas 2-3: The design engineer deploys the CMRS and gets all but one attachment locked down while the assistant continues to apply the KED to Annie.

The single CMO attempt to attach KED without adequate general restraints appeared to be

difficult. SSF will offer an array of general restraints and mobility aids which will simplify this procedure. Future uses of the node fixture would benefit from inclusion of handholds in areas currently baselined for the flight nodes.

Deployment of the CMRS from its stowed location at the inboard wall was quick, while actual attachment of the ANCRA anchors posed some alignment difficulty. The CMRS was located at the center of the aisle leaving adequate space at the aft wall for the ALS pack.

The CMRS seemed "loose" when initially attached for use, but upon tightening the patient restraint straps, the CMRS was drawn tight against its anchors. This trait could be used to advantage in a future revision to the design.

Alignment of anchors to seat track was a problem. As currently configured, the ANCRA anchors require "sideways" motion to engage to the tracks. With the anchors in fixed positions on the pallet, this sideways motion requires bending or shifting of the entire pallet to engage the track. Anchors on short adjustable straps would ease engagement and alignment.

The "head" end of the CMRS overhangs the end of the node fixture and is to be tied out to the outboard (end cone) racks for the flight configuration. In the KC-135, however, no tension straps were available. One of the CMRS snap straps (used to hold the CMRS closed) was wrapped around a proximal bungee cord which was in turn fastened to anchor points on the aircraft deck. Attachment of the head end of the CMRS MUST be achieved in some fashion during subsequent evaluations. Failure to attach this end causes the CMO restraint bungee cords and the head restraint to remain loose during further activities.

Parabolas 4-5: The design engineer begins securing Annie to the CMRS using the foot, leg, thigh, chest, head, and neck straps. The assistant deploys the ALS pack from the rack, secures it to the c-track beside the CMRS, and then assists the design engineer with restraining Annie.

C-Collar was not present in this evaluation. The KED device, with its complement of straps, did "hang up" on the CMRS a little bit during Annie positioning. This tendency can be designed out of a flight specific KED-type device.

Annie has foam-filled legs with no joints. This softness is uncharacteristic of a human patient. The mass of a human's limbs is used in the CMRS as a way to induce a curve in the rigid panels when straps are tightened.

The ALS pack was strapped to the rack for takeoff and landing. Access to pack contents has been the subject of prior flight experiments. During this test, the ALS pack was located to the patient's right side at the shoulder, with the lid against the wall and the larger mass of the pack on the floor. With the CMRS at the middle of the aisle, the pack was too close to the CMRS, and impinged on the CMO's working space. An alternate location for investigation in later flights/evaluations is with the ALS pack horizontal and attached to the wall. Two-g pull-out might be a problem with the current ALS pack in this orientation.

Parabola 6: The design engineer and the assistant tighten all the straps on the CMRS. CMO reach/access to the ALS pack is evaluated by the design engineer.

CMRS straps squashed Annie's foam-filled legs. Nevertheless, tightening the straps did improve CMRS rigidity. The head strap of the CMRS did not "ride" on the forehead of the manikin as intended. Additional work is required in this

area. The pad on the head strap was too wide. A narrower strap would allow easier adjustment, especially for smaller head sizes. A means of assuring proper head alignment for head strap placement is needed. This might take the form of a backstop against which the patient's head could be positioned prior to attachment of restraining straps. The variation in distance from the top of the skull to the eyebrows for people of widely varying statures is relatively small. Thus, the compliance of the strap will adapt to various patient statures assuming initial identical location of the top of the skull.

The "tabs" sewn into the ends of the straps to prevent them from backing out of the buckle were too short. More strap should be folded over and a double layer should be stitched to prevent backing out and to offer more of a grasp for straps that have been pulled nearly out of the buckle.

Straps stow attached at one side to two adjacent female buckles so that they will be clear of the patient surface when the patient is brought into contact with the pallet. The prototype has the double-buckle feature on alternating sides on successive straps. Some people who were not familiar with the device were initially confused. Color applied to buckles and straps might address some of this confusion. Another alternative is to eliminate the second female buckle at one side and retain the strap in a ready position with a Velcro® patch. A third alternative is to originate the strap without a buckle and provide an adjacent buckle or Velcro® patch for strap retention. This third alternative offers the option of originating all straps from one side without resulting in additional thickness buildup at one side of the stowed CMRS.

Straps along the torso originated too close to the center of the pallet, causing the adjustment buckles to fail to lock the strap in a fixed adjusted position (due to angle induced by patient width). Greater distance between strap origin and insertion at the torso area will solve this problem.

The ALS pack attachment using ANCRA anchors on short straps worked well due to the added flexibility of the straps easing alignment of the anchors. Anchor alignment and CMRS tensioning could be improved through the use of similar features on the CMRS

Access to Annie's head and entire body seemed attainable, but not optimal by any means. Direct overhead access was the most difficult due to the lack of a rigid floor plane below the CMRS in this area. Tethers to outboard racks would help. Grab handles were used as mobility aids around the patient. Handles were also used as foot loops with some success. The CMO restraint bungee cord wasn't tight enough to hold the design engineer securely to the deck. Some of this looseness could be attributed to insufficient tension on the pallet itself. Given that the bungee is continuous for two circuits around the pallet, some additional tension could be provided without approaching the stretch limit of the bungee, and probably without causing the pallet to be unmanageable because of bungee loading during deployment. Non-CMRS restraints and mobility aids in the node will play a part in medical operations which was not evident in this evaluation. Subsequent tests should include an array of handrails in areas where they are baselined for node outfitting.

The design engineer could easily reach all the subpacks from the ALS pack even from the opposite side of the CMRS. A shorter person might have a harder time. Items restrained to the lid of the pack (against the wall) were farther away, but could be reached. Handles on the CMRS were helpful in achieving the reach required for all access and mobility tasks.

Parabola 7: The assistant opens and secures the ALS pack while the design engineer secures himself to the CMRS by sliding his leg under the bungee.

The ALS pack adjacent to Annie's right shoulder hindered access to Annie's right side. ALS pack restraint entirely to the wall would improve access around both sides of the patient. (ALS

restraint on the wall might cause some problems of spontaneous contents release during 2-g pullout in the current configuration.)

Parabolas 8-9: The design engineer releases Annie from the CMRS, passes her to the assistant to remove the KED, and unhooks the CMRS to restow it.

The restraint strap buckles are easy to release, since they are large and actuate with two fingers. However, once tension is applied to load the CMRS into a "trough," the quick-release snaps become harder to actuate. Releasing tension first eases the problem. It would be easier to detach the anchors if tension load could first be released. Also, better finger access to the anchors would help. Both of these characteristics would be attainable if the anchors were on short adjustable tension straps.

Parabola 10: The design engineer secures the CMRS in its original, stowed position. The assistant finishes removing the KED, packages it, and restows it on the CMRS.

Lack of adequate mobility aids in the node fixture was evident during CMRS stowage and deployment. Nevertheless, the CMRS was folded and stowed without undue difficulty. The node fixture had no specifically unique provisions for stowed CMRS attachment. It should be possible to stow the CMRS without unique interfaces. The current prototype as stowed was too floppy. A bungee was used to hold the CMRS against the IB closeout while stowed.

KED stowage was provided by a Velcro® strap. Proper design of straps would surely improve the security of this provision. The KED, as currently stowed, was accessible on the outermost panel of the stowed CMRS. Once the CMRS was deployed, the KED was inaccessible on the bottom surface of the CMRS just below the knees.

Parabolas 11-12: The design engineer deploys the CMRS and removes the KED. During the 11th parabola, one hook is secured while the remaining three c-track attachments are locked in during the 12th parabola.

CMRS deployment was quicker on the second attempt. The stowed-state anchors remaining in place is an advantage, as they provide a force reaction point for deployment. If the CMRS were initially "free," the first step in deployment should be to anchor the folded unit using attachments which remain in place to anchor the CMRS while deployed.

Parabolas 13-14: The design engineer places Annie on the CMRS and secures her with a loose thigh strap. The assistant slips the KED into position under the patient and attaches it to the patient.

The design engineer found that lifting the CMRS handles made it easier to align the ANCRA anchors to the tracks.

Though initially the attachment of Annie to the CMRS the second time was intended to be done without the KED, the decision was made to use the KED. This decision was made during the CMRS deployment process, causing the investigators to stop deploying and go for the KED which was attached below the partially deployed CMRS. However, access to the KED was not difficult even from this location, due to the looseness of the Velcro® strap holding it to the CMRS. The straps were in a disarrayed state for the second deployment, again indicating a need to simplify the strap retention scheme.

Parabola 15: The assistant begins restraining Annie to the CMRS with the other straps while the design engineer attempts to engage one of the c-track connectors which is loose.

Subpack attachment was accomplished with most of the subpacks, and there was no indication that the rest of the packs wouldn't work the same way. Variable locations are attainable due to the array of snaps on the pallet and patient restraint straps. The deployed subpacks did not lie flat against the pallet in most cases, but the contents could still be accessed. An improvement would be to provide "male" snaps at all locations on the CMRS, and "female" snaps on all deployable items. This would increase location options and eliminate incompatibilities. (All ALS subpack snaps are currently female; CMRS snap array offers alternating male and female snaps.) The snaps worked fine for engagement and disengagement, and the design engineer noticed no tendency toward unwanted force reaction during use. Another improvement would be to provide an additional circumferential array of snaps inward on the pallet, approximately at the side panel fold-line.

Parabolas 16-17: The design engineer finishes securing the remaining straps of the CMRS while the assistant accesses the ALS pack for the Airway roll and attempts to secure it at the head of the patient.

Initial attempts to secure the Airway roll to the CMRS were thwarted by the snap matrix. The alternating male and female snaps caused no compatible snap interfaces in the necessary area.

Parabola 18: The design engineer deploys the Drug and IV rolls from the ALS pack to the chest and abdominal straps of the CMRS. The assistant adjusts the Airway roll to secure it to the CMRS snap matrix.

Many items from the ALS subpacks were removed and restrained to various accommodations on the CMRS. Restraint locations, quantity, and options resulted in convenient places to put things falling conveniently at hand. The elastic straps were too loose and should be tighter to the surface on later models. Even if the elastic restraint straps were taunt against the pallet surface, the padding of the pallet would allow items to slip under the strap once they are initially pressed into the padding slightly.

The Airway roll could be attached to the CMRS though not flat to the surface. This caused a lot of "play" in the roll, especially in the middle.

Parabola 19: The design engineer moves the IV roll from the abdominal strap to the CMRS snap matrix beside the patient's left arm. Meanwhile, the assistant accesses supplies out of the Airway roll.

Deployment of supplies out of the Airway roll was possible though not optimal considering the loose position of the roll on the CMRS.

The snap matrix on the CMRS allows the individual rolls to be deployed to the area of use which makes it an excellent work surface.

Parabola 20: The design engineer deploys drug supplies from the Drug roll which is attached to the chest strap. The two investigators stow the Drug and Airway rolls in the ALS pack.

Bristojetts are easily removed from the roll though replacing items may cause smaller, less secure items to deploy spontaneously. Replacing rolls in the ALS pack was accomplished without problems.

Parabolas 21-22: While the assistant removes the restraints on the defibrillator in the rack, the design engineer tests the Grumman c-track restraints.

Access of the defibrillator was hindered by the bungees holding the hardware in the top drawer

(for zero-g); therefore, deployment took longer than necessary.

The Grumman c-track attachments were easy to attach and disengage unless the c-track was near a corner. Also, once in place, the attachments provided handholds.

Parabola 23: The design engineer stows the IV roll in the ALS pack and deploys the Suction roll from a position straddling the patient, both legs under the CMRS bungee. The assistant deploys the defibrillator from the rack drawer.

Access to the ALS pack and all areas on the patient was possible though was not tested by a person smaller than the design engineer.

Parabolas 24-26: The design engineer secures the Suction roll to the CMRS using a single snap and accesses the V-vac. The assistant passes the defibrillator to the design engineer in exchange for the V-vac. The design engineer positions the defibrillator under the bungee on patient's left facing the feet and the patient's side. The assistant simulates suctioning the patient and places the V-vac under the bungee for future use.

Defibrillator (Lifepak 10 in Lifepak soft carrying case) was shoved under the CMO bungee adjacent to the left hip of the patient. Alternate orientations were tried, with the "face" toward the patient (for viewing form opposite side) and facing toward the patient's feet. In both cases, visibility to displays was not very good and would have been worse if Annie's legs were thicker and less spongy. Visibility of controls was better, but controls access was not good. Access to controls and particularly the "FIRE" trigger(s) was not specifically addressed in the available time. It seems that surface area around the patient is at a premium as soon as larger items of equipment are deployed. Also, in the case of the defibrillator, access while "clear" must be specifically noted as a design goal. The defibrillator will undergo additional development to create a "soft-pack" which adapts the device for SSF use in conjunction with the CMRS and ALS pack. Special attention should be given to identifying optimal orientation/ location of the defibrillator relative to the rest of the medical suite currently in development.

The V-vac was deployed and tucked under an elastic strap. A general comment regarding all elastic straps is that they could have all been tighter at rest to more securely retain items tucked beneath them.

Parabola 27: The design engineer evaluates the restraint mechanism on the straps for routing the defibrillator cables through for containment. The assistant manages the patient's airway using supplies from the deployed Airway roll.

From a straddle position or side position, access to the patient through the straps was possible. Even releasing a strap should be possible without harming the patient's restraint since there are numerous straps.

The releasable straps on the patient restraint straps were accessed and operated to simulate CMRS functions associated with electrocardiogram (ECG) line routing. No problems were encountered. Adjustability of strap tension at both ends of the patient restraint straps creates the potential for straps to become offcenter such that the releasable straps are too close to the buckle at one side. Fixed orientation straps (anchored at their origin on the CMRS) would eliminate this potential.

Parabola 28: The design engineer unsnaps the Suction roll and removes a syringe which he places in a restraining loop on the leg strap. The assistant accesses the BVM from the ALS pack.

The loops on the patient straps work well for quick restraint of loose objects though larger loops may not be useful for smaller items. Access of BVM from the ALS pack was unremarkable and easily accomplished.

Parabola 29: While the assistant ventilates Annie with the BVM, the design engineer begins chest compressions thereby demonstrating CPR on the CMRS.

CPR using only CMRS as a restraint was ineffectual due to excessive compliance of the restraint straps. Inverted CPR using counterforce against the aircraft ceiling was attempted also, and worked as well as it had in prior attempts with other medical restraint candidate designs.

Parabola 30: The assistant stows the defibrillator in the rack while the design engineer returns all the deployed rolls to the ALS pack.

Repacking the rolls into the ALS pack was not difficult especially if rolls were smaller due to use of the supplies normally located within.

Parabolas 31-34: Two investigators configure the CMRS for the hyperbaric airlock (as much as possible in the node fixture) using bungees and the side wall. They accomplish this by positioning and attaching CMRS to aft wall with side panel folded up and stretching straps across aisle to anchor points on opposite wall

This evaluation was inconclusive, since the CMRS and node fixture were unprepared to support the task. Future assessment of the HAL application must occur either with additional provisions for node fixture use in the KC-135, and/or in a one-g mockup of the airlock, and/or in the Weightless Environmental Training Facility.

Bungee cords were used to stretch the CMRS across to the opposite wall of the node fixture. The side panel of the CMRS was not adequately attached to the wall of the node fixture. As a result, the CMRS was stretched flat rather than in the envisioned "Z" condition. No upward or downward restraints were used to limit CMRS deflection. The result was a "trampoline" sprung with bungee cords; therefore, no useful data was collected.

Parabola 35: Two investigators detach the CMRS from the node fixture and configure it for patient transport.

Again, the need for handrails in the node was evident as movement was attempted without anything (hardware or flyers) restrained.

Parabola 36: While an investigator stabilizes the patient, the design engineer attempts to fold the side panels of the CMRS underneath in the transport configuration.

The stitching was so close to the panels that it did not allow enough room for the sides to fold under. If the side panels could be folded in continuous microgravity, the reconfiguration of the CMRS for transport may be accomplished by a single crewmember.

Parabola 37: Because the side panels cannot fold under, the design engineer tightens the patient restraint straps until the middle panels bow, providing rigidity to the CMRS.

When the straps were tightened, the CMRS was adequately rigid. Future testing needs to be done using a person in the CMRS to determine if the straps become too tight. Also, the manikin's legs were not anatomically correct and were loose within the restraints even when they were pulled taunt.

Parabola 38: Two investigators use the handholds to translate the CMRS around the aircraft cabin.

Control of the patient on the CMRS was easily accomplished using the handholds; but, again, lack of mobility aids in the node fixture inhibited evaluation.

Parabolas 39-40: Two investigators translate the CMRS through the simulated hatch and around the node fixture using the handholds.

Minimal effort was targeted at evaluation of the transport characteristics of this prototype. However, the "bowed center panel" approach seemed to provide considerable rigidity even while accommodating the marginal Annie manikin.

RESULTS

Equipment restraint options with the CMRS appeared to accommodate all situations presented by the evaluation scenarios. The CMRS evaluation did suffer from the fact that it could not be configured for transport or hyperbaric use (though hyperbaric configuration testing was not originally planned for this flight).

CMO restraint using the circumferential bungee cord and handles was assessed in a variety of orientations to the patient. This evaluation suffered somewhat from the lack of a radial port well at the "head" end of the patient, and also from the lack of tension straps at the same end. The CMO restraint bungee was too loose to provide secure restraint.

Interfacing the supplies to the CMRS was shown to be extremely beneficial. The provided work surface allowed the supplies to be located in the area of use thereby allowing immediate access. Interfaces between the equipment, such as the defibrillator, and the CMRS needed to be prepared prior to the flight so that hardware could be tested in various positions using different restraint mechanisms.

CONCLUSIONS

The CMRS needs to be developed to consider findings from continual evaluations. Although the designer can attempt to envision all aspects of its use and behavior, only actual testing provides adequate feedback on the functionality of a device with such varied and user-sensitive interfaces.

Further evaluation of the CMRS must use higher fidelity manikins at least, but preferably human subjects, as the patient. Only this will properly assess the restraint's performance with a restrained patient during both static and transport operations.

ALS, respiratory support pack, defibrillator jacket and CMRS must all be developed and designed together to ensure ideal coordination.

PHOTOGRAPHS

S91-39779: Two investigators translate the patient (Annie) down the node fixture simulating movement through the hatch. The CMRS was easily manipulated using the handhold down the sides as long as the rigidity was maintained by tightening the straps.

S91-39780: Two investigators lift the MRS from the node floor simulating transport of the patient. Activities and comments are recorded.

S91-39781: Two investigators test the transport capabilities of the CMRS by moving the patient around in various configurations.

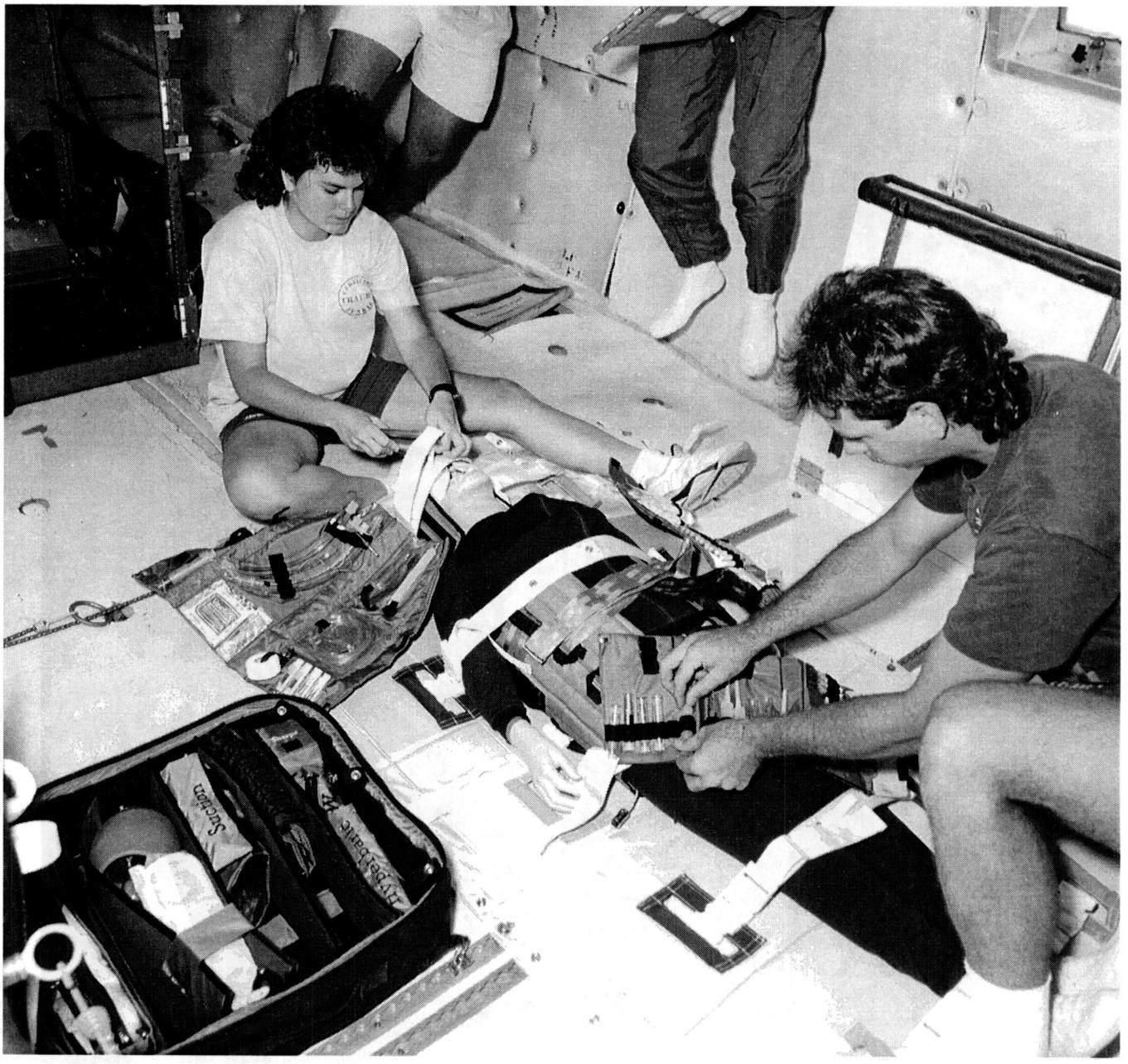
S91-39782: While two investigators move the patient about the node fixture, they experience some difficulties in maintaining their own stability due to lack of mobility aids in the structure. As shown, one handhold and the edge of the CMRS were used.

S91-39800: Two investigators test the work surface features of the CMRS by deploying various subpacks from the ALS pack. One investigator performs airway management techniques while the other accesses drugs from the ALS Drug roll which was restrained to the abdominal strap. The Airway kit was secured to the head area of the CMRS on the snap matrix.

S91-39811: Two investigators move the patient, previously placed in the KED, into the CMRS prior to performing any medical procedures. Another investigator holds the top of the CMRS which overhangs the node pallet.

S91-39812: As one investigator secures the patient head with the CMRS head strap, another investigator restrains the lower limbs. A third investigator assists by securing the part of the CMRS which overhangs the node pallet with his foot.

NASA Video 904798.



S91-39800: *Investigators attach various subpacks of the ALS pack to the CMRS.*

S91-39781: *Investigators test the transport capabilities of the CMRS.*

Advanced Cardiac Life Support Using Man-tended Capability Health Maintenance Facility Equipment

Flight Date:	June 19, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigators:	Maureen Smith (KRUG Life Sciences) Michael Barratt (KRUG Life Sciences) Victor Kizzee (KRUG Life Sciences) Debra Krupa (KRUG Life Sciences) Susan Shimamoto (KRUG Life Sciences)

GOAL

The purpose of this flight was to evaluate the medical functionality of MTC HMF equipment/ supplies by performing ACLS protocols during a simulated megacode.

OBJECTIVES

1. Determine the effectiveness of the prototype MTC MRS when used during a code.
2. Evaluate the second generation ALS pack as used during a code including its interfaces to the MRS.
3. Evaluate the interfaces between the MRS and the equipment.
4. Evaluate the trash generated, time required, etc. when a code is run.

MATERIALS

Node Pallet

A mockup of the node area where medical procedures would be performed on the space station was built by MDSSC to be used on the KC-135 aircraft. The pallet is constructed of wood with 30-inch walls that fold up during the flight to form a volume envelope. Because the pallet is representative of the node area available to the crew during a medical contingency, crew choreography, equipment placement, patient position, and other related issues can be assessed.

The node fixture adequately represented the constraints of the typical node aisle. However, lack of a radial port well at the outboard end of the aisle did affect the fidelity of the simulation and the performance of the CMRS. Also, no restraint and mobility aids (handrails, primarily) were present in the fixture. This caused some difficulty in deploying and stowing the CMRS. Future evaluations would benefit greatly from inclusion of these features.

