Ultrasonic Detection of Organ Displacement in Micro Gravity:
A Proposal for 2000 Student Reduced Gravity Opportunities Program
Topic area: Medical science

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Team members:
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KC-135 Quick Reference Data Sheet

Principal Investigator: Dr. Michael Bailey
Experiment Title: Ultrasonic Detection of Organ Displacement in Microgravity
Flight Date(s): March 8-17 Flight Group III

Overall Assembly Weight (lbs.):
Assembly Dimensions (L x W x H):
Equipment Orientation Requests: none requested
Proposed Floor Mounting Strategy (Bolts/Studs or Straps): bolts
Gas Cylinder Requests (Type and Quantity): none requested
Overboard Vent Requests (Yes or No): none requested
Power Requirement (Type and Amps Required):

Flyer Names for Each Proposed Flight Day:

Peter Derrick   Ryan Ollos

Laurence Tomsic   Nicole White

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Flight Manifest

Flight Day One:	*Flight Day Two:*
<u>Peter Derrick</u>	<u>Ryan Ollos</u>
<u>Laurence Tomsic</u>	<u>Nicole White</u>

No team member has ever flown on the KC-135a prior to the anticipated flight in March.

Experiment Background

The lack of rigidity in the loosely overlaid structure of the organs in the peritoneal cavity makes it difficult to identify normal organ structure and position by sonography in a micro-gravity environment. The nature of sonographic imaging, an extremely difficult skill that relies on the ability to identify landmarks in the body to locate structures, exacerbates the problem. NASA has used ultrasound imaging previously on the KC-135 Reduced Gravity Flight and in space. Early experiments were confounded by, and in some cases, failed because of the movement of an astronaut's organs in space [Wayne Sternberger Ph.D., John Hopkins Univ. APL, Jan 24, 2000] [Steve Carter M.D., Dept. of Radiology, University of Washington, personal communication, Feb 27, 2000]. The Applied Physics Laboratory (APL) of the University of Washington has undertaken an extensive effort to develop technology that would permit minimally trained personnel to utilize diagnostic and therapeutic ultrasound to terminate both external and internal bleeding, ultimately to be used in space [Lawrence Crum, NSBRI proposal]. Such a procedure is complicated by the phenomenon of micro-gravity induced organ shift. NASA owns two SonoSite 180 handheld ultrasound-imaging units [Steve Carter M.D., Dept. of Radiology, University of Washington, personal communication, Feb 24, 2000], which is the same instrument this flight team will use.

The objectives of this project are two-fold. First, the flight team will measure organ displacement using ultrasound. In these measurements, taken at 0-, 1- and 2-Gs of acceleration, the locations of specific landmarks will be identified in three dimensions from the collected data. By taking repeated measurements of organ position as a result of different gravitational environments and comparing the images, this project will characterize organ shift patterns for the kidney, and thereby increase the predictability of organ location for future endeavors with ultrasound in micro-gravity environments. Additionally, by collecting ultrasound data at specific values of gravitational forces, we hope to identify problems that have not yet been anticipated so that future missions involving ultrasound can be better prepared for space flight. Our second objective is to provide an outreach program. By visiting local schools, publishing a web site, evoking local media coverage, and presenting our findings at a scientific conference, we will reach out to a broad spectrum of people, thus providing positive publicity for NASA, APL, and the UW.

Experiment Description

The goal of this experiment is to make the comparison of organ location in 0-, 1- and 2-G environments. We chose to image the kidney as our reference organ because there exists an optimal window to view the entire organ. The borders of the organ are well defined allowing us to precisely view its location superiorly and inferiorly and make quantitative comparison in varying gravitational environments. The primary impedance to making an adequate comparison will be organ movement due to respiration. It will be required that the subject be immobilized and the transducer spatially fixed. We designed our experiment with the goal of being able to make a relevant comparison by accounting for these factors. The test subject will be prone to provide the best window to image the kidney.

One flyer will help to secure the other to the Subject Positioning Table. Data will be collected continuously while the test subject is being scanned. The transducer is mounted to a frame that slides out from the equipment rack and over the subject. The transducer will be positioned over the area of interest and then adjustments made by the other flyer to both the transducer position and setting on the SonoSite, so that the desired images are obtained. The transducer will be allowed to move in the "Z" direction and laterally relative to the subject, but is inferiorly and superiorly fixed. A small amount of rotation of the transducer is desirable in order to optimize images on different subjects due to varying physical characteristics, but the transducer will be locked into place once the desired view is obtained. The general positioning of the transducer will be predetermined through our practice procedure so that we can quickly obtain the desired image. In order to improve data analysis, our group has specific goals for our preflight ground-based practice activities. It will be necessary that each team member will have practiced extensively with their flight partner, and will be familiar with the appearance and location of the other's anatomy, specifically the kidney. It is essential that quantitative data be recorded to determine normal displacement of the kidney due to respiration. Respiration will be measured over time using a nasal anemometer and then compared to the movement of the organ. This preflight data will allow us to better assess a true organ shift due to varying gravitational environments. In addition to looking for a shift of the kidney, our team will be trained to look for pathologic effects that may result in the kidney (i.e. dilation of renal pelvis or hydronephrosis due to vesicoureteral/ureterorenal reflux). Using Color Doppler or Power Color Doppler we may also have the opportunity to look for a qualitative indication of hyper or hypovascularization within the kidney. Finally, our team is exploring the feasibility and usefulness of acquiring 3D images.

The scan subject should be adequately prepared for test procedures by removing upper portion of flight suit to expose the abdomen. High viscosity scanning gel will be applied and the transducer positioned above the subject. The position of the transducer and the adjustments to the SonoSite will be made as described above. We have taken into account the hazards associated with motion sickness and restraining one of the flyers, this is expounded upon the hazards analysis section. In short, the subject will be able to release themselves from the restraints within 5 seconds.

Equipment description

The equipment described herein contains the elements required to obtain ultrasound images aboard the KC-135 in such as way as to reduce anticipated error and obtain the necessary data to draw a relevant conclusion from our hypothesis. The layout of our experiment may be broken down into three necessary components: image acquisition, data acquisition, and subject positioning table.