Two Miniracks (21"x31"x54")

Racks were used to hold equipment for take-off and landing. Also, the equipment was stowed in the racks in as close to MTC configuration as is currently known in order to evaluate deployment.

ALS Pack

The latest prototype of the ALS pack, built by Bushwalker, is designed for PMC of the space station. The prototype pack contains supplies which are not included in the MTC ALS pack and does not accommodate items baselined for MTC. The flight was not affected by the fact that the pack does not meet MTC requirements because the pack size and weight does not change from MTC to PMC and the mechanisms for restraining items within the pack will not necessarily change. Also, overall layout was considered which will not change too much from MTC to PMC.

Data was acquired by videotaping activities and self-report post-test.

METHODS

An electrocution scenario written to use every piece of MTC hardware was performed. The equipment for the procedures was deployed out of the ALS pack and the miniracks. Participants with primary responsibility during parabolas 1-10:

Michael Barratt	CMO 1
Maureen Smith	CMO 2
Victor Kizzee	Crewmember
Debra Krupa	Code Director/Camera
Susan Shimamoto	Comments

Parabolas 1-2: CMO 1 found Annie floating in the "Lab," called for deployment of the medical equipment, and began the primary survey. The crewmember deployed the CMRS and began attaching it to the c-tracks. CMO 2 deployed the ALS pack and attached it to the wall of the node fixture.

Deployment of the CMRS was rapid though securing it to the c-tracks was difficult due to lack of finger space on the ANCRA anchors. Also, the tension in the CMRS combined with the fixed attachment of the ANCRA anchors makes alignment to the c-track difficult.

The ALS pack was quickly deployed and secured to the floor of the node fixture. The anchors on the ALS pack are the same as those on the CMRS but they are attached to the D-rings which allows some play for aligning the anchor to the c-track.

Parabolas 3-4: CMO 1 gave Annie two breaths then checked for a pulse. CMO 2 deployed the c-collar and BVM from the ALS pack then moved to assist with Annie while the crewmember continued securing the CMRS to the c-tracks. CMO 1 placed the c-collar on the patient.

As stated previously, attaching the CMRS to the c-track was difficult and took more time than expected. Accessing supplies from the ALS pack was easy and rapid. Problems may arise in the pocket containing the BVM and IV fluids if they are unrestrained; deploying one of the items relieves the pressure holding them all in place.

Parabolas 5-6: The CMO 1 and crewmember positioned Annie in the CMRS using the chest strap. CMO 1 delivered another ventilation via mouth-to-mouth while the crewmember set up the Barratt CPR restraint. As soon as the CPR restraint was in place, CMO 1 began chest compressions. Meanwhile, CMO 2 opened and

secured the ALS pack, deployed the BVM, and moved to the patient's head to take over ventilations.

The single strap across the chest did not adequately restrain the patient to the CMRS. Because only one strap was used, the CMRS was not rigid. Tightening the straps causes the panels to bow, thus providing the stiffness.

The CPR restraint, which was stowed on the CMRS, was quickly set up for compression by attaching one end to the other side of the patient. As soon as the strap was in place, the crewmember just slid the strap over his head and began compressions.

Deploying the BVM allowed the other loose items (IV bags) stored in the same section to float free; a restraining strap is necessary to hold the loose items in place.

Parabolas 7-8: While the crewmember continued to secure the CMRS to the c-tracks, CPR continued with CMO 1 performing chest compressions and CMO 2 managing the airway.

Without a means of maintaining an airtight seal between the patient's face and the BVM, CPR requires two people to be effective, unless mouth-to-mouth ventilations are employed. Since mouth-to-mouth only provides 16% oxygen compared to the 21% delivered by the BVM (without supplemental oxygen), the BVM will probably be used over mouth-to-mouth.

Difficulties encountered while deploying the CMRS (aligning and engaging the anchors) were covered previously.

Parabolas 9-10: The crewmember took over chest compressions and CMO 1 switched to airway management while CMO 2 deployed the Airway roll from the ALS pack to the CMRS near the patient's head.

Switching positions was easily accomplished; CMO 1 moved out of the restraint and to the patient's head in one motion allowing room for the crewmember to position himself over the patient for chest compressions. By changing positions in this manner, CMO 1 was now in place to attempt intubation with the supplies CMO 2 had deployed from the ALS pack.

Turnaround: Debra replaced Michael as CMO 1 and Susan took over video responsibilities.

Parabolas 11-12: As CMO 2 deployed the defibrillator from the rack and the crewmember continued chest compressions, CMO 1 intubated the patient.

Intubation has been tested previously and was not a consideration on this flight. Instead, placement of the roll, deployment of the supplies from the Airway roll, and overall transition from bagging the patient to ET tube ventilations were evaluated. To avoid the complications involved with rescue breathing (like gastric distension) and to ensure a patent, secure airway, intubation was performed early in the protocol.

Parabolas 13-14: Following intubation, CMO 1 connected the ambu bag to the ET tube and CMO 2 accessed the Assessment roll for the stethoscope to check ET tube placement. Meanwhile, the crewmember placed the defibrillation pads on Annie's torso and used the stethoscope to listen for breath sounds. Because pacing pads were used to simulate defibrillator pads, the leads did not attach to the pads but the crewmember did not realize this until later.

Parabolas 15-16: While the crewmember attached the leads to the defibrillation pads and CMO 1 ventilated the patient, CMO 2 collected the free-floating trash. Once the defibrillator was positioned and the leads attached, the crewmember and CMO 2 switched places.

Excessive time was taken attempting to connect the leads to the pads because of the incompatibility. Therefore, CMO 1 continued bagging and collecting loose items while CMO 2 stowed waste and used supplies.

Parabolas 17-18: Because the patient was intubated early, the crewmember performed one-person CPR. Meanwhile, CMO 1 evaluated the patient's condition per the defibrillator monitor and CMO 2 deployed the IV roll to the ALS pack and took over airway management.

If one-person CPR can be done the third crewmember (CMO 2) is free to deploy needed supplies and set up procedures. CMO 2 took over airway management so the crewmember could clear for defibrillation.

Parabolas 19-20: As CMO 1 conducted two defibrillation attempts, CMO 2 controlled the patient's airway while the crewmember deployed the oxygen bottle.

Since CPR was not performed between the initial three defibrillation attempts, the third crewmember was free to deploy the respiratory pack and hook up the oxygen for use with the BVM for 100% oxygen delivery.

Turnaround

Parabolas 21-22: CMO 1 continued through the ACLS protocol with the third defibrillation attempt, then repositioned the defibrillator so she could access the patient, equipment and supplies. Meanwhile, the crewmember continued one-person CPR and CMO 2 deployed the Drug roll from the ALS pack to the CMRS.

As soon as the third defibrillation attempt was completed, the crewmember returned to CPR, allowing CMO 2 to continue accessing supplies while CMO 1 readied herself for the next procedures. A CMO 2 trained in some invasive procedures could alleviate the burden on CMO 1 of having to perform every procedure sequentially and possibly reduce treatment time.

Parabolas 23-25: Following the three defibrillation attempts, CMO 2 administered Epinephrine on the ET while CMO 1 prepared for IV catheterization. The crewmember continued CPR with CMO 2 hyperventilating the patient to assist in drug administration.

Because the patient was intubated, ventilations did not have to coincide with chest compressions allowing hyperventilation. The ease of one-person CPR with unsynchronized ventilations and compressions was not tested. Since a route of drug administration was established previously, ACLS protocols did not rely on achieving a free-flowing IV line.

Parabolas 26-28: As CMO 1 attempted a peripheral IV on the patient's right arm, CMO 2 set up the fluid and administration set and secured the IV bag to the CMRS. Because the patient was still pulseless, the crewmember continued CPR.

Though one-person CPR is extremely beneficial and frees CMO 2 to assist CMO 1, the crewmember performing CPR may rapidly become exhausted. Changing techniques of chest compressions may alleviate some fatigue.

Parabolas 29-30: The crewmember performed one-person CPR without the Barratt restraint by placing his feet on the ceiling. Meanwhile, CMO 1 and CMO 2 completed the IV procedure. CMO 1 then charged the defibrillator for the first defibrillation following drug administration.

A great deal of time was saved having CMO 2 free from airway management to assist CMO 1 in set up and procedures.

Turnaround

Parabolas 31-32: Defibrillation performed by CMO 1; patient still pulseless. The crewmember continued CPR using feet high method while CMO 1 prepared Bristo-jett of Lidocaine for injection. Meanwhile, patient vomited so CMO 2 deployed the mechanical aspirator and suctioned the patient's mouth and pharynx.

Deployment of the mechanical aspirator was not difficult since the pocket opens in both directions. As long as the patient has an IV line and ET in place, both methods can be used for drug administration though effectiveness of ET tube injection is unknown since some of the drug clings to the inside of the tube.

The Barratt CPR restraint was not comfortable to the crewmember causing head and neck pain. The crewmember switched to feet high compressions.

Parabola 33: CMO 1 injected the Lidocaine® intravenously, then CMO 2 tried feet high chest compressions to circulate the drug. The crewmember managed the airway.

CMO 2 was not familiar with the feet high technique of chest compression and found it difficult to position her hands properly. Also, she was unable to manage the airway simultaneously. Practice may alleviate the difficulties she encountered.

Parabolas 34-35: Patient's pulse was restored and rhythm was now normal sinus. The crewmember continued to ventilate patient and suction airway as necessary. CMO 2 finished restraining Annie in the CMRS while CMO 1 accessed the suction roll for the nasogastric (NG) tube.

The mechanical aspirator was restrained under the CMRS bungee near the patient's head for easy access as necessary which proved convenient.

Access to items within the rolls was rapid. Identification of the supplies was quickly achieved due to the clear packaging. Attaching the rolls to the CMRS proved most effective for quick and convenient location of the supplies.

The CMRS was much more rigid when the patient was fully restrained and the straps were tightened.

Parabolas 36-37: While CMO 1 monitored and assessed the patient's status, CMO 2 took vitals and the crewmember continued airway management.

The CMRS allowed for patient access by all crewmembers. Because the patient's arms were both used during protocol (IV in right, BP on left), they should not be restrained under the main patient straps though they need some restraint in order not to float as they do in sleep or flail when patient is defibrillated.

Parabola 38: Decision was made to prepare the patient for transport to Shuttle. CMO 1 returned the various rolls to the ALS pack, the crewmember ventilated the patient, and CMO 2 assessed the patient's BP.

Restowing items in the ALS pack was rapid though some items were not in original position or returned as neatly as initially packaged.

Parabolas 39-40: The CMRS was released from the c-track on the left side. The defibrillator was strapped across the patient's legs using one of the patient restraints on the CMRS. ALS pack was repacked and prepared for transport.

Because of the excessive number of patient straps, one could easily be removed on the lower

extremities (without harming the patient) to secure the defibrillator to the CMRS in view of the CMO.

Release of the c-track attachments was not extremely difficult though alignment and rigidity caused problems similar to the ones encountered during deployment.

RESULTS

The node fixture needs restraint and mobility aids to assist the crew during procedures as well as during transport of the patient. Because the node did not contain any handholds or foot loops, the lack of CMO restraints on the CMRS were more obvious. If station-provided restraint and mobility aids were present, they may prove sufficient for the crew's needs during medical protocols.

Approximately 2-1/2 minutes elapsed between discovery of patient and CPR on the CMRS which falls well within the time (4 to 6 minutes) after which brain damage may result though this may have been a faster response than could be expected from the crew. Rescue breathing should be initiated immediately while free floating; then, if time becomes a factor during CMRS deployment, CPR might be required without restraint.

The Barratt CPR restraint was used by two crewmembers. Because one crewmember was more familiar with the technique, he did not experience discomfort while doing chest compressions though he only did compressions for three parabolas before becoming sick. The other crewmember performed CPR for approximately 15 parabolas before switching to the feet high method due to head and neck pain brought on by the CPR restraint device.

Intubation should probably take precedence over IV access since the airway would be insured as well as a route for ACLS drug administration. Since CMO 1 is presently the only crewmember capable of advanced procedures, CMO 1 should perform intubation following the initial three defibrillation attempts of the ACLS protocol (assuming the patient still requires intubation).

CONCLUSIONS

Although the electrocution scenario used on this flight has a low probability of occurrence, it used all of the equipment in a "worst case" situation so was useful in evaluating the MTC hardware and supplies. The assumption was made that if the hardware and supplies can treat the worst case, a less severe medical event could be accommodated by the equipment. Few instances of injury in the space station should result in the need for c-spine immobilization; but, for time considerations as well as CMRS and ALS pack interfaces, the c-collar and KED were used. Once the hardware and supplies are baselined to accommodate the worst case scenario, medical operations will address when and what hardware will be used for each patient.

The technique to perform chest compressions/CPR on space station has yet to be determined. Since the entire crew will be trained in adult CPR and will, therefore, know proper hand placement and depth of compression, will they be allowed to use the method most comfortable to them or will they be trained on a specific technique?

Overall, tasks may not prove as arduous in microgravity as they can be on the KC-135 which has intermittent microgravity as well as negative gravity. On the other hand, the crew

may not be as familiar with the equipment and procedures causing a delay in action.

PHOTOGRAPHS

S91-39849: The crewmember performs one-handed CPR using the ceiling to provide a counterforce to the chest compressions. Because the patient was intubated early on in the code, the crewmember also ventilates the patient with his other hand. Extubation may be a problem in this CPR configuration. CMO 2 sets up the IV administration set while CMO 1 establishes IV access in the patient.

S91-39850: CMO 2 finishes preparing the IV administration set then hands it to CMO 1 who tries to connect the IV tubing to the catheter. While IV access is being established, the crewmember ventilates the patient. Epinephrine has already been administered down the ET tube and 1 minute of CPR for circulation continues.

S91-39851: The crewmember reattaches the ambu bag to the ET to continue ventilating the patient while CMO 1 tapes the IV site and CMO 2 assists.

S91-39858: Because intubation was performed early in the protocol, the crewmember is able to perform one-person CPR though extubation is a concern. Meanwhile, CMO 2 accesses the Airway kit attached to the CMRS snap matrix.

S91-39859: While the crewmember performs one-person CPR, CMO 2 secures the patient's head to the CMRS using the head strap. On the patient's right, CMO 1 positions the defibrillator for use.

S91-39860: CMO 1 ventilates the patient while the crewmember checks for breath sounds to ensure that the ET is in the correct position. As soon as the placement is verified, CMO 1 inflates the cuff using the syringe in her right hand.

S91-39861: Following CMO 1's intubation attempt, the crewmember checks for breath sounds while she ventilates the patient. Also, CMO 2 deploys the defibrillator so that the CMO 1 may check the patient's EKG and determine if defibrillation is necessary.

S91-39862: With the Airway management kit deployed on the CMRS, CMO 1 prepares to intubate the patient while the crewmember continues chest compressions.

S91-39863: CMO 1 hyperventilates the patient to prepare for an intubation attempt while the crewmember performs chest compressions using the Barratt CPR restraint.

S91-39864: CMO 1 hyperventilates the patient to prepare for an intubation attempt while the crewmember performs one-handed chest compressions using the Barratt CPR restraint and a handle on the CMRS.

S91-39865: CMO 1 attempts one-person CPR using the Barratt CPR restraint while CMO 2 tries to tape the BVM to the patient's face. The crewmember secures the patient with the CMRS straps.

S91-39866: CMO 1 performs one-person CPR using the Barratt CPR restraint while CMO 2 prepares tape to secure the mask to the patient's face.

NASA Video 904798.

S91-39851: *Investigator ventilates the patient with the ambu bag.*

S91-39849: *Investigator performs CPR using the ceiling as a counterforce.*

Surgical Overhead Canopy Evaluation

Flight Date:	June 20, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigators:	Smith Johnston, M.D. (KRUG Life Sciences) Roger Billica, M.D. (NASA-JSC) Mark Campbell, M.D. (Consultant) Terrell Guess (KRUG Life Sciences) Elizabeth Richard (KRUG Life Sciences)

GOAL

The systems of the surgical overhead canopy (SOC) to be evaluated are the outside and inside chamber pre-parabolic, zero-g, and component, particulate matter counts; the laminar flow device (LFD) airflow characteristics; the suction and irrigation hardware; the procedure pack and surgical tray; the surgical techniques by simulation on a manikin arm; and the lighting and filming equipment.

OBJECTIVES

1. Determine the functionality and effectiveness of the various component systems of the SOC prototype (which has been designed for operational animal surgery in the microgravity environment).

2. Rehearse techniques and procedures for the animal surgery KC-135 flights to be performed in July 1991.

MATERIALS AND METHODS

SOC

A clear vinyl enclosure approximately 40" x 25" x 20" held in place by a wire frame and containing two pairs of arm ports with sleeves on the sides and a large access door on one end to deliver supplies. This canopy was placed on the HMF prototype MRS.

A support structure inside the SOC which produces a horizontal sheet of laminar airflow across the surgical field after filtration through a 99.997% HEPA filter. It also contains a device that collects the airflow and debris particles after passage over the surgical field and acts as an attachment point for the surgical tray.

Surgical Tray

A 40 cm x 42 cm tray that attaches to the LFD that contains five areas for supplies and instrument fixation: a large magnetic area for securing ferrous instruments, a styrofoam block for sharp objects, and three areas with various size elastic cords for miscellaneous supplies.

Supply Management

A 45" x 55" procedure pack with a sterile field which attaches to the minirack contains various size pockets for storage of sterile instruments and supplies. Minirack (21" x 31" x 54") drawers are used to store nonsterile supplies.

Trash Management

Dry trash was placed in a fishnet device, wet trash in a plastic Ziplock® storage bag and sharp objects in a sharps container. Flypaper areas and disposal pockets were also available inside the SOC.

Surgical Headlights

Two commercial surgical headlights were evaluated.

Suction Devices

The Yankauer, single 2 mm opening and single 1 cm opening tips were evaluated.

Irrigation Devices

The cc syringe with 18-gauge needle, IV tubing with IV pressure bag, and Irrijet systems were used.

Data was acquired by video and audio documentation and in-flight and postflight written questionnaires.

Parabolas 0-5: Recorded particle count readings at initial, middle, and end of descent, and middle of ascent over the five parabolas. Made periodic inside and outside canopy particle count measurements throughout the entire set of parabolas.

Parabolas 6-10: Surgeon and assistant deployed equipment from procedure pack and surgical tray under semisterile technique. Headlights and filming techniques were evaluated.

Parabolas 11-20: Three sets of suction and irrigation equipment were evaluated on various fluids on the surgical manikin arm along with waste management equipment and LFD evaluation.

Parabolas 21-30: Evaluated the procedure pack and surgical tray by simulating surgical techniques on a manikin arm.

Parabolas 31-40: The LFD was tested with various sprays and powders with waste management system evaluation.

RESULTS

The SOC worked extremely well to prevent cabin atmosphere contamination. Fluid and debris were contained and the only leakage occurred through the bottom during the 2g pullout. Although difficult to deploy in prototype form, there was excellent visualization and good operator maneuverability.

The ability to perform standard surgical technique appeared to be no more difficult than in a one-g environment. Suturing and irrigation were not difficult. The important principles appear to be:

System to avoid cabin contamination

Adequate laminar flow and suction pressures

Supply and trash management systems in place

Good restraint of operator, patient and instruments

Adequate lighting system

The particle counts initially were 2600 to 3100 (micrometers/m^3) outside the SOC and 1400 to 2100 inside the SOC, indicating that the SOC can protect the surgical field from a higher particle count in the cabin atmosphere. Counts increased to 4100 to 7700 with the initiation of laminar flow due to the airflow stirring up resident particles. Counts greatly increased to 28,000 to 50,000 after irrigation and to 31,000 to 61,000 after using talc. Counts slowly decreased over the last 10 parabolas due to settling or laminar airflow clearance.

Particle counts were consistently lower outside compared to inside the SOC after using talc. This represents adequate field containment with the cabin atmosphere being protected from contamination by the SOC. Counts outside the chamber were higher than expected. This was attributed to contamination of the probe by unrealistically high talc particle counts. To improve the data from future surgical flights, the following procedures are to be employed with a particle counter.

- Improve the LFD to achieve lower initial inside particle counts and to improve particle clearance.

- After irrigation inside the SOC, obtain particle counts first outside and then inside the SOC to avoid probe contamination. A larger differential would indicate cabin atmosphere protection.

The airflow was easily seen by irrigation droplets and the talc cloud. Turbulence existed with no laminar flow. Poor clearance of talc and irrigant existed. The LFD was deficient in both airflow produced (which can be increased with higher pressure settings) and suction generated (which can also be increased by removing the in line fluid trap). Hardware should be modified to allow some control over flow and suction during flight and to maximize both. The LFD was ineffective probably due to incorrect pressure settings. There was poor particle clearance and turbulent, non-laminar flow. Both flow and suction were inadequate and should be maximized and the hardware reevaluated.

The Yankauer suction tip worked well, while the other suction tips were inadequate. The 60 cc syringe was simple and worked well. No advantage was noted in the more complex irrigating devices. Local control of irrigation did not appear difficult with suction and 4 x 4s and irrigant dispersal was far less of a problem than expected. Irrigant particles that escaped local control were contained well by the SOC, but the LFD was ineffective.

Management of supplies and trash in the SOC were facilitated by the presence of the flypaper areas and the pockets. Access to the surgical tray through the access door did not appear to be difficult. A more secure method of closing the access door is needed. All other deficiencies have been addressed earlier and are corrected on the newer models. Sterile technique appeared to be easy to maintain especially with tighter sleeve elastic on the newer model. Trash management did not show any deficiencies. The flypaper areas and disposal pockets inside the SOC worked well and will be improved when placed centrally on the newer model.

Operator restraint was adequate using the MRS footbar. Waist restraint was absolutely unnecessary. The surgical tray worked well with only an intermittent instrument becoming unsecured. It was easily accessible by the CMOs and the "circulator." A wedge should be added for better stability on the LFD. All the surgical supplies should be prepackaged on the tray to minimize the use of the "circulator." There was adequate space containment and easy organization of instruments.

The sterile procedure pack was easily deployed and secured to the minirack. It provided fast accessibility to sterile instruments with maintenance of the sterile field. Time did not allow for a full evaluation, but instruments and supplies remained secure. By not employing individual sterile wrapping of the supplies, accessibility should be increased. Supply management should be adequate by prepackaging all required items in the surgical trays and having backup items in the minirack (nonsterile) or procedure pack (sterile).

The ability to maintain sterility was not strictly evaluated on this flight, but no difficulties were seen.

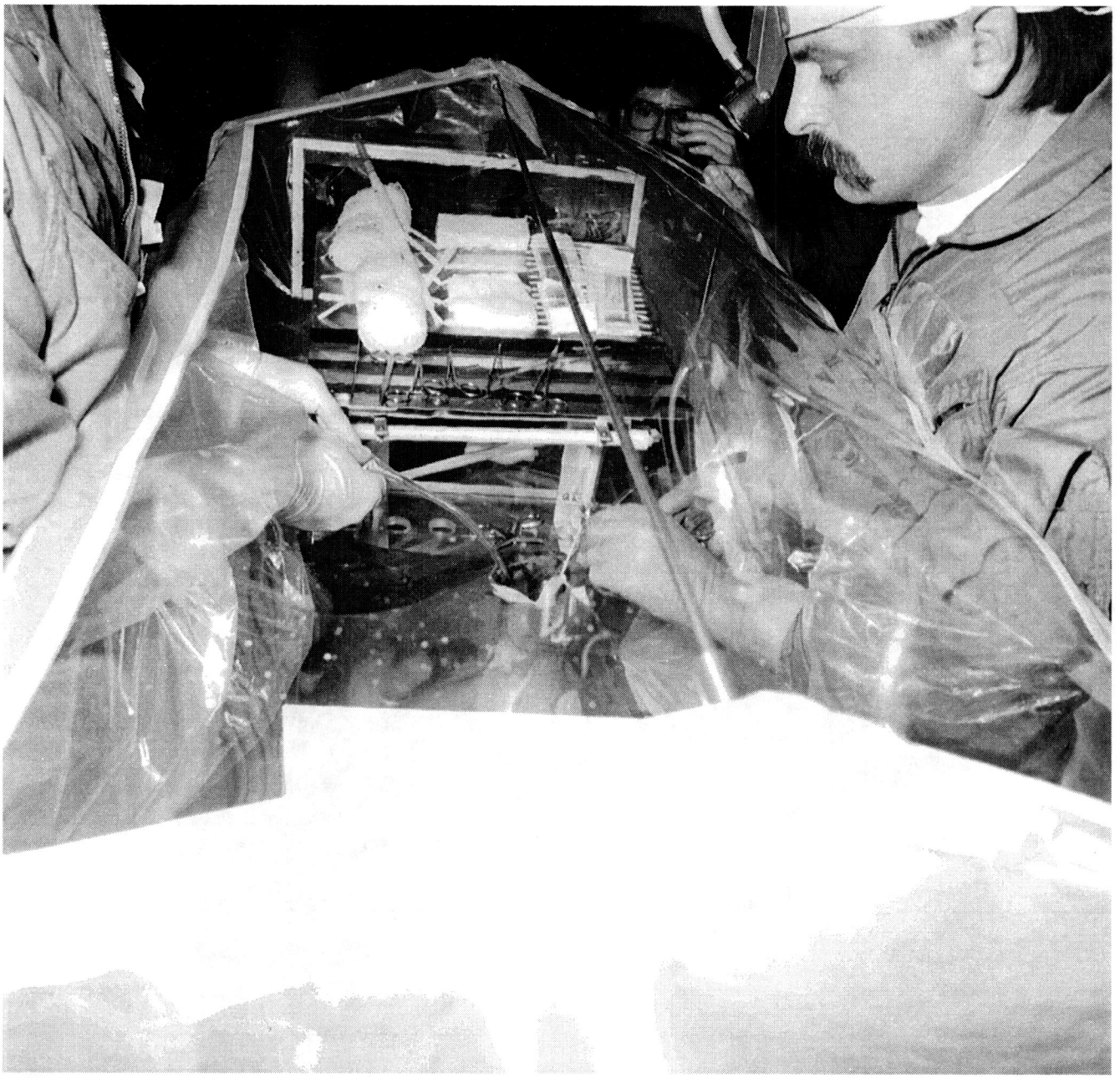
The surgical headlights provided good illumination, but some difficulty occurred with directing the light beam on one unit due to improper setup.

Team coordination will be critical on the upcoming simulations involving animals due to severe time constraints, complex supply and trash management, and difficult communications on the KC-135. Every effort should be made to simplify the simulation.

Photography had good results, especially with the tripod-mounted camera. See photograph section for illustrations.

PHOTOGRAPHS

S91-39754	Irrijet irrigation device
S91-39756	Suturing/LF/Surgical tray
S91-39757	Suturing of manikin arm
S91-39761	Recording particle counts/ Canopy
S91-39764	Yankauer suction tip/surgical tray
S91-39765	Syringe irrigation with 4 X 4
S91-39766	Syringe irrigation with 4 X 4
S91-39777	Canopy/Instruments in Microgravity



S91-39764: *Surgical technique and suction are demonstrated.*

S91-39777: *Surgical instruments float freely within SOC.*

Omni-vent Ventilator Flight Test: Verification of Function in Microgravity and Hypergravity

Flight Date:	July 17, 1991
Principal Investigator:	C. W. Lloyd (NASA-JSC)
Co-investigator:	Michael Barratt M.D. (KRUG Life Sciences) William Norfleet M.D. (KRUG Life Sciences)

GOAL

This test was performed to verify function of the Omni-Vent Series D automated ventilator and the Ohmeda under microgravity and hypergravity conditions.

INTRODUCTION

JSC31013, "Requirements of an In-Flight Medical Crew Health Care System (CHeCS) for Space Station," outlines the requirement and performance specifications for an automated ventilator for space station. The ventilator is to function in critical care delivery at the space station's HMF, in the Hyperbaric Airlock (HAL) during the course of decompression sickness treatment, and in the ACRV in the medical transport role. Inherent in this spectrum of conditions are various environmental factors which might affect ventilator performance. These include wide ambient pressure fluctuations in the HAL, microgravity while on orbit, and hypergravity during the reentry profile of the shuttle or ACRV.

The Stein-Gates Omni-Vent Series D time-cycled ventilator is a candidate to fulfill this role. This is a pneumatically powered, single circuit, constant volume ventilator designed for military field work. Other stated conditions of use include hyperbaric chambers, aeromedical transport, and emergency medical facilities. The KC-135 flight test is complimentary to other evaluations under hyperbaric conditions. All will evaluate ventilator function under a variety of settings such as might be encountered in an actual medical care scenario for space station. In particular, these will include variations in tidal volume (VT), respiratory rate (RR), pulmonary compliance (CL), and airway resistance.

To monitor ventilator function and detect variations resulting from test conditions, a gas flow meter is required in the breathing circuit. For this test, the Ohmeda Volume Monitor, Model 5410 was used. This model uses an expendable turbine vane flow transducer to measure respiratory gas flow. Tidal volume, minute ventilation, respiratory rate, and other data are displayed on a backlit LCD screen. As the Ohmeda flow meter also includes the capability of performing pulmonary function tests, it becomes an attractive candidate for meeting the space station requirement. Evaluation of function under conditions of varying pressure and gravity is necessary for the flow meter as for the ventilator.

To evaluate ventilator and flow meter function, a mechanical test lung was used in the breathing circuit to simulate the volumes, airway resistance, and lung compliance values of the human respiratory system.

MATERIALS AND PERSONNEL

Stein-Gates Omni-vent Series D Ventilator
Ohmeda respiratory flow meter (using internal battery pack)
Dual Adult Training/Test Lung, Michigan Instruments, Inc.
One K-cylinder of compressed breathing air at 2200 psi
Regulator to supply 50 psi operating pressure from gas cylinder
Work table to secure above equipment (2' X 4', flown previously)
3-liter calibration syringe, Hans Rudolph, Inc., flown as stowable hardware
Handheld audio tape recorder

See Figure 15 and appended PMC configuration diagram for hardware/test equipment configuration. Also see included photographs of flight test.

This verification test was designed for single operator performance. The investigator performed several dry runs in the laboratory and in the aircraft prior to flight.

METHODS

Evaluation of ventilator function was planned to require 20 parabolas, and was flown in conjunction with another experiment - *Abdominal Shape in Microgravity*. Should further parabolas have been required regarding ventilator function, they would have been used until evaluation was completed, deferring the abdominal shape study.

The ventilator and test lung were configured for nominal operation with baseline settings of respiratory rate and tidal volume (rate = 8, VT = 1.2 L; lung compliance C_L = 80 ml/cm H_2O). R_p5 resistors were used for test lung tracheal and bronchial airway connections. (Normally, R_p20 resistors would be used in the bronchial airway connections to simulate normal adult settings. Under these conditions, during laboratory dry runs, breath stacking was noted in the test lung at high respiratory frequencies. The use of R_p5 resistors, with larger orifice, allowed for the relatively high respiratory rate tested, ensuring that the test lung cycles would be complete.)

In-flight calibration of the flow meter was performed with the 3-liter calibration syringe prior to entry into parabolic flight. The ventilator was then activated, and settings and function were verified with the flow meter in stable level flight and reassessed under varying gravity conditions. When adequate values had been recorded, test lung and ventilator settings were reconfigured and further assessments were made. The flow meter's reverse flow alarm, which emits an audible tone upon sensing a reverse flow of 50 ml, was activated. Data were obtained for at least two complete parabolic maneuvers for each configuration. The proposed flight test plan is given below.

Parabola	Action
Level flight	Calibrate flow meter using 3-liter calibration syringe, delivering measured volume of 2 liters.
1-5	Measurements using baseline configuration (V_T = 1.2 L, rate = 8 bpm, C_L = 80 ml/cm H_2O) during zero and 2g.

6-10	Reconfigure to V_T = 1.2 L, rate = 8 bpm, C_L = 20 ml/cm H_2O. Turnaround recalibrate flow meter using 3-litre calibration syringe
11-15	Reconfigure to V_T = 1.2 L, rate = 30 bpm, C_L = 80 ml/cm H_2O
16-20	Reconfigure to V_T = 1.2 L, rate = 30 bpm, C_L = 20 ml/cm H_2O

Experimental Conditions

Cabin pressure: nominal 12.5 psi with +/- .5 psi tolerance.

Cabin altitude: nominally 5000', flux up to 7000', depending on throttle position.

Temperature: 76 - 77°F (24.4 - 25°C).

Gas operating pressure: 43 psi via gauge.

RESULTS

See separate data matrix sheets for respiratory flow meter readings and calibration values. Both observed values and mean values are presented with respect to the parabola in which they were performed. Values were recorded only during stable periods of micro- or hypergravity.

Calibration of the Ohmeda flow meter was performed in level flight at altitude and in stable microgravity and hypergravity. Level flight results demonstrate consistency within repeated values and with ground observations. Switching turbine transducers during the calibration made no significant difference. Each calibration involved a measured delivery of 2 liters of ambient air directly to the transducer. Bear in mind that the Ohmeda's calibration is based on respiratory gas at body temperature, 98.6°F. From calibration curves supplied in the Ohmeda manual, the observed value may be translated into a temperature corrected value. The correction factor for 76°F is approximately 0.9318; for 77°F, 0.9288. After consideration of these correction factors, the Ohmeda consistently reads 5 - 7% high. These values remain within specifications, which define an accuracy of +/ - 8% or +/- 40 ml, whichever is greater.

Calibrations performed in stable micro- and hypergravity on the eighth parabola both showed a consistent increase in measured V_T, by about 50 ml. Calibrations performed during the 17th parabola during micro- and hypergravity are more consistent with the level flight values.

The initial stabilized settings (V_T = 1.2 L, rate = 8 bpm, C_L = 80 ml/cm H_2O) were maintained during stable microgravity, generally within 20 ml. During periods of stable hypergravity (generally 1.7 g, 5-10 second periods), stable V_T was also noted, although at a slightly higher level (1.25 - 1.27). A consistent observation during this and all configurations was a tendency to read a lower V_T during entry into the parabola (variable, but down to 700 ml) and higher during the initial pullout into hypergravity (variable, up to 1.4). Decreasing test lung compliance to 20 (V_T = 1.2 L, rate = 8 bpm, C_L = 20 ml/ cm H_2O) was accompanied by a consistent but stable increase in V_T from 1.20 to 1.25 liters. Respiratory rate was well maintained at 8 bpm throughout.

As the ventilator was adjusted for the higher respiratory frequency (V_T = 1.2 L, rate = 31 bpm stabilized, C_L = 80 ml/cm H_2O), an increase in the measured V_T was noted. This quickly stabilized at 1.35 liters. In lieu of immediate time constraints, this was taken as a new baseline for the high frequency evaluation. The mean measured V_T in this configuration

remained within 40 ml, with the exception of the 12th parabola readings. As these are progressively increased, it is suspected that parabola entry or unstable microgravity influenced their values. Reconfiguring to the lower compliance setting (V_T = 1.2 L, rate = 31 bpm stabilized, C_L = 20 ml/cm H_2O), measured VT remained within 40 ml of 1.35 with the exception of the 15th parabola during hypergravity. These values are seen to be progressively decreasing and are probably influenced by unstable hypergravity. Respiratory rate was again well maintained at 31 +/- 1 bpm.

DISCUSSION

It is apparent that evaluation of the ventilator depends on the nominal functioning of the gas supply, flow meter, and test lung. Under stable microgravity and hypergravity, the measured V_T was seen to remain within the 40 ml specification limit of the Ohmeda flow meter. Ventilation rate was well maintained at all settings, and no significant effect of compliance on V_T was observed. An increase in V_T, from the original 1.2 to 1.35 liters, was seen to correspond with increasing respiratory frequency from 8 to 31. This did not occur in preflight dry runs and is assumed to be the result of inadvertent changes in the V_T or flow rate settings. These are very sensitive control inputs and may have been altered during the configuration change.

The varying V_T readings associated with parabola entry and pullout probably resulted from numerous factors including flux in ambient cabin pressure and its influence on the test lung bellows, mechanical effects of variable gravity on the test lung, lift/drag changes on the transducer turbine due to pressure swings, and mechanical effects of variable gravity on the transducer. The net effect of these influences is difficult to predict. What was observed was lower V_T readings corresponding to transition to decreased gravitational force and decreased cabin pressure. Some of the variability was reproduced in the lab postflight by delivering 2-liters of calibration gas through the meter erratically; this caused an over-reading of the volume and varied with the irregularity and particularly the number of "stops"; the more stops and restarts, the higher the measured volume. Lower measured volumes could not be reproduced by varying calibration flow rate or pattern. These represent conditions that would not be expected in the stable microgravity environment. They would, however, warrant consideration for the evacuation scenario of a ventilated patient aboard an orbiter or the ACRV proposed for space station.

CONCLUSIONS

The Omni-vent ventilator and Ohmeda respiratory flow meter appear to function within specifications for stable microgravity conditions and stable hypergravity conditions in the range of 1.7 - 2.0 g's. Erratic measurements of V_T are observed during periods of unstable g's and variable ambient pressure. Evaluation of ventilator function is constrained by performance of the flow meter and mechanical test lung under these conditions. It is suggested that further evaluation of candidate ventilators for space station be performed during parabolic flight with a more physiologically correct model, such as an intubated animal. This could perhaps be accomplished in conjunction with a future surgical evaluation.

PHOTOGRAPHS

S91-42754 and S91-42787: Investigator records comments on the tape recorder. The Omni-vent ventilator, Ohmeda flow meter and test lung are on the test stand.

S91-42785: Investigator checks the equipment before beginning the tests.

S91-42786: Investigator calibrates the flow meter with a 3-liter calibration syringe.

Table 1. Ventilator Flight Test

Condition		2 Liter Cal.	Comp.	Rate	Vt Ohmeda	Notes
LEVEL		2.27,2.28,2.3	80	8	1.20,1.21,1.20,1.20	
LEVEL		2.27,2.28,2.29,2.27	80	8	1.20,1.21,1.22,1.21	
PARAB	/ G					
1	0		80	8	1.20, 1.17,1.17	rev flow alrm
1	2		80	9	1.40, 1.23, 1.2	rev flow alrm
2	0		80	8	0.99,0.93, 0.90	loop entry
2	2		80	8		
3	0		80	8	1.20,1.17,1.23	erratic at
3	2		80	9	1.25,1,25, 1.25	entry/pullout
4	0		80	8	1.20, 1.20, 1.20	readings
4	2					
5	0					
5	2					
6	0					
6	2					
7	0		20	8	1.21,1.25,1.25,1.25	lower values
7	2					on entry;
8	0		20	8	1.25, 1.25, 1.25	higher values
8	2	2.31,2.31,2.35				on pullout
9	0	2.31,2.32,2.31				
9	2					
10	0		20	8	1.17,1.21,1.25	
10	2		20	8	1.30,1.31,1.25	
11	0		80	31	1.35,1.38,1.39	
11	2		80	31	1.38,1.40,1.39	
12	0		80	31	1.24,1.27,1.32	
12	2					
13	0					
13	2					
14	0		20	31/30	1.35,1.37,1.40	Rev Flow alrm
14	2		20	30/32	1.33,1.42,1.40	
15	0		20	30/32	1.28,1.35,1.36,1.35	
15	2		20	30/32	1.46,1.42,1.35	
16	0					
16	2					
17	0	2.27,2.29,2.28,2.29				
17	2	2.28,2.29,2.27,2.29				
18	0					
18	2					

Table 2. Flight Test Means

Condition	2 Liter Cal.	Comp.	Rate	Vt Ohmeda	Notes
LEVEL	2.283	80	8	1.202	
LEVEL	2.278	80	8	1.21	
PARAB / G					
1 0		80	8	1.18	rev flow alrm
1 2		80	9	1.276	rev flow alrm
2 0		80	8	0.94	loop entry
2 2		80	8		
3 0		80	8	1.2	erratic at
3 2		80	9	1.25	entry/pullout
4 0		80	8	1.2	readings
4 2					
5 0					
5 2					
6 0					
6 2					
7 0		20	8	1.24	lower values
7 2					on entry;
8 0		20	8	1.25	higher values
8 2	2.32				on pullout
9 0	2.313				
9 2					
10 0		20	8	1.21	
10 2		20	8	1.287	
11 0		80	31	1.373	
11 2		80	31	1.39	
12 0		80	31	1.277	
12 2					
13 0					
13 2					
14 0		20	31/30	1.373	Rev Flow alrm
14 2		20	30/32	1.382	
15 0		20	30/32	1.335	
15 2		20	30/32	1.41	
16 0					
16 2					
17 0	2.283				
17 2	2.283				
18 0					
18 2					

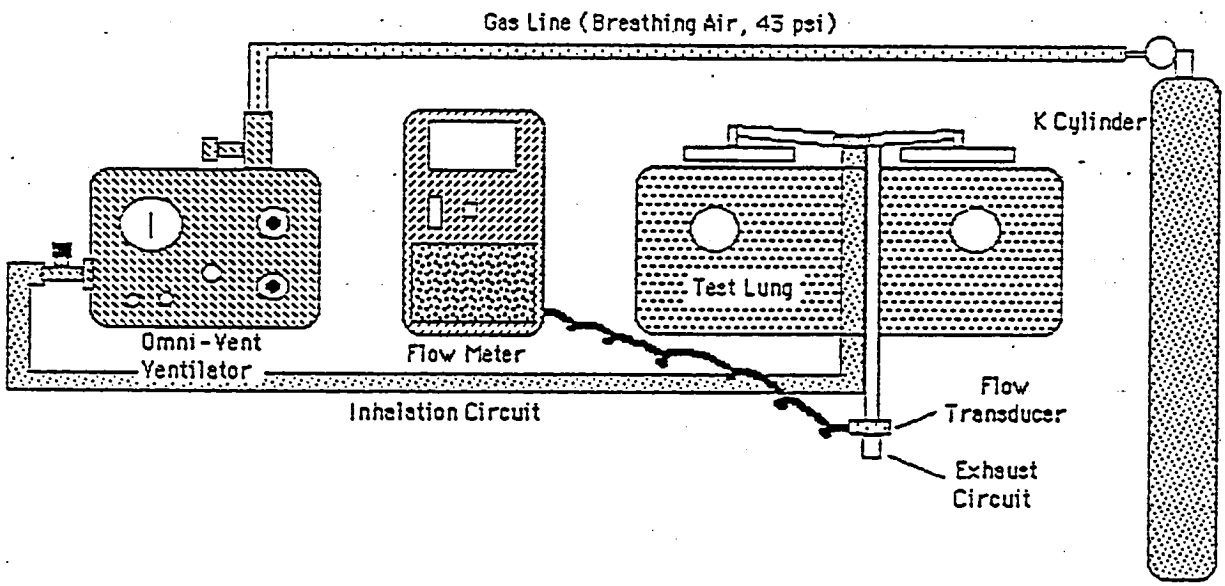


Figure 15. Ventilator Test Configuration.

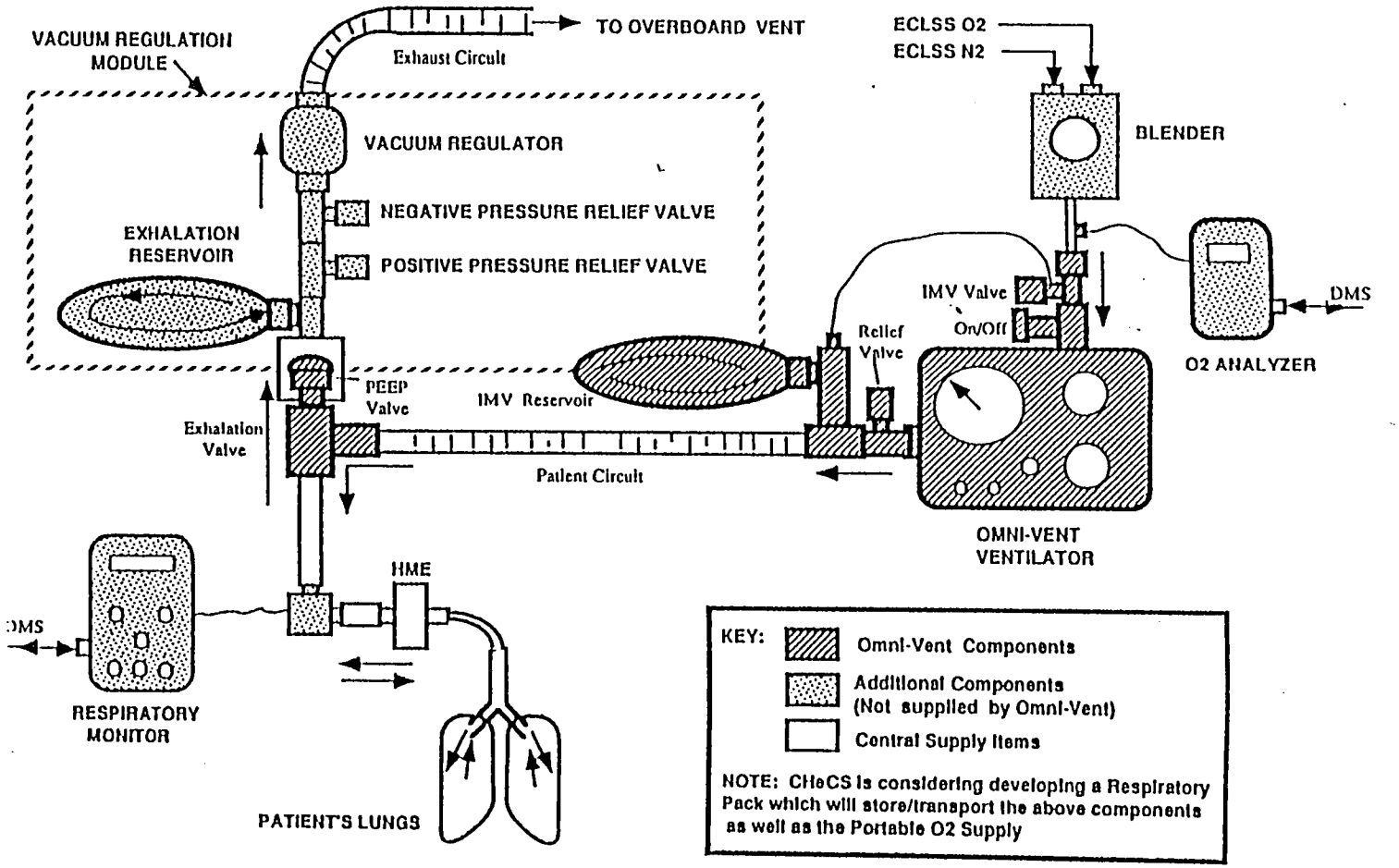
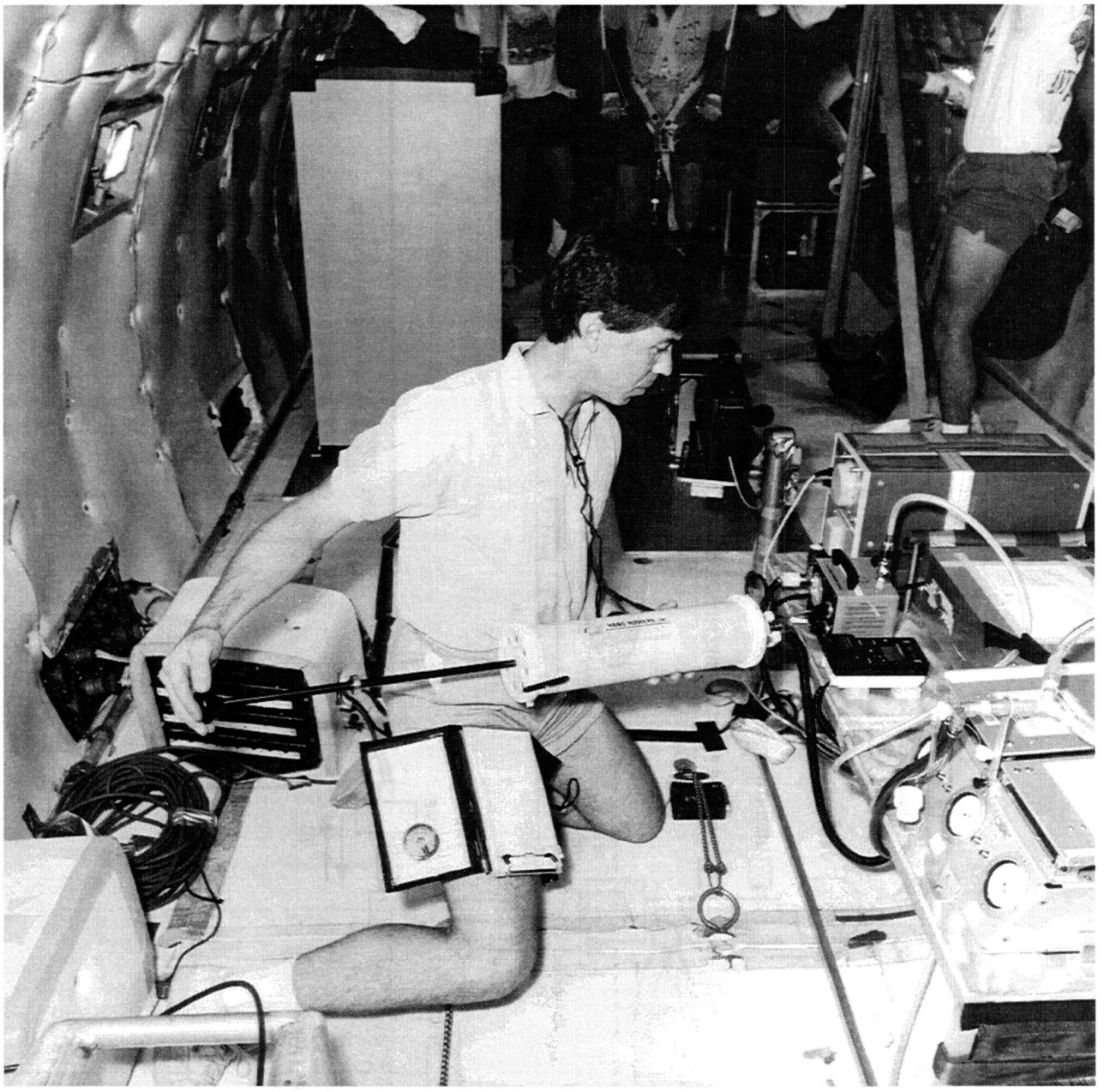


Figure 16. Omni-vent Ventilator System Components
(PMC Configuration)



S91-42786: *Investigator calibrates the flow meter with a 3-liter calibration syringe.*

Animal Surgery in Microgravity

Flight Dates:	July 17 - 19, 1991
Principal Investigators:	Roger Billica, MD (NASA-JSC)
Co-investigators:	Mark Campbell, MD (Consultant) Smith Johnston, MD (KRUG Life Sciences)

GOAL

The purpose of this flight was to evaluate the feasibility of developing a more realistic surgical simulation by using an animal model for the first time in a micro-gravity environment.