The image acquisition portion of our experiment is relatively straightforward and uses manufactured components to obtain and record real-time ultrasound images. The SonoSite 180 Ultrasound System will be used for image acquisition. The images will be transferred to the monitor via the composite video output. The images are routed from the VCR to the video monitor mounted on the front of the video rack. The purpose of the monitor is to provide adequate viewing of real-time images while in flight so that the position of the transducer may be adjusted to obtain appropriate images in the desired views. BNC cables and the appropriate adapters will be used to transfer video data between components. The Horita SCT-50 Serial Control Titler allows us to post text in a small corner of the monitor. Data from the accelerometer, nasal flow meter, and time/date stamp generated by the unit will be posted to the screen. This allows us to properly synchronize the data with the images. Displaying this data to the monitor also allows us to view feedback from our system to ensure that the system is operating correctly. The acquisition method and a description of this data are provided in more detail in the data acquisition system.

The purpose of the data acquisition system is to correlate our images with the present gravitational environment and the state of respiration of the subject. The accelerometer is constructed using three Analog Devices ADLX105 chips to provide data in the X-Y-Z directions. The analog signal is subsequently fed to an analog-to-digital converter and routed to the serial port of the laptop computer. A Labview program has been written to format the data to text to be displayed on the video monitor. Text is transferred via the RS-232 serial port to the SCT-50 to display accelerometer data on the monitor. The SCT-50 has an internal clock calendar that generates time data to a tenth of a millisecond resolution and allows us to post time data to the screen.

The Subject Positioning Table will be constructed of a _” sheet of plywood covered with foam padding. The plywood base plate will measure 30” in width by 70’’ in length. Four bolts and washers will be used to secure the base plate to the aircraft floor grid. The washers will measure at least six times the diameter of the bolts used. Hard foam padding, one- inch thick, will be secured to the plywood using screws. In order to secure the subject to the table 3 inch nylon strapping will be located across the width of the subject’s upper torso and thighs. The quick release straps will be located to the side so that the subject may release him/herself.

Below is a description of each piece of equipment we will bring.

Device:	Laptop
Function:	Data acquisition/ formatting
Dimensions:	2”(H) x 12”(W) x 8”(D)
Weight:	6 lbs.
Operating conditions:	5-35°C

Device:	SonoSite 180 hand-carried Ultrasound System
Function:	The ultrasound machine will be used to obtain real-time gray-scale images.
Dimensions:	13.3”(H) x 7.6”(W) x 2.4”(D)
Weight:	5.4 lbs.
Operating conditions:	10-40°C
Other:	FDA approved for use on humans.

Device:	Positioning System/Equipment Rack
Function:	The equipment rack secures the components of our experiment.
Dimensions:	32.375”(H) x 44”(W) x 24”(D)
Weight:	75 lbs.

Device:	3-axis Accelerometer
Function:	The accelerometer outputs data to the laptop to be recorded.
Dimensions:	Mounted in a box measuring 6”(H) x 4”(W) x 3”(D)
Weight:	1 lb.

Device:	Monitor/Video Cassette Recorder
Function:	The monitor displays the real-time image.
Dimensions:	15”(H) x 14”(W) x 15”(D)
Weight:	25 lbs.
Operating conditions:	0-35°C; 0-90% humidity

Device:	Horita SCT-50 Serial Control Titler
Function:	Allows character script to be posted to monitor.
Dimensions:	1.75”(H) x 3”(W) x 5”(D)
Weight:	1 lb
Operating conditions:	0-35°C; 0-90% humidity

Electrical Analysis

This section includes the schematic, the load table and the emergency shutdown procedures.

Schematic

Attached in (Appendix C) is a schematic of our electrical wiring. It is approximately to scale, and shows approximate wire routing and component layout. Please see the structural analysis for precise component locations.

One aircraft outlet is used. Each wire is uniquely labeled, with a description of each wire in the below table. Current limiting devices will be placed in series prior to each device that does not contain such a device internally. Circuit breakers will precede the accelerometer, the video titler, and the power strip. Two master kill switches exist in our circuit. The first is the on/off switch present on the power strip. The second precedes the power strip and is located and identified in such a manner that it is easily recognizable from a distance, and can be tripped with no difficulty. All metal surfaces will be grounded to the equipment frame, which in turn will be grounded to either the plane's frame or power supply ground.

Wire	Gauge /Type	Current (Amps)	Description
W1	18	2.8	Power-in to SonoSite, from Adapter B
W2	18	2.4	Power-in to Laptop, from Adapter C
W3	12	1.0	Power-in to Monitor/VCR, from Power Strip
W4	12	1.5	Power-in to Adapter C, from Power Strip
W5	12	1.0	Power-in to Adapter B, from Power Strip
W6	12	1.5	Power-in to Adapter D, from Power Strip
W7	18	0.3	Power-in to Accelerometer, from Adapter D
W9	18	1.0	Power-in to Video Titler, from Adapter D
W10	12	6.0	Pwr Cord A; Pwr-in to Pwr Strip, KC-135 Pwr Supply
W11	BNC		Video-in to Monitor/VCR, from Video Titler output
W12a	18	.01	Data-in to Laptop, from Accelerometer
W12b	18	.01	Serial-out to Video Titler, from Laptop
W13	BNC		Video-in to Video Titler, from SonoSite

Table 4: Wire Descriptions, as labeled on Electrical Schematic

Emergency Shutdown Procedure

An emergency kill switch will be located in an accessible location on the equipment rack through which all power devices will be routed. The switch will be located within reaching distance of the test subject and the flight crew. With the power off, all systems will be shutdown.

Pressure/Vacuum System Documentation Requirements

No pressure vessels are included in our experiment.

Laser Certification

No lasers are included in our experiment.

Parabola Details and Crew Assistance

We have no special requirements.

Free Float Requirement

We do not require any part of our experiment to be free floating.