OBJECTIVES

1. Observe venous and arterial bleeding in microgravity for the first time and evaluate the ability to control bleeding and prevent cabin atmosphere contamination.

2. Evaluate wound closure using staples followed by removal of staples.

3. Evaluate:

   - Operator, patient, and instrument restraint
   - The ability to perform standard surgical techniques
   - The ability to maintain sterile technique
   - Sterile supply management
   - Trash management
   - SOC
   - LFD
   - The MRS
   - The surgical tray
   - The procedure pack
   - The surgical headlight
   - Suction/irrigation techniques

INTRODUCTION

Surgical procedures were performed on adult, albino New Zealand rabbits weighing approximately 4 kilograms and sedated with a cocktail consisting of ketamine, xyloxine and acepromazine at 0.5-0.7 ml/kg. Animal anesthesia and care were initially handled by the St. Joseph Surgical Training Lab animal care technician (Marcia Walters), and monitoring and maintenance was then transferred to the surgeon during the flight. Also in attendance were Dr. John Young, Dr. Richard Jennings, and Dr. Mike Barratt. On two of the flights, IV

access was available to further support the animal with normal saline volume and epinephrine. Ground consultation pre- and postflight with Dr. Leslie Yarborogh, D.V.M. was used. An exploratory laparotomy was performed with incision and repair of the renal artery and abdominal aorta followed by abdominal wall closure. Venous bleeding was evaluated using mesenteric vein incision and ligation. Neck exploration and carotid artery incision and repair were also used to examine arterial bleeding. The wound was closed by either suture or staples. Staple removal was also evaluated. Standard surgical techniques and sterile field maintenance protocols were followed on all procedures. The principals of operator, patient, and supply restraint were used and evaluated. The MRS was the focal point for all restraint. Operator restraint was achieved by a horizontal foot bar alone.

MATERIALS

SOC

The canopy is a clear vinyl enclosure approximately 40" x 25" x 20" held in place by a wire frame and containing two pairs of arm ports with sleeves on the sides and a large access door on one end to deliver supplies. It was placed on the HMF prototype MRS.

LFD

This device is a support structure inside the SOC which produces a horizontal sheet of laminar airflow across the surgical field after filtration through a 99.997% HEPA filter. It also contains a device that collects the airflow and debris particles after passage over the surgical field and acts as an attachment point for the surgical tray.

Surgical Tray

This 40 cm x 42 cm tray attaches to the LFD and contains five areas for supplies and instrument fixation: a large magnetic area for securing ferrous instruments, a styrofoam block for sharp objects, and three areas with various size elastic cords for miscellaneous supplies.

Supply Management

This 45" x 55" procedure pack with a sterile field attaches to the minirack and contains various size pockets for storage of sterile instruments and supplies.

The minirack (21"x31"x54") is a rack of drawers for storage of nonsterile supplies.

Trash Management

Dry trash was placed in a fishnet device, wet trash in a plastic Ziplock® storage bag and sharp objects in a sharps container. Flypaper areas and disposal pockets were also available inside the SOC.

Surgical Headlights

Two commercial surgical headlights were evaluated.

Suction Device

Yankauer

Irrigation Device

60 cc syringe with 18-gauge needle

METHODS

The protocol over the three consecutive 40 parabolic flights had been carefully orchestrated by three ground and one KC-135 flight rehearsals and was changed very little. The deviations from the preflight preparation and in-flight surgical procedure was kept to a minimum. This was required in part by the time constraints of only 17 minutes of microgravity during the 40 parabolas, and also because of the use of high-speed video photography for capturing the arterial bleeding and laminar flow characteristics of the experiment.

The animals were delivered by the St. Joseph Surgical Training Lab animal care technician and Dr. Leslie Yarborogh, D.V.M. for preflight anesthesia and loading on board the KC-135. The animals were secured to the MRS and the SOC was erected and made functional during pre-parabolic flight. The surgical exploratory laparotomy with incision and repair of the renal artery and abdominal aorta followed by abdominal wall closure was initiated and completed on each flight.

The only deviations included:

- The addition of a continuous IV infusion of normal saline for adequate hydration of the animals during the second and third flights. (Initiated at the preflight).
- The addition of a surgical stapling evaluation by Richard Jennings and Mark Campbell on day two.
- The laceration and repair of the abdominal aorta added to the protocol on the final flight for evaluation of arterial bleeding.
- The particle count readings that were made periodically inside and outside the SOC throughout the entire set of parabolas on the first flight.

RESULTS

Rigid adherence to the principal of restraint of operator, patient and equipment allowed simplification of all aspects of the procedure. Standard surgical technique and maintenance of sterile technique appeared to not be more difficult than in one-g. Better sterile field maintenance could have been achieved by having the surgical tray opposite the access door and by having a surgical chamber with a floor. The method of operator restraint using the MRS foot bar alone was found to be superior to previous harness restraints.

A system of sterile supply management consisting of prepackaging most supplies on the sterile surgical tray and using a rack-mounted procedure pack as a sterile "back table" was found to be important. The procedure pack was used to store additional sterile supplies and was easily accessible by a circulating nurse who delivered the items to the surgical field through the access door of the SOC. It was found that restraint of the circulating nurse was also necessary. A simple method of restraining supplies close to the operative site (sterile bungee cord) would have been useful.

A trash management system consisting of a styrofoam block for sharp disposal, flypaper areas inside the SOC for small items, and pockets inside the SOC for wet and dry articles was adequate. A more sophisticated system will need to be developed for final disposition of trash items.

Greater care had to be used in opening the abdomen compared to one-g as the bowel does not fall away with the introduction of air into the

abdominal cavity, but instead continues to press against the peritoneum. Bowel evisceration was not a problem and abdominal wall closure was not difficult. Wound closure with staples and staple removal were without difficulty.

Venous bleeding pooled at the operative site and showed no tendency to disperse. In fact, dislodging the pooled blood into the atmosphere was found to be difficult. Local control methods (sponges and suctioning) were adequate. Subjectively, it appeared that the amount of venous bleeding was increased compared to one-g. Arterial bleeding occasionally formed a stream of droplets which traveled until stopped by the wall of the SOC. Creating the formation of the stream was difficult, as it was usually disrupted at the wound and formed a large fluid dome. This is thought to be due to the increased significance of surface tension in a microgravity environment. Local control methods were adequate except when a droplet stream formed momentarily.

In general, cabin atmosphere contamination could be prevented with local methods (sponges and suctioning) alone, unless an arterial droplet stream formed. The SOC contained arterial streams and irrigation fluids that escaped due to splattering.

DISCUSSION

The SOC functioned well in protecting the cabin atmosphere from contamination and also facilitated the maintenance of a sterile field. It provided a simple method of trash management through the use of pockets and flypaper areas. There were no difficulties in operator maneuverability or visualization. Access to the surgical field through the supply door was adequate, although not optimal due to the position of the surgical tray. This could be improved by attaching the tray to the wall of the SOC opposite the access door. Particle counts inside the SOC were logarithmically decreased.

The LFD was effective in keeping the surgical field clear of surgical debris, cauterization fumes and fluids but could not prevent arterial bleeding from escaping. The suction funnel should be more efficiently designed and the suction flow increased. Better control of the height, angle and intensity of the flow is necessary on any future modifications.

The surgical tray allowed excellent restraint and organization of instruments and supplies on a sterile field. Prepackaging the majority of instruments and supplies with the tray was important in simplifying the set up of the procedure. A variety of restraint options (magnetic, elastic and Styrofoam) and the presence of the 30° tilt was useful. Having a sterile back table (procedure pack) allowed the storage of additional sterile supplies that, although not immediately needed, could be accessed quickly.

The surgical headlights produced adequate illumination but needed to be smaller and with less cumbersome fiber-optic cords.

The suction tip needed an on/off control, an angled neck and a sterile tubing sleeve (to prevent breaks in sterile technique). The suction/irrigation system was simple and efficient.

CONCLUSIONS

The use of an animal model is extremely helpful in the realistic evaluation of procedures and hardware. Due to the large surface tension forces present, arterial and venous bleeding forms large fluid domes that can be controlled by local methods such as sponges and suction-

ing. This should be adequate to prevent cabin atmosphere contamination. An SOC would be necessary in situations where it would be likely to encounter a large amount of arterial bleeding, irrigation fluids or purulence.

Restraint of operator, patient and all equipment allows the ability to maintain a sterile field and to use standard surgical techniques. A supply management system and a trash management system are essential components to efficiently perform a procedure. Staples provide a simple and fast method of wound closure.

The SOC protects the cabin atmosphere in situations where local control methods would fail, such as the momentary formation of an arterial droplet stream. It also is valuable in lowering the particle count of the operative environment, acting as an attachment point for supplies and trash disposal and facilitates the maintenance of a sterile field. A valuable modification would be a surgical tray area incorporated into the wall of the canopy. The LFD keeps the surgical field clear and lowers the particle count of the operative environment. Future prototypes of both should be smaller in weight and volume, easier to deploy and more adaptable to true clinical situations.

PHOTOGRAPHS

S91-42758: Preparing workstation.

Neg. VPS 21: Syringe in right hand with incision made; bowel partially exposed.

Neg. VPS 5: Gauze in right hand, incision just made.

Neg. VPS 34: Suturing.

Neg. VPS 32: Exploring cervical region.

Neg. VPS 39: Cervical region.

Neg. VPS 31: Cervical region.

Neg. VPS 17: Syringe in right hand, bowel extended, suction in right hand.

S91-42796: Exploring the bowel.

Neg. VPS 35: Suturing the neck.

Neg. VPS 29: Suturing the abdominal area.

Neg. VPS 28: Suturing the abdominal area.

Neg. VPS 20: Retracting bowel.

Neg. VPS 24: Completion of suturing.

Neg. VPS 37: Reaching for the LFD and cervical exploration.

Transport Aspirator Separation and Containment Concept

Flight Date:	July 18, 1991
Principal Investigators:	C. W. Lloyd (NASA-JSC)
Co-Investigators:	Linda Murphy: (MDSSC) Lawrence Caselilni (Umpqua Research Company) Ted Lunsford (Umpqua Research Company) Neil Streech (Umpqua Research Company)

GOAL

The purpose of this flight was to evaluate a new concept for the separation and containment of air/fluids/solids for the transport aspirator, a component of the Space Station CHeCS HMF.

OBJECTIVES

1. Evaluate the maximum collection capacity of the separation/containment units in microgravity.
2. Evaluate the efficiency of separation/collection of various viscosity fluids.
3. Evaluate the efficiency of collecting various air/fluid mixtures.
4. Evaluate separation/containment units' outlet port sealing mechanisms, which are designed to activate when the cartridge is full.
5. Evaluate the possibility of the unit design indicating amount of fluid contained.
6. Evaluate unit performance when used with powered and manual vacuum pumps.

INTRODUCTION

The KC-135 parabolic flight test followed the standard protocol of 40 parabolas with 20-25 seconds of microgravity at each apex.

The separation/containment units were connected upstream to a fluid source and downstream to a vacuum source. The fluids suctioned were yogurt, 75% yogurt/25% cottage cheese, pudding, and water. The vacuum source was either a mechanical medical suction unit or a piston hand-pump. A V-Vac medical manual suction pump was also used for two parabolas. Fluids were suctioned into the test units until the units reached maximum storage capacity and fluid was present at the unit outlet port. Fluid at the outlet port was indicated by loss of fluid flow due to activation of the outlet port sealing mechanism (designed to activate when fluid reached the outlet port) or observation of fluid exiting the port.

The transport aspirator provides suction and collection/containment of biological fluids from an ill or injured crewmember. The transport aspirator suctions fluids and solids from the upper and lower airways and supplies sustained suction of the chest. Aboard space station, the transport aspirator may be operated during medical emergencies away from the HMF, during hyperbaric treatments, and during transport to Earth in a rescue vehicle.

The CHeCS plans to modify a commercial transport aspirator to meet space station flight hardware requirements. Since all commercial transport aspirator designs incorporate air/liquid separators which are gravity dependent, CHeCS plans to replace the commercial separator with a new technology, gravity independent design. A passive (non-powered) separation/collection unit design is preferred due to hyperbaric operation safety concerns.

The prototype separation/collection units tested on the flight were developed by Umpqua Research Company. The units use a variety of materials to passively "capture" any fluids/solids suctioned into the unit. The small test units have an interior volume of 230 ml, which roughly consists of 10 ml of actual matter and 220 ml of void volume. Therefore, a unit which captures fluids with 100% efficiency should use 95% of its total volume. (Actually, a small percentage of the void volume is dedicated to providing an open air/fluid path.)

MATERIALS AND PERSONNEL

Umpqua Research Company Support Rack: This support rack was used as a worktable.

Cooler Chests: Three cooler chests were used to store test equipment and as seats for the investigators.

Separator Test Units: See Appendix B for the dimensions of the small and large test units. The middle of the cylinder case of the small test unit was clear plastic which permitted viewing of the unit's interior. The ends of the large test units were clear plastic and permitted viewing; the cylinder case was a white plastic. Both sizes had the same type and arrangement of internal materials.

Test Fluids

IV Bags: Two bags each stored 1 liter of water colored with food coloring for enhanced visibility

Container Bowls: Each bowl stored approximately 150 ml of one of the following fluids blueberry yogurt, 75% blueberry yogurt mixed with 25% cottage cheese (small curd), and Swiss Miss pudding (vanilla or chocolate). The fluids were chilled to maintain their normal viscosity.

Vacuum Pumps

Laerdal Suction Unit: Battery powered (also accepts 120V power) medical suction unit with free air flow of 27 L/min and maximum vacuum of 600 mm Hg.

Mityvac hand vacuum pump: 35 cc/stroke piston pump with maximum vacuum of 635 mm Hg.

V-Vac: Manual medical bellows pump, which also provides one-g separation and containment.

IV Stat: This device was used to pressurize the IV bags filled with water.

Tubing: Tygon® tubing was used to connect the various pieces of equipment. The water feed line was 1/8" ID and the remaining fluid feed lines were 5/16" ID

Bungee Restraints

Trash Containers

Towels

Video Camera

Three investigators supported the flight and had the following responsibilities: one person suctioned the fluids, a second person operated/controlled the vacuum source, and a third person provided dedicated video. Test data were collected by a fixed mount video camera, dedicated video, and individual audio recordings.

METHODS

Test Set Up/Fluid Flow

Fluids Other Than Water: With Laerdal Suction — An operator controlled one end of a piece of tubing to suction fluid (and air) from open containers. The suctioned air/fluid mixture traveled through the tubing to the inlet of a small separation/collection unit. The unit "captured" the fluids and solids while the air passed through the unit to its outlet port. At the outlet port, a second piece of tubing routed the air to the inlet of a backup separation unit. (This unit provided protection to the vacuum pump in the event any fluid flowed through the main unit.) A third piece of tubing connected the backup separation unit outlet to the vacuum source. The vacuum source was controlled/operated so that vacuum was provided only during the microgravity portions of the flight. All tubing was 5/16" ID Tygon® tubing.

With Mityvac Suction, the same set up was used except the second piece of tubing and the backup separation unit were eliminated.

Water: The IV bag with water was pressurized by the IV STAT and hand pressure to force water to flow into 1/8" ID outlet tubing. The end of the outlet tubing loosely fit into a 5/16" ID line. The loose fit allowed water and air to be suctioned into the 5/16" tubing. The suctioned air/fluid mixture traveled through the tubing to the inlet of a large separation/collection unit. The fluid path from the separation/collection unit to the vacuum source (Laerdal) is the same as that described in "Fluids Other Than Water."

Tests Performed:

Unit A: Suctioned yogurt into small test unit with the Laerdal

Unit B: Suctioned yogurt/cottage cheese into small test unit with Mityvac

Unit C: Suctioned yogurt/cottage cheese into small test unit followed by vanilla pudding with the Laerdal

Unit D: Suctioned remaining vanilla pudding from Unit C test followed by chocolate pudding into small test unit with Mityvac

Unit E: Suctioned yogurt into small test unit with V-Vac

Unit W1: Suctioned water into large test unit with Laerdal

Unit W2: Suctioned water into large test unit with Laerdal

RESULTS

NOTE: See Appendix A for a matrix of the test results.

Unit A

Suctioned yogurt into small test unit with the Laerdal: Unit A separated and collected yogurt suctioned from two containers. With the first container, large volumes of air were suctioned while refining the microgravity suction technique. Yogurt was quickly suctioned out of middle of the container. The yogurt remaining on the walls was not influenced by the vacuum source unless in direct contact with it. With the second container, straight yogurt was initially suctioned; increased volumes of air were suctioned as the yogurt volume decreased. The pump pulled about 200 mm Hg while suctioning the first container. The pump was pulling 450 mm Hg when we realized (by vacuum application to only the test unit) that the unit outlet sealing mechanism had activated. Shortly before the unit sealed, we observed yogurt

toward the end of the fluid collection path. No yogurt exited the test unit.

Analysis after the flight indicated that 199.8 ml of yogurt had been contained by Unit A. This was 87% of the interior volume of the unit.

Unit B

Suctioned yogurt/cottage cheese into small test unit with Mityvac: Unit B separated air from and collected approximately 1 1/2 containers of yogurt/cottage cheese. As with the second yogurt container above, straight fluid was initially suctioned, followed by increased suctioning of air as fluid volume decreased. Chunks of fruit in the yogurt and the cottage cheese curds flowed well. Slugs of fluid were suctioned when the first container was almost empty. The pump was manually operated as fast as the return spring allowed. The pump would peak at about 250 mm Hg and fall back to about 100 mm Hg. Flow was lost and vacuum application to only the test unit verified that the unit outlet sealing mechanism had activated. The pump pulled 600 mm Hg against the sealed unit. Shortly before the unit sealed, we began observing yogurt at the end of the fluid collection path.

Analysis after the flight indicated that 194.5 ml of yogurt/cottage cheese had been contained by Unit B. This was 85% of the interior volume of the unit.

Unit C

Suctioned yogurt/cottage cheese followed by vanilla pudding into small test unit with the Laerdal: Unit C separated air from and collected all of the yogurt/cottage cheese from one container followed by about 3/4 of a vanilla pudding container. The viscous pudding was suctioned somewhat slower than the yogurt. The pump pulled about 225 mm Hg while suctioning the yogurt/cottage cheese. Suction increased to 450 mm Hg while suctioning the yogurt. The sealing mechanism of this unit did not activate and allowed a small volume of pudding to exit the test cartridge. Shortly before the yogurt broke through, we observed a few patches of yogurt at the end of the fluid collection path.

Analysis after the flight indicated that 203.8 ml of yogurt/cottage cheese and vanilla pudding had been contained by Unit C. This was 89% of the interior volume of the unit.

Unit D

Suctioned remaining vanilla pudding from test Unit C followed by chocolate pudding into small test unit with Mityvac: Unit D quickly separated air from and collected the remaining 1/4 container of vanilla yogurt from test Unit C followed by a full container of chocolate pudding. Large volumes of air were suctioned. The pump would peak at about 350 mm Hg. Time was not available to suction additional fluid so the test unit never reached its maximum capacity. No pudding was observed at the end of the fluid collection path.

Analysis after the flight indicated that 135.6 ml of pudding had been contained by Unit D. This was 59% of the interior volume of the unit.

Unit E

Suctioned yogurt into small test unit with V-Vac: Unit E was set up to separate air from and collect suctioned yogurt. The vacuum source used was the V-Vac. However, the V-Vac initially had to suction pudding, which was in the suction line from the previous test. The pump could not pull enough vacuum to move the pudding with one expansion of its bellows,

and the pump did not have a check mechanism to provide increased suction from additional pump strokes. Since another suction line was not available, this test was discontinued.

Unit W1

Suctioned water into large test unit with Laerdal: Unit W1 separated air from and collected water supplied from the pressurized IV bag. The loose fit of the water supply line to the suction line resulted in approximately 75% of the mixture being air. The pump pulled about 150 mm Hg. The test unit had material left off its end so that the fluid collection path was visible. When approximately 1/3 of the total liquid suctioned had been collected by the unit, wicking action began pulling captured liquid somewhat out of the collection path. (Umpqua noted that this issue can be resolved.) When approximately 1/2 of the visible fluid path contained water, water was observed exiting the test unit. Apparently, the sealing mechanisms had not been effective.

Analysis after the flight indicated that 740.3 ml of water had been contained by Unit W1. This was 90% of the interior volume of the unit.

Unit W2

Suctioned water into large test unit with Laerdal: Unit W2 separated air from and collected water supplied from the pressurized IV bag. Tape was applied around the loose fit of the water supply line to the suction line to reduce the amount of suctioned air to about 10%. The fluid collection path was not visible with this unit. Water became visible at one side of the top of the unit. The water had spread to over 1/3 of the top area when water was observed exiting the test unit. Again, the sealing mechanism had not been effective.

Analysis after the flight indicated that 568.3 ml of water had been contained by Unit W2. This was 69% of the interior volume of the unit.

CONCLUSIONS

The prototype separation/collection test units performance was excellent. The units which suctioned the higher viscosity fluids (those other than water) used between 85% and 89% of the interior volume of the separation/collection test units and up to 95% of the void volume. The units which suctioned water used 57% and 90% of the test unit interior volume.

The units maintained high efficiency collection with varying viscosity fluids, even the worst case low viscosity water. The solids (fruit in the yogurt and cottage cheese curds) which were mixed with the fluids were also separated out and did not appear to degrade test unit efficiency.

The test units' outlet port sealing mechanism requires refinement to activate consistently for all fluids. The sealing mechanisms activated properly in two out of five units tested to capacity. The mechanisms in both of the water units failed. Umpqua has indicated that the mechanism is a very preliminary design which can easily be improved.

With refinement, the separation/collection units should be able to indicate the volume of fluid collected. (Graduations could be added along the fluid collection path to indicate volume.) Although only minimal viewing was possible with the small test units, they provided a clear indication that the unit was approaching maximum capacity. The material at the end of the fluid collection path began filling with liquid shortly before each unit reached maximum capacity. The large water test units provided

poor indication of fluid volume collected. Volume indication problems included wicking and lagging indication of the actual volume captured. Umpqua has indicated that the wicking can be prevented. Additional work is required to force the fluid to fill the full face of the fluid collection path before any fluid is collected further along the path.

Umpqua testing indicates that the units can be compacted to 20% of their initial volume. This feature appears to make Space Station storage of the units feasible. Total transport aspirator collection volume required per medical event has not yet been determined.

Test unit performance was consistent whether vacuum was supplied by a mechanical or manual pump.

Overall, the performance of the prototype separation/collections units was excellent. They are a prime candidate for transport aspiration air/fluid separation flight hardware development. Medical Sciences is considering the possibility of using the units with manual suction to provide medical suction at MTC.

PHOTOGRAPHS/VIDEO

S91-42773: Suctioning with Test Unit A

S91-42774: Suctioning with Test Unit B

S91-42792, S91-42793: Suctioning with Test Unit C

NASA Video

906128: (Non-dedicated)

Dedicated Video

Zero-G Transport Aspirator Fluid Separation
Confidential (Original copy stored at CHeCS.)

APPENDIX A

Test Unit Containment Matrix

CARTRIDGE	FLUID COLLECTION	PRE-TEST CARTRIDGE WEIGHT (g)	POST-TEST CARTRIDGE WEIGHT (g)	WEIGHT OF CONTAINED FLUID	VOLUME OF CONTAINED FLUID (g)	VOLUME OF CONTAINED FLUID (g)	VOLUME OF CONTAINED FLUID (g)	COMMENTS
A	Yogurt	117.2	331	213.8	199.81	230	87	Full cartridge
B	Yogurt Cottage Cheese	117.1	325.2	208.1	194.49	230	85	Full cartridge
C	Yogurt/ Cottage Cheese + Pudding	117.7	335.8	218.1	203.83	230	89	Broke through cartridge outlet
D	Pudding	116.6	265.8	149.2	135.64	230	59	Suctioned < cartridge capacity
W1	Water	329.1	1069.4	740.3	740.30	824	90	Broke through cartridge outlet
W2	Water	333.5	901.8	568.3	568.30	824	69	Broke through cartridge outlet

Note:

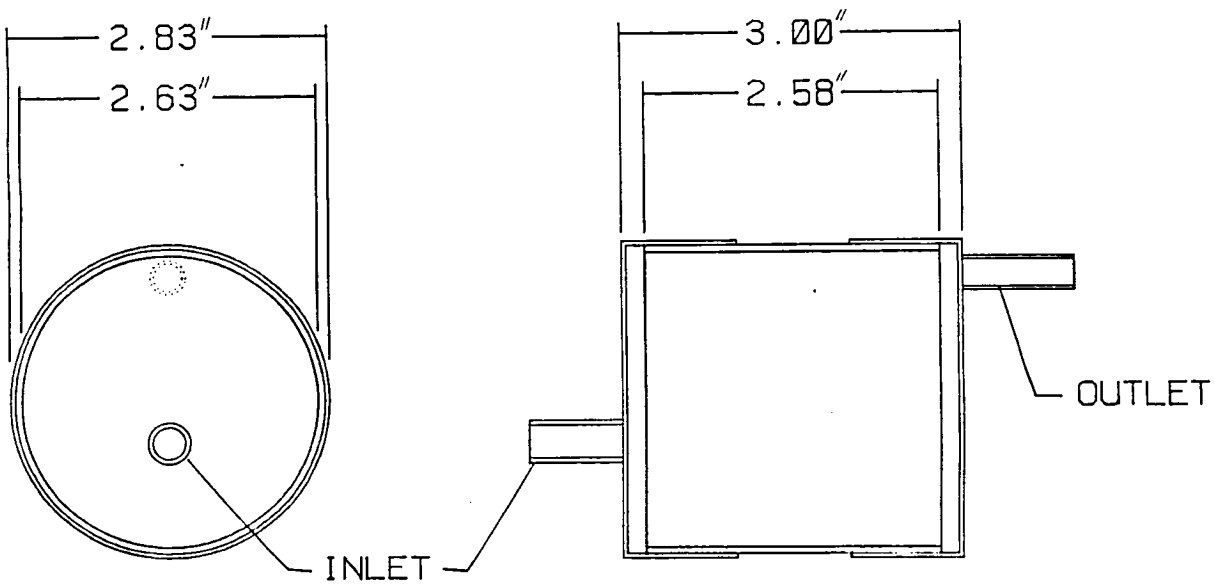
Water Density = 1.0 g/ml

Yogurt and Yogurt/Cottage Cheese Density = 1.07 g/ml

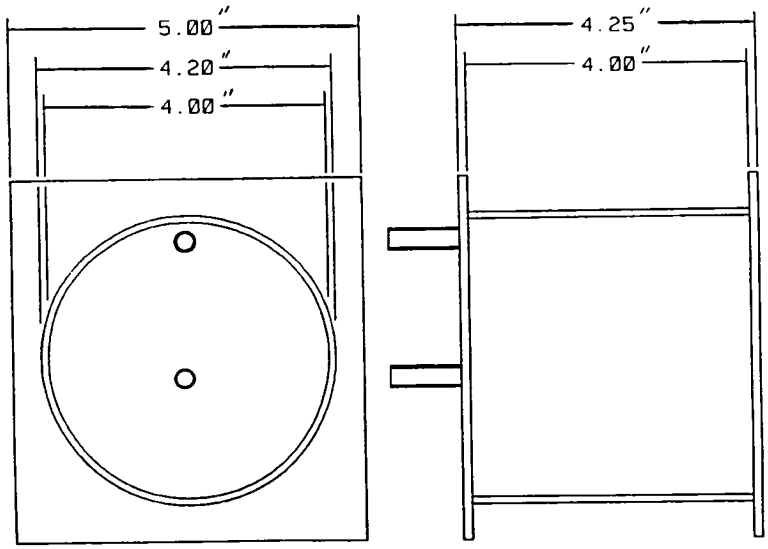
Pudding Density = 1.10 g/ml

APPENDIX B

Separation Units Dimensional Diagrams



KC-135 Flight Aspirator Separation Containment Unit



4-inch Zero-g Separation and Containment Test Unit

Aerosolized Medications During Parabolic Flight Maneuvers - Phase 2: Glove box

Flight Date:	August 15, 1991
Principal Investigator:	C. W. Lloyd, Pharm. D. (NASA-JSC)
Co-investigators:	William J. Martin, Pharm.D. (St. John Hospital, Mt. Clemens Michigan) Debra Orsak (MDSSC) Charles R. Doarn (KRUG Life Sciences)

GOAL

The purpose of this flight was to determine if using an aerosolizing device to administer medications is an acceptable method of drug delivery in a microgravity environment.

OBJECTIVES

1. Compare patterns of spray dispersion under control one-g and zero-g conditions.
2. Determine the total available quantities of drug for each delivery system under control one-g and zero-g conditions.
3. Close examination of the spray dispersion of the Albuterol spray during parabolic flight using high-speed film photography.

INTRODUCTION

This proposal outlines a procedure designed to evaluate the utility of selected aerosolized medication devices under zero-g conditions during KC-135 parabolic flight. Results obtained from this experiment will be extrapolated to the situation of a continuous microgravity environment, such as aboard SSF. There is concern that such devices may not consistently deliver the manufacturer's preset quantity of drug per unit of use (i.e. inhalation, puff, nozzle depression) under zero-g conditions. The current draft of the HMF pharmaceutical formulary contains three aerosol preparations: Benzocaine 20% (topical anesthetic), Albuterol (bronchodilator), and Nitroglycerin (vasodilator).

MATERIALS AND PERSONNEL

Benzocaine 14%, Butyl Aminobenzoate 2%, Tetracaine Hydrochloride 2% topical Anesthetic Spray (**Cetacaine**), manufactured by Cetylite Industries. Average expulsion rate is 200 mg per second (Quantity = 3 bottles). 56 gm net weight. Also contains benzalkonium chloride 0.5% and cetyl dimethyl ethyl ammonium bromide 0.005%. Lot 299-4, Exp Date 6/91.

Microcrystalline suspension of Albuterol Inhaler (**Ventolin®**) 17 gm, Allen & Hanburys, Division of Glaxo Pharmaceuticals, 200 metered inhalations, 90 mcg/actuation (Quantity = 3). Also contains trichloromonofluoromethane and dichlorodifluoromethane. Lot Z13679HA, Exp Date 2/92.

Sodium chloride 0.65% (**NaSal, Nasal moisturizing mist**) 15 mL, Winthrop Consumer Products, Division of Sterling Drug Inc., **Fine Nasal Pump.** Also contains benzalkonium chloride, Thimerosal 0.001% as preservatives, mono and dibasic sodium phosphates as buffers, and purified water. Lot S001FJ, Exp Date 8/92 (Quantity = 2).

Sodium chloride 0.65% (**NaSal, Nasal moisturizing spray**) 15 mL, Winthrop Consumer Products, Division of Sterling Drug Inc., **Squeeze Bottle.** Also contains benzalkonium chloride, Thimerosal 0.001% as preservatives, mono and dibasic sodium phosphates as buffers, and purified water. Lot B319FL, Exp Date 10/93 (Quantity = 2).

Glove box and supporting stand

Velcro® material to secure drug products

Flat black absorbent cloth to line inside of glove box

Bungee cord to secure investigator in flight

Duct tape

Cleaning solution and towels

Hand-held tape recorder

A number of people and organizations were involved in the conduct of this experiment. Three investigators were on board during the flight and a seat was dedicated to a high-speed video.

The flight team included Charles Lloyd, Charles Doarn, and Debra Orsak. Debra Orsak worked in the glove box, spraying each of the different containers of drug. Charles Doarn and Charles Lloyd assisted in recording all anomalies during the flight and assisting both Debra Orsak and the photographer.

METHODS

1. Shake pressurized container well

2. Hold the device in the appropriate orientation for administration of the drug product and depress the plunger (command given by photographer) to provide one to two actuations.

3. Positioning of the device by the investigator working in the glovebox will be determined preflight and marked inside the box. The high-speed photographer shall determine the proper positions.

4. Repeat above procedure x 3 for each drug.

5. Camera specs for preflight testing performed in building 8, JSC, photography studio (August 9, 1991):

SHUTTER	FPS	SIZE (mm)	CAMERA VIEW
140°	250	25	Closeup of spray
140°	250	18	Wide view of spray and bottle

6. All spray devices to be used on the KC-135 were tested first holding the device in the upright position and then upside down. For the nasal squeeze/pump devices, the containers were also tested in a horizontal position.

7. Still photographs will be taken prior to the flight on the aircraft and in flight.

8. In-flight procedures per parabola:

   P1 THOUGH P8:

   Evaluate the Ventolin® inhaler (VI) in the upright and upside-down, configuration.

   NOTE: THE SECOND CAMERA CONFIGURED TO SHOOT THE CLOSE UP OF THE SPRAY SHOULD ALSO BE COMPLETED AT THIS TIME.

P9 THROUGH P16:

Evaluate the Chloraseptic spray container in the right side up and upside-down configurations using three different filled containers.

P17 THROUGH P24:

Evaluate the nasal pump spray container in the upright, upside-down, and level configurations using 2 different filled containers.

P25 THROUGH P32:

Evaluate the nasal squeeze bottle container in the upright, upside-down, and level configurations using two different filled containers.

P33 THROUGH P40:

Evaluate the Cetacaine bottle in the upright and upside-down configuration with three different filled containers.

The experiment required the full width of the plane and was situated in the forward section of the plane stretching nearly 12 feet in length.

RESULTS

Projected

It is believed that the aerosols will perform properly until the pick-up stem of the canister begins to contain air/fluid mixture secondary to the micro-g environment. Afterward, the output should become erratic and not deliver a full dose of medication.

Preflight (one-g testing) Results - July 9, 1991

Hand positioning is critical to be able to see both the bottle and the spray.

The Windex bottle was determined to be too large. We decided to use Chloraseptic mouth spray (an over-the-counter drug product) which comes in a clear bottle and requires the use of a pump spray.

Three fill volumes were used for the testing: FULL, HALF FULL, and 1/8 FULL. These fill volumes should identify the most likely problems with the use of these devices in microgravity.

All spray devices must be in the glove box prior to the start of the flight. Velcro® will be used to secure the bottles to the walls of the glove box behind the foam platform.

A hand-held tape recorder will be used to note which bottle was being used per parabola for better postflight editing of the film.

Retesting in the studio was required since the wide-angle view did not have the operator's hand in focus. The retesting will be completed 1 week before flight.

When the Cetacaine spray bottle was turned upside down and actuated, it failed to function properly as soon as the pick-up straw emptied. The VI fails to spray properly within two puffs when operated upside down. The pump spray and standard spray bottles are also positional dependent and fail quickly when operated in the improper position.

August 14th Studio and Ground Results

Follow-up studio high-speed filming was completed August 9, 1991. This testing followed the in-flight procedures. Retesting was required because that the entire view of filming was not in focus. Bottles used were the VIs, finger pump, nasal squeeze, and Cetacaine spray devices. The internal layer and hand position of the box was discussed.

The supplies required for flight were reviewed and restraint systems identified. Velcro restraints were placed inside the box behind the foam block used for hand positioning. Velcro was also placed on the bottom of all in-flight bottles and in the glove box.

Clear VIs were available for the flight. The bag marked Lot 314-51A - FULL, was used. Only two of the five bottles appeared to be full, one was about 1/2 full and two appeared to be nearly empty. One of the full bottles was used prior to the flight for camera placement and calibration. The height of the solution in each bottle was determined to be 13 mm (FULL), 8 mm (1/2 FULL), and 5 mm (NEARLY EMPTY). These measurements were determined by placing a ruler next to the bottle sitting on a table and noting the fill level. The glass base of the bottle was included in these measurements.

Three Chloraseptic bottles were purchased for in-flight testing. The glass bottles contained a blue aqueous solution and used a standard pump spraying device with a pick-up straw which went straight down to the bottom of the bottle. Bottle 1 was marked FULL and contained 184 mL of solution. Bottle 2 was marked 1/2 FULL and contained 92 mL. Bottle 3 was marked NEARLY EMPTY and contained 46 mL. Only two fill levels were deemed necessary for the nasal pump and squeeze devices:

NASAL **PUMP** FULL:	15 mL
NASAL **SQUEEZE** FULL:	15 mL
NASAL **PUMP** 1/2 FULL:	7.5 mL
NASAL **SQUEEZE** 1/2 FULL:	8.0 mL

To estimate the fill volume for the Cetacaine bottles, the volume as it was shipped was defined as FULL and fluid was sprayed from two other bottles to represent the 1/2 FULL and NEARLY EMPTY volumes. The measurements were FULL: 46 mm, 1/2 FULL: 23 mm, and NEARLY EMPTY: 12 mm.

Immediately prior to the flight the high-speed cameras were calibrated and still photography was completed of all flight articles.

August 14th - In-Flight Results

Parabola Set 1: During the filming and testing of the clear VIs, Charles Doarn shot standard video. During this set, both close-up and wide-angle high-speed filming was completed for the VIs and the Chloraseptic finger-pump devices. The Nearly Empty VIs failed to function. Both the Full and 1/2 Full VIs appeared to function properly in the normal configuration and upside down. Each time the V I was tested, it was first primed during zero-g, actuated twice, shaken, and then actuated upside down twice. High-speed film ran out during parabola 5, and commenced again for parabolas 7, 8, and 9. During these parabolas, the three different volumes of the Chloraseptic bottles were filmed. All three fills functioned properly in the upright position. However, it was noted during parabola 8 that the 1/2 FULL Chloraseptic bottle failed after several actuations in the upside-down configuration. There was no activity during parabola 10. The lowest volume in the Chloraseptic bottles appeared to be sufficient to allow the system to function properly.

Parabola Set 2: Camera malfunction occurred on parabola 11; however, the system was functional the next parabola and high-speed filming was completed for the nasal pump and squeeze bottles. We were also able to film some of the Cetacaine bottles during this set. The nasal pump bottles appeared to function normally in all positions (upright, horizontal, and upside down). Both the FULL and 1/2 FULL volume bottles were actuated two to three times in each position. Since these bottles are opaque, it was not possible to determine what was occurring inside the bottles. The FULL Cetacaine bottle was filmed in the upright and upside-down positions. After 2 to 3 seconds in the

upside-down position, the pick-up straw lost its prime and the system failed to function. This container appeared to function only slightly better in the upside-down position during zero-g, versus this configuration in one-g.

Significant negative g's were noted during this set. On several occasions the spray nozzle of the Cetacaine bottle came off the bottle during the zero-g portion of the parabola causing us to have to repeat the test. Still photography of the Cetacaine bottles was completed during parabola 20.

Parabola Set 3: Still photography was completed during the first three parabolas of the set. The 1/2 FULL volumes were used. Starting with parabola 24, the Cetacaine bottles were filmed. In each case the device failed to function when placed upside down. It is not unclear if the Cetacaine spray lasted longer upside down in zero-g when compared to one-g. Also during this set, the Chloraseptic bottles were filmed again. They all appeared to function properly in the upright position and failed in the upside-down position.

Parabola Set 4: All the clear bottles were refilmed during this set. Film ran out during parabola 37 and the experiment was terminated.

CONCLUSIONS

After an in-depth review of the photography, it was determined that the Cetacaine spray device and the VIs functioned the most effectively. Some containers worked better in the upright configuration when compared to the upside-down configuration. Failure of the Cetacaine spray bottle in the upside-down configuration did not occur as quickly as was expected. In general, the pick-up straws in the Cetacaine spray bottles functioned well even when challenged with a foamy solution. If the bottle had been upright, activated and reversed, the pick-up straw would probably have continued to function properly. The VIs appeared to display a proper plume of spray with most actuations. It is believed that proper function of the VIs is a direct result of the internal mechanism.

It was determined that the nasal pump squeeze devices worked "normally," independent of the position. It must be noted, however, that in the upside-down configuration, these devices do not work whether in a one-g or zero-g environment. The rate of failure seemed to depend on fill volume. Performance of the FULL containers was more optimal than performance of the NEARLY EMPTY containers. This does not take into account erroneous actuation malfunctions that occurred, no matter the fill level or position of the device.

The high-speed film turned out to be poor. In most cases, it was either too grainy or out of focus. Since there were no margins accounted for, the hand position and bottles could not be seen. Also since there was a need to transfer the data from film to video, at least 1/2 to 1 inch margins would be lost in the transfer. This was partly because of inflight shifting of the table. Future photography of this type work would be improved by using a blue background, improving side and back lighting, ensuring that margins are sufficient for the viewing of critical functions, and improving methods of restraint for the test stand.

It is recommended that actual samples be obtained of selected drug products supplied in these types of delivery systems to ensure that the proper amount of drug product is delivered in zero-g. Specific drug products recommended to be sampled would include Albuterol and nitroglycerine since they both specify a specific amount of drug product delivered per actuation. It would be ideal to rerun this experiment

to obtain better high-speed photography of the spray devices and the fluid dynamics of these systems.

REFERENCES

1. Biomedical findings during the Apollo Program.

2. Lloyd CW, Martin WJ, Gosbee J. Evaluation of aerosolized medications during parabolic flight maneuvers. Medical Evaluations on the KC-135 1990 Flight Report Summary, NASA Technical Memorandum 104740, 83-96.

PHOTOGRAPHS

S91-44494: Three vials of Cetacaine filled to different levels: FULL, 1/2 FULL and NEARLY EMPTY. The containers are in the glove box.

S91-44495: Two containers of NaSal Moisturizing Spray and two containers of NaSal Moisturizing Mist are located in the center of the glove box.

S91-44496: Three containers of Chloraseptic filled to different levels: FULL, 1/2 FULL and NEARLY EMPTY. The containers are in the glove box.

S91-44497: Four VIs, containing albuterol are In the glove box. The inhalers are filled to different levels: FULL, 1/2 FULL and NEARLY EMPTY.

S91-44498 and S91-44499: The test stand as it appears on the KC-135. At the right is the glove box, where all the spraying was done. Investigator sprays a bottle into the glove box. At the right the high-speed video camera records the events.

S91-44503: Investigator sprays a clear VI into the glove box.

S91-44504 and S91-44505: Investigator actuates the Cetacaine into the glove box. The aerosolized stream can be seen in the foreground to the left.

S91-44506, S91-44508, S91-44509, S91-44510, and S91-44511: Investigator actuates the Chloraseptic into the glove box. The aerosolized stream can be seen in the foreground to the left.

S91-44507: Investigator prepares another VI for actuation.

High Speed Film

S91-020: This reel contains the first studio testing preflight. The film has a soft focus however, there are some good shots of the spray devices.

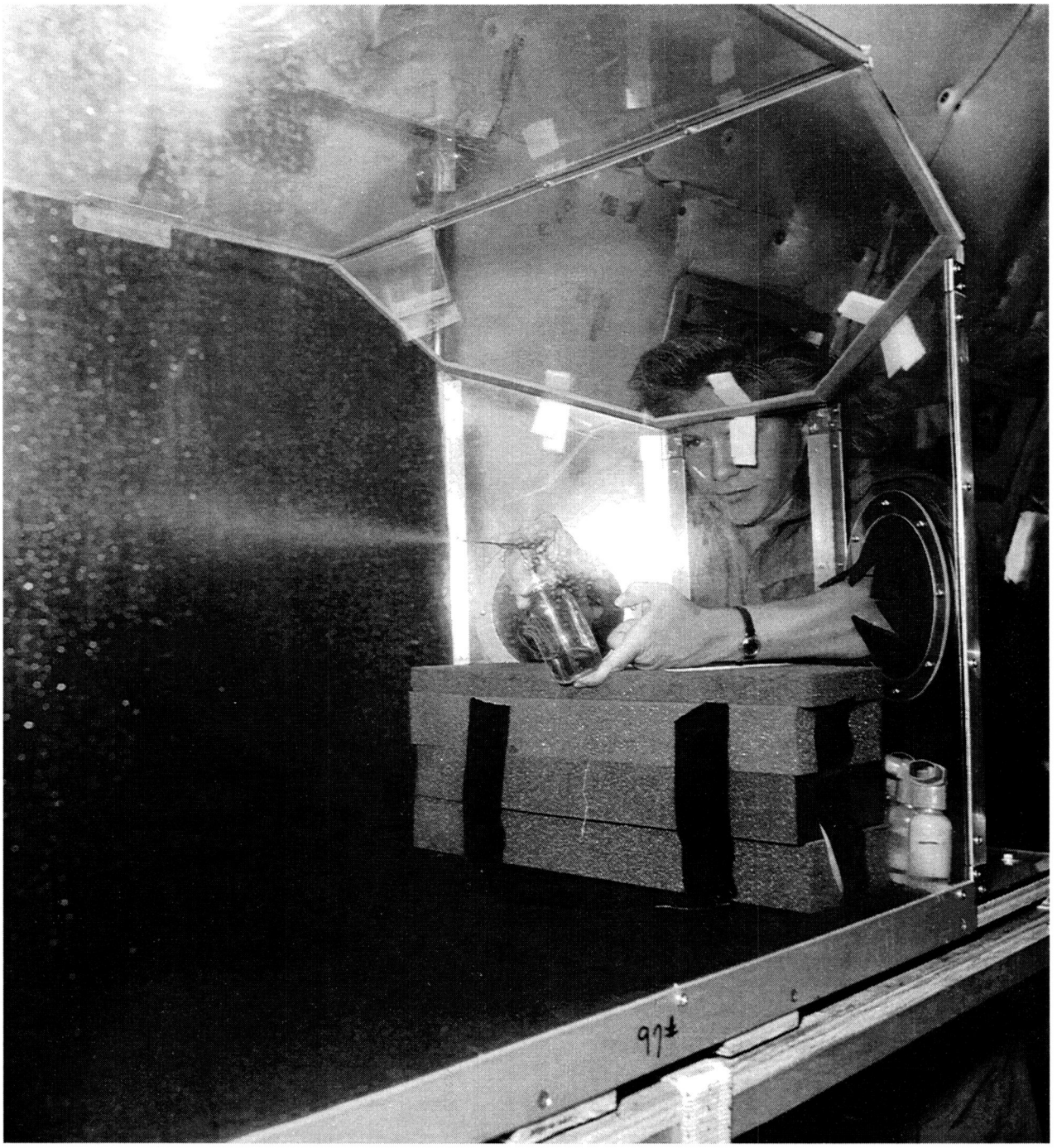
S91-021: This reel is a continuation of Day 1 studio testing. This reel is all close-up photography of the sprays and must be compared to S91-020 which shows the devices being sprayed.

S91-029: This reel contains the second day of studio testing. Soft focus.

S91-030: This is the first of three reels from the KC-135 flight test. Reel 1 contains footage of the VIs. Since the glove box shifted early in the flight, very little of the devices and the hand can be seen.

S91-031: Reel 2 from flight contains footage of the other spray devices (Cetacaine, pump and squeeze bottles). Footage is in focus but the hand and bottles cannot be seen.

S91-032: Reel 3. No specific comments noted.



S91-44505: *Investigator sprays Cetacaine into the glove box.*

Advanced Cardiac Life Support Protocols for Microgravity Conditions Using Man-Tended Capability Health Maintenance Facility Equipment

Flight Dates:	August 15 - 16, 1991
Principal Investigator:	C. W. Lloyd, Pharm. D. (NASA-JSC)
Co-Investigator:	Michael Barratt, M.D. (KRUG Life Sciences) Maureen Smith, EMT (KRUG Life Sciences)

GOAL

Along with evaluation of the modified Advanced Cardia Life Support (ACLS) protocols, the flight test was designed to assess functionality of the MTC HMF hardware as an integrated critical care system.

OBJECTIVES

1. Determine the effectiveness of ALCS protocols modified for the microgravity environment.
2. Determine the effectiveness of the current generation MTC CMRS when used during ACLS activity.
3. Evaluate the second generation ALS pack as used during a cardiac arrest.
4. Evaluate the interfaces between the CMRS and the equipment.
5. Evaluate the trash generated from opening packaged equipment, considering content and immediate management.

INTRODUCTION

The capability for delivery of ACLS on space station at the MTC phase has been set forth as a medical requirement in JSC 31013, "Requirements of an In-Flight Medical Crew Health Care System (CHeCS) for Space Station." Hardware is currently being assembled and developed to this end. To ensure this requirement, crew capability must be equal to that of the hardware and integrated system. It is clear from recent flight experience (Orbiter and KC-135) that standard ACLS protocols will require modifications for the microgravity environment. In particular, procedures that nominally require gravitational forces, such as chest compressions, necessitate alternative means of delivery. Adequate restraint of the patient and CMO has been shown to be a limiting factor in ACLS performance during parabolic flight. The order in which certain procedures are performed, such as endotracheal intubation, IV line access, etc., requires reevaluation in lieu of the environment, personnel, and hardware availability. This will involve integration and testing of new hardware and system components using analogous crew sizes and medical scenarios most likely to be encountered on space station.