Institutional Review Board

Our team has obtained the consents necessary to perform an experiment using flyers as test subjects. The JSC IRB, as well as the University of Washington Human Subjects Committee, has granted approval for human subject use. (Documentation is attached in Appendix B).

Hazard Analysis Report Guidelines

Hazard Number: 1

Title: Frangible Material

Hazard Description:

The monitor used in our experiment has the potential for breakage of the screen.

Hazard Causes:

Flying objects, or repeated blows by blunt or sharp objects may puncture the glass monitor, thereby shattering it.

Hazard Control:

Plexiglas shields will be constructed to fit over the monitor.

Hazard Number: 2

Title: Over Temperature Explosive Rupture (including Electrical Battery)

Hazard Description:

The SonoSite houses a self-contained lithium-ion, 6-cell battery. The potential exists for explosive rupture.

Hazard Cause:

SonoSite specifications indicate operating temperatures of over 40°C may lead to battery rupture.

Hazard Control:

Operating temperature of the battery will be maintained below the specified threshold. The SonoSite unit will be located an adequate distance from other heat producing devices such as the monitor. The SonoSite will use an external power supply, with the battery in place only as a backup measure. The battery also contains a safety device.

Hazard Number: 3

Title: Sharp Corner/Edge/Protrusion/Protuberance

Hazard Description:

Any flyer colliding with our aluminum equipment cabinet may be injure on any of its right angles.

Hazard Cause:

Free-floating crewmembers may fall onto and possibly be injured by the equipment bench.

Hazard Control:

Foam padding will cover all exposed edges of the cabinet.

Hazard Number: 4
Title: Hardware Cooling/Heating Loss
Hazard Description:

The potential exists for any of the electrical components to short circuit and/or have a heat sink failure that results in extreme heating and possibly combustion.

Hazard Cause:

No predictable causes exist.

Hazard Control:

A circuit breaker will exist in series with the power supply and an emergency cut-off switch will be clearly located and marked so that it is accessible and identifiable to anyone on the plane.

Hazard Number: 6
Title: High Voltage
Hazard Description:

Voltages of 10-20 volts may exist, if a grounding failure occurs.

Hazard Cause:

An improper or failed ground.

Hazard Control:

Proper grounding.

Hazard Number: 7
Title: High Static/Electrical Discharge Producer
Hazard Description:

Static electricity may build up on the equipment frame, or on any of the pieces of hardware.

Hazard Cause:

An improper or failed ground.

Hazard Control:

All equipment will be grounded to the equipment rack and the rack will be grounded to the aircraft.

Hazard Number: 8
Title: Test Subject Vulnerability
Hazard Description:

Because test subjects will be lying in a prone position and strapped down with quick release Velcro straps, other teams' members or apparatuses may fall into and injure our subject. Additionally, if sickness is imminent, the subject may choke on their vomit.

Hazard Cause:

Floating objects/people will quickly accelerate as the parabola ends. They may hit and injure our test subject.

Hazard Control:

Test subject release protocol

A: Pre-positioning

1. Test subject will be lying in a prone position reducing the chance of aspiration in the event of micro-gravity induced emesis.
2. Test subject's arms will never be restrained.
3. Nylon straps with quick-release buckles hold test subject in place.
4. Test subject will be positioned to the side of the equipment rack.
5. Transducer positioning arms will be extended
6. Transducer positioning rack will be padded and all edges machined off.

Note: While test subject is restrained, equipment operator will be near to assist in releasing test subject.

B: Normal release

1. Equipment operator will slide the transducer mounting arms away back under the equipment rack.
2. Equipment operator will then assist test subject with releasing from the straps.

Note: Flyers will monitor each other for signs of motion sickness. The flyer acting as the test subject will be immediately released from restraints if signs of motion sickness are present.

Motion sickness signs: loss of appetite, malaise, nausea, vomiting, gastrointestinal disturbances and fatigue.

C: Quick release

Strap mounting buckles are located such that the subject will be able to release oneself with little effort.
They are then able to push the transducer mounting arms back away from over the top of themselves and are free from any restraint.

Note: Normal release and quick release will be practiced. Each release method will meet the five-second standard.

Motion sickness prevention strategy:

Limit head movement and visual disorientation during the periods of micro-gravity.
Medication.

Tool Requirements

We anticipate that JSC will not need to provide us with any tools as we plan to bring everything we may reasonably need. We will use no tools aboard the plane—except as needed to secure our equipment to the aircraft frame before and after take-off.

We will limit the tools we bring to an absolute minimum.

Tools: duct tape, soldering iron and solder, foam tubing, wrenches, screwdrivers.

Photo Requirements

No special photo requirements exist.

Aircraft Loading

We will assemble our cabinet in the hanger. The cabinet assembly is fitted with casters. Handles will be provided. We anticipate not needing a forklift, provided that we can wheel our assembly into the plane. The wheels will then be removed and the handles used to manipulate the equipment rack onto the grid to be bolted down.

Ground Support Requirements

Our team will need space and access to the facility to set up and test our equipment four or more hours prior on the day of flight. We do not anticipate requiring any special ground handling equipment. We will require a standard 100-120 VAC, 50/60 Hz power supply to test our equipment and collect data prior to flight.

Hazardous Materials

We will not be using any toxic, corrosive, explosive, or flammable materials. The transducer coupling gel that will be used is safe and commonly used in clinical practice with no special precautions. No special disposal provisions are necessary.

Experiment Procedures Documentation

Equipment Shipment to Ellington Field

Equipment will be shipped freight by United Parcel Service (UPS) by Tuesday, February 27, 2001 to arrive in Houston on Monday, March 5, 2001, at least three days prior to the arrival of the flight team.

Our equipment is required to be stored at temperatures between 10-40° C in a cool, dry area. The SonoSite unit and the laptop computer will be transported to Houston with the flyers. We anticipate needing only the area occupied by our equipment rack, which is 24” x 24” x 36”.

Our equipment rack will be completely assembled in the hanger, allowing the flight team to test all equipment, as well as acquire images prior to flight. Team members will assemble the experimental set-up to the point where it will only need to be loaded onto the KC 135, bolted to the floor, and attached to a power supply. The flight team will be fully able to demonstrate the readiness and integrity of our experimental design prior to flight. We would like to be able to power up our equipment prior to flight so that it has warmed up and is in a ready state when we begin parabolas.