Training level for the CMO for space station has not been finalized, and degree of proficiency in ACLS delivery is as yet unclear. As such, development of set reference protocols for ACLS unique to the microgravity and space station environment is mandatory. ACLS protocols designed to accommodate the microgravity environment were developed based on past flight experience, one-g simulations, and committee input from representatives of the HMF, Flight Medicine, and Astronaut offices. The two test flights served to evaluate the modified ACLS protocols using a complete package of chosen flight medical equipment.

MATERIALS AND PERSONNEL

A low fidelity mockup of the space station Node 2 floor constructed and flown on previous flight experiments was used. This was fitted with c-tracks for variable positioning of restraints and equipment and afforded appropriate dimensionality and size constraints.

Adjustable soft restraints were fashioned of nylon webbing for this flight to provide handholds and footholds at various positions along the c-tracks.

A single minirack representing a one-time configuration of CHeCS MTC hardware stowage was used for this flight.

The current generation soft CMRS was flown. This contains fasteners to articulate along the c-tracks and secure the CMRS to the floor of the node.

CPR restraints are dedicated restraint systems to provide the rescuer with a way to deliver effective compressive force during CPR. For this flight, the restraint system currently baselined for use on the Orbiter middeck was modified to fit the CMRS. In addition, an active restraint system was used that included bungee cords to provide elastic recoil force to compensate for the lack of gravitational force in delivering chest compressions.

The baselined configuration of the ALS pack contains medications, IV supplies, airway management equipment, and other diagnostic and management accessories necessary to deliver ACLS.

The PhysioControl Lifepak 10 defibrillator, selected for use aboard space station, was flown without its battery pack, rendering it unable to deliver an electrical current. Defibrillator pads and leads were used without alterations.

The portable oxygen supply consists of a small cylinder maintained in a soft pack capable of providing 1 hour of flow at 10 liters/minute.

The ventilation mask currently baselined for Orbiter CPR delivery, consisting of a standard face mask attached to a fabric and elastic head restraint system, was used. (The mask in the current ALS pack contains an intrinsic head restraint system.)

CPR manikin

Adequacy of chest compressive force and ventilation volume was displayed aurally and visually. Other procedures capable of being performed on the manikin include endotracheal intubation, IV infusion, gastric tube placement, and bladder catheterization.

Ventilator

Although part of the original hardware manifest, the ventilator was not flown. It has been determined that it would not be used during the actual arrest protocol.

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METHODS

A simulated medical emergency involving cardiac arrest was presented to three representative crewmembers, who were to initiate ACLS procedures. The patient was translated to the HMF site and the appropriate medical hardware deployed from the CHeCS rack, secured, and used as needed. This included the current CMRS, ALS pack, defibrillator (Lifepak 10), ventilator, and CPR restraint device. Simulated patient responses were called out by a test director. An ACLS manikin capable of assessing adequacy of compressions and ventilations via audio and visual displays was used. All activity took place only during the microgravity phase, with ACLS procedures "held in position" during pullout and climb phases. A running time log kept track of zero-g elapsed time. Activities were continued to the point of stabilization and transport to the Orbiter or ACRV for evacuation from space station.

Equipment for the procedures was deployed from the CHeCS miniracks used on previous flights.

The test protocol centers on the modified ACLS protocol for ventricular fibrillation (Vfib). The American Heart Association (AHA) protocol for Vfib is shown in the appendix. In this scenario, the acute priorities are

- rapid defibrillation for Vfib or pulseless ventricular tachycardia (Vtach)
- continued effective CPR with establishment of secure airway and 100% O_2
- epinephrine, repeatedly/as needed in dose to maintain coronary and cerebral perfusion

Along with past flight experience, several operational assumptions were made in generating the test protocol.

- 4-man crew: CMO is not an EVA crewmember.
- Victim is not the only CMO (one or two CMOs).
- All crewmembers are adequately trained in CPR.
- Only CMO is adequately skilled in rhythm recognition, IV and intubation skills.
- Maximum medical training at paramedic level.
- As cervical spine injuries are much less likely in microgravity and cervical stabilization is time-intensive, defer unless known or highly suspected c-spine trauma.
- Specialized ACLS protocols will exist, with at least CMO and ground monitor trained.
- Ground should have protocols available at all times.
- No defibrillation is to occur unless victim positioned on CMRS, due to insulation concerns.
- No defibrillation is to occur unless all crewmembers restrained clear of CMRS; assuming body fluids are saturating CMRS and rendering it conductive.
- Ventilator will not be employed on a patient without established vital signs. Deployment and configuration of the ventilator for use is time-intensive, and manual pulmonary resuscitator delivers adequate ventilations.

Test Protocol for Vfib in Microgravity
Patient responses denoted by **

1. Time Zero, witnessed arrest, audible awareness of event, or crew alerted audibly upon discovering crewmember; medical emergency is declared.

2. First crewmember to reach victim assesses airway, breathing, circulation—if witnessed or time definitely known recent—check pulse.

   - If no pulse, crewmember is backed against nearest hard, safe surface and precordial thump is delivered.

** ***no pulse, respiration***

   - Ventilations delivered, free flying.

   - Other crewmembers to HMF, immediately destow CMRS and begin securing; defibrillator and O_2 are destowed and positioned.

   - Free-flying CPR (e.g. Heimlich-type) delivered until CMRS secure.

3. When CMRS secure, one crewmember leaves to help translate victim to HMF.

   - Other crewmember remains at CMRS and readies Lifepak paddles, O_2 mask, O_2 supply.

4. Transfer victim to CMRS.

   - Two crewmembers secure victim to CMRS.

   - Third crewmember attaches mask/head restraint and delivers ventilations, O_2.

5. When victim adequately restrained, chest pads immediately applied, quick look done.

** ***Coarse Vfib noted***

6. CMO charges paddles to 200 volts, calls clear when charged.

   - All crewmembers must be restrained clear of CMRS prior to discharge of defibrillator.

   - CMO goes "legs high" (to ensure free of CMRS), delivers shock.

** ***Continued coarse Vfib***

   - CMO recharges to 300 volts; other crewmembers remain restrained clear of CMRS.

   - CMO calls clear, delivers second shock.

** ***Continued coarse Vfib***

   - CMO recharges to 360 volts; other crewmembers remain restrained clear of CMRS.

   - CMO calls clear, delivers third shock.

** ***Continued Vfib, a bit finer***

7. Crewmembers resume CPR.

   - Compressions delivered via CPR restraint.

   - Other crewmember continues ventilation via mask.

   - CMO prepares to intubate.

8. CMO intubates when possible.

   - Chest leads applied.

   - Check tube placement.

9. Continue CPR.

- One crewmember compressing, one ventilating with ambu (manual pulmonary resuscitation bag).
- CMO prepares epinephrine, 10 cc 1:10,000.

10. Hold CPR, check for rhythm and pulse.

** ***no pulse, Vfib***

11. Detach ambu, deliver epinephrine via ET.

12. Resume CPR

- CMO prepares IV infusion set.
- Tracheal suction is used prn.

13. CMO checks rhythm and pulse.

** ***no pulse, Vfib***

14. CMO charges defib, all crewmembers move to be restrained clear of CMRS.

- CMO delivers 360 volts.
- CMO checks rhythm and pulse.

** ***no pulse, Vfib***

15. Crewmembers return and resume CPR.

16. CMO establishes IV.

17. Lidocaine®, 1 mg/kg IV when available (consider generic dose of 70 mg)

- If IV placement fails or is delayed, Lidocaine® is prepared by CMO and handed to crewmember managing airway for endotracheal administration.

24. Code proceeds, now with standard ACLS protocol less altered by environmental constraints; CMO administers drugs and electricity as indicated while other crewmembers compress and ventilate, interchanging as needed.

IF STABLE RHYTHM, PULSE, APPEAR AT ANY POINT

1. BP cuff applied, BP verified.
2. Firm IV access established.
   - Consider two lines if time permits.
3. Several contingency decisions to be made at this point.
   - If patient not intubated, maintain bag/mask ventilations until spontaneous respiratory efforts are established or decision is made to intubate.
   - If early recovery, e.g., from electric shock scenario, evacuation may not be automatic.
4. If decision is made to evacuate, patient is "packaged"; Lifepak, O_2 supply, needed ALS and airway equipment attached appropriately to MRS.
5. CMO remains with patient while others prepare Orbiter and station for evacuation.
6. When above is complete, patient is translated to Orbiter, restrained and tied into onboard O_2 supply.
7. If intubated, ventilator is activated and attached/stabilized at this point.

As stated above, actions and positions were "frozen" during periods of unstable gravity and level flight so that procedures were performed only in microgravity. On flight day one, a running log of actions versus elapsed zero-g time was maintained by one of the investigative team. Further documentation was provided by a fixed video camera focused on the CPR manikin, as well as mobile video coverage by a NASA camera operator to cover free-floating CPR and patient transport. Still photographs were also provided by NASA personnel. In addition, a handheld audio recorder was used for flight notes. At the completion of the flights, video tape footage was reviewed by team members and written comments and observations were collected.

Zero Gravity Elapsed Time (Minutes)	Action/Procedure
Time Zero	Medical emergency declared, free-floating CPR begun within 20 seconds.
2:07	CMRS deployed and secured (adequately but not completely).
2:55	Manikin restrained on CMRS.
3:40	Defibrillator pads/monitor connected to enable "quick look," O_2 delivered via face mask.
3:51	CPR resumed on CMRS, including O_2 delivery with ventilation bag.
4:11	First shock delivered (200 v).
4:28	Second shock delivered (300 v).
4:40	Third shock delivered (360 v).
5:03	Airway kit removed and restrained.
5:57	Begin intubation.
6:50	Intubation complete, tube placement verified.
7:32	Emergency drug kit removed and restrained.
7:56	Epinephrine delivered via ET.
8:47	Additional shock delivered (360 v).
9:05	Lidocaine delivered via ET.
9:21	IV kit removed, secure.
10:42	IV established, right antecubitum.
11:09	Additional shock delivered (360 v).

Methods of CPR delivery were varied and based on crew preference and size. Several methods were available and employed, with immediate feedback of adequacy given by the CPR manikin monitor.

RESULTS

Appendix A contains the action versus zero-g elapsed time (code time) obtained on flight day one. A synopsis containing the major priorities and procedures is shown below.

At this point, the actual protocol was suspended and crewmembers practiced various methods of CPR delivery. It should be noted that most of the unique characteristics of microgravity have their greatest influence on procedures and movement of personnel or equipment. Once the patient and care providers are adequately restrained, and the patient intubated and IV line established, further performance of ACLS differs little from terrestrial delivery.

Appendix B contains a listing of MTC medical hardware.

The precordial thump should be retained in the Vfib protocol, as per AHA guidelines for witnessed arrest when a defibrillator is not immediately available. This is performed while other crewmembers are deploying the MRS and associated medical hardware. An adequate precordial thump was easily delivered by the CMO backing the manikin against a hard surface, in this case the CHeCS equipment rack. CMO restraint was accomplished with one foot in a foot loop and the left hand grasping the rack.

Free-floating Heimlich-type CPR could be effectively delivered, as indicated by the manikin's compression and ventilation monitors. This has been demonstrated on previous KC-135 flights. Optimally, the CMO would be restrained at the feet, being able to freely turn the patient to alternate delivering compressions and ventilations. This method requires practice and is rapidly fatiguing, as all of the compressive force stems from flexion of the arms. There is a natural tendency to place the point of compression too low, and as the chest is not visible to the rescuer, great care must be taken to avoid compressive force over the xiphoid. However, this method does appear to suffice as a "stop-gap" means of delivering CPR until the CMRS is deployed and more definitive measures can be taken. The rescuer performing free-floating CPR must remain clear of the node to allow the remaining crewmembers to assemble the CMRS unhindered. Of note, the rescuer was easily able to translate the patient to the CMRS unaided.

Securing the CMRS was identified as a rate-limiting step in ACLS delivery. Two crewmembers required over 2 minutes to deploy and secure the CMRS to the extent that it could be used effectively. This stemmed primarily from difficulty in articulating CMRS connectors with the c-tracks along the floor of the node, both from the standpoint of physical effort required and difficulty in determining proper position along the c-tracks. Each connection is a two-handed operation. The first connections are difficult due to lack of restraint for the deploying crewmembers, and the last few connectors are hindered by the tension on the overall unit. One connector could not be attached due to this tension. Nearly an additional minute was required to restrain the manikin to the CMRS, and an additional 30 seconds was needed to attach a CPR restraint with a total compression interruption time of 92 seconds. First compressions were given with the elastic CPR restraint. Although ventilations with in-line O_2 were delivered after only a 30-second delay, this represents an unacceptable duration of interruption of CPR. Of note, both CPR restraint systems were deployed along with the CMRS to avoid having to access from different storage areas.

CPR was performed a variety of ways, all of which have been demonstrated on past KC-135 and shuttle flights. Effectiveness depended on crew size and technique. Since the requirement was made that all crewmembers be clear of the manikin for defibrillation, rapid egress was also assessed critically. The elastic restraint sufficed if attachment points were fixed on either side of the manikin at the level of the umbilicus, with the rescuer straddling the manikin. It was quick to don and doff once attached and allowed effective force delivery, but was uncomfortable and caused neck stiffness. The modified shuttle CPR restraint, in which the rescuer dons a belt and kneels by the side of the patient with attachment straps securing the waist to the surface, was also effective. However, rescuers complained of knee and lower back stiffness, and egress was not rapid once the restraint straps were tightened. The most popular method among several team members was the "legs-high" position, with the feet pushing against the cabin ceiling and the force of compression being delivered with the shoulders and arms. This was performed by crewmembers of varying size, and all reported a minimum of fatigue. The position is rapidly assumed and the CMRS rapidly cleared for defibrillation. A major benefit is that this method allows the CMO maximal access to the chest and upper arms for electrode placement, auscultation, IV placement, and other critical procedures. This method is counter to any standard CPR training, and the CMO would have to carefully monitor hand position and depth of compression.

The head restraint system for the face mask performed well, although the quick-release buckles often inadvertently tripped and required retightening. In addition, it is difficult to orient when initially destowed, and invariably requires some untangling of the straps and fabric. It is clear that some type of head restraint is mandatory to restrain the mask and ventilation bag and to avoid frequent repositioning of the mask. An enhanced version of the system currently used for shuttle should suffice.

In our scenario, it worked well for the CMO to deploy the hardware from the ALS pack for use and restraint as needed. Again, it was assumed that only the CMO was adequately skilled in procedures and use of the medical equipment. With two crewmembers delivering CPR, the CMO was positioned at the patient's right side in view of the defibrillator/monitor and within easy reach of the ALS pack. Essentially, in deploying hardware and restraining it within reach as needed, the CMO builds a workstation around himself while monitoring and controlling the ongoing CPR, as depicted in Figure 17. The CMO was able to prepare the ET; quickly translate to the head; intubate, secure, and check the ET placement; and return to the workstation position to observe the monitor and prepare drugs and IV. The crewmember managing the airway would then commence ventilations with the ambu bag attached to the ET. One observation here was that the ALS pack stethoscope might best be kept in the airway kit rather than with the sphygmomanometer. The most urgent need will probably be in airway assessment, and the stethoscope can then be easily retained out by the CMO for later BP measurements once a pulse is established.

In general, it was not a problem for the rescuing crewmembers to disengage the manikin and be restrained clear for defibrillator use, and the CMO also went legs-high to ensure clearance of the CMRS. These maneuvers should be baselined. During the initial shocks of progressively increasing voltage, successive shocks are delivered as rapidly as the defibrillator can charge; this usually requires 12 seconds. It is possible during the charging time for the crewmember managing the airway to move forward and deliver two ventilations, as his legs will most likely be restrained in the radial port of the node at a level below the CMRS, allowing rapid

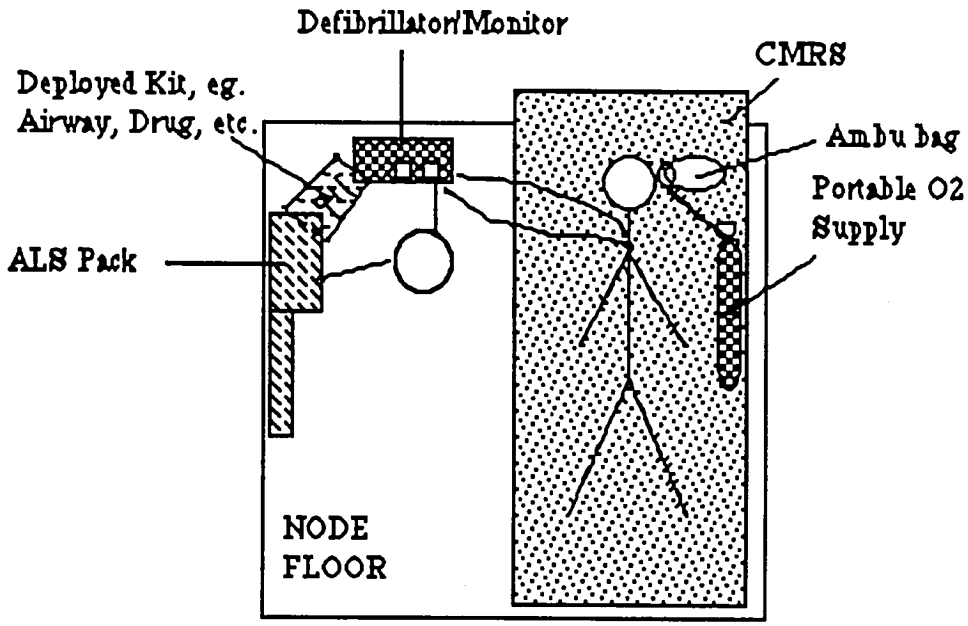


Figure 17. The CMO Workstation.

movement toward and away from the CMRS. This will be a judgment decision by the CMO.

Once the manikin was intubated, the airway kit was quickly stowed and the drug kit removed. A simulated delivery of epinephrine via the ET was performed. This was a nominal operation, with minimal interruption in CPR. It appears prudent to restow used items in the ALS pack. With the current configuration, this is a rapid process and ensures ready access should the components be needed again. Trash, particularly wrapping from sterile packages, can quickly become a problem. This was best dealt with by tucking it between the ALS pack and the wall of the node, and it suggested that a trash receptacle would best be close to the ALS pack rather than on the CMRS.

IV placement was shown to be difficult and time-consuming, driving its deferral until later in the protocol and emphasizing early intubation and endotracheal drug delivery. This stems largely from the multiple, individually packaged components required to begin an IV infusion, including the fluid bag, infusion tubing, angiocath, tourniquet, tape, etc. All of these must be identified, destowed, removed from their packages and trash stowed, and restrained until the time of immediate use. A simulated IV placement was successfully performed during this exercise after 10 minutes elapsed time, and these problems were confirmed. Ideally, this should be a quick, one-man operation. More rapid IV access for delivery of drugs and fluids should be sought for the ALS pack.

As stated above, once the manikin was secured to the CMRS and the ET, defibrillator pads, monitor electrodes, and IV line were placed, the cardiac arrest scenario more closely resembled its terrestrial counterpart. Further CPR and drugs could be delivered for an extended period, being then limited by response to treatment, exhaustion of resources, or a stop decision by the CMO. Actual transport of the patient on the CMRS was not simulated.

DISCUSSION

CMRS

Assuming that no electrical defibrillation can occur until the patient is secured to the CMRS and other ACLS procedures are not fully enabled until this point, deployment of the CMRS must be streamlined.

- Connectors which articulate to the c-tracks must be easier to use and preferably designed for single-handed attachment.
- Dedicated markers on the c-tracks at CMRS tie-down positions would avoid confusion during deployment.
- Depending on stowage and volume concerns, stowing the CMRS in a partially deployed configuration, e.g., with one end secured and folded against the wall of the node, would speed up full deployment.
- Some difficulty was encountered in adequately restraining the manikin head during CPR. This is necessary during CPR to avoid cyclic cervical flexion, which might affect ET position.
- It should be regarded as mandatory that all crewmembers are restrained clear of the CMRS prior to defibrillator discharge. This is easily and rapidly accomplished and is the CMO's responsibility to ensure.

Airway

Establishing ventilations and endotracheal intubation were not a problem with the current ALS equipment and the shuttle mask/head restraint.

- Some type of head restraint for the ventilation mask for the space station ALS pack should be considered mandatory. An enhanced version of that currently used on shuttle would be desirable.
- Keep stethoscope in the ALS pack airway kit rather than with the sphygmomanometer.
- Although not tested during this flight, the ability to deliver adequate endotracheal suction must be ensured.
- If the emergency scenario is a complication of decompression sickness and hyperbaric treatment will be necessary, the endotracheal cuff must be filled with fluid rather than air. Since rapid intubation is a high priority and drawing up the required fluid requires more time, it will be a judgment call as to whether to inflate the cuff first with air for later exchange when vital signs have been established.

CPR Delivery

Several different methods will deliver adequate compressive force and will depend on crew technique, body size, degree of deconditioning, and preference. Crewmembers may be expected to change positions during a medical emergency to circumvent fatigue, and it is reasonable to assume that effective CPR can be provided for the expected duration of the scenario. It must be stressed that all crewmembers will require training and practice in microgravity CPR. The legs-high method will depend on crewmember size and node dimensions, was the preferred method among several test participants, is rapidly begun and ceased, and leaves optimal CMO access to the patient's chest.

CMO Considerations

The concept of building a workstation as medical hardware is deployed and restrained by the CMO seems a good plan to follow for training. Each CMO will have preferences, which can be developed during practice and training scenarios. Adequate restraints must be provided at the site for the CMO with multiple attachment points for equipment. If an individual pack is deployed, used, and not immediately needed, it should be restowed in the ALS pack; this can be done rapidly and easily, and ensures its easy access if needed at a later time. CMO training optimally would include several drills with actual flight crewmembers to solidify the process. Also:

- A protocol checklist should be readily available, perhaps attached to the defibrillator, for rapid reference by the CMO.
- Although the CMO will probably be familiar with electrode color coding, defibrillator/monitor leads should be clearly labeled with prominent letters as to their position on the chest.

IV Access

Although endotracheal delivery of many ACLS drugs can be accomplished, IV access ensures optimal drug and fluid delivery, and the capability of quick, early IV access is highly desirable. One of several possible solutions would be to attach a small infusion bag, perhaps 250 cc, to a short infusion line incorporating a simple flow valve and side port and further attach it to an 18 Ga. butterfly infusion set. This would be optimally packaged as a single unit, with a single motion required to make the system patent (e.g., inserting an infusion spike into the fluid bag). A tourniquet could be included in the kit, and the infusion rapidly begun in the antecubital vein. Once IV access is established, the tourniquet could be used to secure the bag to the distal arm and provide a small amount of infusion pressure, with flow regulated by the flow valve. Drugs and fluids would be administered via the side infusion port. Once vital signs were established, a more definitive IV could be started by the CMO for transport. It should be possible to assemble such a system with off-the-shelf equipment, and the entire set should require minimal volume in the ALS pack. A rough diagram of such a system is shown in Figure 18. It must be determined how to package the entire system in a sterile manner, as each of the subcomponents may require different sterilization processes.

CONCLUSIONS

Protocols for the delivery of ACLS in the microgravity environment were tested in parabolic flight, and it was demonstrated that effective ACLS could be performed using ALS pack hardware baselined for space station MTC phase. From a personnel standpoint, it is reasonable to assume that a single CMO trained at or above the paramedic level, with proficiency in required procedures, could direct two other crewmembers during this scenario. All crewmembers should be trained in CPR with microgravity considerations, including being able to deploy and use the mask/head restraint and the CMRS. Some problems were identified which could be addressed to make the process smoother and faster. Abbreviated ACLS protocols for space station will be compiled in the near future. Further testing will include transport scenarios and emphasize CMO training requirements.

New hardware recommended:

- CMRS modifications (These are currently underway, directed by McDonnell Douglas and KRUG CHeCS personnel.)

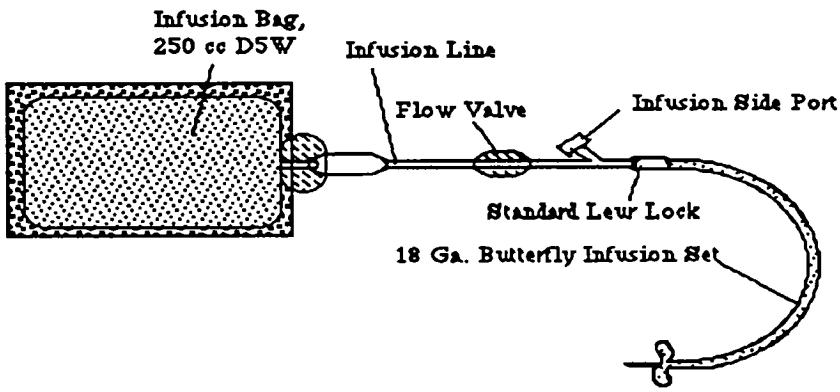


Figure 18. Pre-Assembled Rapid IV Access Kit.

- Ventilation mask head restraint
- Rapid IV access kit

PHOTOGRAPHS

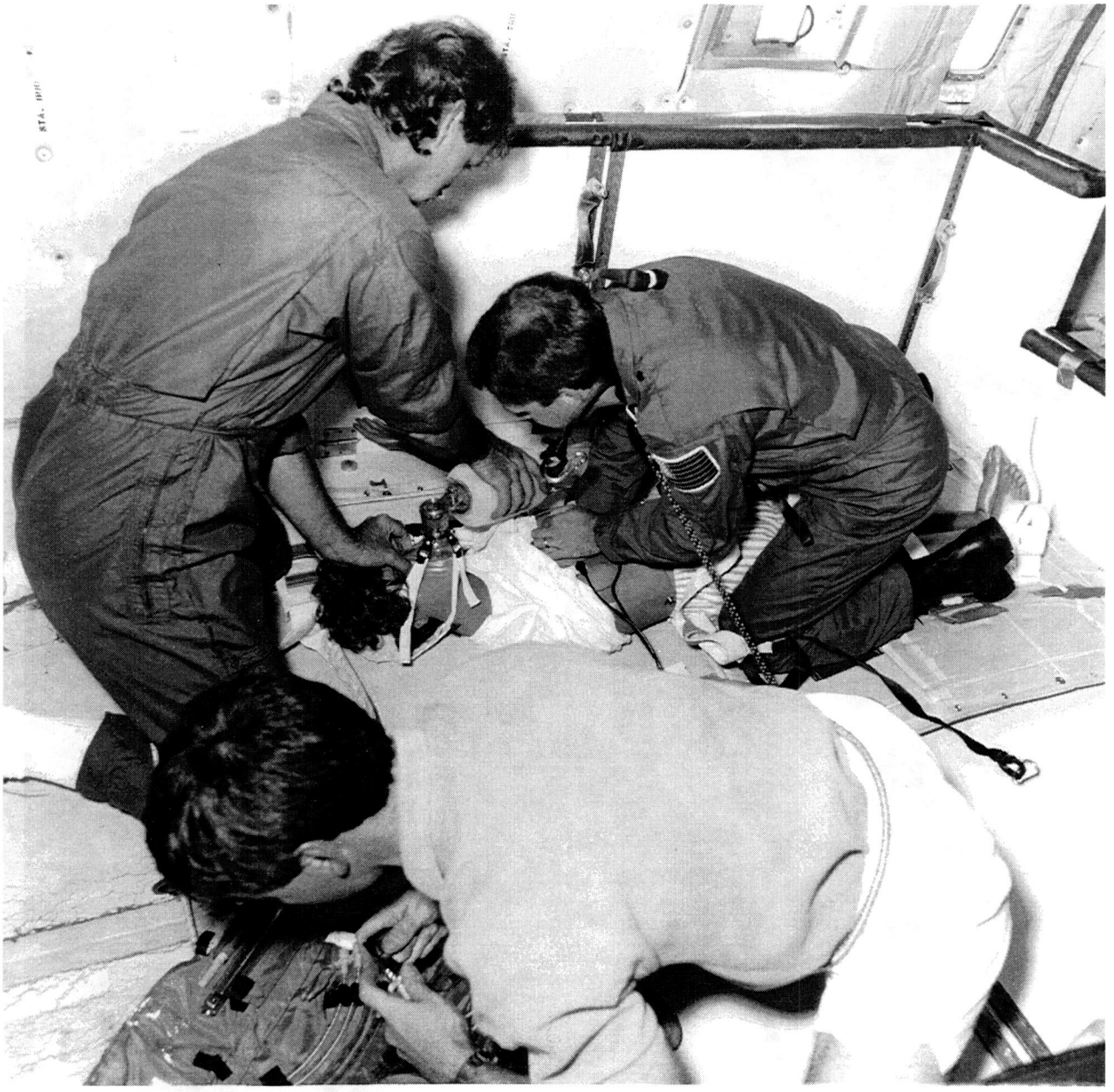
S91-44480: The CMRS is being deployed and secured within the confines of the node mockup. The ALS pack is being secured and accessed on the right.

S91-44473: A crewmember delivers compressions using the elastic restraint, while another delivers ventilations using an ambu bag and mask. Defibrillator pads are attached to the manikin's chest. Not seen is an oxygen line attached to the ambu bag and the portable oxygen supply attached at the manikin's left side. The CMO in the foreground is accessing the airway kit and preparing for intubation.

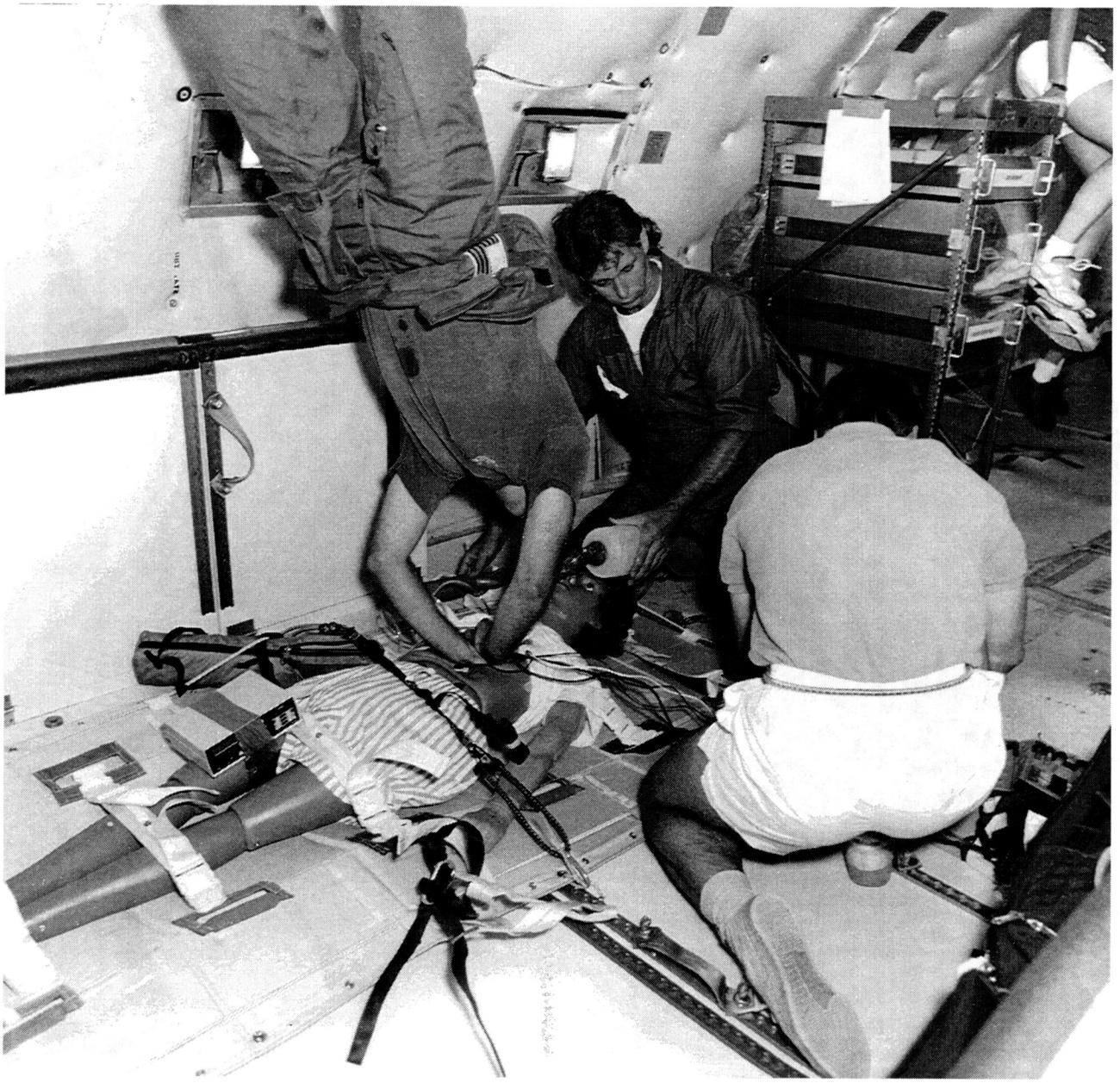
S91-44472: The CMO intubates the manikin, while another crewmember prepares the monitor electrodes for attachment.

S91-44465: This photo shows the most commonly preferred method of CPR delivery - legs-high. The chest and right arm of the manikin are easily accessed by the CMO. The portable oxygen supply in the blue pack is seen restrained on the manikin's left side. The manikin is intubated with the ambu bag connected to the ET and chest leads are attached. The CMO has constructed a workstation with the ALS pack restrained on his left, the defibrillator/monitor restrained just in front, and the emergency drug kit attached between the two. The airway kit has been restowed.

S91-44462: Another view of legs-high CPR and airway management. It is imperative to have adequate restraints for all crewmembers. Note that the manikin's upper chest restraint strap routes over the shoulders and through the axillae around the upper back. This restrains the upper chest while leaving the anterior chest free to access and prevents longitudinal movement of the manikin along the CMRS.



S91-44473: *CMOs deliver chest compression using an elastic restraint.*



S91-44465: *The CMOs demonstrate advanced life support on a manikin.*

APPENDIX A

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	1 (23 sec.)	58		21	Acclimation to zero gravity
0 sec.	2 (22 sec.)	14			Crewmember floating
					Ed finds Annie floating
					ABC's
					Ed: "Help!"
					Ed performs free-floating CPR
					Mike: "Go for the MRS!"
					MRS destowed
22 sec.				36	MRS in proper position for attachment
					Ed has begun to transport Annie toward node
Break: Looking for smoother air					
	3 (23 sec.)	11			Free-floating CPR
36 sec.			25		Frank attaches left-foot bolt
38 sec.			27		Frank moves to right-foot bolt
					Mike stretches out MRS
45 sec.				34	Frank attaches right-foot bolt
					Mike at head of MRS
	2 G				Mike restrains head of MRS with bungee cord
	4 (23 sec.)	34			Frank works on right middle bolt
					Mike destows ALS pack
57 sec.			46		One point on ALS pack secured
1:07			56		Foot end bolts and 1 side bolt of MRS secure
1:08				57	
	5 (24 sec.)	53			
1:29			14		Two points of ALS pack secure
1:32				17	Bag-valve fell out of pack; MRS crooked
Break: Looking for smoother air					

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	6 (24 sec.)	37			Frank works on left-head bolt
1:41			46		ALS pack secure
1:56				1	Defibrillator destowed, but not secure
					Left-head bolt secure
					Frank works on right-head bolt
	7 (23 sec.)	56			
2:07			7		MRS down and secure
2:08			8		Defibrillator secure
2:13			13		Oxygen destowed
2:19				19	Ed moves Annie over to MRS
					Oxygen restrained
					Annie in proper position (Ed at head; Frank at feet)
	8 (21 sec.)	17			Frank and Ed work on restraining Annie to MRS
					Mike removes oxygen from kit
					Frank secures MRS foot restraint
					Frank secures knee restraint
					Mike returns oxygen to kit
					Ed restrains shoulders
2:40				38	Mike stows oxygen on MRS left-head
	2 G				Discussion: Shoulder restraint is incorrect
	9 (22 sec.)	32			Frank loosens knee restraint
2:50			42		Ed unrestrains shoulders
					Frank unrestrains hip restraint
					Frank and Ed scoot Annie down MRS
2:55			47		Ed re-restrains shoulders
					Frank secures hip restraint
					Ed deploys oxygen from kit
					Frank tightens knee restraint
3:02				54	Mask out
	TURNAROUND				
	2 G				Frank uses plastic loop to secure right-middle bolt
					Mike hands Ed mask and Snoopy restraint

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	10 (21 sec.)	44			Frank and Ed switch positions
					Ed hands Frank mask/restraint during switch
3:11			53		Frank restrains himself at MRS head
					Ed grabs Barratt CPR restraint and maneuvers into position
3:23				5	Frank places mask and struggles with Snoopy restraint
					No compressions
					Mike deploys leads and pads
					Mike lifts Annie's shirt and begins to place pad
	11 (22 sec.)	55			Ed holds onto soft restraints
3:33			5		Frank positions snoopy restraint/mask in place
					Mike places pads
					Defibrillator monitor is on
					Frank tightens 2 mask straps
					Ed positioned under Barratt CPR restraint
					Frank tightens the other 2 mask straps
3:44			16		Mike checks pulse -- No pulse
3:45				17	
	2 G				Frank obtains bag valve
	12 (22 sec.)	6			
3:51			12		Ed gives first restrained compression
					Frank delivers breaths
					Mike: "Let's deliver a round here. I've got everything on."
					Frank: "Do you want Annie on?"
					Mike checks; "Annie is on."
					Mike: "Stop CPR."
4:07				28	No pulse
	2 G				Ed unrestrains himself from Barratt restraint
					All restrain clear

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	13 (23 sec.)	15			Defibrillator charging
					Restrain clear
4:11			19		Mike delivers first shock
4:14			22		Frank delivers ventilations
					Ed remains clear
					Defibrillator charging
4:24			32		Mike: "Everybody clear!"
4:28			36		Second shock
4:30				38	
	14 (26 sec.)	28			Frank delivers ventilations
4:36			34		Restrain clear
4:40			38		Third shock
					Mike: "Shocks have been delivered. No rhythm. No pulse. Resume CPR."
					Frank restrains himself at head
					Mike: "Airway pack is coming out."
					Ed ducks under Barratt restraint
					Frank gives breaths
4:56				54	3 shocks have been delivered
	2 G				Ed releases Barratt restraint
	15 (26 sec.)	43			Frank gives breaths
5:03			50		Ed ducks under Barratt restraint
					Mike: "Airway kit is restrained."
					Ed positions knees at Annie's waist
5:06			53		Ed gives compression
					Frank gives breaths
					Mike destows intubation supplies
5:22				9	

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	16 (25 sec.)	58			Ed ducks from Barratt restraint
					Ed moves to Annie's right side, attaching Shuttle CPR restraint to MRS
5:26			2		Frank hyperventilates Annie
					Mike puts on stethescope
					Mike translates over to airway
5:36			12		Frank unrestrains from head of MRS; continues breaths
5:39			15		Ed begins compressions
					Mike: "Stop ventilations. Continue compressions."
					Frank moves away from Annie's head
					Mike attempts to restrain himself to head of MRS
5:47				23	Mask off; free-floating
	17 (25 sec.)	11			Mike restrains himself
					Mike begins intubation
					Ed continues compressions
					Mike intubates
					Frank untangles leads
5:57			21		Mike: "Hold compressions."
					Ed stops compressions
6:12				36	Mike continues to intubate
	2 G				Pads applied to leads
					Tube out completely
					Prepared for re-try
	18 (23 sec.)	38			Ed continues compressions
					Mike continues intubating
					Frank untangles leads
6:30			56		Tube in
6:32			58		Cuff off
6:35				1	Hand on bag-valve

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	19 (24 sec.)	51			Mike attaches mask
					Ed attaches leads
6:43			59		Mask free
6:50			6		Mike checks tube placement with stethescope
					Mike unrestrains himself
					Mike: "Trade places."
					Ed begins compressions
					Frank moves to Annie's head
6:59				15	
	20 (21 sec.)	10			
7:05			16		Frank restrains himself at head
					Ed continues compressions
					Frank gives breaths
7:12			23		Mike: "Airway pack is stowed, almost."
					Ed tries one-handed CPR
7:20				31	Mike: "Emergency drug kit is out."
	21 (23 sec.)	29			Ed unrestrains himself from waist restraint
					Frank gives breaths and compressions
7:28			37		Epi out ??
7:32			41		Drug kit out
7:43				52	Epi out
	22 (24 sec.)	42			Frank continues to compress and ventilate
					Ed manuevers into ceiling CPR
7:50			49		Ed delivers first ceiling compression
					Mike: "Detach mask."
					Frank detaches mask
7:54			53		Mike: "Hold compressions."
7:56			55		Mike squirts in epi
					Mike: "Apply positive pressure."
					Frank reattaches mask and pumps
					Mike: "Resume CPR."
					Ed begins compressions

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
8:07				6	Mike: "Epi is in."
8:11	23 (22 sec.)	5	9		Continue CPR Ceiling compressions Breaths Mike puts syringes away
8:28					Mike: "We're going to continue CPR for about 30 sec. and let that epi circulate a little bit."
8:29			26	27	Mike: "The Lidocaine is out, but I won't give."
8:32	24 (23 sec.)	28	31		Ed gives compressions
8:36			35		Frank gives breaths Mike: "Hold compressions." Mike: "No pulse." Mike: "Monitor check."
8:40			39		Mike: "No rhythm." Mike: "Clear." Frank continues to give breaths Mike: "Charging to 360." Mike: "Everybody restrain clear."
8:47			46		Mike: "Shock." Mike: "Bang." Check pulse/rhythm -- none
8:52				51	Mike: "Resume CPR"
8:58	25 (22 sec.)	50	56		Compression
9:02			0		Detach mask
9:05			3		Lido down ET tube
9:14				12	Suspend compressions Mike: "Give a positive ventilation." Mike: "Resume CPR."

APPENDIX A *continued*

Action Versus Zero-g Elapsed Time – Flight Day 1

Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	26 (24 sec.)	18			Mike: "Continue effective CPR now."
					Mike: "IV kit is open."
9:21			25		Ed gives first compression
					IV tubing out
9:38				42	
	27 (23 sec.)	30			Continuing effective CPR
9:41			33		Compressions started
9:42			34		Defibrillator cord in way of compressions, moved
10:00			52		IV bag out
10:01				53	
	28 (23 sec.)	42			Frank and Ed switch positions
10:12			53		Frank does first ceiling compression
					Ed delivers ventilations
10:24				5	Frank: "I could do this all day."
	29 (22 sec.)	1			
10:32			9		Frank tried one-handed compressions
10:35			12		Frank moves to ceiling
					Mike is attaching tubing to bag
10:39			16		Mike: "We're going to say this bag is connected to the line."
10:42			19		Mike: "This bag is patent."
10:46				23	
	30 (24 sec.)	14			CPR
10:54			22		Frank delivers first compression
10:58			26		Mike applies tourniquet
					Mike: "Hold CPR."
					Pulse check
					Mike: "No pulse. No rhythm."
					Mike: "Everybody clear the patient."
11:01			29		Mike: "Restrain clear."
11:04			32		Mike: "Charge to 360. Twelve seconds go by."
11:09			37		Bang

APPENDIX A *concluded*

Action Versus Zero-g Elapsed Time – Flight Day 1

11:10				38	
Code Time +	Parabola (Duration)	Start	Interim	Stop	Actions
	31 (22 sec.)	30			Breaths
11:18			38		Frank gives one-handed compressions
11:22			42		IV started
					Frank: "CPR is really hard. My back hurts."
11:31			51		IV connected to bag and ready to infuse
11:32				52	
	32 (24 sec.)	45			
11:37			50		Frank continues compressions
					Mike gets the tape out
11:48			1		Mike tapes IV tubing onto arm
11:56				9	
	33				Susie gives ceiling compressions
	34				Susie gives Barratt restraint compressions
	35				Susie gives Shuttle side restraint compressions
	36				Mike gives Shuttle side restraint compressions
	37				Frank gives ceiling compressions

APPENDIX B

MTC Medical Hardware

	MTC ALS PACK CONTENTS PLUS ADDITIONAL SUPPLIES	PACK QUANTITY	EXTRA QUANTITY
AIRWAY MANAGEMENT KIT:			
	nasal airway size 36	2	
	oral airway size 100 mm	1	
	oral airway size 90 mm	1	
	endotracheal tubes sizes 6.5 and 7.5	2 each	
	stylet	1	
	10 cc syringe	1	
	10 cc syringe (loaded w/saline)	1	
	tongue depressor	2	
	laryngoscope blade: mac 3	1	
	laryngoscope blade: miller 3	1	
	laryngoscope handle (with batteries)	1	
	crycothyrotomy set	1	
	tape 1 "	1	
	hand operated, re-expanding bag and mask (main pack)	1	
	accumulator (O2 reservoir)	1	
	non-rebreather face mask	1	
	vaseline gauze (4x4) (cut to 27)	4	
	betadine prep	2	
	lubricant packet (Lidocaine Jelly)	2	
	helmlich valve	1	
	cloth ribbon	1	
	2.0" x 14g IV Catheter	2	

APPENDIX B *continued*

MTC Medical Hardware

	MTC ALS PACK CONTENTS PLUS ADDITIONAL SUPPLIES	PACK QUANTITY	EXTRA QUANTITY
IV FLUIDS KIT:			
	1000 cc ringer's lactate	2	
	IV catheters 1.5" x 18g	4	
	1.5" x 16g	4	
	start packet:	4	
	a. Bioclusive transparent dressing (1)		
	b. Betadine prep pad (1)		
	c. 4x4 gauze (1)		
	d. tourniquet (disposable, penrose) (1)	Not 1 per pack	
	administration set	2	
	non powered infusion device (size: one lit	2	
	tape 1"	1	
ALS DRUG KIT:			
	Albuterol metered spray solution	1 AEROSOL	
	Amikacin 500 mg, 2 mL	2 SYRG	
	Atropine sulfate-0.1 mg/mL-10 mL	2 SYRG	
	Bretylium-50 mg/mL-10 mL	2 SYRG	
	Diazepam-5 mg/mL-2 mL	1 SYRG	
	Diphenhydramine-50 mg/mL-1 mL	1 TUBX	
	Epinephrine 1:10,000-0.1 mg/mL-10 mL	5 SYRG	
	Epinephrine 1:1000-1 mg/mL-1 mL	1 TUBX	
	Heparin flush 100 units/mL, 1 mL	8 TUBX	
	Lidocaine 2%, 20 mg/mL, 5 mL	5 SYRG	
	Lidocaine-20 mg/mL-5 mL	2 SYRG	
	Mannitol 25%, 50 mL	6 SYRG	
	Meperidine 100 mg/mL, 1 mL	6 TUBX	
	Metoprolol 1 mg/mL, 5 mL	7 SYRG	
	Morphine-10 mg/mL-1 mL	2 TUBX	
	Naloxone-0.4 mg/mL-1 mL	4 SYRG	
	Nitroglycerin lingual aerosol 0.4 mg	1 AEROSOL	
	Pancuronium 1 mg/mL, 10 mL	2 VIAL	
	Succinylcholine 20 mg/mL, 10 mL	1 VIAL	
	Verapamil 2.5 mg/mL, 2 mL	3 VIAL	

APPENDIX B *continued*

MTC Medical Hardware

	MTC ALS PACK CONTENTS PLUS ADDITIONAL SUPPLIES	PACK QUANTITY	EXTRA QUANTITY
BANDAGING SUPPLIES:			
	multitrauma dressing	2	
	4x4's multipack (non-sterile)	5	5
	4x4's individual (sterile)	10	10
	kerlix rolls 4"	8	8
	elastic bandage 4" roll	2	2
	benzoin swab	5	5
(NSN: 6515-00-727-6175)	gloves, sterile (size 61/2, 81/2)	4 pair	4 pair
	adhesive tape 2"	2	2
SUCTION KIT:			
	salem sump	1	
	lubricant	3	
	gloves, non-sterile (size medium)	2 pair	
	mechanical aspirator	1	
PHYSICIAN ASSESSMENT SUPPLIES:	sphygmomanometer	1	
	straight hemostat	1	
	stethoscope	1	
	heavy bandage scissors	1	
	penlight	1	
	restraints	2 Sets	
	flight rules	1	
	thermometer (disposable)	1	
SPLINTING SUPPLIES:			
	sam splint	2	

APPENDIX B *concluded*

MTC Medical Hardware

	MTC ALS PACK CONTENTS PLUS ADDITIONAL SUPPLIES	PACK QUANTITY	EXTRA QUANTITY
WASTE MANAGEMENT:			
	sharps container	1	
	soft trash container	1	
	wet trash container	1	
	foley catheter (12 Fr,14 Fr)		2
	foley bag		2
	foley start kit		2
CERVICAL SPINE SUPPLIES:	cervical collar	1	
HYPERBARIC KIT:			
	pin wheel	1	
	myringotomy knife	1	
	otoscope	1	
	afrin	2	
	sudafed	2	

Effects of 0-1.8 G_z on Abdominal Shape

Flight Date:	August 16, 1992
Principal Investigator:	C. W. Lloyd, Pharm. D. (NASA-JSC)
Co-Investigators:	William Norfleet (KRUG Life Sciences) Michael Reid (Baylor College of Medicine)

INTRODUCTION

The original proposal for this series of experiments called for quantitation of changes in abdominal dimensions during exposure to G_z varying from 0-1.8-g. This study was intended to occupy "left over" parabolas from a series of two flights which demonstrated the function of a patient ventilator under these conditions. However, the ventilator studies were completed during the first half of the first flight, and the KC-135 aircraft's mechanical functioning, weather, etc., permitted two full flights. Hence, an opportunity was available to expand the scope of the original proposal to include aspects of rib cage mechanics in addition to studies of abdominal shape, permitting an overview of the mechanical functioning of the respiratory system during active ventilation with a specified tidal volume in one individual.