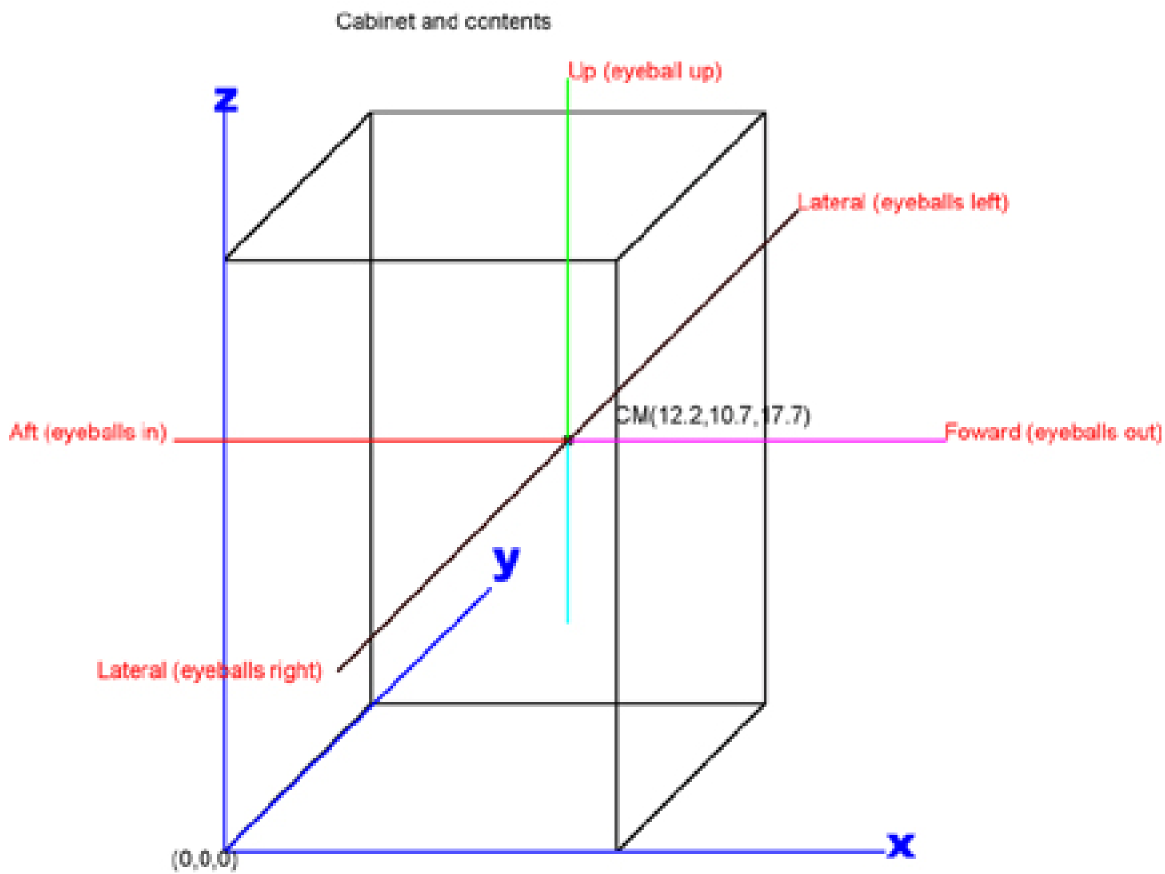
We anticipate that we will be able to load our equipment into the aircraft by hand by wheeling it on casters provided that there is an aircraft-loading ramp. Otherwise we may need assistance in the form of a forklift in order to load the equipment.

In-flight procedures

No extraordinary procedures will be required to prepare for the next day's flight.

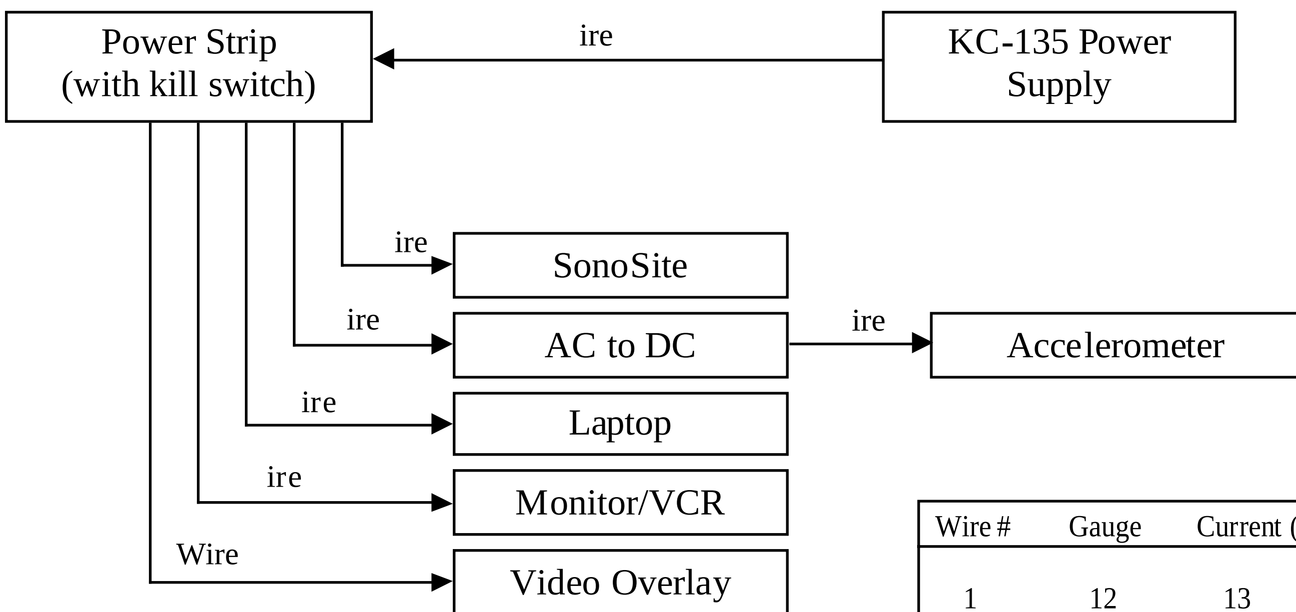
The equipment will be off-loaded in a similar way that it was loaded; disassembly will then take place in the hanger. Arrangements will be provided to have the equipment scheduled to be shipped back to Seattle following our last day of flight.