Previous studies of chest wall configuration in parabolic flight[1,2] demonstrated, upon transition to zero-g, a reduction in end-expiratory thoracoabdominal volume (Vw) which was due entirely to changes in abdominal volume (Vab), the volume of the rib cage (Vrc) remaining unchanged. These studies were performed using inductive plethysmography to determine Vrc and Vab. In contrast, a detailed biomechanical analysis of the behavior of the respiratory system when exposed to a gravity vector that varies in magnitude and direction indicates that a transition to zero-g should increase Vrc as well as decrease Vab.[3] The reason for this discrepancy in conclusions regarding Vrc may relate to the fact that, in reference 1, difficulty was encountered in achieving adequate relaxation of respiratory muscles in the novel environment experienced by the subjects during parabolic flight. Resolution of these conflicts is relevant to spaceflight operations because proper mechanical ventilation of a stricken crewmember will depend on a basic understanding of the biomechanical behavior of the respiratory system. Consequently, the present study was undertaken during parabolic flight to determine the dimensions of the rib cage and abdomen at relaxed end-expiration as well as during active tidal breathing with a specified tidal volume in a subject who had extensive experience with the performance of respiratory maneuvers.

METHODS AND MATERIALS

The subject was a mesomorphic 38-year-old male individual with extensive experience in accomplishing respiratory maneuvers. He was seated in a chair equipped with arm rests and was restrained by a lap belt.

To quantitate the dimensions of the rib cage and abdominal wall, pairs of magnetometer coils were fixed along the anterior and posterior midline at the levels of the mid-sternum, upper abdomen, umbilicus, and lower abdomen. Signals produced by the magnetometers were proportional to the anteroposterior diameter of the chest wall at the location of a given pair of coils. Magnetometer output was displayed on a storage oscilloscope, and representative traces of this display were recorded on paper sketches. Data were collected at relaxed end-expiration and during tidal breathing from a 750 ml rebreathing bag. These respiratory maneuvers were accomplished during the stable one-g, zero-g, and 1.8-g phases of parabolic flight. Technical and logistical difficulties permitted collection of only a few data at one-g.

RESULTS

Changes in anthropometric dimensions during relaxed end-expiration upon transition from 1.8-g to zero-g were as follows:

Anatomic Location	Dimensional Change (mm, mean + SD)
Rib Cage	+5.3 ± 1.4
Upper Abdomen	-6.9 ± 0.8
Mid Abdomen	-23.1 ± 2.1
Lower Abdomen	-33.9 ± 2.6

Excursions in anthropometric dimensions during active tidal ventilation at a specified tidal volume of 750 ml at 1.8-g and zero-g (mm, mean + SD) were as follows.

Anatomic Location	1.8 g	0 g
Rib Cage	5.8 ± 1.0	3.1 ± 0.4
Upper Abdomen	5.6 ± 1.4	11.7 ± 3.0
Mid Abdomen	4.8 ± 1.0	12.6 ± 1.2

DISCUSSION

Concerning the relative contributions of rib cage and abdominal excursions to tidal ventilation, we observed with decreasing G_z a shift from rib cage to abdominal breathing an increase in rib cage end-expiratory diameter, and a decrease in abdominal dimensions. The last two changes could explain the shifts in patterns of tidal ventilation through attenuation of the length-tension characteristics of the rib cage musculature and, conversely, facilitation of diaphragm shortening. Alternatively, changes in passive compliance of the abdomen and rib cage could explain these findings as follows: decreasing G_z may increase abdominal compliance to a greater extent than rib cage compliance. (The latter occurs as a result of a shift of blood and abdominal contents into the thorax and a consequent decrease in lung recoil.) Diagrammatically, this can be represented by:

$$1.8\ g \longrightarrow 0\ g \Longrightarrow \begin{matrix} \uparrow C_{rc} \\ \\ \uparrow C_{abd} \end{matrix} \longrightarrow \text{Shift of tidal excursions to the abdomen}$$

where C_{rc} is compliance of the abdomen

These changes in regional compliance may be modified by the behavior of the abdominal contents in terms of the distribution of pressures *within* the abdomen. Some investigations have observed significant regional pressure differences in the abdomen that might modify the transmission of pressures to the diaphragm;[4] other studies dispute this.[2,5,6]

The finding of an increase in passive rib cage dimension measured at end-expiration upon transition from 1.8-g to zero-g is in agreement with the predictions of one study[3] but contrasts with the experimental observations of other investigations.[1,2,7] This might be explained by a relatively greater ability of the subject used in

the present study to perform relaxed respiratory maneuvers in the novel environment encountered during parabolic flight.

CONCLUSION

Further studies of the passive mechanics of the respiratory system during exposure to various G_z would resolve some of these issues because they would isolate the contributions of changes in regional compliance from those of alterations in the effectiveness of active respiratory musculature. These studies would also directly relate to the behavior of the pulmonary system of a patient receiving mechanical ventilation in microgravity. Such work will be formally proposed for inclusion in future flights of the KC-135.

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PHOTOGRAPHS

None taken.

Aerosolized Medications During Parabolic Flight – Phase 2: Metered Dose Albuterol Dose Sample Acquisition

Flight Date: September 20, 1991

Principal Investigators: C.W. Lloyd, Pharm. D. (NASA-JSC)
Janet L. Fox, Pharm. D. (Glaxo Pharmaceuticals)
William J. Martin, Pharm.D. (St. John Hospital, Mt. Clemens, Michigan)

Co-investigators: Charles R. Doarn (KRUG Life Sciences)
Debra Orsak (MDSSC)
Smith L. Johnston, M.D. (KRUG Life Sciences)

GOAL

The purpose of this flight was to determine if delivering medications through an aerosolizing device is an acceptable method in a zero-g environment.

OBJECTIVES

1. Obtain metered dose samples of Albuterol during the zero-g portion of parabolic flight for postflight chemical analyses.

2. Determine the total amount of drug for each delivery system under control (one-g setting).

3. Compare the amount of drug delivered per unit dose under controlled (one-g) and reduced gravity conditions (zero-g).

MATERIALS AND PERSONNEL

Albuterol IV, manufactured by Glaxo Pharmaceuticals, 17 gm, 200 metered inhalations, 90 mcg/actuation. There were 15 of each specially filled inhalers:

- FULL
- 1/2 FULL
- NEARLY EMPTY

All inhalers were weighed preflight (Table 3).

In-flight storage containers for separatory funnels
Forty, 250 mL glass separator funnels with cotton pledget in place
One metric analytical balance
One large roll of 1" paraffin tape
Vacuum pump, Tygon® tubing and pressure gauge
Foam block test Stations 1 and 2
Waste containers for priming the inhalers
MRS workstation

Standard AC power outlet for vacuum motor
Straps or bungee cords to secure the test stand to the MRS
Digital thermometer
Accelerometer data acquisition system

The flight team included Charles Lloyd, Charles Doarn, Debra Orsak, and Smith Johnston. Each individual had primary responsibilities: Charles Lloyd and Debra Orsak worked on either side of the test stand preparing each separatory funnel, Charles Doarn performed the actuations during each of the 40 parabolas, and Smith Johnston recorded all anomalies and took notes during the flight.

The ground support team included Janet Fox and Skip Hagan of Glaxo Pharmaceuticals and Terry Guess and Art Freemen from KRUG Life Sciences. The Glaxo personnel were responsible for providing the aerosol devices for preflight, in-flight, and postflight testing, all analytical processing of the samples, and other necessary supplies in support of the test. The KRUG personnel were responsible for the design and development of the in-flight storage containers and test stand.

METHODS

Test Stand

The experimental workstation, consisting of the MRS and a test stand, was placed in the forward part of KC-135. A test stand, consisting of foam blocks and Velcro, was attached to the MRS with bungee cords. A vacuum pump was affixed to the bottom of the MRS with Tygon® tubing running up to the test stand. The two containers used to store the 250 mL glass separatory funnels were placed behind the experimental workstation.

Before the flight, VI was weighed using a standard analytical balance (Mettler AE163). A class S1 calibration weight was used to check the calibration. The VIs were then placed on a block of foam that had 50 holes bored into it. This foam block can be seen in the foreground of Photo S91-47823.

Each separatory funnel was outfitted with a piece of parafilm stretched across the opening and a cotton pledget in the stem ahead of the valve. The pledget was used to prevent any aerosolized drug from leaving the separatory funnel. Tygon® tubing, connected to a vacuum pump, was attached to each separatory funnel. This pulled air through the separatory funnel and prevented any drug from escaping into the cabin.

An accelerometer data acquisition system was used to obtain three directional data on g forces. In addition a digital thermometer was affixed to the surface of the MRS. Cabin temperature was recorded during each parabola.

In-Flight Procedures

During the flight, each VI was actuated twice in a waste separatory funnel thereby priming the VI for actuation in one of the test separatory funnels. Each separatory funnel was labeled, serially 1 to 40. The VIs were similarly numbered by Glaxo before they were received by the flight team. The numbers corresponded to the parabolas, e.g. VI 10 was actuated in separatory funnel 10 during parabola (P) 10.

The experiment was set up so that one person would record data, two people (Operator A and Operator C) would work the test stand moving the separatory funnels into and out of the foam blocks. The fourth person (Operator B) actuated the VI into the separatory funnel.

Actuation of the VIs proceeded as follows. Operator A retrieved a separatory funnel from the storage container located directly behind him and placed it in the foam block. A Velcro strap kept the funnel in place. The Tygon® tubing was attached to the stem of the funnel, and the valve on the funnel remained closed until the actuation. The parafilm, covering the opening of the funnel, was pushed down so that the mouth piece of the VI could be inserted into the opening of the funnel. Operator B removed a VI from the foam storage block. The VI was shaken in an up and down motion during the 2-g portion. As the zero-g portion began, Operator B placed the VI mouthpiece in the opening of the waste funnel, and the VI was primed twice. Operator A opened the valve on the test funnel initiating vacuum, and Operator B moved the VI to the test separatory funnel which had the same number as the VI and corresponding parabola, waiting 5 seconds before the first of two actuations. After the first actuation, the VI was removed, shaken again, and inserted into the opening of the funnel. After waiting 5 seconds, a second actuation was made. Operator B returned the VI to the foam storage block and retrieved the next VI. Meanwhile Operator A turned the valve off, sealed the opening with parafilm and placed the funnel in the storage case. While Operator A was doing this, Operators C and B were preparing for the next parabola. Each parabola consisted of the same steps with Operator C and A taking turns moving the separatory funnels back and forth.

During the entire flight, the fourth team member was recording all activities including temperature, cabin pressure, number of actuations in the test funnel and waste funnel, and any problems associated with the parabola or the VI.

At the end of the flight, all of the VIs were reweighed (Table 3). The separatory funnels were sealed, packaged in shipping containers, and sent to Magellan Laboratories for chemical analyses. The actual concentrations determined by high-pressure liquid chromatography (HPLC) analyses are shown in Table 3. Additional one-g testing was performed by the flight operators at Glaxo for comparison.

RESULTS

The parabola-by-parabola data for each VI flown can be found in Table 3. Table 3 also identifies the following parameters: pre/post container weight, delta weight, number of actuations per canister, temperature, and concentration of drug deposited in the separatory funnel per actuation. The concentration of drug was determined by HPLC performed by Magellan Laboratories 5 days postflight. Column eight is the ambient temperature in the aircraft cabin. At the beginning of the flight, the cabin temperature was noted to be 72°F; slowly dropped and stabilized around 65°F by the 20th parabola. The cabin pressure fluctuated between 5500 and 6000 feet, which would correlate to approximately 12.0 psi throughout the testing.

Table 4 lists the three sample directional gravity data per parabola of the flight. During the zero-g portion of each parabola, three directional g profiles were recorded by the accelerometer data acquisition system. The data was collected at a rate of 50 samples per second for a period of about 25 seconds. Figure 19, graphically represents the Gz versus the number of samples. This data suggests that there was nearly zero-g in both the Gx and Gy axes. Review of the graphical representation of Gz versus the number of samples taken reflects an inordinate amount of fluctuation about the X axis. This can be attributed to the vibration of the plane as the detector is affixed to the floor. Figure 18 shows a representative Gz gravitational force versus time, starting just prior to entering the zero-g portion of the parabola and terminating during the pull out portion of the parabola.

Table 5 contains statistical data for subsets in which the operator was B and there were four actuations per VI; no negative comments reported. Four of the last six containers were tested by other investigators and have been eliminated from the data analysis. Shots 16, 28, 29, 34 and 36 had comments indicating there were problems with the actuation and were, therefore, dropped from further analysis. Container number 5 (FULL) and container number 6 (HALF FULL) were dropped from the comparison since the concentration reported for these two containers deviated significantly from the other values reported.

DISCUSSION

Further investigations will be required to determine if the results of this study are a direct result of the zero-g environment or some other factor. Potential differences between this test and the usual protocol used for testing lots of VIs for commercial distribution include:

1. A 250 mL separatory funnel was used (instead of the 2000 mL type) to reduce the stowage space required, simplify handling, and reduce the risk of breaking funnels.

2. The special lot of the VIs produced for this test had three different fill volumes.

3. There was a delay between the time the samples were produced in-flight and the time the samples were prepared for assay because they needed to be shipped back to Magellan Laboratories in North Carolina.

CONCLUSIONS

Analysis of the data implies that there is a larger amount of material delivered than is normal. The data obtained from this experiment will be compared to the DATA obtained from similar experiments performed on the ground. Based on the outcome of ground testing it may be advantageous to perform additional studies on the KC-135 using refined methods.

REFERENCES

1. Lloyd CW, Martin WJ, Gosbee J. Evaluation of aerosolized medications during parabolic flight maneuvers. Medical Evaluations on the KC-135 1990 Flight Report Summary, NASA Technical Memorandum 104740, 83-96.

2. Crogan, SJ and Bishop, MJ. Delivery Efficiency of Metered Dose Aerosols Given Via Endotracheal Tubes, Anesthesiology 70:1008-1010; 1989.

PHOTOGRAPHS/VIDEO

S91-47823: The test stand is attached to the MRS with the VIs in the foreground. Operator B actuates the VI in one of the 250 mL separatory funnels during the zero-g portion of the parabola.

S91-47824: Operator A demonstrates the effect of zero-g as Operator B prepares for the next actuation.

S91-47835: The flight team stands behind the test stand. The 45 VIs are stored in the blue foam platform attached with a bungee cord to the MRS.

S91-47837: Operator B actuates a VI. A digital thermometer in the foreground is attached to the MRS. The other team members restrain themselves from floating free.

S91-47838: As Operator B finishes up the actuation, Operator A begins the process of moving the separatory funnel from the test station. Events are recorded during the parabola.

S91-47841: Operator B holds the VI at the opening of the separatory funnel as Operator C prepares to remove it when the actuation is completed. Operator A displays the containers of VIs.

S91-47842: Operator B actuates the VI into the separatory funnel as Operator A prepares to seal the opening with parafilm. Another team number releases a VI and the original package to demonstrate zero-g during the parabola.

Table 3. Albuterol Aerosol Sample Data Summary

Parabola	Container #	Initial Weight (g)	Final Weight (g)	Weight (g)	No. of Shots	Concentration (mg)	Temperature (F)	Comments	Shooter
1	42	29.4445	29.0972	0.3473	5	114.5618	72		Doarn
2	2	37.9329	37.581	0.3519	4	113.8417	71	5 sec delay in sep funnel valve opening	Doarn
3	3	29.8479	29.5073	0.3406	4	119.1893	71		Doarn
4	4	22.357	22.0163	0.3407	4	114.2611	71		Doarn
5	5	37.9383	37.596	0.3423	4	167.1312	71		Doarn
6	6	30.0738	29.7354	0.3384	4	156.1244	70		Doarn
7	7	22.0872	21.6751	0.4121	5	114.212	69		Doarn
8	8	38.1897	37.8341	0.3556	4	122.3496	70		Doarn
9	9	29.5282	29.1798	0.3484	4	126.45	69		Doarn
10	10	22.9081	22.5701	0.338	4	132.4735	69		Doarn
11	11	38.1451	37.794	0.3511	4	127.2452	69	1st spray in test sep funnel was light	Doarn
12	12	29.73	29.3809	0.3491	4	123.4684	68		Doarn
13	13	22.8099	22.4696	0.3403	4	104.9311	68		Doarn
14	14	38.0347	37.6898	0.3449	4	136.6391	68		Doarn
15	15	29.4368	29.0817	0.3551	4	128.3805	67		Doarn
16	16	22.8301	22.5457	0.2844	4	104.5793	67	both test shots bad	
17	17	37.9427	37.6079	0.3348	5	110.045	68		Doarn
18	18	29.6323	29.2791	0.3532	4	127.038	68		Doarn
19	19	22.2004	21.8176	0.3828	6	157.6183	68	three shots in test sep funnel	Doarn
20	20	37.9596	37.5275	0.4321	5	110.202	68		Doarn
21	21	29.848	29.5003	0.3477	4	101.9716	66		Doarn
22	22	22.5072	22.1825	0.3247	4	108.9191	65		Doarn
23	23	38.0937	37.7564	0.3373	4	144.9245	66	2nd shot in test funnel slow	Doarn
24	24	29.5948	29.2626	0.3322	4	115.0951	65		Doarn
25	25	22.7196	22.3756	0.344	4	110.2342	66		Doarn
26	26	38.0747	37.7411	0.3336	4	123.1369	65		Doarn
27	27	30.1534	29.8106	0.3428	4	104.2326	65		Doarn
28	28	22.8542	22.4324	0.4218	5	146.1	65	1st shot in test funnel bad	Doarn
29	29	38.0943	37.7611	0.3332	5	214.8711	67	1st shot in test funnel bad	Doarn
30	30	29.9343	29.5983	0.336	4	116.1291	67		Doarn
31	31	22.1885	21.8403	0.3482	4	119.5178	66		Doarn
32	32	38.2231	37.8781	0.345	4	129.169	65		Doarn
33	33	29.694	29.3407	0.3533	4	108.572	65		Doarn
34	34	21.7215	21.3925	0.329	4	99.3205	66	both test shots were bad	Doarn
35	35	38.1546	37.8115	0.3431	4	164.9435	66	shots were poor	Doarn
36	36	29.7988	29.5297	0.2691	4	163.8971	66	1st shot was poor	Doarn
37	37	22.6094	22.2899	0.3195	4	96.6744	64		Doarn
38	38	37.9013	37.5425	0.3588	4	160.7514	66		Orsak
39	39	29.8799	29.5391	0.3408	4	93.9128	67		Orsak
40	41	38.062	37.6563	0.4057	4	106.076	65		Orsak

Table 4. Three Directional Gravity Data

Gx	Gy	Gz
-0.01	0	0.38
0.06	-0.1	0.33
-0.08	-0.04	0.4
0.09	-0.02	0.31
-0.05	-0.06	0.39
0.11	-0.1	0.33
-0.05	-0.04	0.39
0	-0.03	0.39
-0.14	-0.02	0.33
-0.02	-0.02	0.15
-0.03	-0.05	0.16
-0.02	0.08	0.23
-0.1	-0.14	0.3
0.04	0.03	0.2
0.01	-0.04	0.22
0.09	-0.04	0.28
-0.04	-0.22	0.3
0.01	-0.09	0.29
-0.08	-0.05	0.27
-0.07	-0.04	0.32
-0.04	-0.03	0.18
-0.05	0.06	0.28
0	-0.07	0.19
-0.03	0.08	0.2
-0.04	-0.04	0.17
-0.01	-0.01	0.14
0.01	-0.05	0.19
-0.03	-0.08	0.19
0.04	-0.07	0.22
-0.01	-0.04	0.27

Table 5. Albuterol Drug Concentrations Per Fill

CONTAINER TYPE	# SAMPLES	MEAN CONC (mg)	SD CONC (mg)
FULL	6	132.0	18.8
HALF FULL	10	120.6	14.9
NEARLY EMPTY	7	112.4	11.4

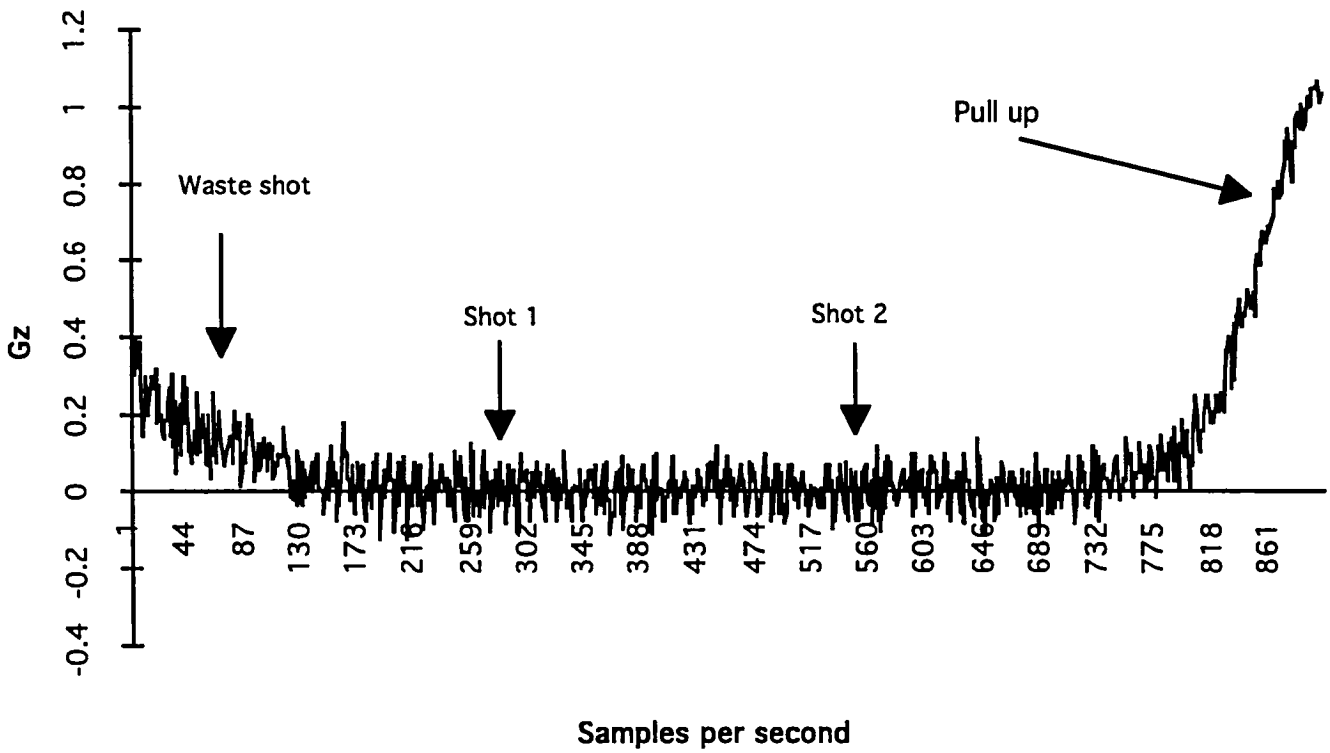

Figure 19. Albuterol in Microgravity: Parabola 1.

S91-47823: *Investigator sprays a VI into a glass separatory funnel.*

S91-47838: *Investigator prepares to remove a test separatory funnel.*

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13. ABSTRACT *(Maximum 200 words)*

This document represents the medical investigations completed on the KC-135 during FY 1991 in support of the development of the Health Maintenance Facility and Medical Operations. The experiments consisted of medical and engineering evaluations of medical hardware and procedures and were conducted by medical and engineering personnel. The hardware evaluated included prototypes of a crew medical restraint system and advanced life support pack, a shuttle orbiter medical system, an airway medical accessory kit, a supplementary extended duration orbiter medical kit, and a surgical overhead canopy. The evaluations will be used to design flight hardware and identify hardware-specific training requirements. The following procedures were evaluated: transport of an ill or injured crewmember at man-tended capability, surgical technique in microgravity, transfer of liquids in microgravity, advanced cardiac life support using man-tended capability Health Maintenance Facility hardware, medical transport using a model of the assured crew return vehicle, and evaluation of delivery mechanisms for aerosolized medications in microgravity. The results of these evaluation flights allow for a better understanding of the types of procedures that can be performed in a microgravity environment.

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