FIGURE 1



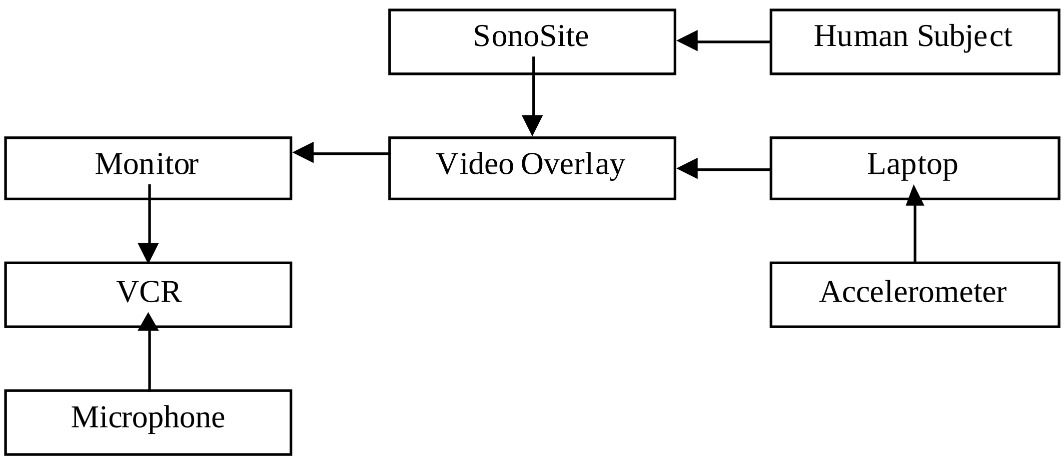
Cabinet and contents
Up (eyeball up)
z
Lateral (eyeballs left)
CM(12.2,10.7,17.7)
Aft (eyeballs in)
Foward (eyeballs out)
y
Lateral (eyeballs right)
(0,0,0)
x

POWER FLOW SCHEMATIC
FIGURE 2



Wire #	Gauge	Current (Amps)
1	12	13
2	12	5
3	12	1
4	12	5
5	12	2
6	12	1

DATA FLOW SCHEMATIC
FIGURE 3



SCHEMATIC OF ELECTRICAL SYSTEM
FIGURE 4

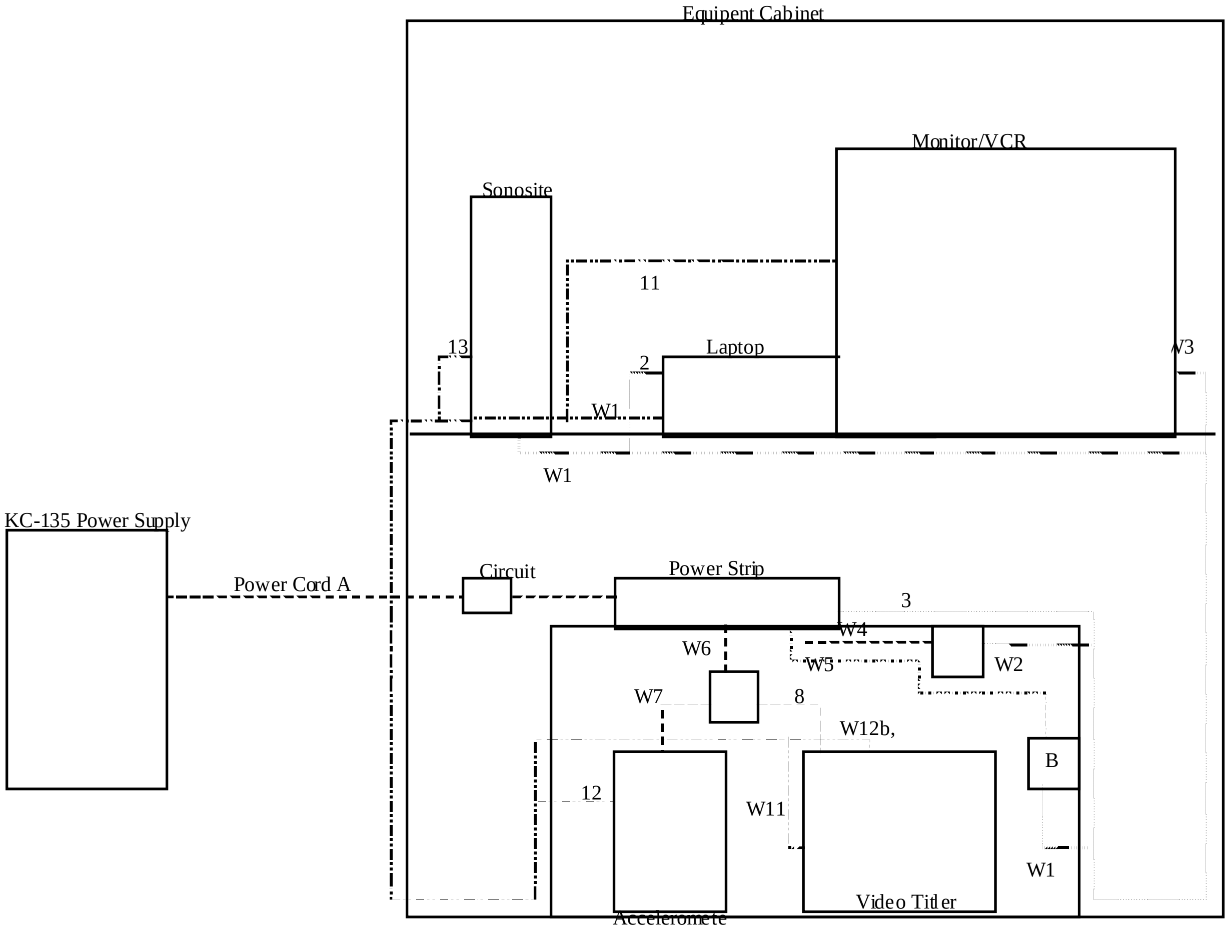


FIGURE 5

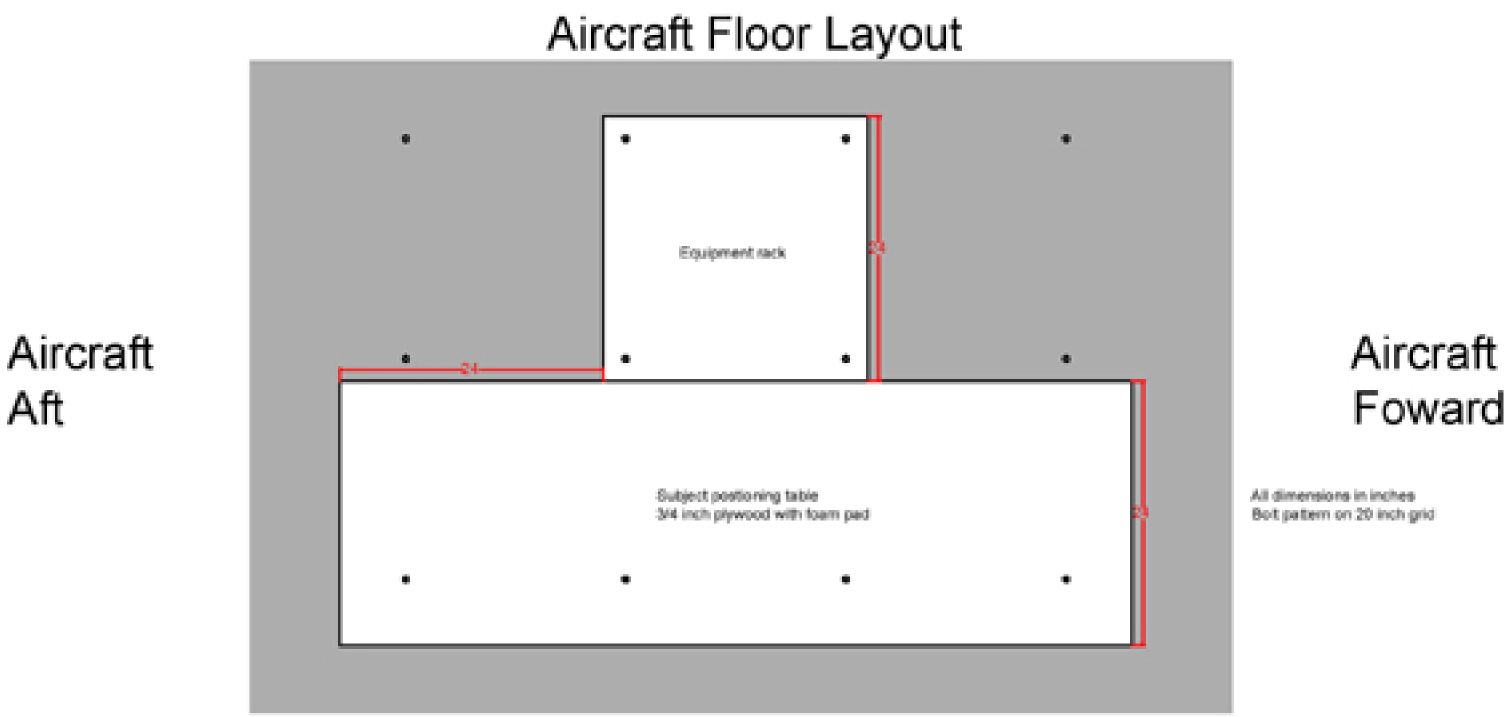

Aircraft Floor Layout
Aircraft Aft
Aircraft Foward
Equipment rack
24
24
24
Subject positioning table
3/4 inch plywood with foam pad
All dimensions in inches
Bolt pattern on 20 inch grid

FIGURE 6

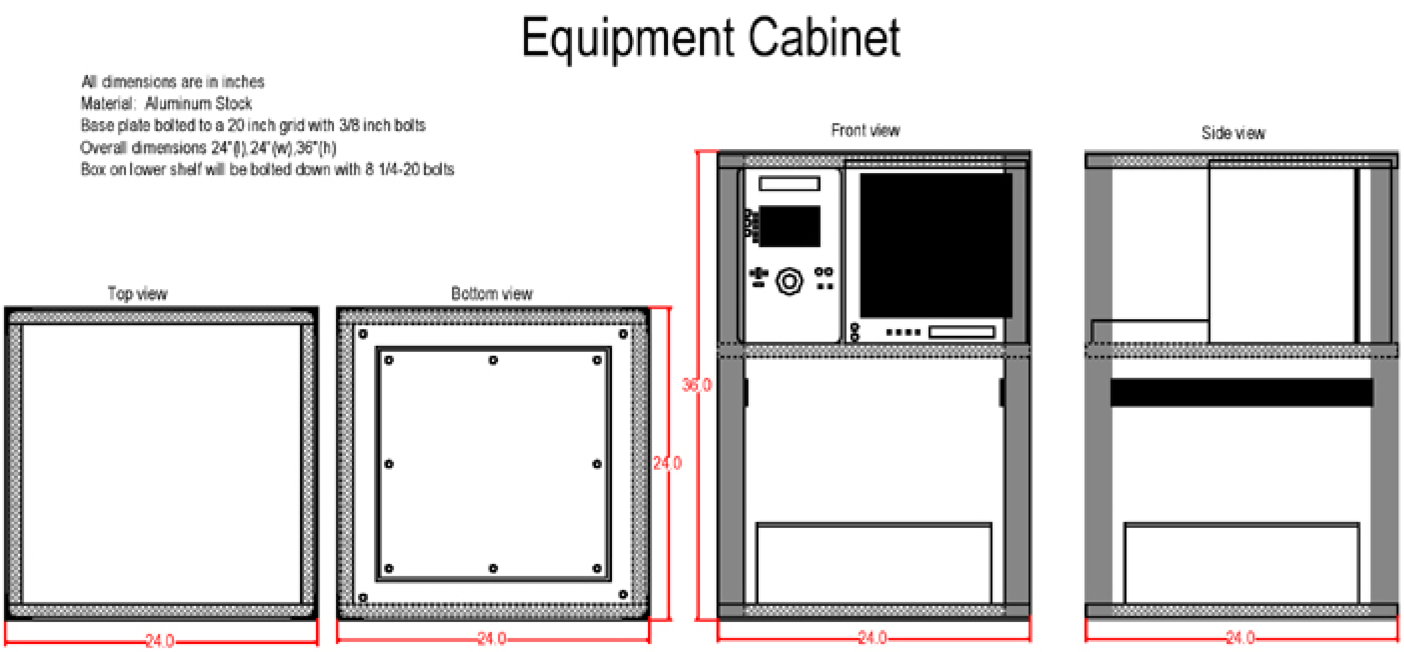
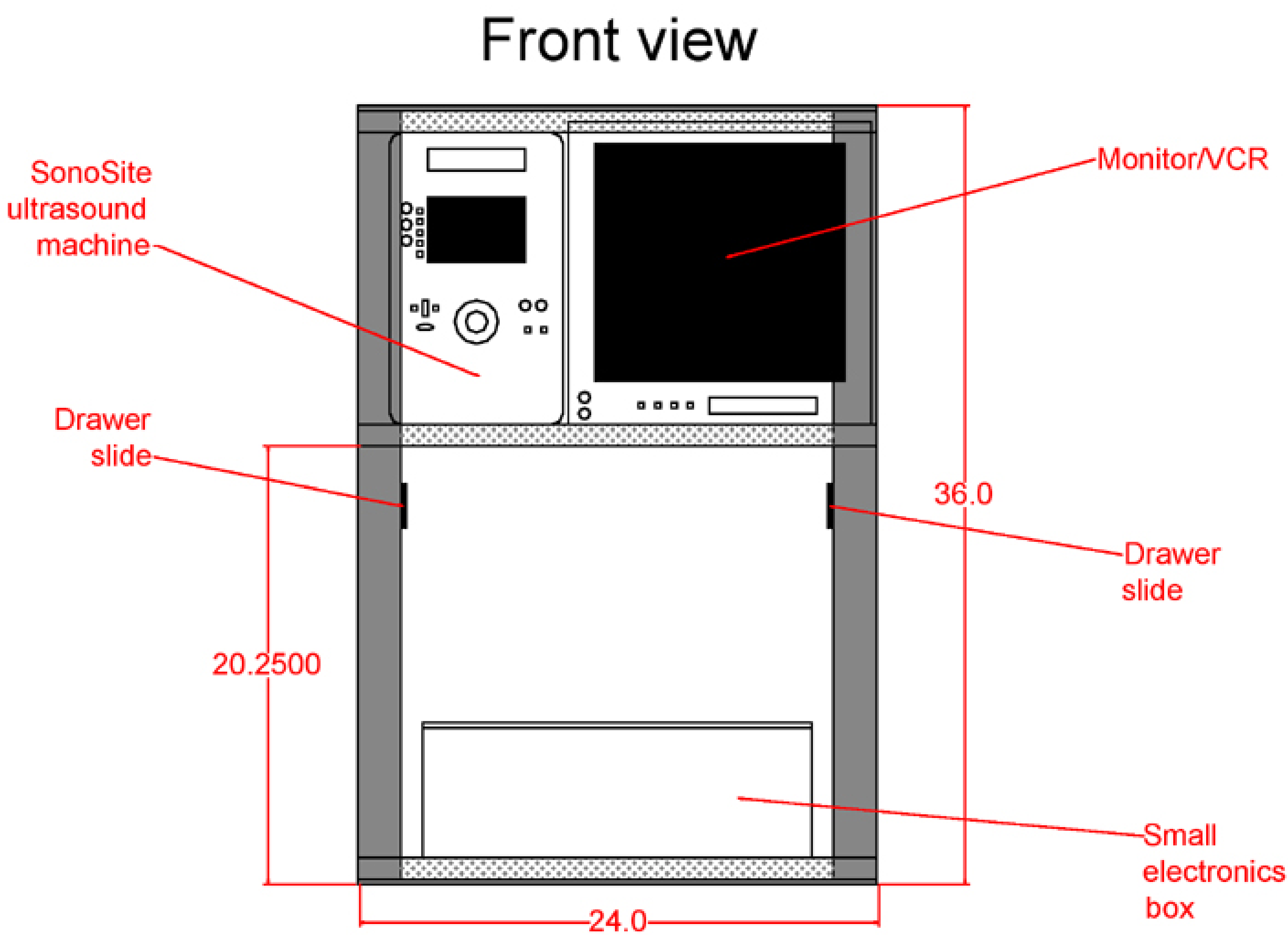
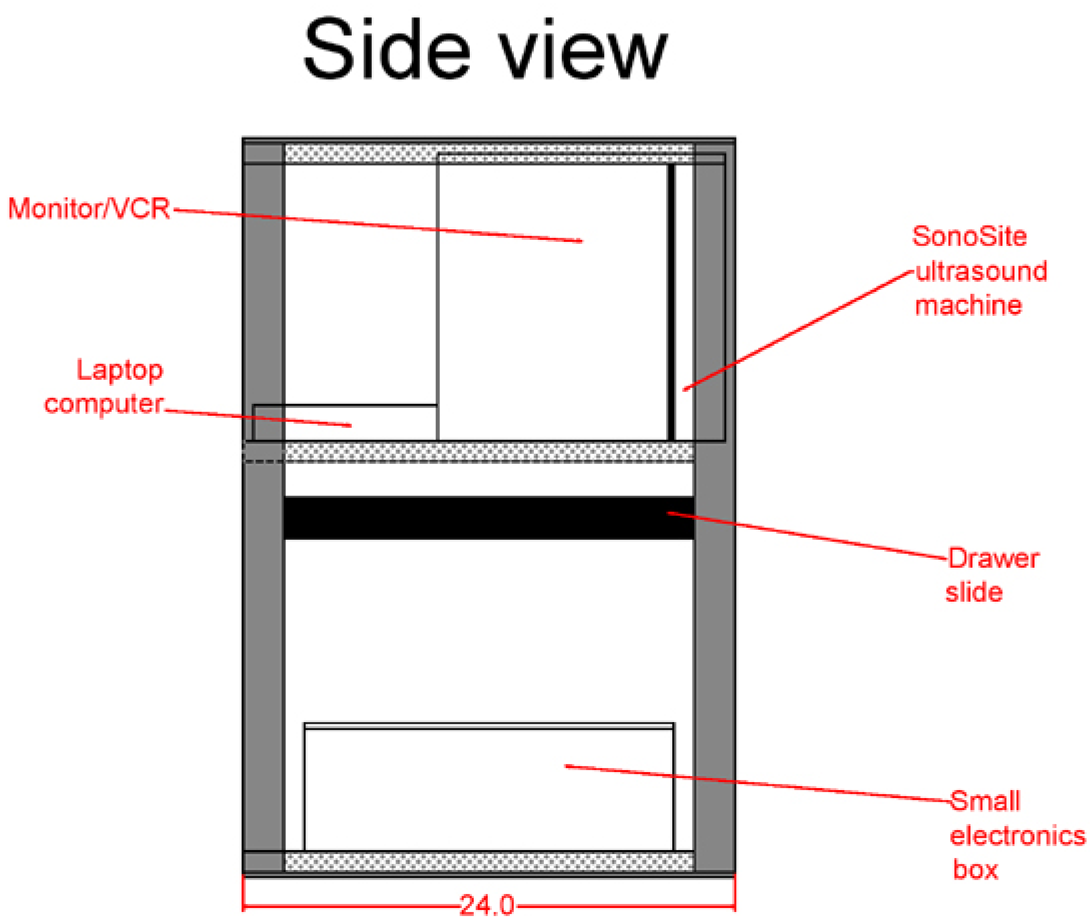

Equipment Cabinet
All dimensions are in inches
Material: Aluminum Stock
Base plate bolted to a 20 inch grid with 3/8 inch bolts
Overall dimensions 24"(l),24"(w),36"(h)
Box on lower shelf will be bolted down with 8 1/4-20 bolts
Top view
Bottom view
Front view
Side view
24.0
24.0
24.0
24.0
24.0
36.0

FIGURE 7



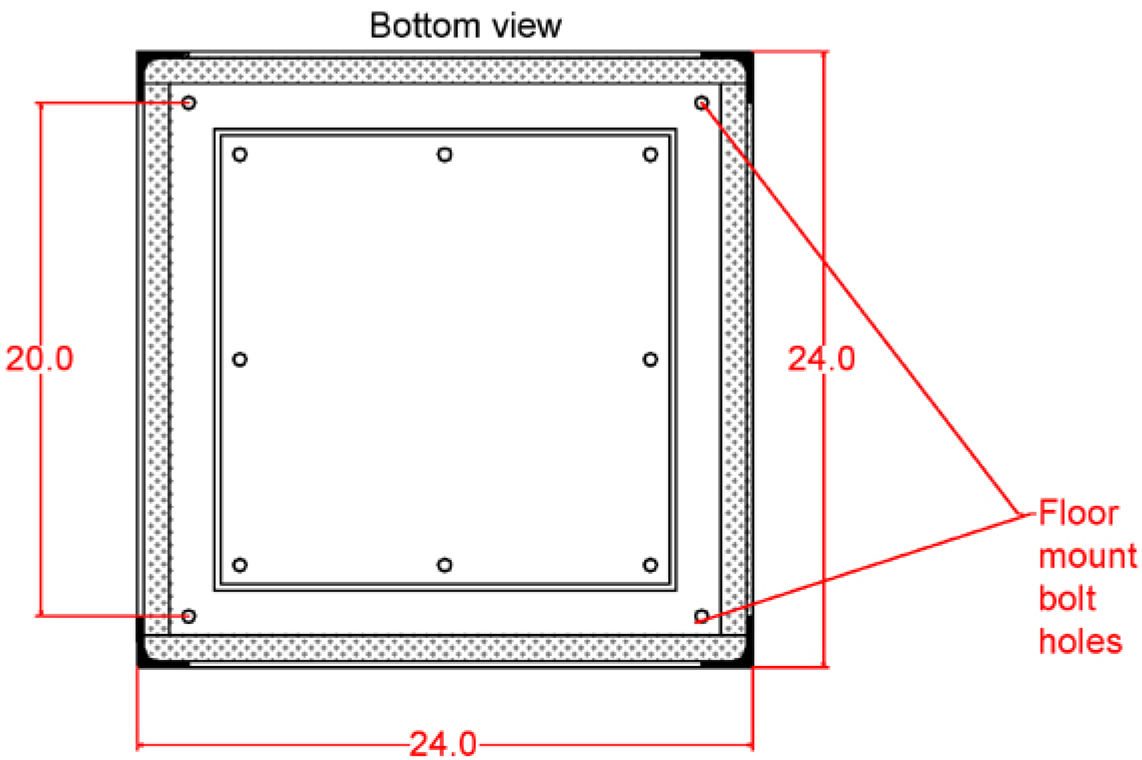
Front view
SonoSite
ultrasound
machine
Monitor/VCR
Drawer
slide
36.0
Drawer
slide
20.2500
Small
electronics
box
24.0

FIGURE 8



Side view
Monitor/VCR
SonoSite
ultrasound
machine
Laptop
computer
Drawer
slide
Small
electronics
box
24.0

FIGURE 9



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